JOURNAL OF THE
AUDIO ENGINEERING SOCIETY
AUDIO / ACOUSTICS / APPLICATIONS

The Phonograph and Sound Recording After One-Hundred Years

VOLUME 25 NUMBER 10/11 OCTOBER/NOVEMBER 1977

AUDIO ES ®

Centennial Issue...

The Phonograph and Sound Recording After One-Hundred Years

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JOURNAL OF THE

AUDIO ENGINEERING SOCIETY

AUDIO / ACOUSTICS / APPLICATIONS

VOLUME 25 NUMBER 10/11 **OCTOBER/NOVEMBER 1977**

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The authors of this Centennial Issue were each invited to write and contribute an article in a specific subject area. Since the nature of these articles is different from the usual technical and professional papers published regularly in the *Journal of the Audio Engineering Society*, it was decided that the Centennial Issue was to be published under the editorial direction of a guest editor. The editorial responsibility for this issue was accepted by the guest editor.

Journal of the Audio Engineering Society, Volume 25, No. 10/11, October/November 1977. Published monthly except January/February and July/August when published bi-monthly, by the Audio Engineering Society and supplied to all members in good standing. Publication and Executive Offices, Lincoln Building, 60 East 42nd Street, New York, N.Y. 10017. Second class postage paid at New York, N.Y. and at additional mailing offices. Subscription to nonmembers, $35.00 domestic; $45.00 foreign.

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CONTENTS

FOREWORD

Before the Phonograph ..... Warren Rex Isom 656

SECTION I/HISTORICAL

Introduction: A Wonderful Invention but not a Breakthrough ..... Warren Rex Isom 657

Edison and his Contributions to the Record Industry . Walter L. Welch 660

Emile Berliner, Eldridge Johnson, and the Victor Talking Machine Company ..... Edgar Hutto, Jr. 666

SECTION II/TECHNOLOGY

Introduction: The Technology of the Record Industry—Perfection Without Notice ..... Warren Rex Isom 674

Microphones for Recording ..... Harry F. Olson 676

Loudspeakers ..... John Eargle 685

Studios and Studio Equipment ..... John Borwick 689

Magnetic Recording for Original Recordings ..... John T. Mullin 696

Record Manufacturing: Making the Sound for Everyone ..... Joseph C. Ruda 702

Record Materials

Part I: Chemical Technology in the Edison Recording Industry ..... Leah S. Burt 712

Part II: Evolution of the Disc Talking Machine ..... Warren Rex Isom 718

Part III: Vinyl Compound for the Phonographic Industry . S. K. Khanna 724

The High-Fidelity Phonograph Transducer ..... B. B. Bauer 729

Record Changers, Turntables, and Tone Arms—A Brief Technical History ..... James H. Kogen 749

Electronic Home Music Reproducing Equipment ..... Daniel R. von Recklinghausen 759

Home Music Reproducing Equipment—Performance and Styling ..... M. L. Alexander 772

SECTION III/THE INDUSTRY

Introduction: Great Music for All and for All Occasions ..... Warren Rex Isom 777

The Graphic Arts and the Record Industry ..... Lewis Garlick 779

The Record Industry in the United States ..... Stephen Traiman 785

The Record Industry in Europe ..... Peter Jones 789

The Record Industry in Latin America ..... George M. Tavares 795

Far East—Problems and Growth Potential ..... Tokugen Yamamoto 800

The Recording Industry in Japan ..... Toshiya Inoue 802

Mechanical Sound Recording in Czechoslovakia ..... Jiri Struska 809

Corroboree and Other Music ..... Ray Darnell 813

SECTION IV/INNOVATIONS

Introduction: Before the Fine Groove and Stereo Record and Other Innovations ..... Warren Rex Isom 815

The LP and the Single ..... William S. Bachman 821

The Coming of Stereo ..... H. E. Roys 824

Magnetic Tape Recording—Reels, Cassettes, or Cartridges? ..... Oscar P. Kusisto 828

The Jukebox, the Radio and the Record ..... A. G. Bodoh 836

Quadraphony—A Review ..... J. G. Woodward 843

Electronic Music ..... Robert A. Moog 855

SECTION V/THOSE WHO CREATE

Introduction: The Art of Becoming a Creative Member of the Record Industry Has Become a Science ..... Warren Rex Isom 862

The Audio Engineer—Circa 1977: What Does He (or She) Do? ..... DeWitt F. Morris 864

Recording, Art of the Century? ..... Peter K. Burkowitz 873

The Musician and the Record ..... Emil L. Torick 880

The Great Artists ..... John F. Pfeiffer 885

Records of the Future ..... Thomas G. Stockham, Jr. 892

100 Years of Phonography ..... H.-W. Steinhausen 896

THE WHITE HOUSE RECORD LIBRARY 898

REVIEW OF SOCIETY'S SUSTAINING MEMBERS 958

ABOUT THE AUTHORS 974

THE AES: Its Function and Development 988

AUDIO ES

Centennial Issue...

The Phonograph and Sound Recording After One-Hundred Years

WARREN REX ISOM
Guest Editor

FOREWORD

Before the Phonograph

Before the phonograph, there was, for centuries, a very great interest in machines that talked. Almost every exposition of any size had one on demonstration. The most famous of all was the Faber talking machine demonstrated at the Paris Exposition of 1876. Its speech was so perfect and its voice so natural in tone and enunciation that it was regarded as a fake and Mr. Faber judged to be a ventriloquist. But twenty years after Leon Scott displayed the working of his phonautograph in 1857, the phonograph was invented, and the talking machine as such has scarcely been heard of since.

In retrospect, it is interesting to speculate as to the reason for the demise of the interest in the talking machine. Could it be that since almost everyone can and does talk, what the world needs least of all is one more non-thinking piece of equipment that can talk but has nothing to say? Computers that speak do not fit this category. True, they do not think, but they do have something to say and they say it only when asked.

But, it is more germane for us, 100 years after the invention of the phonograph, to ask: What changes has it brought about in the lives of the people who inhabit the world? The fact that it has been an important development can be shown by its relationship to every advance in technology that has involved recording during the past 100 years. However, detailing such relationships would be herculean, could become farfetched, and certainly would end up controversial. Besides, in no instance would it make sense.

A better answer to the question is a self-review of the industry and the profession that has been to a very large extent based on the invention of the phonograph, on its perfection, and on its use for this same period of time. Just that has been undertaken, completed, and now presented. There is confidence that its worth is considerable.

The techniques of the motion picture profession were employed to still-frame the activities of the recording industry and of the Audio Engineering Society. In this presentation, word "pictures" are used instead of filmed pictures. This has the advantage of allowing your attention to be immediately directed to the areas of interest by the most knowledgeable in the field, unencumbered by dependence upon the skill of another in a different profession. This assures scenes full of meaningful action.

The number of scenes to be covered was determined by dividing the industry and the profession into its basic parts, always remembering the international character of this worldwide organization. After reviewing this list of some twenty scenes to be covered, large voids were found and eliminated by adding to the list. After repeating the review a few times, voids remained, but the list continued to grow in length. When the number became greater than thirty, a cut-off was made.

Authors were invited to depict the scenes on the basis of logical choices, availability and willingness. Thirty-three acceptances came from thirty-five invitations that were issued almost totally without prior inquiry.

The format for each is to 1) include a mention of the past, 2) emphasize the present, and 3) guess what the future might be.

These vignettes are published in this issue of the *Journal of the Audio Engineering Society.* They provide the most authentic description possible of this Society, the recording industry, and the audio engineering profession. In addition to the description, these vignettes give an indication of where the Society and its members have been, where they are, and where they might be headed.

There are also descriptions of the activities of each of the Society's sustaining members. These descriptions are equally important in the construction of the overall view of the Society and its members.

We have reprinted a listing of the record library of the White House. It was included to document what music might be found in an extensive private library today. This list is published through the offices of the Recording Industry Association of America.

The papers are organized around five focal points of interest; namely, History, Technology, the Industry, the Innovations, and Those Who Create. Almost without exception, every contribution contains new, previously unpublished information. While this is remarkable and appreciated, it may also mean that this Centennial Issue has afforded the occasion for some to make permanent some of their observations. If so, it makes solid the achievement of another but unmentioned objective of this Centennial Issue: to leave behind for those who may follow us a hundred years from now, a compilation of significant and important events that characterize the Society, the industry, and the profession today. The Society is extremely grateful to the most distinguished and prestigious group of authors who have given this Centennial Issue of the *Journal* landmark status among the publications of the 100th anniversary year of the invention of the phonograph. It is also pleasing that this collection of contributions is truly worldwide in origin.

Warren Rex Isom
Guest Editor

A Wonderful Invention but not a Breakthrough....

by WARREN REX ISOM

There are very few inventions or new technical developments that are scientific breakthroughs. By far, more breakthroughs come from those who state the conceptual principles than from those who actually make it happen. In other words, the stage is often set for a new development by the course of events just preceding it. The only question is who will be the person to apply the existing theoretical framework and turn it into something concrete. Such was the case with the phonograph.

Edison once said that the phonograph was his best invention. The patent was issued 57 days after the application was filed. It was a clean patent in that no references were cited to prior patents. That fact is the best certification that he was "first." Nevertheless, it was no technical breakthrough. The scientific world had been expecting it. In fact, every element in the device had been known at least since the time, 20 years before, when Leon Scott had made the phonautograph known by wide distribution throughout the scientific community. The description of a method of recording using a flat disc by Charles Cros in 1877 was evidence of the depth of this knowledge even among the nontechnical cognoscenti.

The capability of a sound- (voice-) powered diaphragm to do work had been demonstrated by Edison with a toy he built for his daughter. He had attached a pawl of a ratchet to a diaphragm in such a manner that when it was yelled or shouted at, a little man would busy himself sawing wood. (The invention was the toy; not the yelling at workmen to get results.) Telegraphic repeaters had used indented paper discs and tapes. Edison arranged all of these known elements together in such a way as to produce novel and unusual results. It was a wonderful and great invention; it was not a breakthrough. It was rather the next logical step.

The fact that the telegraph came first, then the telephone, followed by the phonograph was an historical accident rather than a logical sequence. This sequence of events actually postponed the development of the phonograph to its full potential for several decades. Since the phonograph was a simple mechanical-acoustical device, there was no logical reason why it could not have come first. It is a challenge to imagine what the effect could have been on the telegraph if the order of the inventions had been reversed.

The invention of the phonograph would have been a breakthrough if it had come 50 years earlier. And it could have and—with a little luck—might have happened a hundred years before. There are some fine threads of evidence from which this speculation can be woven. Would it have been unreasonable for someone to have correlated the delay of the sound of distant lightning and thunder rattling the window panes to the nature of the transmission of sound through air? Or, for one to realize that the down-wind sounds were diminished in loudness more than proportionately to the ratio between the speed of the wind and the distance to the source of the sound? Every aborigine driven by hunger to stalk game was an expert on this subject since early childhood. Probably the best tip as to how sound might be recorded was known to those who operated lathes on which irregular and mishapen material (stock) was turned to produce cylinders and other forms with precise dimensions. When the cutting tool vibrated during the turning operation, it produced a sound that was recorded on the workpiece. It was recorded in the groove produced by the chattering tool. To adjust the tool to get rid of the chatter was to produce a smoothly turned surface free of chatter marks. Millions of lathe operators throughout the machine age and since have experienced this condition. It is unreasonable to have hoped that maybe one of them could have seen and understood the connection between the chatter marks and the noise? If the invention of the phonograph had happened this way, it would have been a breakthrough. To those of us today with perfect hindsight, there are dozens of other well-known phenomena that contained the clue to understanding the nature of sound and how it might be recorded and reproduced. In comparison, though, it is not too bad, for it took civilization more than 1600 years after the birth of Christ to understand gravitational force, and then, only after Newton had been hit on the head by a falling apple.

So it was; but there were some near misses. Leon Scott with his phonautograph was on target in 1857 but he did not recognize his target nor did he realize that he had but a short distance to go. Unquestionably, Leon Scott contributed more to the invention of the phonograph than all the others before Edison.

An Englishman named F. B. Fenby obtained a patent on January 13, 1863, for an "Electro Magnetic Phonograph." This was the first use of the word "phonograph" to describe a recording device. Mr. Fenby had invented a mechanism for recording on paper tape the manipulation of the keys in sequence of any keyboard instrument as it was played. On playback, the keys were manipulated by the device in the same sequence as when they were played by the artist. He missed the boat by concentrating on the specific rather than the general. He passed up the easy job, so it turned out, for the more difficult one. There is no record of a model of this device ever being built. The idea

later became the basis for the player piano. Player-piano technology in turn was basic to a wide range of sequential process controls in the automation of the manufacturing industry.

It is interesting, in this context, to note that Edison never officially claimed to have invented the phonograph. His patent application was for an "Improvement in Phonograph or Speaking Machines," filed on December 24, 1877, and granted as titled on February 19, 1878, as U.S. Patent 200,251. The improvement was twofold; to record sounds in "permanent . . . characters so that such sounds may be produced and rendered audible at a future time." While not stated, the improvement had to be of the Scott phonautograph.

Why had the invention of the phonograph been missed for so long? People were then, as now, so tied up with their day-to-day necessities such as making a living, that they could not visualize a projected use for a device for which no current demand existed. Edison himself was in that category. After a little more than a year during which he had been idolized and dubbed the "Wizard of Menlo Park" because of his invention of the phonograph, he tired of his "baby," condemned it as a "mere toy, which has no commercial value," and abandoned it for the challenge of the incandescent light and the business of invention itself. What was to become the first phase of the history of the phonograph was over. Thus for Edison, the invention of the phonograph was an interlude which broke the spell of his adherence to practicalities.

Thanks to Alexander Graham Bell, the second phase of the history of the phonograph started with a letter written by the inventor of the telephone to his father-in-law, Gardiner G. Hubbard, on March 18, 1878, from London, where he had heard of the invention of the phonograph. It read in part: "It is an astonishing thing to me that I could possibly have let this invention slip through my fingers when I consider how my thoughts have been directed to this subject for so many years." He went on to relate the descriptions he had given during his lectures of how the Scott phonautograph tracings could be used to reproduce audible sounds. This letter is on exhibit as Item 14 in the Great Hall of the Library of Congress honoring the 100th Anniversary of the invention of the phonograph. It is also reproduced on page 8 of "A Wonderful Invention," the brief history of the phonograph and the catalog of the exhibit ably authored by James R. Smart and Jon Newsom.

The lamentations of Bell did not end his interest in the phonograph. As the inventor of the telephone, he had won a 50 000-franc prize from the French government in 1880. In 1881, he used this award to establish a laboratory in Washington, D.C., staffed by his cousin Chichester A. Bell and a Boston scientist named Charles Sumner Tainter. Soon the Volta Laboratory was dedicated to the improvement of the existing talking machine and the development of new phonographic technology. The story of the groove cut in wax and other improvements are well known. It is an interesting parallel that Edison had let the invention of the telephone slip through his fingers, but he never claimed to be its inventor. He did, however, set about improving and developing new telephone technology to the extent that his work became a very critical factor in the commercial success of the telephone as did Bell's work with the phonograph. Bell had unequivocally recognized the importance of the phonograph, scientifically as well as commercially. Edison had not, until he was confronted with the basic and practical technical achievements of the Volta Laboratory in 1886-87. This prompted father Edison to end the neglect of his "baby" and to become determined to improve it and to nurture it to maturity.

The third phase of the history of the phonograph starts with the era of improvement and commercialization. This period is covered in the historical section of this issue. Two points might be mentioned. In almost all instances, the invention of an item is only the beginning of the creative work and thought required to transform it into a commercial product. The phonograph was no exception. Edison's invention was really only a feasibility model proving the idea could work. Inventors as product managers or as manufacturers of their "babies" have one or the other, if not both, of two faults. The first is the "Not-Invented-Here" syndrome characterized by an unwillingness to recognize the capabilities of others to contribute to the improvement of the invention. Edison had a full measure of this. In his defense, it might be said that he used it as a ploy to free himself for other work. But it did not help him in his relationship with the Volta Laboratory. The other fault is to base all decisions on technical considerations. Edison had full measure of this, too. But it almost worked for him in the case of the phonograph. Edison had a reputation for technical excellence, which he played to the hilt. His portrait and signature were his trademark, leaving little space on the record label or package for the title of the selection or the name of the artist. But the quality and reliability of his cylinder and disc records explains their endurance in the marketplace in spite of all the repertoire and promotional strategy amassed by the competition.

Leon Scott has been named the most important contributor to the phonograph in the period before it was invented. Alexander Graham Bell best evaluated it. Now the question is who made the most of it? The answer can be loud and clear: Emile Berliner. There were, of course, a host of others, many of whom had been recruited into the industry by Berliner. Among them are Eldridge R. Johnson, the Gaisberg brothers, Barry Owen, and Berliner's brother Joseph. Unfortunately, Berliner's luck with the commercialization of his early products undoubtedly robbed him of the titular leadership of the industry during his lifetime.

Berliner was a scientist with broad interests and practical ideas in many fields. His U.S. Patent 534,543 covering the phonograph is a classic in the annals of the industry. Here are some of the firsts disclosed in this 1895 document: the pickup stylus guided across the record by the record groove; a high-speed flywheel for good motion, a rim-drive, pluck driven turntable, and the weight of the horn assembly carried by a separate pivot bearing under its center of gravity. Sometimes it is the technology of

improvement which sustains the commercialization of the product.

Since the publication in 1959 of the comprehensive historical treatise on the evolution of the phonograph, titled *From Tin Foil to Stereo* by Oliver Read and Walter L. Welch (published by the Bobbs-Merrill Co.), few discussions of the history of the phonograph can proceed for long without reference to this book. This history is itself a historical milestone. All those who would be knowledgeable of phonographic history are filled with gratitude to the authors of this book. This is recognition not only of the value of this book, but a belated "thank you" to the authors for disseminating so much of what went on in the industry during the period. We are also indebted to all other authors and professionals in the field who have recorded in print the progress of the industry.

Edison and His Contributions to the Record Industry

WALTER L. WELCH

Thomas Alva Edison Re-Recording Laboratory, Syracuse University Libraries, Syracuse, NY

Thomas Alva Edison discovered natural principles fundamental to the electronic era while working on telegraphy and telephony. As with the phonographic principle, he incorporated them in useful devices. From Edison's contributions to recording science and art, the author selects twenty-four he considers of major importance.

Thomas Alva Edison made some of his more important contributions to the record industry two or more years before he invented the first phonograph.

No less than eight of these earlier contributions are fundamental to the technology of the industry today and may continue to be in the future because they are the results of his discovery of natural principles which he embodied into demonstrable, useful inventions.

The first of these was the discovery of "etheric force" in 1875 in the pre-Menlo Park period in a laboratory in Newark, New Jersey. While working on some experimental telegraphic apparatus, he observed that some unusual sparks were emitted from the core of an electromagnet, differing from any he had ever seen. After intensive testing of this new phenomenon, Edison and his associates realized that they had stumbled onto the "new force" for which they had been seeking [1].

James Clerk Maxwell, distinguished Scottish physical theorist and mathematician, had first predicted in 1873 that electrical circuits would be found to radiate energy. He predicted that this would be in the form of radiant waves, in general obeying the laws applicable to the behavior of light. The copy of Maxwell's work owned by Edison is in the reconstructed library at Dearborn, Michigan. Perhaps this is why Edison called it "etheric force," which is derived from "ether," a word often used at that time in connection with otherwise unoccupied space. In any event, Edison and his associates verified with exhaustive tests that this was indeed a new and different manifestation of electricity. He devised an instrument for detecting it, a black box with an eye shade at the top, so that one could look inside without letting light in. There was a spark gap inside with two finely pointed electrodes of graphite, with the width of gap made adjustable by a micrometer screw. This was the world's first detector of wireless, or electromagnetic waves. This new force was destined to make possible wireless telephony, which became radio. It is equally important to television and has enabled the development of communication through both the earth's atmosphere and the stratosphere, and was indispensable to the landing of a man on the moon. Even now it is a vital factor in reaching out into the far reaches of space without the necessity of manned flight via satellites and electron telescopes. In the other direction we look into the innermost recesses of organic or inorganic materials via the electron microscope and the scanning electron microscope. The latter right now is giving us new information pertinent to carrying forward the seemingly endless possibilities in the development of the central principle of Edison's phonographic conception, the groove–stylus relationship.

That Edison was the first to discover evidence of the phenomenon of what he called "etheric force" is now well documented.[1] Moreover, the remarkable foresight of Henry Ford, Sr., in having the Menlo Park buildings removed to Dearborn and reconstructed as they were in 1879, including the laboratory and library, is in large measure responsible for this. Here is the original black box, or etheroscope as Edison named it, used in the tests in 1875 to prove that messages could be sent from one place to another without wires, as well as the transmitting

[1] Edison did not write articles for scholarly journals, but kept laboratory notebooks, and key artifacts.

devices, the same equipment used by Charles Batchelor in demonstrations at the Electrical Exposition in Paris in 1881.[2] This is still five years before Heinrich Hertz began his well-known and important investigations of this same manifestation of a new form of electricity in 1886, in which he also used a black box with electrodes and micrometer adjustment as a detector, similar to that of Edison.

Edison was later criticized for using the term "etheric force," as the term "ether" became unpopular in scientific circles. He never let terminology interfere with his investigations, however. In view of his prior mastery of telegraphic systems and his major contributions to telephonic development, his lack of interest in wireless and radio is difficult to understand. However, he did receive one patent covering two different principles. One would permit communication between moving trains and the way stations. In this, induction was used between the telegraph wires along the right of way, and antennas were installed the length of the trains. The other system was for communication between land stations and ships at sea, etc., in which conduction as a principle would not work. The drawings show towers and antennas quite modern and adequate for wireless telegraphy using "etheric force" as a principle. Moreover, the electrical components, use of the ground, and circuits are quite consistent with early wireless telegraphy, but the term "induction" seems incorrectly applied to the latter. Then Edison was working with Ezrah T. Gilliland, who had not been with him at the time of the discovery and demonstrations of "etheric force," which may have been responsible for this. In any event, U.S. patent 465,971 was granted to Edison in 1891 and sold to Marconi Wireless Telegraph Company in 1903 [2].

The train-to-way station system was installed on the Lehigh Valley Railroad in 1886, the year after Hertz began his work in this area at the Karlsruhe Polytechnic in Germany [3].

The second major contribution of Edison was the invention of the first incandescent lamp. Others were in the field prior to Edison, so the basic principle of the lamp was known, but in the competition for a successful lamp he was first to consider it as a part of a total system, in itself something rather important. We use his incandescent light in so many ways. But the incandescent lamp also became central to the recording industry development primarily because of another Edison discovery, the emissions from the heated filament. He observed, in working with a lamp in 1883, that a shadow was cast of one leg of the filament in the customary darkening of the glass near the base only, as in a photographic negative. So Edison constructed a lamp with a plate intercepting the particles being emitted to find out why. He found that these particles, later called electrons, were attracted by only one leg of the filament as he was using direct current. But more important to this industry, he found that he could derive a current from the use of this energy collected by the plate, which he found varied with the voltage applied to the filament. So he designed a "voltage indicator" that would be useful in regulating voltage.

Edison was granted a patent for this purpose October 21, 1884. This Edison U.S. patent 307,031 became the foundation patent of the electronics industry. John W. Howell, while experimenting with one of these "Edison effect" tubes in his laboratory at the Edison Lamp works at Harrison, New Jersey, discovered that it could be used as a rectifier of alternating current and wrote an article about it, which appeared in the *Transactions of the American Institute of Electrical Engineers*. This immediately stirred great interest. In 1885 Edison made up some of these tubes for Sir William Preece who had given the first demonstration of the phonograph in England. Preece later gave one or more to Ambrose J. Fleming,[3] which resulted in the "Fleming valve" of 1903. This was identical with the Edison voltage regulator tube, except for a different external circuit for its use as a detector of wireless waves.[4] Lee De Forest, of course, vastly expanded the usefulness of this basic radio tube by his introduction of the third element, the grid, of which the first patent of many was applied for and granted in 1905.

In this connection, the article on "Exoelectrons" by Ernest Rabinowicz in the January, 1977 issue of *Scientific American* emphasizes the advantages of heating in the stimulation of electron emissions, as well as of high vacuum in the much rarer phenomenon he is dealing with. Who knows how much the process of development of electronics would have been delayed if Edison had not persisted in his search for a practical incandescent lamp?[5]

Of course, the discovery of the phonographic principle occurred to Edison while he was working on something else—this was integral to Edison's method. It happened when he was intensively developing the components for a successful telephone system, involving diaphragms suitable both for transmitters as well as for improving receivers. This moment of conception of the principle is written

[2] The telegraph key, electromagnetic vibrator, and the etheroscope, etc., are in the reconstructed Menlo Park Laboratory in Dearborn, Michigan. The tests and test equipment described in *Scientific American*, and as demonstrated in Paris by Charles Batchelor in 1881, were used recently in reenacting the tests at the Edison Institute in Dearborn, Michigan as they had been performed in 1875-1876 and in 1881, together with other tests. This was done by Robert G. Koolakian, Curator, at the time.

[3] Ambrose J. Fleming worked for a time as a consultant in the Edison work at No. 57 Holborn Viaduct where a trial Edison central electric system was in planning from 1880 to 1882 for the English Edison Electric Light Company. Opened on April 11, 1882, Fleming and Dr. J. Hopkinson, also of England, conducted the final testing.

[4] The identity of the two is established in decision of Federal Court for Southern District of New York in suit of Marconi Co. vs. De Forest Co. (236 Federal Reporter 942).

[5] The story of crystal and other detectors of the wireless area, and the invention of the transistor by Shockley and others, is not within the scope of this article, but the vacuum tube was decisively important to the establishment of the radio and broadcasting industry in the 1920s, as well as international communications via telephone, wireless telephone, and even cable operations.

succinctly in his own hand on a page of a Menlo Park notebook (see Fig. 1):

> "Just tried experiment with a diaphragm having an embossing point and held against parafin paper moving rapidly. The Spkg. (Speaking) vibrations are indented nicely and there's no doubt that I shall be able to store up and reproduce automatically at any future time the human voice perfectly."

The story of the invention of the tinfoil phonograph was exaggerated by everyone in the beginning, including Edison, following an article which produced an unexpectedly great public reaction all over the United States. Edison had proposed a practical use of the principle as a telephone repeater, and a provisional application had been filed and acknowledged by the British patent office before there had been any publicity about his invention. The story was written by Edison pioneer Edward H. Johnson to *Scientific American*, published November 17, 1887, in which the editor wrote a highly enthusiastic editorial headlined:

"A Wonderful Invention—Speech Capable of Indefinite Repetition from Automatic Records."

The tinfoil phonograph was invented in part to satisfy the demand for demonstrations and also to isolate the embodiment of the principle of a groove–stylus relationship which he had conceived but had not the time to develop. This also would receive a firm patent without involving electromagnetic complications, with which he already was very much troubled in his work with the telephone.

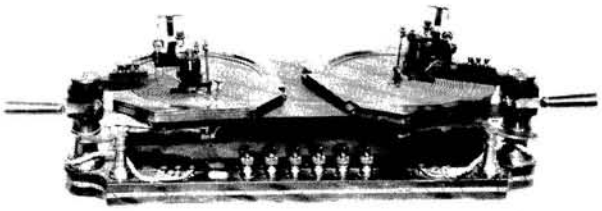

Fig. 1. The Edison disc telegraph repeater (from the rear) suggested the possibility of recording the human voice to Edison, Menlo Park, 1876. *Collections of Greenfield Village and the Henry Ford Museum.*

Edison immediately turned over the design and manufacture of the demonstration tinfoil phonographs to Sigmund Bergmann who made much of his telegraphic apparatus. To hold the phonograph development in abeyance until he could find time for it, Edison, Charles Batchelor, and others drafted a provisional patent, outlining numerous improvements and applications with well drafted drawings and specifications covering cylinder, disc, and tape instruments.[6] Duplicate copies were sent to both the U.S. and the British Patent Offices. The latter, as was its practice, assigned a number quite promptly, and this was dated April 24, 1878. At that time the British did not have patent examiners.

On that same day the Edison Speaking Phonograph Company was organized, but it became only the owner of patents then in effect. It was intended to assume the manufacturing and distribution of the demonstration phonographs, and that was all. About 600 machines had been made in varying sizes and decor to suit the needs of professional exhibitors, and territories were assigned so that the phonograph could make some money while Edison was busy with the telephone and the electric light.

But there are four further contributions that are the results of Edison's priorities established even before that time. They will be listed briefly, for, in each, their importance in the present era is recognized as well as their spheres of usefulness in the future. These are as follows.

1) The discovery of the principle of the carbon-button telephone transmitter (later developed into the first practical wireless telephone and broadcast microphones by others). The fundamental patent applied for April 18, 1877, was recognized in England with little delay, but was not finally adjudicated by the U.S. courts for years. Variants of the Edison transmitter are still used in telephones all over the world.

2) The application of the moving-coil principle to the telephone transmitter (later developed by others into the dynamic microphones, and into dynamic and electrodynamic loud speakers).

3) The discovery of the feasibility of recording sound onto steel, an application using steel discs (patent received by Edison).

4) The application of the electrostatic effect to a telephone transmitter (condenser microphone prototypes).

Edison was compelled to do something with his phonograph in 1887 as a result of the failure of the U.S. patent office to grant him a provisional patent. It had been denied after a long delay on the basis that the application so long before had been anticipated by the issuance of a provisional patent by the British Patent Office, which, it was claimed, gave him adequate protection. If so, why the delay? However, in 1886 a series of patents had been issued to others, and in 1887 the imminent introduction of the Graphophone forced Edison to protect his interest in his favorite invention.

As a result, the first Edison phonograph intended seriously for use in communications was introduced in 1888. Like the first Graphophone, it was a cylinder machine, but the features introduced by Edison and his associates have had a great effect on the subsequent development of the recording industry (see Fig. 2). First are listed the more important elements achieved by 1890, not only pertinent to the period but at least through the acoustic recording era.

1) Solid wax blanks, shavable for multiple reuses, interior sloping bore to fit mandrel[7]

2) Use of imported French plate glass for both recording and reproducing diaphragms,

3) Electric motor operation, with governor; operation

[6] Edison's British patent no. 1644, pp. 28A-28T, is complete in [4].

[7] Solid wax blanks were used in nearly all record-producing studios until the introduction of acetate-coated discs. Now lacquer-coated discs are used.

from 2½ volt cell,[8]

4) Shaver with blade of artificial hard sapphire made by patented Edison process,

5) Recording sapphire stylus, with burnishing surfaces to produce smooth groove,[9]

6) Reproducing sapphire stylus, spherical tip, to fit groove properly.

Features 1), 2), 4), and 5) were adapted to lateral disc recording by Eldridge R. Johnson in producing the improved Berliner Records introduced in 1898, extremely important in the later Victor Talking Machine period, and virtually all of the disc industry until 1925. Pathe, the American Graphophone Company (after reorganization in 1896), and nearly all cylinder manufacturers also used these features.

From 1898 to 1925 nearly all of the acoustical records were made with recording heads with glass diaphragms.

Fig. 2. Arthur Middleton, bass-baritone, and Karl Jörn, tenor, singing in direct comparison with the Edison phonograph. *Edison National Historic Site, West Orange, NJ.*

Edison was first and foremost a chemist. His work in developing plating methods used in record making, which was published between 1888 and 1902 in patents granted before he could make use of them himself, served to educate the lateral disc industry. The problems of plating cylinders were simple, but those of removing molded records from the molds, plus allowing for shrinkage in processing from original wax to final molded cylinder with 100 grooves per inch proved very difficult.

Actually, Thomas B. Lambert beat Edison with a molded cylinder of celluloid to fit on the standard Edison sloping mandrel in 1900. This was not construed as a violation of the Edison sloping mandrel patent because it only touched it at each end. However, the granting of this crucial patent delayed Edison's use of celluloid, with which he had made experimental records prior to 1900, until 1912, when he purchased the rights from a successor of Lambert.

Edison and the reorganized Graphophone Company[10] began producing molded cylinders of harder records of waxlike compositions in 1902. In connection with reproducers to get the utmost quality from these new records, which were unbelievably smooth when new, Edison introduced the knob-shaped sapphire stylus, the first elliptical stylus of the industry.

Improvements in diaphragms also ensued, particularly in substituting sheet mica for glass, then concentrically built up layers of mica, and finally a deformed copper alloy with embossed concentric rings.

But of even greater importance to the industry was the advertising slogan "As Loud and Clear as the Original." This was ever his goal. In 1908 Edison had increased the number of grooves per inch to 200, molding "Amberol" cylinders of the same dimensions. These played twice as long, nominally 4 minutes, compared to the former capacity of about 2 minutes, with the speed of 160 revolutions per minute established as standard for the cylinder industry in 1902. It is unfortunate that the disc industry did not adopt fixed revolution speeds until much later.

In 1912 Edison purchased rights to use the celluloid process and immediately converted many of the records made by the 200-groove/per inch process to use on the new and highly advanced reproducer. It was equipped with heavier floating weights and a radically new self-damping diaphragm made of multiple layers of rice paper imbedded in shellac, with a shallow domical-shaped cork element over most of the diaphragm, on the side away from the horn, with a pyramidal hard button in the center to receive the pulls from the stylus bar through a variable compliance of woven silk cord.

In development at the same time the Edison diamond disc phonograph was being developed, and for this a reproducer was designed of similar design as described above, but with larger diameter diaphragms and heavier

[8] Later wound for 110 volts dc or 110 volts ac, optionally.

[9] Sapphire styli, cut and polished, with burnishing surfaces, are still unexcelled, and this art continues.

[10] After the collapse of the North American Phonograph Company, organized by J. B. Lippincott to lease the new Edison business phonographs and the Graphophones for use in industry and commerce under a state's rights program, the American Graphophone Company had to be reorganized, and it began production of cylinder machines using the Edison mandrel, solid wax blanks.

Meanwhile, from the first, its sister company, Columbia Phonograph Company, had used Edison type blanks and had kept going by producing musical and entertainment records for the local companies, which increasingly were using the Edison phonographs for coin operation. The Edison Phonograph Works had begun issuing records for this purpose in 1890.

floating weight. The important contribution here is that both cylinders and discs were to be reproduced by accurately ground and polished diamond styli. This, in my estimation, was one of Edison's greatest achievements with his phonograph.

This seems proven by the fact that it was well into the LP era, which really began in 1949, before diamond styli gradually became standard in the lateral disc industry. The first Columbia LP record players still had sapphire styli.

Of greater importance to this industry is the commitment of Edison and his associates to the principle of "high fidelity" which had not been coined as yet. In designing the official laboratory model phonograph mechanism, Edison and his men made exhaustive tests of horns and reproducers. The precision of the making of every part was to incredibly fine standards.

Direct-comparison tone tests were made publicly in auditoriums large and small all across the United States and Canada and from Hudson Bay to Mexico. Both important and lesser artists, vocalists, and instrumentalists sang or played in comparison with the reproduction of the new Edison phonograph (see Fig. 3).

It is unfortunate that Edison's troubles in maintaining a quiet surface during World War I years stemmed from the shortage of a German chemical used in finishing the condensite varnish surface for the process of printing into this phenolic resin, which was so wonderful when it was good and abominable when bad, though most problems were from the cores.[11]

At the end of World War I, just when Edison was again able to consistently produce discs as smooth as those of 1913 before chemical shortages, and when splitting due to unequal shrinkage of surface and core no longer was a problem, the era of free radio entertainment was at hand. Thus the contributions he had made to this industry came back to haunt him through radio broadcasting, which likewise adversely affected others in the record industry.

As if to show what might be done even though the Edison catalog did not have recordings of complete symphonies, operas, or musical shows to warrant the experiment, Edison issued long-playing records with 450 grooves per inch in both 10- and 12-inch diameters in 1927. Attachments were offered to owners of Edison disc phonographs to fit most models, including a reproducer which had to have a diamond to track grooves only half the width of those of LPs or stereo records today. The trouble was that even with the hard condensite varnish surface, in the direction of travel a much larger radius was necessary to prevent exceeding the elastic limits of the surface. As the playback styli were formed by a rather expedient process, the somewhat boat-shaped stylus occasionally would plow through the land between grooves, which, because of vertical recording, had to be carefully controlled. Nevertheless, to those in the art these were a triumph of record engineering. However, at 80 revolutions per minute acoustical reproduction required ounces of pressure on the groove instead of a gram or less today. Think what might be done with this fine, but unsuccessful disc with the electrical reproduction. With such a fine groove 30 revolutions per minute would have been technically adequate (which was being experimented with in the Edison laboratory in 1929). At this speed a 12-inch disc would play for over 50 minutes on one side and, if constant groove speed was adopted, for an hour—an excellent conversion medium for relating to broadcasting. This would eliminate the need for tape as an intermediate medium.

Of all media, the phonograph record with a standard playback instrument provides the best historical evidence of artists and their preformances. No measurements are superior to A-B auditioning.

All of Edison's long-playing records were rerecorded from the conventional discs, and the metal parts for them still have been preserved. For indefinite storage in the future, perhaps phonograph discs made with cores of glass similar to these may be the answer.

Edison's adherence to his ideals and his loyalty to the purchasers of his phonographs and records over the years, for example, is one of his outstanding contributions. Belatedly realizing that electrical recording was inevitable, Edison finally permitted his son Charles Edison, then President of Thomas A. Edison, Inc., to purchase the Splitdorf Radio Corporation as a means of acquiring licenses to enable electrical recording and the production of radio phonographs.

This was already 1927, and the Edison laboratories did not have an ac outlet in the place! Nevertheless, within a few months it was found possible to record Edison diamond discs electrically. Condenser microphones were used as developed by others, the first prototypes of which had been made by Edison for the telephone years before, and which are still preserved at Dearborn. Of course his incandescent lamp had shown him the way to utilize the filament to produce the "Edison effect," which now because of the work of Fleming, De Forest, and others, made it possible to record Edison discs electrically for reproduction on the laboratory model Edison disc phonograph.

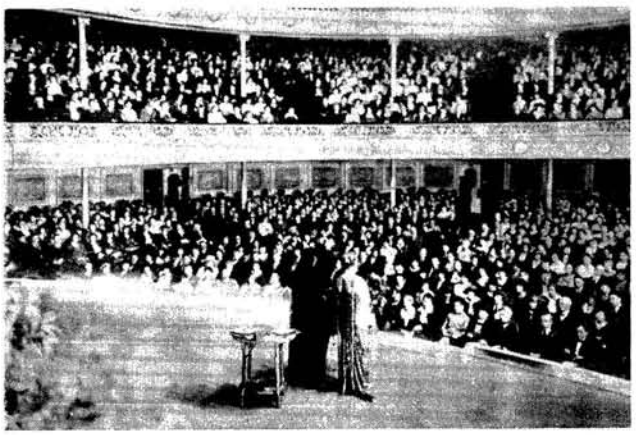

Fig. 3. Marie Rappold, Metropolitan Opera soprano in tone test recital, Carnegie Music Hall, Pittsburg.

[11] The Edison chemists invented the process of producing condensite varnish at the same time Leo Backeland and others invented Bakelite varnish, the same hard thermoplastic phenolic resin, for other purposes.

This Edison insisted upon. These records also were a complete technical success. Although publicly conducted tone tests were not demonstrated, they are known to have been tried in the laboratory. The well-known propensity of microphones for picking up reflected sound may have interfered. In any event, the correctness of Edison's work from 1908 to 1915 in providing a standard that could be used in 1972 for a system of constant-velocity electrical recording is worthy of our admiration. The conclusions of Maxwell and Einstein indicate that constant velocity is inevitable.

Edison had a care not only for his customers, but for posterity. Remember his phrase in the 1877 notebook, ". . . to reproduce at any future time"? Unfortunately, there has not as yet been a determined effort to preserve our recorded heritage of sight and sound for that elusive posterity that is always somewhere ahead.

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Emile Berliner, Eldridge Johnson, and the Victor Talking Machine Company

EDGAR HUTTO, JR.

RCA Corporation, Camden, NJ

Berliner's disc records became competitive with cylinders after Johnson produced a spring motor for the Gramophone. When legal restraints forced Berliner Gramophone to cease sales, Johnson began his own manufacturing company for records and instruments. For the next quarter century the Victor Talking Machine Company became the industry leader by offering a quality product combined with intensive sales and advertising policies.

INTRODUCTION: After Edison's invention and demonstration of his tin foil phonograph in 1877, he became involved in a long effort to make the incandescent lamp and electrical distribution systems practical. Interest in the further development of the phonograph centered in Washington, DC, at the Volta Laboratory in the work of Alexander Graham Bell, Chichester Bell, and Sumner Tainter. Instead of Edison's vertical indentation of metal foil, Bell and Tainter's recording stylus cut a vertical groove in a wax-coated cylinder. Five Bell–Tainter patents were granted, which included the use of wax as the recording medium. Bell and Tainter considered disc recording, but preferred cylinder recording because of the constant speed of the recording surface.

THE GRAMOPHONE

Emile Berliner (Fig. 1), also working in Washington, had sold a telephone transmitter invention to Alexander Graham Bell for $75 000 and remained on a $5000 yearly retainer fee. This invention and that of the continuous-current transformer brought the German-born Berliner professional prestige and provided him with the financial security to pursue an alternate approach to the phonograph. Berliner investigated etching sound as a horizontal pattern on a metal disc. The disc was coated with an acid-resistant material. During recording, the vibrating diaphragm caused the stylus to remove the acid-resistant material from the sound trace on the disc. After an acid etching process, the disc was used as a master to make stampers for the production of duplicate records in a soft material that hardened when cooled.

Berliner discs provided several advantages over cylinders: ease of duplication; a groove which guided the sound box, eliminating the need for a propelling mechanism; hard groove walls which provided louder reproduction and longer wear; and ease in storage and shipment. However, the process produced extraneous noise. The walls of the grooves were rough due to the etching procedure. Berliner named his hand-propelled reproducing instrument the "Gramophone" and demonstrated it to the Franklin Institute in Philadelphia in May, 1888. A German toymaker was licensed to make miniature Gramophones in 1889. It was not until 1893, however, after a satisfactory method of producing a stamping matrix for hard rubber records, that Berliner felt he could offer the Gramophone for sale. The United States Gramophone Company was organized by Berliner with the help of friends and relatives. A hand-propelled Gramophone selling for $12 was introduced along with several more expensive electrically powered models.

Fred Gaisberg was engaged to direct the recording activities for the company. He had been a talent scout and accompaniest for the Columbia Phonograph Company. Seven-inch (177.8-mm) discs recorded on one side were issued on a monthly schedule for sale in the District of Columbia. Berliner hoped to encourage financial interests

to invest in the company so that a national sales effort could be made. In the fall of 1895 a group of Philadelphians headed by Thomas S. Parvin provided $25 000 to set up the Berliner Gramophone Company of Philadelphia as a manufacturing unit. Parvin became the president of the company with Berliner a minority stockholder. Berliner's basic disc phonograph patents were held by the U.S. Gramophone Company. The Berliner Gramophone Company's operations were at 1026 Filbert Street and 424 South 10th Street in Philadelphia. The latter was the recording studio, but the complex processing of matrices was done by Berliner's Washington facility.

The hand-propelled Gramophone could not maintain constant pitch during playback. Sales were poor and by February, 1896, it was realized that the instrument would have to adopt a spring-wound motor similar to that used by cylinder machines. A design for a clockwork motor originally intended for sewing machines was submitted to machine shop operator Eldridge R. Johnson of Camden, New Jersey, for the construction of a model. The design proved impractical and was turned down by Berliner. Johnson was attracted by the Gramophone just the same. He later wrote, "It sounded like a partially educated parrot with a sore throat and a cold in the head, but that wheezy instrument caught my attention and held it fast and hard. I became interested in it as I had never been interested in anything before." Johnson turned from his wire-stitching machine business and borrowed sufficient capital to develop a satisfactory spring motor for the Gramophone. It operated at uniform speed, could be regulated, was quiet in operation, and was inexpensive to make and easy to use. It has been estimated that between 1896 and 1900 a little less than 25 000 motors were made. From 1896 to the summer of 1898, Johnson made motors, sound boxes, and metal parts, and delivered completed instruments to Berliner Gramophone.

The Berliner Company was inexperienced in promotion and marketing so they signed a contract with New York advertising man Frank Seaman. The Gramophone's future was to be in the hands of three separately owned and managed companies. Seaman's National Gramophone of New York was in charge of advertising and selling, the Berliner Gramophone Company of Philadelphia manufactured instruments and records, and the United States Gramophone Company in Washington controlled the patents. The hand-propelled instruments offered at $15 were joined in November, 1896, by the Johnson built Gramophone selling for $25. The latter soon outdistanced their $50 cylinder machine competition.

Fig. 1. Emile Berliner, inventor of Gramophone.

By 1898, National Gramophone's sales had topped the million mark, and Johnson's shop had a $40 000 profit. Frank Seaman's sales manager, William Owen, was sent to London to sell European rights to Berliner's patents. When this did not work out, Owen resigned and joined with Trevor Williams, an Englishman, to form the Gramophone Company, Ltd., to sell Berliner records and Johnson's improved Gramophone. Fred Gaisberg went to London to set up recording facilities; and Joseph Berliner, Emile's brother, established a record pressing and phonograph assembly plant in Hannover, Germany, that was ultimately to become the Deutsche Grammaphon A.G.

The wax cylinder companies, the American Graphophone—Columbia Phonograph combination in particular, were concerned with the success of disc records and began a legal attack against National Gramophone and Frank Seaman. Meanwhile, friction developed with the Gramophone companies as Seaman was not satisfied with his markup. The Berliner Company and Johnson refused to produce an inferior product, so Seaman formed the Universal Talking Machine Company to produce a less expensive model of the Gramophone, calling it the Zonophone. Seaman put his sales effort behind the Zonophone, and Gramophone sales in the U.S. suffered. However, those of the Gramophone in England continued to boom. Since April, 1896, Johnson had been working on an improved method of recording. Rather than the Berliner etching process for producing the master matrix, the original lateral cut recording was made in a flat wax disc. A fine electroplated matrix was formed on the disc, and multiple male stampers were produced for record pressing. The introduction of the new process which produced recordings superior to both the cylinders and Berliner discs was postponed due to uncertainties of the legal suits and Seaman's actions.

Early in 1900, Seaman obtained an agreement with American Graphophone and with Columbia Phonograph to use the Bell-Tainter "floating" stylus in the manufacture of the Zonophone. Berliner regarded Seaman's manufacture and sales of the Zonophone as a forfeiture of the Berliner-Seaman exclusive sales contract and, in June, refused to sell him additional machines. On June 25th, based on the contract, Seaman secured an injunction which forbade all other sales by Berliner and his Gramophone Company. This effectively took Berliner out of the record business in the U.S. and left Johnson with a new factory, $50 000 worth of Gramophones, and no customers.

THE BEGINNING OF VICTOR

In August, 1900, Leon F. Douglas, who had grossed $33 000 with an Edison Exhibition Model at Chicago in 1878, joined with Johnson (Fig. 2), and they formed the

Consolidated Talking Machine Company. The first recording, listed as number A-1 in Johnson's matrix log, was a recitation by George Broderick of Eugene Field's poem "Departure." It was recorded at the 10th Street studio in Philadelphia in May, 1900. The new Johnson recording process was used for making the record matrices, and an improved Gramophone was introduced. The "His Master's Voice" painting of Nipper by Francis Barraud, which had been purchased by the Gramophone Company, Ltd., in England and copyrighted in the U.S. by Emile Berliner, was used in Consolidated's catalog and advertising. Nipper and the improved Gramophone were to become the most widely used and recognized trademark in the world.

Johnson introduced paper record labels which replaced the indented legends on Berliner and Zonophone discs. Later in 1900 the company name was changed to Eldridge Johnson Manufacturing Machinist, and in December the trade name "Victor" was introduced for instruments and 7-inch (177.8-mm) records. At least four sources have been cited for the name Victor: first that it was taken from Leon Douglas' wife's name, Victoria; second that it came from the name of a popular Victor bicycle; third that a Johnson sound reproduction was the victor in competitive tests; and fourth that Johnson had been the victor over Frank Seaman. The trade name "Monarch" was used for 10-inch (254-mm) records and the top-of-the-line talking machines.

By the fall of 1901, Johnson's disc records had made serious inroads on wax cylinders, which had been recognized by the trade and the public as the standard of quality. Discs were being sold through bicycle and other small shops, while the cylinders were sold by music stores. This changed when Wurlitzer, Grinnell, Lyon and Healy, and Sherman Clay, all large and influential music houses, accepted the Victor machines and records.

When the Berliner Gramophone Company whose sales had been nil for more than a year could not pay $350 000 for Johnson's interest, an agreement was reached to pool Berliner's and Johnson's patents and trademarks, and Berliner's manufacturing facilities, and form a new company to be know as the Victor Talking Machine Company. It was incorporated October 3, 1901, and organized October 5th with Eldridge Johnson, President; Leon F. Douglas, Vice President and General Manager; Thomas S. Parvin, Treasurer; A. C. Middleton, Secretary; and Horace Pettit, General Counsel.

Fig. 2. Left to right are: Leon F. Douglas, Vice President, and Eldridge R. Johnson, President, with Louis F. Geissler, General Manager, at the 1915 Convention of the National Association of Talking Machine Jobbers.

Instruments were assembled in the four-story factory at 120 N. Front St., Camden, using purchased cabinets. The recording laboratory remained at Berliner's 10th and Lombard location in Philadelphia. Records were pressed by the Duranoid Company until the Camden operation at 23 Market St. was begun in 1902. An agreement was made with Gramophone Company, Ltd., to purchase up to 50 percent of Victor's instrument output. The Gramophone Company would sell in the British Empire, excepting Canada and continental Europe. Victor would market in the rest of the world, with Berliner Gramophone of Montreal selling in Canada.

Emile Berliner received 40 percent of the stock in the new Victor Company. He did not actively participate in company affairs. He and, in turn, his son Edgar M., headed the Berliner Gramophone Company of Montreal and the Victor Talking Machine Company of Canada, Ltd., until their acquisition by RCA.

Although methods for mass production of cylinder records had been developed by 1901, Columbia saw the advantages of discs and in the fall of 1901 introduced the Columbia Disc Graphophone using lateral cut recordings. After threats, suits, countersuits, and the controversial Jones patent on the new recording process was issued to a former technician of Berliner but assigned to Columbia, a cross-licensing agreement put both companies on a common patent and on practically a common technical ground for record manufacture. This effectively limited competition to the quality of the record and the appeal of the repertoire.

The Victor record catalog, in common with Edison and Columbia, consisted mostly of military bands such as Sousa's, banjo soloists like Vess L. Ossman, recitations, and comic songs. There were no classical music or artists of any stature. In Europe the situation was developing differently. The manager of one of Gramophone's shops in St. Petersburg, Russia, suggested that leading singers of the Imperial Opera be recorded and sold as deluxe, more costly editions with special red labels. Fedor Chaliapin made the first Red Label records, and their success in Russia led the office in London to produce an extensive celebrity series. Gaisberg and Owen of the then Gramophone and Typewriter Company went to Italy in March, 1902, and heard at LaScala the new sensational tenor Enrico Caruso. He had previously made recordings for the Anglo-Italian Commerce Company and Zonophone, but agreed to record for Gaisberg. The ten records made in Milan with Johnson's improved recording process on April 11, 1902, were an artistic and commercial success. They were regarded as the first completely satisfactory Gramophone records yet made. The success of the celebrity recordings in Europe was noted in the U.S. by both Columbia and Victor. In April, 1903, Columbia

introduced its Grand Opera Records at a sales price of $2 for the 10-inch (254-mm) disc.

The first Victor red label, or Red Seal records were released in May, 1903. The records were from imported Gramophone Company matrices, including seven of the Caruso Milan recordings. There were also records by Calve, Plancon, and Renaud. The first domestic Red Seal recording was made in Room 826 at Carnegie Hall on April 30, 1903. The artist was an Australian contralto, Ada Crossley. Subsequent Red Seal artists recorded at Carnegie Hall were Louise Homer, Johanna Gadski, and Antonio Scotti. Caruso had made his Metropolitan debut in November, 1903. He was signed to an exclusive contract by Victor. Caruso's voice complemented the acoustic recording and playback processes. Caruso and the talking machine each contributed to the others' fame and success. Caruso's first American recordings were made in Room 826 on February 1, 1904.

Improvements followed in the instrument line (Fig. 3). The tapered tone arm and goose neck were introduced in 1903. Ball-bearing mounts enabled the sound box to track across the record with little resistance, needles could be changed easily, and the tapered arm provided improved acoustic coupling from the sound box to the horn. Sales in 1902 totaled $615 000 for instruments and $579 000 for records. In 1903 the instrument sales of $683 000 were surpassed by record sales of $742 000. On Sunday, April 21, 1904, a fire destroyed a large part of the four-story brick building in Camden used for instrument assembly. The loss was about $45 000, and it was reflected in a slight decrease in net profits for the year as increasing record sales offset the instrument loss.

Under Johnson's and Douglas' direction the company instituted and maintained an intensive and progressive advertising policy. Heavy use was made of both newspaper and magazine advertising. The expenditure in 1903 reached 5.92% of domestic billings. Advertising stressed the excellence and superior performance of the product, the pleasure and advantage of ownership, the availability of the world's best artists, and the idea of giving the products as gifts. A 1905 ad showed three pictures of opera artists and one of a popular artist, but stated, "Our business is just the other way and more too . . . three times more popular than opera; but there is good advertising in Grand Opera." To emphasize this, the world's largest and most expensive sign, shown in Fig. 4, was erected on a roof at 37th Street and Broadway in New York. The illuminated sign contained 1000 electric lights and was 40 feet (12 m) high and 50 feet (15 m) wide.

Calvin G. Child was the manager of the Victor Recording Laboratory. Harry O. Sooy was the chief recordist, and his brothers Raymond R. and Charles E. Sooy joined the staff in 1903 and 1905, respectively. Arthur Pryor was Victor's first musical director, but found it too confining and was succeeded by Walter B. Rogers.

A trade publication, "The Voice of the Victor," was introduced in April, 1906 (see Fig. 5). It kept dealers

Fig. 4. Giant sign erected in 1906 with opera-oriented advertising.

Fig. 5. Cover of Victor trade publication illustrating early growth.

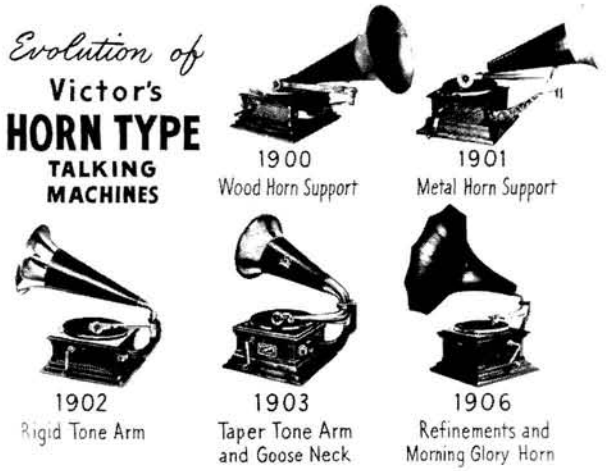

Fig. 3. Development of Victor External horn machines.

informed about new records, sales methods, and artist tours. This year saw the introduction of the enclosed horn talking machine. Although a form of the enclosed horn had appeared in Germany, Johnson desired a fine piece of furniture which would be accepted like a piano in living rooms and parlors where there was objection to the exposed horn. The new instrument was named "Victrola," and it sold for $200. It was an immediate success. The matrix and shipping departments were moved from Philadelphia to Camden, and the Victor cabinet factory was constructed along with a new building for executive offices and the recording laboratory. The first large Dennison Recording Machine was installed in the new laboratory and in January, 1908, a similar machine was installed in the New York recording studio, now located at 234 Fifth Avenue.

Victor's most ambitious recording session was held in New York on February 3, 1908, when Caruso and Scotti were joined with Sembrich, Severina, Daddi, Jacoby, and Journet for the "Lucia Sextette" and the "Rigoletto Quartet." All takes were rejected, but satisfactory matrices were made four days later. The price of single-sided Red Seal recordings depended upon the artist. The sextette recording sold for $7 and the quartet for $6. Caruso's 12-inch (304-mm) solo discs were $3 and his duets were $4. In September, 1908, Victor reluctantly announced it would begin the issue of double-faced popular artist black label records. This began with the 16000 series. Columbia Graphophone had forced Victor's hand.

THE GROWTH YEARS

As the first decade of the century closed, further improvements were made in the Camden complex. Total instrument sales from 1901 through 1910 were 606 596. In 1911, 124 000 instruments were sold. Horn-type machines accounted for 31 000, Victrola table models for 52 000, and large Victrola models for 42 000. Record sales from 1901 through 1910 were about 41 million for a dollar value of 15.3 million. Common stock at $100 per share was increased from 20 000 to 50 000 shares in 1911. Johnson held 50% of the stock, and most of the remainder was held by other company officials. A 6% dividend had been paid yearly since 1902.

In April, 1911, an educational department was established under the direction of Francis Elliott Clark. A program was developed which had the far-sighted objective of building a demand for recorded music by developing an early interest in music. An efficient organization was set up with graded lists of records; special records were recorded and presented; and the music appreciation program was given national attention.

Victor's artist roster additions during the period of 1910–1913 included George M. Cohan, Al Jolson, John McCormack, Mischa Elman, Fritz Kreisler, Alma Gluck, Victor Herbert, Jan Paderewski, Jan Zkubelik, Giovanni Martinelli, and the Flonzaley String Quartet. Dance records were much in demand. Advertising aids supplied to dealers featured dances promoted by Vernon and Irene Castle. Early in 1916 Calvin Child was appointed head of Victor's artist department and Joseph Pasternack, shown in Fig. 6, became musical director later in the year. Joseph C. Smith was also engaged and the Smith Dance Orchestra was Victor's leading dance orchestra until 1920. In October, 1916, Amelita Galli-Curci's first recordings were made. In January, 1917, the New York recording studio was moved to West 38th Street, and in February Charles Sooy successfully recorded the Original Dixieland Jazz Band after an initial recording had been shelved by Columbia. The recording of "Livery Stable Blues" and "Dixieland Jazz Band One-Step" (Fig. 7) became a big seller and influenced a new generation of musicians.

Victor had no reluctance in demolishing older facilities as needs for expansion arose. Johnson's original shop, shown in Fig. 8, was sacrificed when a new shipping building was constructed. Further additions were made to the cabinet factory, a new power house, a record pressing plant, a metal manufacturing building, and an executive office building were all completed by 1916.

The cabinet department in Camden had the reputation of having the finest staff of wood carvers in the world. There were about 125 men in this group. Much of the woodwork

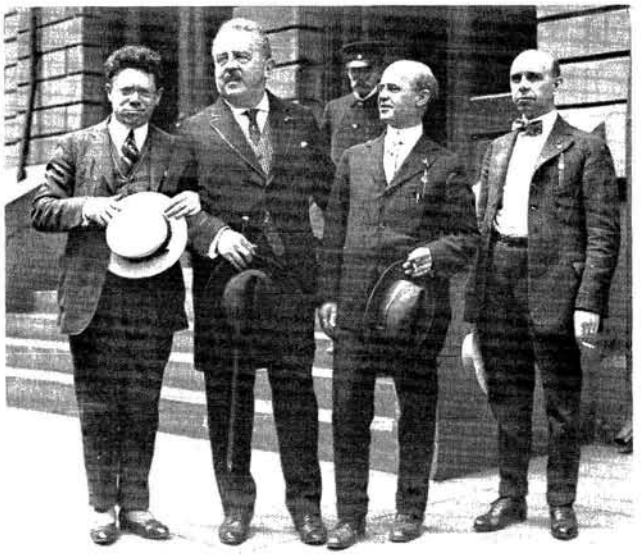

Fig. 6. Left to right are: Joseph Pasternack, Victor Herbert, Charles Sooy, and Raymond Sooy at the Camden Recording Laboratory.

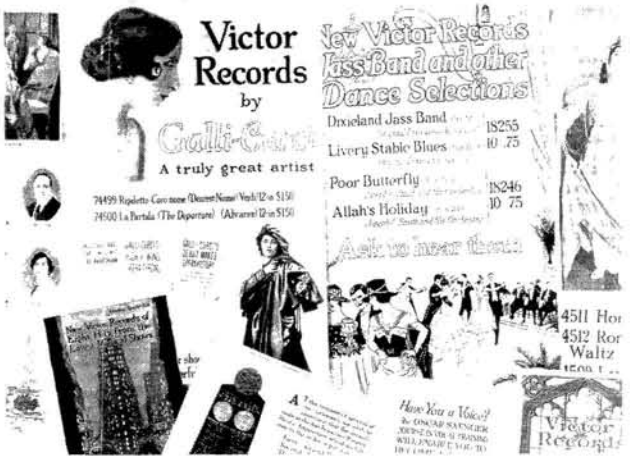

Fig. 7. Typical Victor advertisement in 1917.

for the lower priced instruments was done by machinery, but the higher priced cabinets were finished with great care. The latter process took from 18 to 24 days. An assembly line operation similar to that used in auto production was established. A system of overhead and roller conveyers moved completed cabinets to the shipping department where they were met by motor board assemblies from the metal parts plant. After assembly and performance checks, the conveyor continued to the packing section where the instruments were put in veneered cases, closed by an automatic nailing machine, and sent down to the shipping platform. At busy times, twenty box cars would be loaded in a day. Complex shipping schedules were set up to ensure simultaneous delivery across the nation. At Christmas time shipments to the big Eastern markets were very heavy. A train of 10 or more cars was shipped to New York as late as 10 or 11 o'clock on Christmas Eve with company representatives riding the train to ensure delivery across the Hudson for customers on Christmas day.

THE WAR YEARS

The entry of the United States into World War I in April, 1917, had a great impact on the company; however, some notable firsts in recordings were made during that year. Under the direction of Joseph Pasternack, symphony orchestra recordings were made using 51 musicians. It was necessary to use the auditorium on the 8th floor of the Executive Building in Camden to accommodate the orchestra. Based upon the successful recording of the Victor Symphony Orchestra, the initial recordings by the Boston Symphony under the direction of Karl Muck and the Philadelphia Orchestra under Leopold Stokowski were made in October, 1917. In November, Victor made Jascha Heifetz's first recordings. In order to accommodate large orchestras, the company purchased the Trinity Baptist Church building located three blocks from the main plant. The new studio gained renown because of its pipe organ and fine acoustics.

The Victor Talking Machine Company's participation in the war effort was multifaceted. About 1200 men served in the armed forces. Records and instruments were in demand as morale boosters. The recording artists participated in bond sales, and the skilled workers were called upon to make aircraft parts and assemblies, rifle stocks and parts, shell parts and assemblies, detonator cases, and other war materials. In 1918, instrument production was cut by government order to 70%, then to 40% of 1917 production. In actual practice it fell to 10%. Victor apologized for its dealers through ads like the one shown

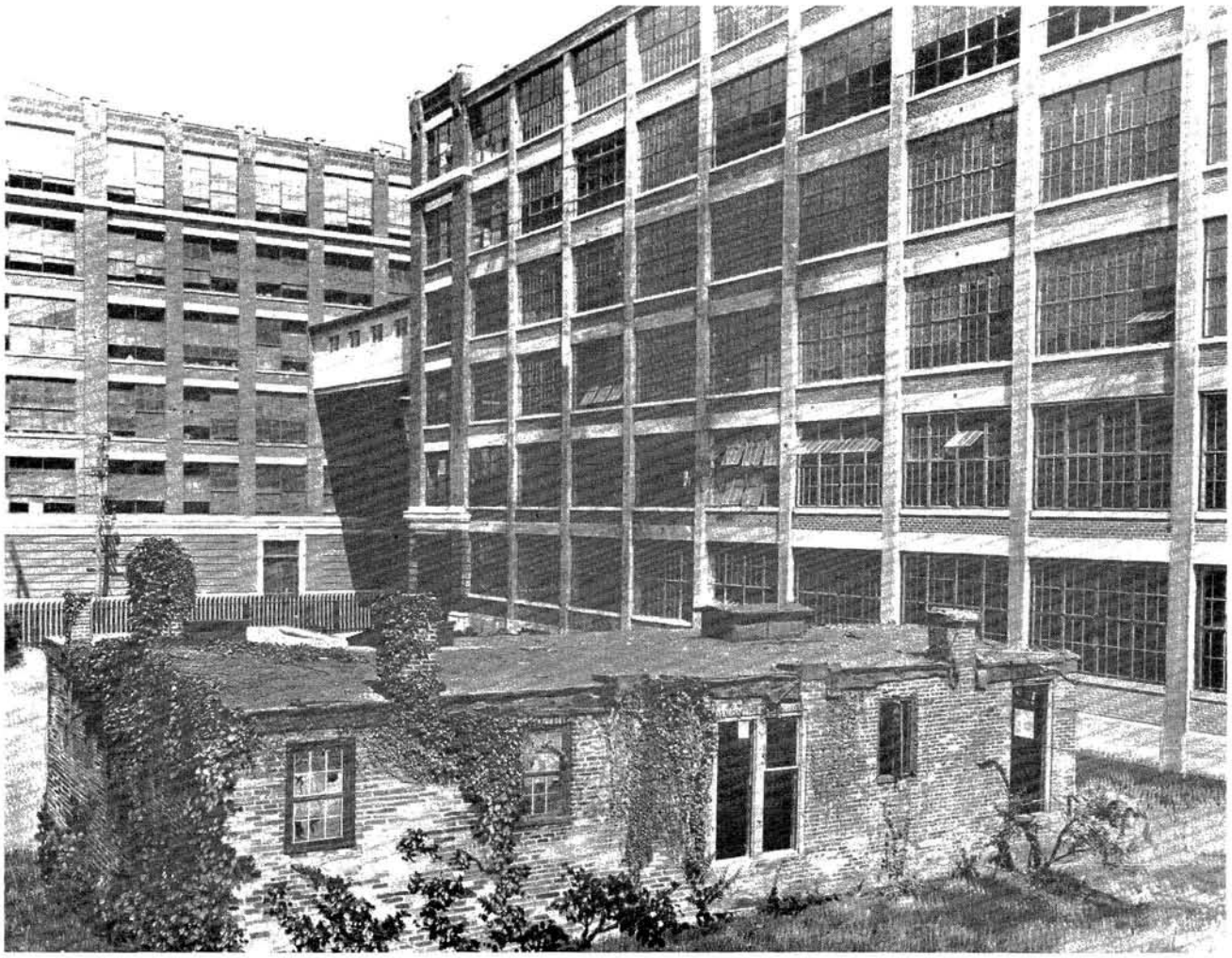

Fig. 8. Johnson's original machine shop with 1915 Victor plant in the background.

in Fig. 9. In addition to a general excise tax of 3%, an extra 5% tax was added to instruments and records. After the war normal production was not reached until October, 1919. Back orders of $200 million were listed after the war, but this amount was probably inflated.

Sergi Rachmaninoff, who had made several recordings for the Edison Company, became an exclusive Victor artist in 1920 and remained with the company until his death. Recording activities in Camden during 1920 included Toscanini and the LaScala Orchestra and Paul Whiteman's initial recordings. After four takes for "Japanese Sandman" and nine takes for "Whispering," a million-selling record was produced.

Enrico Caruso made his last recordings in Camden on September 16, 1920. His death in August, 1921, ended the career of the single artist who contributed most to the success of the Victor Company and the entire phonograph industry. His royalties amounted to $2 million at the time of his death and have since exceeded this sum.

IMPACT OF COMPETITION AND RADIO

Since 1917, Eldridge Johnson's participation in company affairs had been reduced because of his poor health. Instrument sales had peaked at 573 000 in 1917, dropped during the war years, recovered in 1920 to the 560 000 unit level, but dropped to 320 000 in 1921. Victor's competitors, Brunswick and Sonora, were producing flat-top cabinets with great appeal. Victor reacted first with the infamous humptop model and later with flat-top models.

Victor's magazine ads in 1924 featured recordings by Paul Whiteman, Will Rogers, Rosa Ponselle, and the Philadelphia Orchestra's recordings of Schubert's "Unfinished Symphony" and Rachmaninoff's Concerto No. 2. Vying for public attention were ads for radio and radio accessories. Sonora and Brunswick were offering radioacoustic combinations. In 1923, Victor provided an empty compartment in which a customer could insert his own radio. Although Victor did not offer mass-produced radios, it had the foresight to design and produce in 1923 the Victor VV-R-80 radio. About 20 sets were built and sold in interstate commerce to protect the Victor name and trademark in radio. The conventional Victrola console cabinet was used with the radio mounted in the turntable space. The loudspeaker used the normal phonograph horn.

Don't blame the dealer
for the shortage of Victor products
– the Government needed us!

Victor Talking Machine Company
Camden, N. J.

Fig. 9. Advertisement published explaining war-induced shortages of Victor products to help dealers.

Radio sales jumped from $60 million to $350 million in two years. Victor's sales dropped $10 million, or 20%, in 1923 because of the console craze, and they were being further eroded by radio. By the fall of 1924, for the first time in Victor history, sales to the public failed to materialize as anticipated. Sales were subnormal all fall, and even at Christmas heavy inventories existed at the dealers, the distributors, and the factory. Management decided to complete fabrication of partially assembled units, and then instrument manufacture was stopped. A massive sales campaign was initiated. Victor's advertising budget of $5 million was the highest of any company. The sales effort was partially successful in reducing the instrument stock. To assist in the campaign, Victor sponsored on January 1, 1925, its first radio broadcast over a network of 14 stations. The program featured Lucrezia Bori and John McCormack.

ELECTRICAL RECORDING

The phonograph industry had introduced little basic technological innovation to improve its product. Victor had not completely ignored the possibility of electrical recording, but its effort was hardly up to the challenge. James Owens and Albertis Hewitt conducted electrical recording experiments in 1913. Hewitt's diary shows that he used an electromagnetic recording head for making recordings from radio and microphone sources. His approach was strictly trial and error.

Victor had been cool to an offer made early in 1924 by Bell Laboratories to demonstrate Maxfield and Harrison's achievement in electrical recording and improved acoustical playback equipment. By December, however, an arrangement was made for a demonstration in Camden for the entire technical staff. Both Victor and Columbia obtained rights for electrical recording and the re-entrant horn acoustical playback system.

Maxfield was in Camden in late January, 1925, working with Raymond Sooy in making arrangements for the new recording equipment, which was delivered on February 2. The first experimental recording was made a week later. Olga Samaroff and Alfred Cortot were among the first artists to make Red Seal electrical recordings, beginning on March 11. The first popular artist electrical recording was made on March 16 by the Mask and Wig Club Male Quartet and Orchestra. The first electrical recordings made in New York were recorded on July 31, 1925. Victor called the new process "Orthophonic Recording." A number of the new recordings, including "March Slav" by the Philadelphia Orchestra, were chosen for demonstration of the Credenza Orthophonic Victrola, a hand-wound acoustic talking machine with re-entrant horn. Management ordered 10 000 instruments to be built. This model sold for $300 and was the primary demonstration

machine. A total of 19 other models were introduced in 1925 to be followed by 24 more in 1926. Victor had signed with RCA for radio chassis and electrical playback apparatus. One of the most elaborate models, dubbed the "Orthophonic Victrola–Orthophonic Electrola and Radiola," could play records acoustically or electrically, contained an eight-tube superheterodyne radio, and had a list price of $1000. The new instruments and recordings received wide public acceptance, and by the end of 1926, the working loss of $6.5 million suffered in 1925 had been fully recovered.

In June of 1926, the Philadelphia Orchestra made its first recording at the Academy of Music, its home (Fig. 10). During the next few years, the orchestra under Stokowski set a world standard for recorded sound.

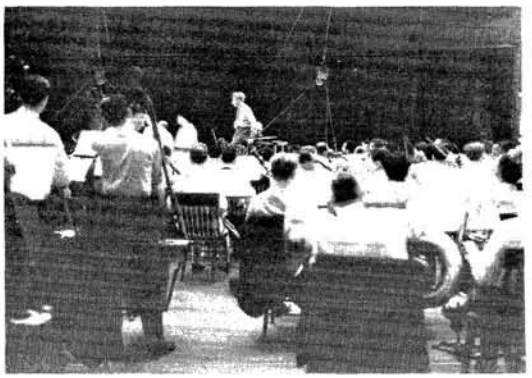

Fig. 10. Leopold Stokowski and Philadelphia Orchestra at an early electrical recording session at the Academy of Music.

THE FINAL YEARS OF VICTOR TALKING MACHINE COMPANY

In December, 1926, it was announced that Eldridge Johnson was selling his interest in the Victor Talking Machine Company to a group of bankers, Speyer and Company, and J. & W. Seligman of New York. Johnson and those close to him received $30 million. Johnson's reasons for selling his interests included his health, which did not permit him to devote as much personal attention as he would have liked. Johnson remained fairly active in civic, political, and philanthropic endeavors, and sponsored and participated in several scientific expeditions using his private yacht. He lived until November, 1945. Eldridge Johnson's inventiveness and business sense had developed the wheezy instrument and noisy discs of the 1890s into a product line that through 1929 resulted in the production of nearly 8 million instruments and more than one half billion records.

E. E. Shumaker, former purchasing agent and director of the company, became the new Victor president. In March, 1927, the first phonograph with an automatic record changer was introduced. Victor's sales from 1926 to 1928 were among the best in the company's history. Over 400 000 instruments were sold each year. Many new dance bands had joined Whiteman as Victor artists during the late 1920s, including Fred Waring, Jan Garber, Johnny Hamp, Ted Weems, Coon-Sanders, George Olsen, and Roger Wolfe Kahn. Jazz-oriented artists included Jean Goldkette, Bennie Moten, Ben Pollack, Jelly Roll Morton, Duke Ellington, and Fats Waller. Gene Austin and Vernon Dalhart were popular vocal artists. Nathaniel Shilkret was the principal conductor of the Victor Orchestra and accompanied many vocalists. Portable electrical recording gear was used in the summers of 1927 and 1928 for sessions in Tennessee, Virginia, North Carolina, and Georgia, where new artists such as Jimmy Rogers, the Carter Family, and Blue Steeles' Orchestra were recorded. Other new Victor artists in the late 1920s included Pablo Casals, Paul Robeson, Ezio Pinza, Lawrence Tibbett, Richard Crooks, the Chicago Symphony, and Vladimir Horowitz.

On March 15, 1929, the Victor Talking Machine Company was acquired by the Radio Corporation of America as a manufacturing facility. The Victor stockholders accepted a plan which offered for each share of Victor stock one share each of RCA preferred and common stock plus $5 in cash.

The Victor Talking Machine Company in slightly less than thirty years made a major impact upon home entertainment through the sale of nearly $700 million in instruments and records. It had spent $52 million for advertising, provided good jobs for 10 000 workers, and at least thirty individuals received investment returns of over $1 million. The merger with RCA enabled Victor records to weather the lean depression years better than any other recording company.

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[2] B. L. Aldridge, *The Victor Talking Machine Company* (RCA Sales, 1964).

[3] *The Voice of the Victor* (Trade Journal, 1906–1929).

The Technology of the Record Industry Perfection Without Notice.....

by WARREN REX ISOM

"How can you stay in the record business?" This question has often been posed to those working in engineering departments of record companies. The attitude of those asking the question is that since records have been made for nearly 100 years and their quality is excellent, there can not be anything new or challenging in record engineering. The question and its underlying compliment reflect the success of the advances which have occurred in record making technology: to succeed is often to go unnoticed.

In answering the question, one must explain that the technology encompasses six professional and engineering fields and roughly ten areas of specialization. Each of the specialty areas may be covered professionally by one or more engineering or scientific disciplines. Depending on the size of the organization and other factors, these several disciplines may be represented by one or more people. For a matter of record, the engineering fields include: acoustical, architectural, chemical, electrical and electronic, mechanical, and musical. The areas of specialties are listed as recording microphones, loudspeakers, studios, magnetic recording, record manufacturing, record materials, phonograph pickups, record players and changers, phonograph electronics, and styling and performance. These specialties are covered in this section.

The alpha and omega of the record is the recording microphone and the loudspeaker. More emphasis is given to these two elements than any of the others. Of the two, microphones seem to have the tactical advantage. They can move in close or, if need be, to a more distant advantageous position. The most important contrast between the two elements is that the recording engineer can pick and choose, place, and shield or expose any number of microphones of varying characteristics for use in a session. For loudspeakers, he has, in the end, a limited choice of type and placement, and—worse yet—little knowledge of what these choices might be. This statement is particularly true as far as the listening area of the general consumer is concerned. The performance of this unknown quantity is the final and all-important link in the success or failure of the recording.

When the loudspeaker is defined as this unknown quantity from which the sound is heard, it follows that the loudspeaker is the weakest link in the reproduction of recorded sound. It is indeed disconcerting not to expect a design breakthrough, because a cure-all is needed—even though it is not expected. This is not to deny that for many years the performance of the loudspeaker in terms of frequency response, sensitivity, coloration and all other characteristics of loudspeaker excellence have given the accuracy of presentation by which the other components of sound reproduction systems are consistently judged.

Before pitying the poor loudspeaker, let us look again at the other end of the chain. Not only can microphones be chosen for their needed special performance patterns, but they can be given the ultimate in favoritism by being assigned to a separate recording channel and track on the tape. This permits the performance of the microphone to be tailored and polished separately by the electronic wizardry of the recording and mix-down consoles. What can be done for the loudspeaker? It must take what it is given. What can be done about the loudspeaker? Nothing. You must take the best you can get even if it is too large. That is the result of the "black magic" that has begotten confusion among buyers of loudspeakers for generations.

In the last few years, the *Journal of the Audio Engineering Society* has been replete with articles on the general subject of computer design of loudspeakers. Programs have been worked out by which the performance of loudspeakers can be specified and obtained. Mr. Eargle in his article in this issue lauds this change from the "cut-and-try" methods of the past. The end of black magic is always the beginning of a new freedom.

It is expected that in the near future a buyer will be able to acoustically and dimensionally describe the area in which he wants to listen to a loudspeaker. A sales person will enter the information into a computer and the read-out will list in the order of price, performance, and size, the loudspeakers designed for such an area. The buyer can then listen and choose with full confidence. The solution has many advantages for all concerned. The recording engineer is relieved of the uncertainty of the response patterns of the unknowns designed by black magic. It will be as simple as walking into a store and saying: "I want to buy a pair of stereo loudspeakers for my study, which is $14' \times 16' \times 8'$ with an acoustical tile ceiling, papered walls and medium-weight lined drapes at the two windows. There is a door, normally opened, on the wall adjacent to that on which the loudspeakers will be mounted. I listen while seated at my desk. Please include mounting instructions."

This will be a giant step in the right direction but it will not go all the way. The loudspeaker will still have the most difficult task in the entire recording chain to perform.

The microphone can be given the advantage of close placement and be equal to the acoustic task set before it. The loudspeaker is confronted with the dominating acoustics of the listening area. The next step is to give the loudspeaker or stereo loudspeakers, some relief. The relief presently in sight is four channel sound, for four loudspeakers are better able to cope with the acoustic disparity; certainly doubly so and perhaps quadruply.

Another situation in record making technology is the relationship between record materials and the phonograph pickup. The loudspeaker has been assigned the most difficult job to do in the reproduction of recorded sound; the phonographic pickup has the second most difficult assignment. Its burden is that maximum performance is expected for minimum cost. Also, like the loudspeaker, its performance limits the system. However, it has less tactical disadvantages than the loudspeaker because a universal pickup is conceivable while a universal loudspeaker is unthinkable.

So far as the record material is concerned, the pickup is a high-powered microscope looking for every flaw and defect in the record. In the limiting case of 45-kHz response from a record with an average groove speed of 12 inches per second, the wavelength is 0.00026 inches. This is equivalent to looking for a surface discrepancy of one-quarter of an inch in a highway 83 feet wide. While the vinyl material does not now have the margin of performance it once enjoyed, it is still a front-runner among the components of a playback system.

Today the quartz crystal-controlled drives for turntables and tape recorder capstans have reduced wow and flutter readings to near the vanishing point. These new techniques just now coming into full use have given time base stability in terms of microseconds and speed accuracies of less than one revolution per month. The residual time errors present in the sound reproduced from phonographic records are the result of manufacturing tolerances prescribing limits on the size of the center hole of the record and its location, the limits on the size and location of the turntable record spindle, and the roundness of the record which can be affected by the differential cooling of the record as it comes from the press. For tape machines, the tape handling parts are also manufactured to tolerances, near perfect but to limits nevertheless. Even so, for practical considerations, the present reproduction of sound has a near perfect score for its time-based performance.

The worldwide energy crisis will center its impact on records in the area of manufacturing. There is good reason to believe that the energy required to manufacture records can be reduced by a factor of five. This cannot be achieved by economy or by refinement of the present processes and methods, but only by taking a different approach. For all practical purposes the record would be the same, only the manufacturing process would be different. Cost considerations and investment justifications are involved in the decision making. The present method uses energy with the abandonment that was stylish until 5 years ago.

Most of the improvements depend upon ideas of the future but occasionally an idea of the past can be recycled and again become a part of the technology. It was a great day for records in August, 1900, when Eldridge Johnson introduced paper labels on records, replacing the previous embossed ones. It may have been, though, an even greater day for records when, on December 1, 1967, the French operation of the Polygram Company began issuing records once again embossed with the label information, thus saving paper. This process is slightly more elaborate than the one used by Berliner. The Polygram embossed area is overprinted directly with color. The photograph (Fig. 1) of the center plate of the stamper from which the label information is embossed on the record was supplied by Han Tendeloo of the Polygram B.V. technical staff. Just as today's embossed label is the result of recycled technology of the past, it would not be surprising to see the laminated record technology recycled for use during the energy-conservation future.

The fourth important step in the evolution of the disc talking machine was the introduction of magnetic recording for original recordings. In less than 30 years it has become a crucial part of the technology of the industry. It released musicians, recording engineers, and producers from bondage to the old technology of recording directly on lacquer or wax discs. Without doubt, it introduced the practice of progressive recording sessions based on the use of multitrack tape machines. As important as it is for records, what it has given the electronics industry worldwide is even more significant. The introduction of magnetic tape to the industry is one of the great contributions of audio engineering and the record industry.

One of the secondary effects of the flexibility of magnetic recording and the advance in electronics based on new circuitry is the decentralization of studio ownership. There is a transition from record company ownership to private producer ownership. The overall effect of this change is expected to be seen in the increased creativity on the part of the artists.

The technology is dynamic. Progress is constant with record players and changers, amplifiers and other electronics; and change is the order of the day in styling. Performance generally is so good that it is taken for granted. Clearly, the technology is being perfected without notice.

Fig. 1. Embossed label of a 45 single over-print with color has two great advantages.

Microphones for Recording

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The sound pickup means during the first half-century of the record industry employed an acoustomechanical system. The microphone, vacuum tube amplifier, and disc cutter initiated electrical recording at the beginning of the second half-century. The historical development, the present status, and the possible future course of the sound pickup means, and in particular the microphone, as related to the record industry are presented.

INTRODUCTION: The record industry employed an acoustomechanical system for recording and a mechanoacoustical system for reproducing during its first half-century. The advent of the microphone, electronic vacuum tube amplifier, electrical disc cutter, phonograph pickup, and loudspeaker initiated electrical recording and reproducing at the beginning of the second half-century of the record business. The purpose of this paper is to describe the historical development, the present status, and the possible future course of the sound pickup means, and in particular the microphone, as related to the record industry.

ACOUSTOMECHANICAL RECORDING AND MECHANOACOUSTICAL REPRODUCING SYSTEMS

In order to provide a complete history of the sound pickup means in the record industry, a brief description of the sound pickup system for acoustomechanical recording together with the mechanoacoustical reproducing system follows.

The acoustomechanical system for recording the cylindrical record is shown in Fig. 1. The sound waves produced by the sound source are picked up by the horn. The net result of the transformer action of the horn is an increase in the sound pressure at the diaphragm. The diaphragm is coupled to the stylus. The cylindrical record is turned at a constant speed by a motor[1]. The motion of the stylus produces vertical modulations in the helical groove of the cylindrical record which correspond to the pressure variations in the sound wave produced by the original sound source.

The mechanoacoustical system for reproducing the cylindrical record is also shown in Fig. 1. The record is turned at a constant speed by the motor[2]. The vertical modulations in the helical groove drive the stylus. The motion of the stylus is transferred to the diaphragm. The vibrations of the diaphragm produce sound waves which are transmitted by the horn to the surrounding space. The resultant sound waves correspond to the sound waves produced by the original sound source.

The acoustomechanical recording system and the mechanoacoustical reproducing system employing the cylindrical record were invented and demonstrated by Thomas A. Edison in 1877 [1], [2].

The cylindrical record system [1], [2] was produced by Thomas A. Edison well into this century. However, it was rapidly being replaced by the disc record at the turn of the century.

The acoustomechanical system for recording the disc record is shown in Fig. 2. The sound waves picked up by the horn are transferred to the diaphragm. The diaphragm is coupled by means of a lever to the cutting stylus. The turntable with the wax record is turned at a constant speed by the motor[1]. The motion of the stylus produces lateral modulations in the spiral cut groove of the wax record which correspond to the pressure variations in the sound wave produced by the original sound source.

The original wax record is electroplated. The electroplating is separated from the wax record and secured to a

[1]. The motor for recording has employed for actuation a hand crank, a governor controlled spring, a governor controlled weight and electric means.

[2] The motor for reproducing has employed for actuation a hand crank, a governor controlled spring and electric means.

heavy plate. This assembly serves as a stamper. The stamper is used to press thermoplastic records which are replicas of the original wax record. In later production techniques [3] two more electroplating steps were added so that many stampers could be obtained from an original wax record.

The mechanoacoustical system for reproducing the disc record is also shown in Fig. 2. The record is turned at a constant speed by the motor[2]. The lateral modulations in the spiral groove drive the stylus. The motion of the stylus is transferred to the diaphragm by means of the lever. The vibrations of the diaphragm produce sound waves which are transmitted by the horn to the surrounding space. The resultant sound waves correspond to the sound waves produced by the original sound source. Even after the advent of electrical recording and reproducing in the mid-1920s the mechanoacoustical phonograph continued to be produced in large quantities [1], [2] up to the mid-1930s.

The acoustomechanical disc recording system and the mechanoacoustical disc reproducing system were invented and demonstrated by Emile Berliner [1], [2] in 1887.

Around the turn of the century Emile Berliner, Eldridge Johnson, and others developed [1], [2] practical and commercial acoustomechanical disc recorders, a process for the mass production of disc records, and mechanoacoustical reproducers. All these factors led to the great success of the disc record business in the third quarter-century of the industry. Thomas A. Edison, inventor and producer of the cylindrical record, adopted the disc system [1], [2] in 1910, but with vertical modulation.

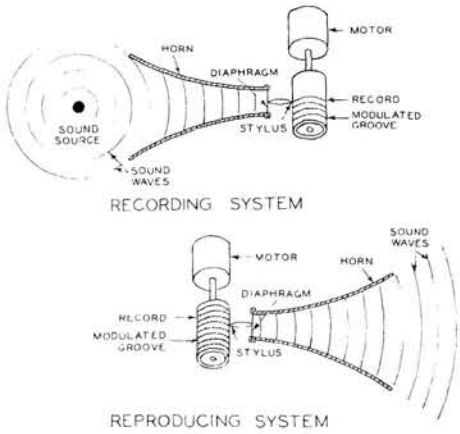

Fig. 1. Acoustomechanical recording and mechanoacoustical reproducing systems for cylindrical records.

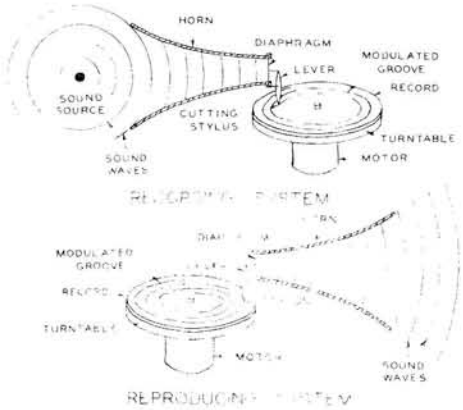

Fig. 2. Acoustomechanical recording and mechanoacoustical reproducing systems for disc records.

ELECTRICAL RECORDING SYSTEM

By the mid-1920s the development of the condenser microphone, the electronic vacuum tube amplifier, and the electrical disc cutter [4] provided the means for the electrical recording of disc records. The advent of electrical recording made it possible to record all voices and musical instruments because there is no limitation on the strength of the sound sources as contrasted to acoustomechanical recording in which only powerful voices and musical instruments can be recorded. The purpose of the sections which follow is to outline the past, present, and future of microphones in the record industry. In view of the complete paper entitled; "The History of High Quality Studio Microphones"[5], only the more significant microphones employed in the record industry will be included in this paper.

CONDENSER MICROPHONE

The first wide-frequency-range condenser microphone [6], [7] was developed in the late 1910s as a standard of measurement. With the advent of radio broadcasting in the early 1920s the condenser microphone was commercialized to supply the requirements for a high-quality microphone. With the inception of electrical recording in the mid-1920's the microphone was used for the sound pickup.

The commercial version of the condenser microphone is shown in Fig. 3. The vibrating system is stiffness controlled. Under these conditions the amplitude of the diaphragm is independent of the frequency for constant sound pressure on the diaphragm. The overall diameter of the condenser microphone is 3 inches, (76 mm). The diameter of the diaphragm is 1.5 inches, (38 mm). The capacitance of the condenser microphone is 300 picofarads. In order to maintain response to 30 hertz, the combined resistance of the polarizing and bias resistors must be at least 50 megohms. In view of the small capacitance of the condenser microphone the amplifier must be located next to the microphone unit.

Typical amplifier enclosures are shown in Fig. 4. One-, two-, and three-stage vacuum tube amplifiers are used with the condenser microphone.

The directional characteristic of the condenser micro-

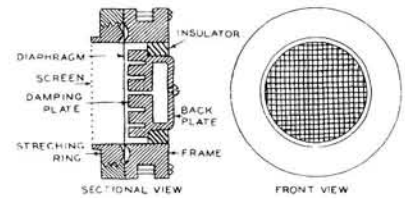

Fig. 3. Sectional and front views of a typical condenser microphone commercialized in the early 1920s.

phone is the omnidirectional pattern of Fig. 5**a**. The large size of the condenser microphone introduces diffraction effects [8] which increases the sound pressure on the diaphragm above 2000 hertz. As a result the microphone is directional in the high-frequency region.

The condenser microphone shown in Fig. 3 was commercialized in the early 1920s and designated as the Western Electric 394 condenser microphone and the RCA 11A condenser microphone.

DYNAMIC MICROPHONE

The first high-quality dynamic microphone [9] shown in Fig. 6 was developed and commercialized in the late 1920s and designated as the Western Electric 618-A moving-coil microphone. The vibrating system is resistance controlled. Under these conditions the velocity is independent of the frequency for constant sound pressure on the diaphragm. Since the open-circuit voltage is the product of the velocity of the voice coil, the length of conductor in the voice coil, and the magnetic flux in the air gap, the voltage output is independent of the frequency for constant sound pressure on the diaphragm. The electrical impedance of the voice coil is 30 ohms. This impedance makes it possible to transmit over long lines to the monitoring console without any loss or frequency discrimination.

The directional characteristic of the dynamic microphone is the omnidirectional pattern of Fig. 5**a**. The diameter of the microphone is 3 inches (76 mm). Due to the size of the dynamic microphone, diffraction effects occur in the frequency range above 2000 hertz, and the microphone becomes directional.

As a result of the simplicity of the dynamic microphone as compared to the condenser microphone and amplifier, the dynamic microphone proved to be more practical for many applications of disc recording employing omnidirectional microphones.

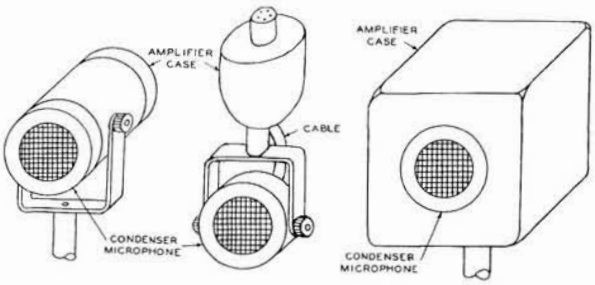

Fig. 4. Amplifier enclosures for condenser microphones.

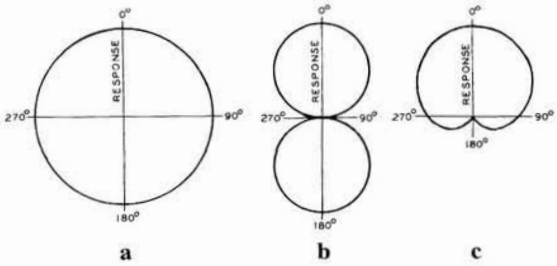

Fig. 5. Microphone directivity patterns. **a**. Omnidirectional. **b**. Bidirectional cosine. **c**. Unidirectional cardioid.

VELOCITY MICROPHONE

A pressure-gradient or velocity microphone is a microphone in which the response corresponds to the difference in sound pressure between two points in space. When the distance between the two points is small compared to the wavelength of the actuating sound wave, the pressure gradient corresponds to the particle velocity.

The velocity microphone [10] shown in Fig. 7 consists of a corrugated ribbon 1/10 mil in thickness, 3/16 inch in width (4.8 mm) and 2 inches (50 mm) in length suspended in a magnetic field supplied by a permanent magnet. The resonant frequency of the ribbon is about 12 hertz. Under these conditions the vibrating system is mass controlled above 20 hertz. The ribbon is driven by the difference in pressure between the two sides of the ribbon. This difference in pressure is proportional to the frequency. The velocity of the ribbon is the ratio of the actuating sound pressure and the acoustical reactance of the mass of the ribbon and the air load. This ratio is independent of the frequency for constant sound pressure in free space. The voltage output of the ribbon is the product of the length of the ribbon, the flux density in the magnetic field, and the velocity of the ribbon. Therefore the voltage output of the ribbon is independent of the frequency for constant sound pressure in free space. The electrical resistance of the ribbon is 0.25 ohm. A transformer is used to step up the impedance to 30, 150, and 250 ohms for transmission over a line to the monitoring console.

The directional characteristic of the velocity microphone is the bidirectional cosine pattern of Fig. 5**b**. The

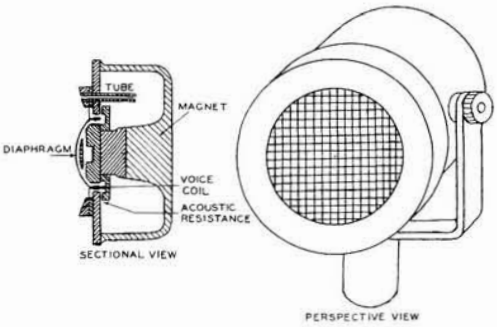

Fig. 6. Western Electric 618-A moving-coil microphone.

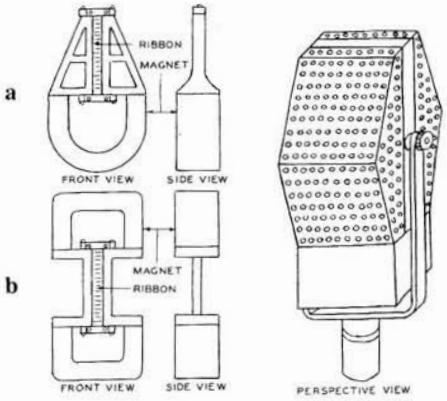

Fig. 7. RCA velocity microphones. **a**. RCA 44A. **b**. RCA 44B.

effective solid angle of sound pickup is one third that of an omnidirectional microphone. This means a reduction of 5 dB in effective sound pickup of reverberation and other undesired sound. The wide frequency range and directional characteristics have made the velocity microphone very useful in recording.

The RCA 44A velocity microphone shown in Fig. 7**a** was commercialized in 1931. The RCA 44B velocity microphone with improved magnetic structure and material and resultant higher sensitivity is shown in Fig. 7**b**.

UNIDIRECTIONAL MICROPHONE

A logical complement to the velocity microphone is the unidirectional microphone with the cardioid directional pattern of Fig. 5**c**. The unidirectional microphone [11], [12] shown in Fig. 8 consists of an omnidirectional pressure ribbon microphone and a bidirectional velocity ribbon microphone. A part of the ribbon is exposed to both sides in the manner of the conventional velocity microphone. The other part of the ribbon is coupled to a long acoustically damped pipe. The damped pipe presents an acoustic resistance to the ribbon, and as a result the pressure section is resistance controlled. The long damped pipe is folded and enclosed in the lower half of the microphone. A permanent magnet supplies the magnetic flux to the air gap as determined by the pole pieces. A transformer is used to step up the low resistance of the ribbon of 0.25 ohm to 30, 150, and 250 ohms for transmission over a line to the monitoring console.

The directional characteristic of the unidirectional microphone is the cardioid pattern of Fig. 5**c**. The effective solid angle of sound pickup is one third that of an omnidirectional microphone. This means a reduction of 5 dB in the effective sound pickup of reverberation and other undesirable sounds.

The RCA 77A unidirectional microphone of Fig. 8 was developed in 1931 and commercialized in 1933. The microphone was an instant success because the cardioid directional characteristic was a very powerful tool in sound pickup. The popularity of microphones with a unidirectional characteristic as depicted by the cardioid pattern of Fig. 5**c** has continued up to the present time. The unidirectional microphone is the most widely used microphone in recording.

SINGLE-ELEMENT UNIDIRECTIONAL MICROPHONES

A unidirectional microphone[13] consisting of a single dynamic element exposed to sound at both the front and the back of the diaphragm and appropriate acoustic elements to provide the cardioid directional pattern is shown in Fig. 9. Sound originating on the axis at the back of the microphone encounters a delay at the back of the diaphragm due to the inertance between the voice coil and pole and a delay at the front of the diaphragm due to diffraction. These two delays are made equal for sound arriving from the back. As a result the response is a minimum. For sound arriving from the front there is no delay at the front of the diaphragm. However, there are two delays at the back of the diaphragm, namely, due to diffraction and the inertance. As a consequence, the maximum response occurs for sound arriving at the front. For sound arriving at the side, the only delay is due to the inertance for sound arriving at the back of the diaphragm and the response is down 6 dB. The resultant directivity pattern is the cardioid characteristic of Fig. 5**c**. The microphone shown in Fig. 9 was developed and commercialized in 1941 and designated as the Shure Unidyne microphone.

A single-element directional microphone [14] employing a ribbon transducer coupled to an acoustically damped pipe with a variable aperture at the back of the pipe connector to the ribbon is shown in Fig. 10. When the shutter closes off the aperture as shown in Fig. 10N, the microphone is an omnidirectional pressure microphone. When the aperture is wide open as shown in Fig. 10B, the microphone is a bidirectional velocity microphone. With an appropriate small aperture as shown in Fig. 10U the microphone is a unidrectional microphone with the cardioid pattern of Fig. 5**c**. In the commercial microphone there are three more positions which provide three additional directional characteristics. For the sake of clarity these are omitted in Fig. 9. The microphone shown in Fig. 10 was developed and commercialized in 1941 and designated as the RCA 77C polydirectional microphone.

A directional microphone [15] employing an electrostatic transducer in the form of two diaphragms and a common back plate is shown in Fig. 11. Each diaphragm

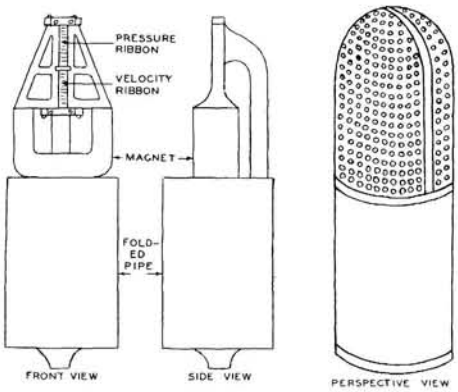

Fig. 8. RCA 77A unidirectional microphone.

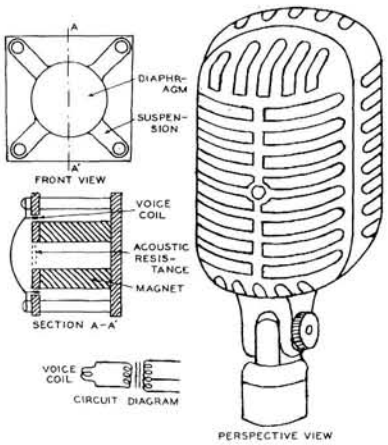

Fig. 9. Shure Unidyne microphone.

is spaced at a small distance from the back plate. The small spacing provides an acoustic capacitance and an acoustic resistance. The cavities behind the diaphragms are interconnected by small holes. The phase shifts in the vibrating system combined with the polarizing voltage provide means for obtaining all the directivity patterns shown in Fig. 5. With the potentiometer set at the full negative position, the bidirectional characteristic of Fig. **5b** is obtained. With the potentiometer set in the zero or midposition, the cardioid characteristic of Fig. **5c** is obtained. With the potentiometer set in the full positive position, the omnidirectional characteristic of Fig. **5a** is obtained. A vacuum tube amplifier is located next to the condenser unit as shown in Fig. 11. The microphone shown in Fig. 11 was commercialized in 1953 and designated as the Neumann M 49 microphone.

AXIAL AND UNIAXIAL MICROPHONES

Axial and uniaxial are terms applied to microphones in which the transducer is located at one end of a case essentially cylindrical in form. The term axial is applied to an omnidirectional microphone. The term uniaxial is applied to a unidirectional microphone in which the maximum sensititivy corresponds to the cylindrical axis of the microphone. By the early 1950s the trend in the design of microphones was toward the axial and uniaxial types. This style has continued to the present time.

A first-order gradient uniaxial microphone [16] with a unidirectional characteristic is shown in Fig. 12. The transducer consists of a ribbon terminated in an acoustically damped pipe with acoustic phase shifting networks. The two apertures in the folded pipe to ribbon connector form the portion of the phase shifting network so that the directional pattern will be of the unidirectional type. There are additional elements that contribute to the increased directivity, namely, the lobes, blast filter, and damped cavity between the magnets. The directivity is slightly sharper than the cardioid pattern of Fig. **5c**. The effective solid angle of pickup is one fourth that of an omnidirectional microphone. This means a reduction of 6 dB in the effective pickup of generally reflected sound. The RCA BK-5B uniaxial microphone of Fig. 12 was commercialized in 1954.

As mentioned in the introduction to this section, the trend has been toward axial and uniaxial microphones in which the transducer is located at one end of a case essentially cylindrical in form. There may be some deviation in which there are cylinders of two diameters with the transducer located in the part with the larger diameter or some other version as, for example, a slightly tapered case. Four typical microphones of the axial and uniaxial types will be described. These four types represent for the most part the present status of high-quality microphones used in recording.

An axial microphone of the dynamic pressure type with the omnidirectional characteristic of Fig. **5a** is shown in Fig. 13. The system is essentially the same as the Western Electric 618A moving-coil microphone shown in Fig. 6.

A uniaxial microphone of the dynamic unidirectional type with a cardioid directional characteristic of Fig. **5c** is shown in Fig. 14. The system is essentially the same as the Shure Unidyne microphone of Fig. 9.

A breakthrough in electrostatic microphones is the foil electret transducer [17]. The diaphragm consists of a thin plastic film that has been electrically charged to produce

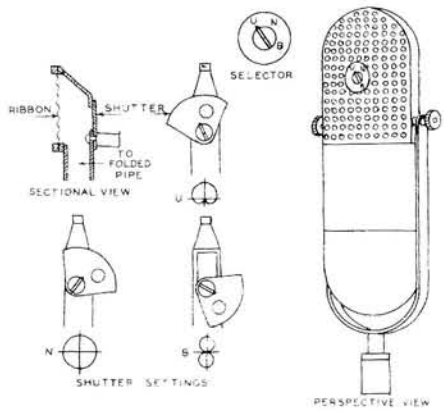

Fig. 10. RCA 77D polydirectional microphone.

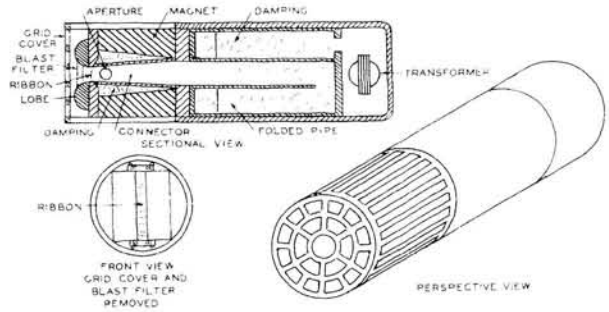

Fig. 12. RCA BK-5B uniaxial microphone.

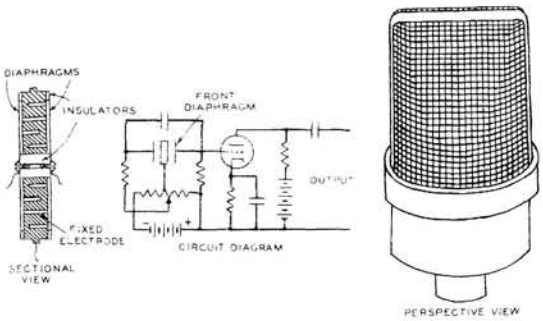

Fig. 11. Neumann M49 condenser microphone.

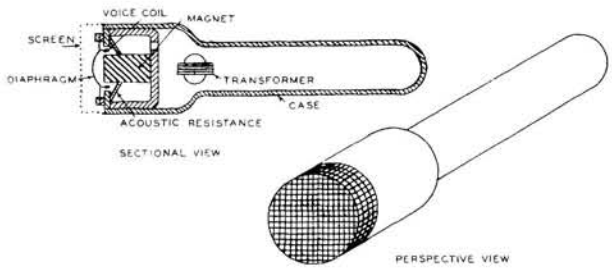

Fig. 13. Axial omnidirectional dynamic microphone.

an external field. An insulating material such as Teflon is well suited for the purpose. The plastic diaphragm is plated on one side. A high voltage is applied to the plastic film. The charge storage is permanent.

Another breakthrough which contributes to the success of the electret electrostatic or condenser microphone is the field effect transistor. The input electrical impedance is very high. As a consequence, uniform response can be maintained down to 30 hertz. The space occupied by the transistor amplifier is very small.

An axial microphone of the electret electrostatic type with the omnidirectional characteristic of Fig. 5**a** is shown in Fig. 15. Since the diaphragm is plastic, only nominal stretching of the diaphragm can be employed. The stiffness control, which is required in order to obtain a uniform frequency response characteristic, is provided by the trapped air between the diaphragm and the back plate. The resonant frequency is usually placed at 10 000 hertz. Some holes in the back plate are connected to a high acoustic resistance to provide damping at the resonant frequency with resultant uniform frequency response to beyond 15 000 hertz.

A uniaxial microphone of the electret electrostatic type with the unidirectional characteristic of Fig. 5**c** is shown in Fig. 16. A similar microphone [18] with a voltage polarized diaphragm and vacuum tube amplifier was developed earlier. The diaphragm is driven by the difference in pressure between the two sides of the diaphragm. This difference in pressure is proportional to the frequency. Therefore, in order to obtain constant amplitude with respect to frequency for constant sound pressure in free space the system must be acoustic resistance controlled as depicted in Fig. 16. The directivity is obtained by means of the gradient system and delay. For sound arriving from the back of the microphone the sound paths to the front and the back of the diaphragm are the same and the response is very low. For sound arriving from the front there is no delay at the front of the diphragm and maximum delay at the back of the diaphragm and the response is a maximum. For sound arriving from the side of the microphone the delay is one half that for sound arriving at front, and the response is down 6 dB from that of sound arriving at the front. The net result is the cardioid directivity pattern of Fig. 5**c**.

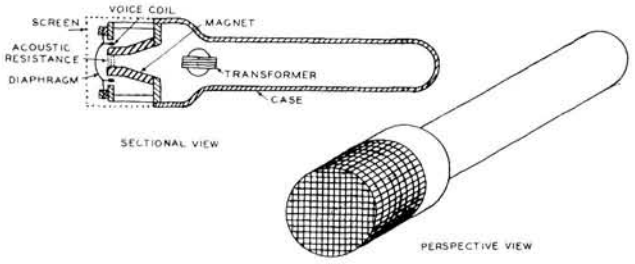

Fig. 14. Uniaxial unidirectional dynamic microphone.

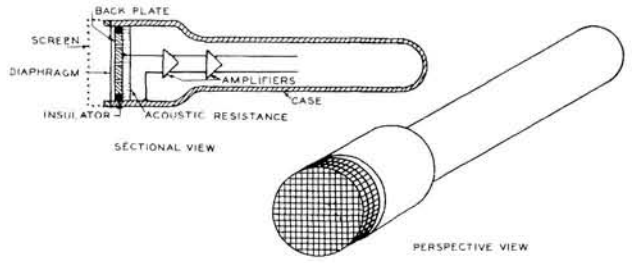

Fig. 15. Axial omnidirectional electret microphone.

EVOLUTION OF MICROPHONES

The preceding sections have traced the evolution of microphones from the inception of electrical recording in the mid-1920s to the present time. The microphones shown in Figs. 12–16 represent the present status of microphone development for recording. However, in some applications many of the omnidirectional, bidirectional, and unidirectional microphones described in the preceding sections are used for recording at the present time, the reason being that all the microphones described in this paper provide high-quality sound pickup. The particular selection of microphones depends upon the desired final result.

SOUND PICKUP ARRANGEMENTS FOR ORCHESTRAS

The purpose of the preceding text has been to outline the historical evolution of the pickup means for the recording of sound. A few examples of the pickup of sound from a musical aggregation will be described with the objective of illustrating the function of the sound collecting system in the recording process. In order to simplify the exposition, the examples which follow will depict the sound pickup from small musical ensembles. However, the principles can be extended to the pickup of a large musical aggregation as, for example, a symphony orchestra.

The recording of a small orchestra by an acoustomechanical recording system is depicted in Fig. 17. The problem in this type of recording is to obtain sufficient sound pressure at the diaphragm so that an adequate

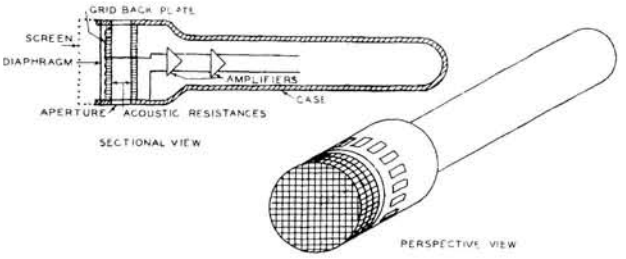

Fig. 16. Uniaxial unidirectional electret microphone.

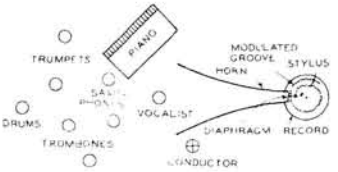

Fig. 17. Arrangement of the musical instruments, vocalist, and horn for acoustomechanical sound recording of a small orchestra.

amplitude of the stylus will be obtained to provide a practical modulation in the groove for reproduction by a mechanoacoustical reproducing system. All of the performers are clustered at the mouth of the horn. The weakest outputs are placed close to the mouth of the horn and the strongest outputs are placed at the outskirts of the cluster. Obviously, in the case of vocalists, the ones with the strongest voices, in general, produce the best records. An example is Enrico Caruso, who had a very powerful voice [19]. In addition, his frequency range (fundamental and partials) was particularly suited to the somewhat limited frequency range of the acoustomechanical recording system.

From the inception of electrical recording in the mid-1920s up to the advent of magnetic recording after World War II, the recording of disc records was made on a single original disc. Therefore, under these conditions the mixing and balance of the instruments of an orchestra must be made at the time of the recording. In some of the early electrical recordings of disc records a single microphone was used. The microphone was located at a distance from the orchestra so that a reasonable balance of the instruments was obtained. However, recourse to multiple microphones was made quite early in the electrical recording of disc records as depicted in Fig. 18. The directional properties of the velocity and unidirectional microphones facilitated the use of multiple microphones by providing isolation between the different sections of the orchestra.

The three-channel magnetic tape recorder and stereophonic sound reproduction changed the method of recording musical aggregations in the mid-1950s. A typical arrangement of musical instruments, vocalist, and microphones allocated to three recording channels [20] is shown in Fig. 19. In the processing, the three recorded channels can be mixed down to two-channel stereophonic sound and one-channel monophonic sound as shown in Fig. 20.

The development and commercialization of 8-, 16-, and 24-channel magnetic tape recorders provides the means for recording the individual instruments of an orchestra. The sound pickup of an orchestra with a microphone for each instrument of the orchestra, a microphone for the vocalist, and microphones for the reverberant envelope is shown in Fig. 21. An advantage of the multichannel magnetic tape recorder is that the vocalist can be recorded at a later time. Even parts of the orchestra can be recorded at different times. Another advantage is that time need not be spent in the balance of the instruments or voices during the recording. After the recording, the 16 channels of Fig. 21 can be converted to quadraphonic, stereophonic, and monophonic records. A great deal of time is usually spent in this mixdown to obtain perfection in the final product.

In order that the type of recording depicted in Fig. 21 be successful, every effort must be made to isolate the pickup of the different instruments without crosstalk between

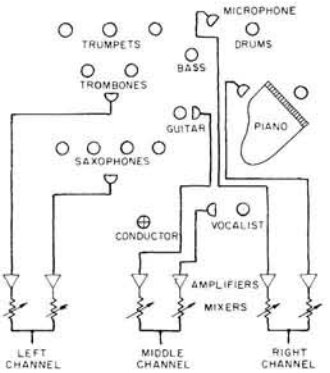

Fig. 19. Arrangement of the musical instruments, vocalist, and microphones for three-channel stereophonic sound recording of an orchestra.

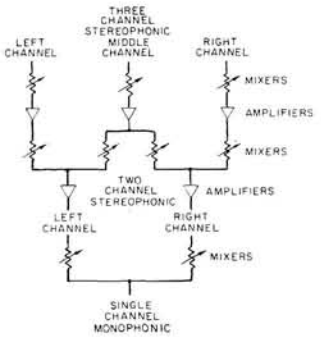

Fig. 20. Schematic arrangement of the equipment for the conversion of three-channel stereophonic sound to two-channel stereophonic sound or to one-channel monophonic sound.

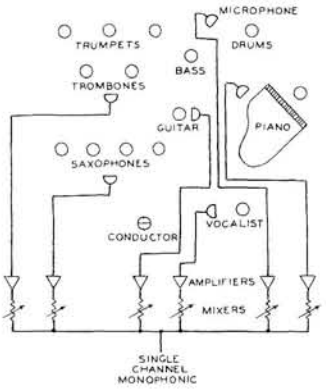

Fig. 18. Arrangement of the musical instruments, vocalist, and microphones for monophonic sound disc recording of an orchestra.

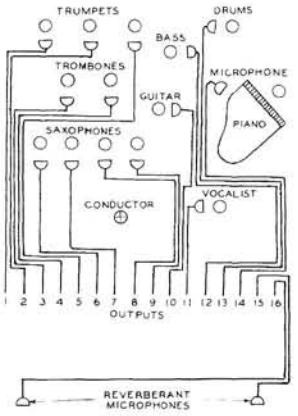

Fig. 21. Arrangement of the instruments, vocalist, and microphones using a microphone for each instrument in the orchestra for 16-channel recording of an orchestra.

instruments. In addition to very close pickup with directional microphones, barriers [21] are also employed to isolate the instruments from each other.

There are other types [3, 22, 23] of sound pickup arrangements for musical aggregations; namely, spaced and coincident microphones as depicted in Figs. 22 and 23. An orchestra and the spaced microphone arrangement are shown in Fig. 22. An orchestra and the coincident microphone arrangement are shown in Fig 23. In a modification of the coincident microphone arrangement, the four microphones are all brought together with 90° between the axes. In this configuration the microphone arrangement is usually surrounded by the orchestra. In the spaced microphone disposition, bidirectional or unidirectional microphones are used. In the coincident microphone disposition [22, 23], unidirectional or a combination of bidirectional and unidirectional microphones are used.

FUTURE MICROPHONES FOR RECORDING

The past and present state of microphones for recording have been outlined in the preceding sections. The characteristics of microphones for use in recording have been briefly described. A final objective of this paper is to predict the possible future course of microphone development. Obviously, it is presumptuous and impossible to predict developments in microphones with any degree of accuracy. However, some of the deficiencies of existing microphones indicate to some extent the direction in which future developments will proceed.

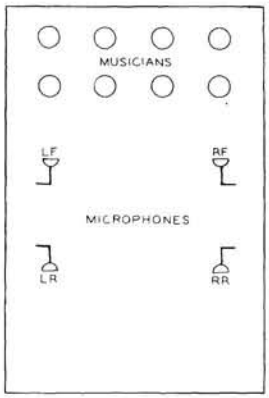

Fig. 22. Plan view of a studio, musicians, and spaced microphones for recording quadraphonic sound.

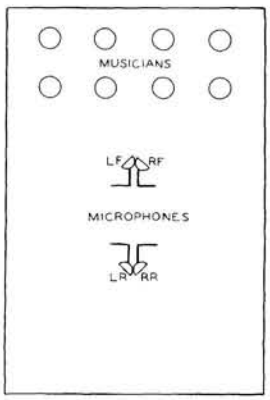

Fig. 23. Plan view of a studio, musicians, and coincident microphones for recording quadraphonic sound.

New transducers will be developed for microphones which will provide improved performance as follows: higher signal-to-noise ratio which will be required as the signal-to-noise ratio in the recording medium is increased; transient response should be improved to ensure faithful reproduction of impulsive sounds; lower nonlinear distortion which is a requirement for the high levels of intimate pickup.

In order to provide new transducers, new materials and new methods of transduction will be required. The electret [17] is an example of a new material and new transducer developed within the last ten years. Recently a new piezoelectric material in the form of a high polymer film has been developed as a transducer [24] for microphones. There will be other new materials for both existing and new transducers.

The general trend in sound pickup in recording is to use a microphone for each musical instrument or voice recorded on a separate track on magnetic tape. These are then combined in the desired fashion in the final product. In this sound pickup technique a fundamental requirement is that there be no crosstalk between the individual records of the different sound sources. This in turn requires a high order of acoustic isolation between the sound pickup of the different sound sources. At the present time this is accomplished by the use of bidirectional microphones with a cosine directivity pattern and unidirectional microphones with a cardioid directivity pattern. If the acoustic separation is not adequate, then baffles [21] are placed between the musical instruments to enhance the acoustic isolation. Greater acoustic separation could be accomplished by microphones with higher and uniform directivity. As the sophistication in both transducers and solid-state electronics is increased, there will be great possibilities for both higher directivity and uniform directivity with respect to frequency.

Adapting from the quotation, "Future events cast their shadow before" from "Lochiel's Warning" by Thomas Campbell, the problems of sound pickup, at any point in time, will indicate and dictate the required developments.

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Loudspeakers

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Outside of recording conditions themselves, there is more variability in loudspeakers than in any other element or process in the sound recording–reproduction chain. No other element has received such wide attention in the pages of the *Journal of the Audio Engineering Society*, and we will assume that the reader is familiar with the basic methods of transduction employed in loudspeakers. Principles have not changed over the years, but attributes and specific goals have. We will look at the major developments of the last fifty years and attempt to point directions for the future.

INTRODUCTION: The centenary of the phonograph record can be divided just about equally into fifty years of mechanoacoustical art and fifty years of electroacoustical art. The introduction of electrical recording in the mid-twenties intersected the electroacoustical transducer development curve at a fairly high point, and there was no need for phonograph reproduction to be concerned with the crude devices that had evolved out of early radio and telephony. Rather, the electrical phonograph could benefit at its outset from the moving-coil direct-radiator loudspeaker developed by Rice and Kellogg in 1925. Curiously, the advent of electrical disc recording did not imply the immediate acceptance of electrical reproduction in the home. Maxfield and Harrison, inventors of the Western Electric disc recording system, said in 1926:

> "Where the power which can be supplied by the record is sufficient to produce the necessary sound intensity, as in the case of home use, it is in general simpler to design one single mechanical transmission system, than it is to add the unnecessary complications of amplifiers, power supply and associated circuits."[1]

This statement, at least on the surface, seems quite naive, but history was on the side of Maxfield and Harrison. The vast majority of home playback sets continued to be acoustical throughout the thirties, and it was only through attrition that they were supplanted by electrical playback systems during the years just prior to World War II. Actually, it was the LP record, introduced in 1948, that spelled the doom of the 78-r/min acoustical phonograph in many parts of the world.

Because playback of records in the home did not necessarily depend upon electronics, the first great emphasis on loudspeaker development did not come from the demands of that art, but rather from the needs of the sound motion picture industry as it developed in the late twenties. The development by Western Electric of high-power loudspeakers during the early years of sound motion pictures, continuing on into the mid-thirties, has left an important legacy scarcely changed up to the present day. In a later section of this paper we will examine their work in some detail.

THE CHALLENGE TO THE DESIGNER

Even experienced transducer engineers and systems designers cannot agree on which attributes and tradeoffs are most desirable in loudspeaker systems. Unlike any other transducer used in the sound recording and reproducing chain, a loudspeaker is called upon to convert substantial amounts of power, and in order to do this it must be fairly large in relation to the shortest wavelengths it must

[1] From Read and Welch, *From Tin Foil to Stereo*, 2nd ed., 1976.

reproduce. Typically, a wide-range loudspeaker system consists of at least three radiating units, each covering a specific portion of a frequency spectrum that may be nearly three decades wide. By necessity, the elements must be displaced spatially, so coherent radiation can be expected only over a fairly small solid angle. This is perhaps the most fundamental design compromise, especially if the designer is thinking in terms of the entire recording–playback chain and the goal of establishing a sound field in the playback environment relating conformally to the sound field present at the time of the original recording. In fact, too much loudspeaker design has taken place in isolation, treating the loudspeaker only as an entity in itself rather than as a subsystem in the recording–reproducing chain.

While it would be fairly easy to specify the attributes of an ideal loudspeaker in an ideal playback environment, it is no simple task to arrive at a consensus among loudspeaker engineers of what a good practical design for home use should be. If engineers have difficulty here, it is not surprising that most amateur, intuitive tinkerers run an even wider gamut in their efforts to come up with new loudspeaker designs. A survey of acoustical patent reviews in the United States will show that the attributes of unique and novel are not necessarily consonant with the laws of physics. It is a testament to the forgiving nature of the ear that many of these designs sound as good as they do.

Perhaps the best way to survey the broad aspects of loudspeaker design and practice is to do it historically. The ordering of attributes has changed many times over the years, and there have been distinct epochs that we might study in our assessment of the present, and future, states of the art.

A SHORT HISTORICAL REVIEW

As we said earlier, the demands of the talking motion picture provided the impetus for the first rapid development of quality loudspeaker systems. The efforts culminated in the monumental Bell Laboratories demonstration in 1933 of three-channel stereophonic long-line transmission between Philadelphia and Washington, D.C. The loudspeakers used for this study were developed by Wente and Thuras. Both high- and low-frequency units were horn loaded and were designed to yield maximum sensitivity over a controlled solid radiation angle with limited signal power input. In the mid-thirties, 10 watts of audio power was a practical upper limit, and these systems could deliver goodly acoustical levels with only that small amount of power. Typically, these systems produced sound-pressure levels (re 1 watt, 1 meter) of about 105–107 dB. Over the midband, these systems exhibited a directivity index of about 7–8, and the corresponding conversion efficiency was in the neighborhood of 15–25%. Loudspeakers such as these were large; the low-frequency assemblies were about 3.5 meters high, 2.5 meters wide, and perhaps 1 meter deep. Today, essentially the same devices are used in motion picture theaters, for general large-scale sound reinforcement, and, of course, at rock concerts. Physical parameters have not changed, but better magnet structures and higher temperature cements and materials have permitted these devices to handle much more power in today's applications with much more acoustical output.

The Western Electric legacy, as it may be accurately termed, carries over into one very important area of present high-fidelity practice, recording-studio monitoring. Gone are the large low-frequency horn assemblies; they have been replaced by single or dual 38-cm low-frequency units, usually in vented enclosures, along with horn-loaded medium-frequency units crossing over in the 500–1000-Hz range, and horn-loaded high-frequency units carrying the spectrum on from 2 to 7 kHz upward. Current practive has purposely cut the low-frequency unit sensitivity back by adding mass to the moving system in order to extend the low-frequency limit down to 30–35 Hz. (The earlier theater systems did not extend much below 50 Hz.) The routine availability of high audio power these days has made this a reasonable tradeoff, and current monitor systems typically exhibit sensitivities of 92–93 dB sound-pressure level (re 1 watt, 1 meter). Because of increased power handling due to the higher temperature stability of modern construction, the new monitor systems can easily reproduce levels in the normal control room exceeding 115 dB sound-pressure level and in substantially smaller enclosures than those of their precursors. This degree of high-level performance may be essential for modern pop/rock recording, but it is not necessary for reproducing music at realistic levels in the home.

A small revolution occurred in the mid-fifties, and it centered about the so-called acoustic suspension low-frequency loudspeaker system. Essentially, this is a low-frequency transducer mounted in a sealed enclosure small enough so that the stiffness of the moving system is due more to the enclosed air than to the characteristics of the loudspeaker spider or surround, which are usually made very compliant. These systems can provide excellent bass response in small enclosures because system resonances can be held to the 40-Hz range. For the first time, the bookshelf loudspeaker became respectable.

These systems were relatively inefficient, but their introduction coincided with a trend toward high ratings in power amplifiers. Typically, the sensitivity of an acoustic suspension system is in the range of 85–87 dB sound-pressure level (re 1 watt, 1 meter).

The fifties also saw the commercial introduction of practical electrostatic loudspeaker designs. These consisted of large rectangular panels, perhaps 2 meters high by 0.75 meters wide, and are invariably of "push–pull" design. The electrostatic loudspeaker is a dipole radiator; its polar pattern is "figure-eight," with the back radiation characteristically out of phase with the front. Further, because it is such a large radiator, the listener by necessity is located in the near field. The better electrostatic devices are characterized by a certain effortlessness of sound, and seem to convey a sense of spaciousness. They are inherently of low sensitivity and cannot be used successfully for high-level reproduction in the home. They have their counterparts in planar radiating systems of recent design

using a printed "voice coil" on a large plastic membrane operating in the proximity of small high-energy magnets.

The sixties saw more emphasis on rational design techniques. The advancing state of the computer art made it possible to model many loudspeaker and dividing network components and their associated enclosures, observing the effects of changes in individual parameters in the design. Work in this area has continued up to the present, with ever increasing dividends for the manufacturer and relief from so many of the "cut and try" design practices of the past.

RELEVANT MEASUREMENTS AND DIRECTIONS FOR THE FUTURE

As we move well into the seventies—and into the second hundred years of the phonograph—we see significant improvements in loudspeaker design as audio engineers begin to pay closer attention to time-domain relationships between transducers. The problem is not new; in the early sound motion picture art there could be significant time delays between low-frequency enclosures and their associated high-frequency horn assemblies. But once these were adjusted to within a handful of milliseconds, the problem was believed solved.

In recent years, as recordings have improved so dramatically and as electronics design engineers have begun to isolate and remove subtle forms of distortion, the niceties of small errors in time-domain accuracy in loudspeakers become more important.

Measurement of the phase response of loudspeakers completes the overall transfer characteristic, which was viewed for so many years as only the amplitude portion of a complex quantity. Actually, the important aspect is not the phase response but rather its derivative with respect to frequency, the group-delay characteristic. With conventional instrumentation, measurements of complex transfer characteristics are difficult, and in recent years discrete Fourier transform methods have simplified the basis for analysis and given the engineer far more to work with. Using these techniques, a loudspeaker is energized with a series of pulses of known frequency distribution. These are observed and transformed into continuous plots of amplitude and phase, or group delay. Further transformations can isolate the minimum-phase part of the response from the total phase response, thus giving the designer a good idea of where his remaining design problems are.

The design of time-aligned systems demands better components than were customary in past years. Rapidly disappearing in serious design work are the highly colored "peaky" devices that were once the staple of the industry. A typical cone transducer has a useful frequency range over which, with a little attention, it will be well behaved. The low-frequency limit is usually established by its main resonance, while the upper limit is established by the tendency of the device to go into complex vibration or to narrow its radiation angle.

This latter qualification is important if the designer wishes to maintain fairly constant dispersion from the system, and proper concern for this often leads to the design of four-way systems. Certainly no less than three components can yield reasonably constant dispersion across the frequency band. Practical considerations usually come into play about 10 kHz, and designers are usually willing to let the response narrow somewhat as the high-frequency radiating surface becomes large with respect to the radiated wavelength.

Another area of loudspeaker performance is finally receiving the attention it deserves, its polar, or directional, response. Many loudspeaker systems are made up of an array of components, and the directional characteristics, the sum of all the radiators in a given direction, can be quite complex. Conventional measurement methods using band-limited noise average out many of the details in this "fine structure" of the systems and often give the impression that all is well, or at least sufficiently smooth. But it may not be so; the ear is sensitive to unevenness in polar response even when the energy, integrated over fairly narrow bands of noise, is reasonably constant. The effect on the experienced listener is one of decreased depth perception in the stereo array and a lesser sense of realism when compared with systems smoother in this respect.

In general there is a tendency, at least in the audiophile sphere, to go to lossier devices in an attempt to get smoother response. Many of the techniques favored for efficiency's sake can lead to resonant and peaky response, and as we have stated before, the tradeoff relates naturally to the application.

Distortion due to system nonlinearities is an important consideration in loudspeaker design. Surprisingly, large-signal nonlinearities, those due to exceeding fundamental linear limits, may not be as aggravating to the listener as various buzzes and noises due to break-up phenomena, audible often at low and moderate levels. Much development work therefore is being done in the materials area in an effort to isolate more stable and better cone and diaphragm materials from those tending to rattle or go into complex modes of vibration. Again, we are concerned with the fine structure of loudspeakers and are faced with the observation that two devices, measuring nearly identically by conventional techniques and differing only in cone material, may sound quite different, even to naive and inexperienced listeners. A typical measurement of fundamental, second, and third-harmonic response versus frequency for a loudspeaker will usually exhibit very choppy and erratic distortion curves, even when the fundamental is fairly smooth. Much of what is being plotted is simply spurious buzzes and noises filtered by the wave analyzer portion of the instrumentation.

THE ELECTRICAL-MECHANICAL INTERFACE

Most loudspeaker systems are designed to operate with a wide variety of amplifiers and with flat electrical input. It is further usually assumed that the amplifier has a negligible internal impedance and that it is effectively a constant-voltage device. Over the years a number of complex systems have been designed that view the amplifier–loudspeaker combination as a single system. Once this association is made, there are some new benefits. Biamplification (or triamplification) can be used to power each transducer with its own amplifier, selected

for the optimum power level, and distortion at high signal levels is reduced in the process. Motional feedback may be employed for greater large-signal linearity in low-frequency devices. The design of dividing networks becomes easier to implement due to the high impedance levels at the amplifier inputs, and minimum-phase designs can be realized accurately and conveniently. Finally, moderate degrees of amplitude equalization may be incorporated into the overall design to facilitate loudspeaker–listening room integration.

OUTLOOK FOR THE FUTURE

There are not many major breakthroughs left in loudspeaker design; most of these were uncovered in the early days of the art. What will continue of course is the reordering of attributes and priorities as loudspeaker design keeps pace with development in the associated areas of the recording and reproducing chain. As each segment of the art improves, fine differences begin to be discernible between like components where none could be heard previously. And any difference at all implies that at least one of the components is less than ideal. Much work remains in developing objective judgments. The ear of a trained listener can detect subtle differences between amplifiers, for example, which cannot be measured by current testing methods, but fortunately the gap appears to be narrowing between cause and effect in this regard.

In the future more attention will be given to the listening environment itself, optimizing it for the job at hand. During the last six or seven years, the industry has seen the first step taken toward proper and consistent interfacing of monitor systems into recording control rooms, and this is a direction which serious home listening will take.

Studios and Studio Equipment

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Today's sound studios are constructed and equipped to provide a wealth of manipulative freedoms undreamed of by the pioneers of recording and broadcasting. As techniques and technology continue to develop at unrelenting speed, engineers and producers have a responsibility to define their artistic objectives. Only then will the huge capital expenditure in acoustic design and electronic control of frequency, dynamic, time, and spatial effects be reflected in better sounds reaching the listener.

INTRODUCTION: Using the kind of sweeping simplification that is permissible only in an abbreviated survey of this sort, we propose to treat the sound studio as a "black box." The input is a musical event, such as the performance of a symphony or a pop number. The end product is a marketable recording in the form of a master tape. Within the studio there must be facilities for converting the musical sounds into the magnetic pattern on the final tape, modified in as many ways as the exigencies of the medium and the artistic vision of the producer/engineer may demand.

This simplified approach has at least the virtue of providing a framework that will fit every studio situation from the earliest acoustic recording days right up to today's computerized multitrack emporia. Using another simplification, it is possible to see the accelerating complexity of studio equipment and techniques as furnishing the producer with a variety of new freedoms. These include freedom of choice in frequency response, dynamic response, time, space, and musical balance.

ARTISTIC CONSIDERATIONS

Armed with such batteries of facilities for manipulating sounds, the producer carries a heavy responsibility to both his musicians and his listeners. First among the many important decisions he has to make is the kind of musical experience he is striving to project. Traditionally the ideal has been held to be a realistic reproduction of "concert hall" sound, but this is not so easy as it sounds.

Crowding 100 players into a living room is physically impossible, and yet we are committed to the objective of reproducing the *sound* of a full orchestra in the domestic environment. The changeover from mono to stereo in the late 1950s certainly helped us along the way to the happy ideal of "suspending our disbelief" that the orchestra was performing live, then and there, for our private delectation. In mono, the only sonic experience available to us was that of eavesdropping on the orchestra as through a narrow tunnel, with very little feeling of involvement. Stereo let us imagine the players spread out across a sonic stage approximately bounded by the two stereo loudspeakers. There remained a sense of sitting somewhat apart from the performance but, on the better recordings, it was as if our living-room wall had been dissolved away and the concert hall opened out just beyond it. Surround sound systems are presently attempting to open out all four walls of our room and immerse us in a believable acoustic environment.

Generally, even in surround sound, producers of classical music material will leave our concert-going traditions intact and keep the orchestra up front, with the listener effectively at some natural distance back in the ambient sound field. But other producers set their sights on a higher target. Viewing the sound medium as an art form in its own right, they feel free to experiment with spacial distributions, as well as other trick effects, in any way that creates the particular sonic experience they are seeking. They have on their side the pianist Glenn Gould, for example, who has forecast that expensive and uncomfortable concert-going will shortly die out in favour of a total canned music situation. Many modern serious composers create with taped and electronic sounds, and the pop market, quite legitimately, acknowledges no rigid ties with traditional music-making procedures.

ACOUSTIC CONSIDERATIONS

In the early days of sound recording, room reverberation was regarded as an enemy liable only to blur the sounds reaching the microphone. Drapes were therefore hung everywhere in the hope of absorbing sound energy and at the same time reducing unwanted sounds from outside. Modern studios take a more enlightened attitude to studio acoustics and will pay large sums of money to acoustic experts and construction teams to provide optimum working conditions.

Background Noise

The lowest attainable level of background noise would seem to be a primary requirement for a sound studio. Yet this is a classic example of the law of diminishing returns: beyond a certain degree of sound exclusion, each further decibel of noise reduction is more expensive to achieve. A set of noise rating (NR) curves is widely used to express the nuisance value of various measured noise levels when specifying a studio's performance. Acceptable values are around NR20 or less.

Ironically, perhaps, improvements in the dynamic range capability of recording and broadcasting systems have shown up studio ambient noise, calling for better sound insulation design. The sources of outside noise include street traffic, underground trains, building work, and aircraft—phenomena which are certainly not getting any quieter. Inside the building too there is the need to isolate the studio from elevator noise, air-conditioning plant, and performances in other studios and control rooms, the latter often creating supernormal sound levels since the emergence of heavy rock music.

Adapting an existing building is difficult and expensive. For a new studio, the proper procedure is to make site measurements of noise levels and then draw up a structure specification to give the design noise rating figure. The insulating property, or sound reduction index (SRI) of a partition is basically proportional to both the mass per unit area and frequency. Thus a 6-dB improvement would result from doubling the mass per unit area (by doubling thickness or using a denser material). At the same time, going down the frequency scale reduces the SRI of any given partition by 6-dB per octave, and the lowest frequencies therefore present the biggest problems. Odd resonance effects complicate the picture and can give disappointing worsening of the results which the "mass law" might predict.

Transmission loss through ceilings, floors, and walls can reach the required values of around 60–70 dB if special sandwich or cavity construction is used. The basic "mass law" is then aided by some of the sound energy being reflected at each material interface. However, care is necessary since the individual "skins" may exhibit resonances and longitudinal waves can reduce SRI at certain frequencies. This is one reason for choosing glass panels of different thicknesses in a double-glazed control room window, for example.

Floating structures, giving complete isolation of the main studio shell from the rest of the building, are now mandatory in the typical city environment and pop studio, with a consequent elevation in building costs.

Studio Reverberation

Within the studio it is necessary to plan for pleasant working conditions, acoustically as well as cosmetically, and a well balanced and diffused sound field that will simplify the placing of microphones, that is, freedom from standing-wave effects, dead spots, and exaggerated bass or treble. Completely nonreverberant (anechoic) conditions might suit the balance engineer for some types of music, since he can in any case add reverberation artificially, but would be oppressive for the musicians who generally like the presence of some reflected sounds. Optimum reverberation times (the time taken for sounds to decay through 60 dB) vary according to the type of music, and so studios are usually designed to perform specific tasks. Reverberation time is reduced by the application of absorbers to wall, floor, and ceiling surfaces, yet, as W. C. Sabine of Harvard pointed out about 70 years ago, it is also proportional to room volume. Larger studios will therefore require extensive application of absorbers, carefully calculated and distributed to give the design reverberation time–frequency characteristic with good diffusion.

Three basic types of absorber can be identified. Porous absorbers such as thick curtains, mineral wool blankets, or fibrous tiles remove energy from incident sound waves due to viscous losses as the air vibrates within the material pores. The absorption is mainly effective at high frequencies, though absorption can be extended to lower frequencies by increasing the thickness of the material. The cutoff frequency occurs at a thickness corresponding to around one eighth of a wavelength.

A second category of absorber will deal with low frequencies. This is a panel or membrane of some lossy material such as roofing felt. As the panel vibrates in response to the sound waves, it dissipates the energy content as heat. Mounting the panel over a closed box permits tuning of the absorption coefficient, and numbers of boxes of different depths can give quite precise control of bass frequency reverberation. The third category of absorber is scientifically of high interest, though less widely used in practice. This is the Helmholtz resonator in which incident sound waves set up sympathetic vibrations in the air contained in a wall cavity. The air mass in the "neck" of the cavity resonates with the compliance of the contained air. To broaden the tuning (lower Q) and ensure absorption rather than reinforcement of the sound, resistive material is incorporated in the neck. Action analogous to the Helmholtz principle may be seen in extended form in the porous absorber tiles having perforations on the front surface. When the percentage of surface area carrying perforations is small, each hole may be regarded as the neck of a resonator with the corresponding area of material behind acting as the cavity.

Studios with variable acoustics have been built, either to accommodate a range of musical ensembles from a symphony orchestra down to a chamber group, or to suit drama productions where each scene is set acoustically by

the reverberance of its environment. Reversible panels can be built on the walls and turned by hand or by remote control to present either absorbing or reflecting faces. Alternatively it is possible to pull lengths of membrane material over box-like cavities and produce widely variable reverberation effects. False ceilings can also be lowered to give the effect of a smaller studio, and they can even be angled to assist a string section compared with brass players, etc.

In another development known as assisted resonance or "ambiophony" the studio is built with relatively dead acoustics and then the reverberation properties are enhanced for the benefit of performers, and incidentally the recording engineer and even the audience, by electronic means. The principle is to place special microphones to collect the sound and then relay the signals, with or without tape or electronic delay, at low level from large numbers of loudspeakers distributed remote from the playing area. The technique has been employed for serious music in television studios, for example, which are generally vast in size but acoustically very dead. Assisted resonance is also a feature of some concert halls, notably the Royal Festival Hall in London.

Screens, Vocal Booths, etc.

In every type of recording, other than a classical music ensemble which is laid out more or less exactly as it is intended to be reproduced, problems arise when the sounds from one voice or instrument spill on to the microphone used for another. Particularly in pop music, the engineer likes to have unique control of the level and left–right panning position of each instrument. This demands good "separation" on each microphone with "unwanted" instruments attenuated by a good 20 dB or better. There is a limit to the distance that artists can be spaced apart for this purpose, since they like to play close together for perfect ensemble. A need therefore arises to screen loud instruments from quiet ones or vice versa.

Movable screens can be moderately effective, having reflecting material on one side and absorbers on the other. They should ideally reach down to floor level, be capable of joining together, and include a transparent glass or plastic area to maintain visual communication. Modern techniques will often require more drastic separation, and studios now tend to include one or more booths designed to house a drum kit or a vocalist, acoustic guitar, etc. Booth design is notoriously difficult if boxy resonances are to be avoided, and a special floating concrete floor may be the only way to prevent loud drum sounds from being transmitted throughout the studio.

As a final note on separation, this has now so grown in importance that it is a principal *raison d'être* for multitrack recording. Instruments and voices are frequently recorded one at a time (while the performer listens synchronously to previously recorded tracks). While there may be other reasons for using this technique, such as a desire to experiment with different harmonies or phrasing without requiring the other players to perform over and over again, it is often the total elimination of spillage that has made such "overdubbing" universally popular. Where electrical instruments are concerned, such as guitars and organs, a direct feed from the instrument's amplifier can be taken to the mixing console instead of (or occasionally as well as) a microphone feed, again giving total acoustic separation.

Control Room Acoustics

At the same time as studio design has progressed from unscientifically draped and gloomy rooms to the modern, efficient workplace with tightly controlled acoustics and comfort orientated facilities, much more attention is now paid to the design of the control room in which the recordings are balanced, mixed, and monitored.

It has always been known that the quality of reproduced sound in a room is a function not only of the particular loudspeaker, but of the combination of loudspeaker, room acoustics, and precise placing of the loudspeaker in the room. Loudspeaker design has kept pace with developments throughout the rest of the chain so that professional monitors, usually rather large systems, can cover the full frequency range and provide as high a sound pressure level as anyone could wish. The trouble is that even the best loudspeaker will usually sound different if installed in another room, or even shifted to a new position in the same room. Where stereo and quadraphony are concerned, quite glaring differences in positional effects will arise in different listening locations. Studio personnel are therefore making final decisions on tonal quality and perspectives in dozens of nonstandard environments. This is acknowledged as being unfortunate since standardization of most other technical parameters has been achieved, and it causes problems when tapes are sent to be overdubbed, remixed, or transferred to disc in other locations.

The conventional rectangular room will always be plagued by modal resonances at frequencies corresponding to the room dimensions. Thus bass response is peaky, and there are standing-wave nodes and antinodes throughout the listening area. Even when these have been reduced to acceptable levels, using heavy bass absorption plus electronic correction with one-third octave graphic equalizers, reflections from equipment racks and room asymmetry make strict control of monitoring conditions practically impossible.

Attempts to rethink the problem from first principles have been successful both in the United States and in Europe. Several dozen of the industry's more prestigious control rooms have been designed and constructed with elaborate bass traps, which eliminate standing-wave problems, all tape machines and racks either recessed or moved into adjoining rooms, total symmetry of layout, and the loudspeakers themselves recessed and integrated into the room design. A new criterion has become the summation level achieved when random noise is fed to the pairs of monitoring loudspeakers. A strict doubling of the level from either loudspeaker alone (+6 dB) will be obtained only when room absorption and standing-wave conditions are truly symmetrical with respect to the measuring microphone (placed where the balance engineer's head would normally be). Good correlation has been established between higher summation levels, ap-

proaching 6 dB, and good subjective acceptance in terms of optimum stereo imaging with minimum listener fatigue over long periods.

Smooth absorption at higher frequencies is achieved by calculated use of a variety of materials such as real wood veneers, lava rock, and exotic cloths. When appearance design is also well conceived, allied to proper lighting, ventilation, and comfortable seating, the working environment can reach new standards of both technical efficiency and human ergonomics.

ELECTRONIC CONSIDERATIONS

The simplest recording chain would consist of a microphone, connected to a line amplifier capable of raising the signal level from its original level of around 0.001 volt to the 1.0 volt or so needed to feed the tape recorder (a gain of 60 dB). Control of signal level would call for the provision of a potentiometer and suitable knob. It might also be desirable to provide a meter giving visual confirmation that the known requirements of the tape medium were neither being exceeded nor underused, since reliance on the human ear for such absolute level judgements is notoriously uncertain.

If two or more microphones are to be used, with individual controls, it would be possible to retain the single amplifier and put a fader in each microphone line. Such "low-level" mixing is fraught with difficulty, however. First, at anything other than full volume, the fader is attenuating the already low microphone voltage and degrading signal-to-noise ratio. Second, each fader output "sees" the amplifier input in parallel with all other fader outputs, and so its current is shared between all these parallel impedances with only a fraction going to the amplifier. This shunting effect can be reduced by putting a series resistor in each fader output line, but this further attenuates the signal levels, and so on.

So, expensive though it seems, studios were very soon converted to "high level" mixing, with each microphone or other source (such as gram deck or tape output) connected directly to a channel amplifier, prior to the fader. This preserved signal-to-noise ratio and made it possible to build in "constant-impedance" mixing so that the level from any one channel was unaffected by the fading in of others. Modular construction of channel amplifiers introduced greater flexibility of desk layout and design. Demands for increasing versatility in regard to frequency correction and routing of individual channels, followed by a universal changeover from rotary stud faders to straight-line slide types, led to the now familiar channel strip (Fig. 1). This has increased in length until it is now quite literally "as long as your arm." A mixing console with, say, 40 input channels and 24 output/monitoring lines can therefore end up with a surface area of about 3 square meters and anything up to 600 knobs, switches, and meters.

Electronic Manipulations

The complexity of a modern control console is not solely caused by the increased numbers of input channels and output lines. It reflects the growing desire of producers, engineers, and artists to manipulate their sounds for heightened musical effect and creativity. Each region of manipulation can be seen as giving the recording a further degree of freedom, and we can briefly consider these regions separately. The apparatus concerned may be built into the desk or housed in separate equipment racks.

Frequency Response Manipulations

Simplest of these is the remedial use of steep 12- or 18-dB per octave filters. Bass or "high-pass' filters will reduce studio rumble or guitar amplifier hum and may have switched turnover frequencies of 45, 80, 120 Hz, etc. Treble filters are useful for curing whistles or unwanted spill of cymbals, for example, on to other microphones. Normal frequency correction circuits may be used remedially or artistically to boost or cut bass, treble, or middle ("presence") frequencies. More elaborate equalizers may divide the 20–20 000-Hz range into numerous bands, up to 28 in a one-third octave unit. The slide fader knobs give a pictorial outline of the response, and so such units are called graphic equalizers (Fig. 2). In the so-called parametric equalizers all parameters are made continuously variable (Fig. 3). The operator can sweep tune to any desired center frequency, perhaps to eliminate a specific unwanted tone or sibilant sound, then independently adjust the bandwidth Q of the circuit and the amount of boost or cut.

Dynamic Response Manipulations

Versatile control of instantaneous signal levels is a frequent requirement, for example, to prevent peaks exceeding the maximum usable value at the input to a tape recorder or radio transmitter (limiting) or to restrict the dynamic spread of signal levels for technical or aesthetic reasons (compression).

A compressor is essentially an amplifier in which the gain changes to a (lower) value when a prescribed input level is exceeded. This is illustrated in Fig. 4 where the input–output transfer characteristic is that of a unity gain amplifier up to a threshold level of 0 dBm. Above this, a 2:1 compression ratio is applied, since every 2 dB further increase in input level produces only 1 dB rise at the

Fig. 1. Two engineers may be needed in a complicated mixdown operation.

output. Adjustments are usually provided for both the threshold level and the compression ratio. A low threshold and high compression ratio might be used, for example, to compress the overall dynamic range to only a few decibels for such applications as background music tapes or AM radio. For serious music recordings, where only slight compression is needed to reduce the 75-dB range of a symphony orchestra to, perhaps, around 50 dB to suit a given medium, a high threshold level would be chosen and a small compression ratio. Even so, the attack and recovery (release) times of the gain control circuitry need careful adjustment if undesirable side effects such as clicks or "pumping" are not to be heard.

A limiter can be regarded as a compressor with a high compression ratio of 20:1 or more (also illustrated in Fig. 4).

It will be noticed that compression reduces the average level through the system, and so an equivalent amount of extra gain makeup is required with consequent degradation of source signal-to-noise ratio. However, if compression is applied at the sending end of a complete chain (recording or radio transmission) and equivalent expansion at the listening end (playback or reception), the original source dynamic range and signal-to-noise ratio can be restored.

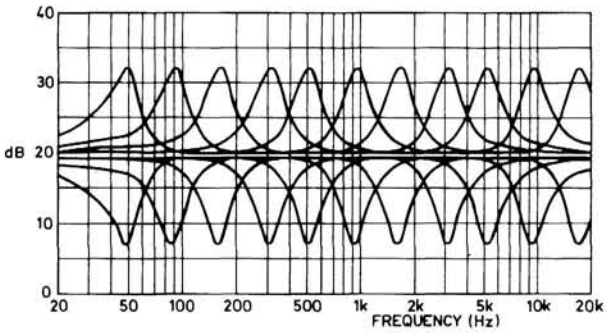

Fig. 2. A graphic equalizer gives boost or cut in a large number of narrow frequency bands.

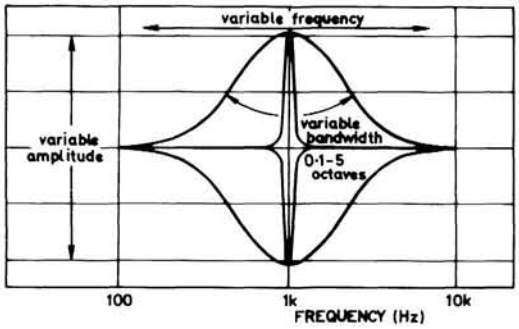

Fig. 3. A parametric equalizer permits independent selection of center frequency, bandwidth, and boost or cut amplitude.

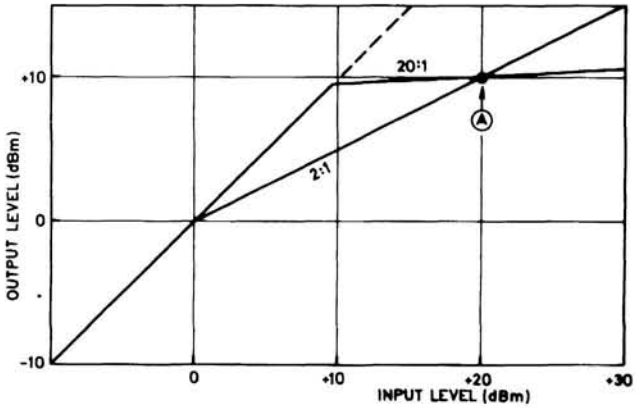

Fig. 4. Input–output characteristics of a typical compressor (2:1 ratio above a threshold level of 0 dBm) and limiter (20:1 ratio above a threshold of about +10 dBm).

A very real benefit can be derived in the process. Note that any noise or interference which entered within the chain (such as tape hiss, print-through, or crosstalk) is subjected only to the expansion process and so is diminished with respect to mean signal level. This is the principle of the various noise-reduction systems now available, such as Dolby, JVC/ANRS, dbx, and Telefunken/Telcom. Chronologically, Dolby came first and elegantly avoided many of the pitfalls of old-fashioned high-level compression and expansion (companding) by leaving the high-level signals alone and working on low-level signals only. He also split the frequency spectrum into four frequency bands which reduced pumping effects and made good use of subjective masking. JVC/ANRS somewhat resembles Dolby, whereas the dbx and Telefunken systems apply companding over the full dynamic range and strive for a higher degree of noise reduction than Dolby's 10–15 dB.

A special type of expander, called a noise gate, is popular in multitrack recording. It attenuates all signals below a certain level. Therefore it "opens" when a given instrument is playing but effectively shuts down noise or crosstalk on that channel at all other times. Frequency selective systems are also becoming popular for such applications as reducing sibilance (de-essing) and improving broadcast sound.

Time Manipulations

The earliest use of time manipulation was to give added reverberation or bloom to sounds by extending their decay time. The first method was to employ a highly reverberant room, or echo chamber. Sounds from the studio microphone which were deemed to be insufficiently reverberant would be relayed to a loudspeaker in the echo room, and the reverberations in that room would be collected by another microphone and returned to the console for mixing in any desired proportion with the original. As alternatives to the echo chamber, various suspended plate or spring systems are now popular with appropriate driver and collector transducers to set the system into vibration and pick up the resulting reverberated signals.

While all these artificial reverberation devices work well enough for most purposes, they lack two characteristics which we associate with true reverberation in a concert hall, namely, an initial time delay and dense packing of the reflected sounds. We normally experience a short time delay (about 30 milliseconds) between the arrival at our ears of direct sound from the musicians and the myriad of multiple reflections that collectively make up reverberation. In artificial devices, including the echo chamber, this time gap is usually foreshortened because of the smaller physical distances involved. It has therefore

become common practice to delay the signal on its way to the reverberation device by some 30–50 milliseconds. This was experimentally found to work surprisingly well by simply routing the echo send signals to a spare tape recorder, preferably one with variable speed, and relaying its playback signal to the echo device. A delay of about the right order was introduced by the physical distance between the record and playback heads. This tape delay idea is still used by many studios despite its obvious disadvantages, but a more sophisticated method is to use digital delay.

Digital time delay units are relatively expensive since they incorporate complementary analog–digital and digital–analog converters and a set of shift registers through which the stored signal is passed in steps initiated by the pulses from a clock generator. Output taps or modular construction with a given number of registers produce a range of time delays from about 5 to 500 milliseconds. Apart from delaying the feed to a reverberation device, digital units are used widely in sound reinforcement systems to introduce optimum delay in the feed to more remote loudspeakers.

Random access memory (RAM) devices have appeared, giving a more flexible choice of delay time. They even permit delay changing while the signal is in transit, so that pitch changes due to the Doppler effect are possible. This has also created new effects, including time stretching without pitch change, automatic harmonies, and pitch restoration of tapes recorded at the wrong speed.

A more conventional trick effect previously performed by tape handling and now better done digitally is automatic double tracking (ADT) in which a fixed time delay of 20–100 milliseconds enhances a solo voice by simulating the effect of a duet in unison. Another is phasing, or flanging, in which the signal passes through two chains (previously two tape recorders) one of which is continuously changing its transmission time. This results in a weird swishing effect like that of a variable comb filter, that is, one which produces alternate reinforcements and cancellations at equal frequency increments.

Space Manipulations

The apparent distance of a singer or instrumentalist from the listener has always been capable of some control by the engineer. In classical terms, this depth of field in the reproduced sound, or aural perspective, is quite naturally captured in those recordings where a single microphone (or stereo pair) is placed at some distance from the front of the orchestra. The more remote brass and percussion instruments, for example, are picked up with a proportionately high ratio of ambient to direct sound, and this makes them sound properly disposed behind the strings. When multimicrophone techniques are employed (the more usual procedure), close microphones are in danger of ruining this natural perspective unless the engineer takes special care in mixing. In pop recording, some additional distance control is contrived by boosting or attenuating the "presence" frequencies around 1–5 kHz.

Left to right positioning in stereo can similarly be derived naturally from pairs of coincident (Blumlein) or spaced microphones. Alternatively, single mono microphones can be panned to any required position. For this the microphone signal is simultaneously routed to both the left and right outputs via a ganged potentiometer. The latter is wired so that in its center position equal voltages go to the left and right loudspeakers giving a central image. Rotating the panpot to left or right increases the relative level in the appropriate loudspeaker, while keeping the combined levels the same, and gives a smooth choice of location. A quadraphonic panpot gives similar freedom of image location over the 360° horizontal sound field and is usually of joystick design to present immediate confirmation of the compass bearing chosen.

Multitrack Recording

The proliferation of input channels at first reflected the growth in popularity of multimicrophone techniques, as discussed elsewhere in this issue. However, the subsequent multiplicity of extra knobs for frequency correction, panning, echo, foldback, group routing, etc., made it virtually impossible for one engineer to mix straight down to two-channel stereo at one go.

This led to the greater use of multitrack tape recording, employing overdubbing and rerecording techniques developed by such pioneers as Les Paul in the United States and the Beatles in the United Kingdom. From three or four tracks in the early days, 24-track has become the normal in the larger pop studios and even 36-track is being mooted. The procedure is to lay a small number of tracks initially, perhaps the main rhythm instruments and a guide vocal (to be replaced finally with the proper vocal rendering). Then the tape can be rerun as often as necessary, while other performers listen on headphones or specially placed loudspeakers (foldback) and record in synchronism on to further tracks until the full arrangement is on tape. The mixdown to eventual stereo (or quadraphonic) master tape will still mean tinkering with these hundreds of adjustments, but at least the engineer can have as many trial runs as he might need to get everything right without damaging the original multitrack tape.

The latest development is a degree of automation in the form of computer-assisted mixing. Several different methods are currently being installed and evaluated by the industry. One essential feature of all of them is to provide the engineer with an infinite memory by storing a digital record of the fader (and certain other control) settings as he performs a mixdown "take." They .also provide him with more arms by means of an "update" facility. This allows him to tackle only some convenient number of control adjustments at each take and build up the final mix by easy stages.

At the heart of these automated systems is the use of voltage-controlled amplifiers (or perhaps attenuators) associated with each fader. The system repeatedly scans these voltages and digitally stores the information as to the fader settings. On replay for updating, the engineer needs to be given some visual indication, by meter for example, of the instantaneous "correct" setting of each fader so that he can intercede with a new setting. In one system so far

proposed, the faders are in fact motor-driven by the digital store to follow their actual movements during the take (Fig. 5). The fader knobs are of the touch-sensitive type, and the mere act of placing a finger on the knob switches that channel from the read (playback) to the write (record) mode. Some systems utilize two tracks of the audio tape for synchronized data storage, so that only two takes are "remembered" at any one time. In others, a single audio track is reserved for storage of the well-known SMPTE time code. This gives consistent synchronism with a separate storage medium, such as a floppy disc type, and extends the memory feature to almost any number of takes. Interface computer facilities give instantaneous recall of any desired take, and permit electronic sequencing, merging, or editing. All this can be carried out and monitored from the data store without magnetic tape being involved, other than the multitrack original, until the final analog master is recorded.

At the present rate of progress it seems certain that digital techniques will soon be extended to the master recording process itself. Indeed such use of pulse code modulation (PCM) circuitry has already been demonstrated successfully using modified video recorders. Eventually the software used by consumers will also be digital, instead of analog, and achieve standards of fidelity so far impossible.

Fig. 5. Closeup of touch-sensitive motor-driven faders used in one system of computer-assisted mixing.

Magnetic Recording for Original Recordings

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Why did it take half a century from the time Valdemar Poulsen applied for a patent on his magnetic recording device for it to become the most important tool in the sound recording industry? This paper reviews the history of this development and dwells for a time on how and why it is the focal point in the everyday operation of the recording studio.

If one asks what the most useful tool in sound recording is today, the response is certain to be immediate and decisive. It is the multitrack professional magnetic tape recorder. It does not merely capture, store, and impeccably reproduce the original audible material, but it makes it immediately available at any time for rebalancing, copying, or an inexhaustible degree of processing and application of special techniques never before considered possible.

This was not always so. The story of magnetic recording reminds one of the story of the ugly duckling, unattractive, pushed aside, always inferior to his associates and competitors, literally forgotten until he suddenly shone forth, commanding the respect and admiration of all his former detractors.

Twenty-two years had elapsed between the time Edison invented his first tinfoil phonograph and the time Valdemar Poulsen demonstrated that he could record and reproduce sound from a magnetized wire. In this period the competitive efforts of Bell and Tainter, Edison, and Berliner had brought mechanical disc and cylinder recording to a remarkable state of development. The acoustic energy in the sound source was sufficient to directly produce an acceptable recording, and the spring motor provided not only the energy to drive the reproducing phonograph turntable but also the reproducing diaphragm, with enough intensity to be heard comfortably anywhere in the "parlor." There was no need for amplification, which was a good thing too, for the De Forest vacuum tube had not yet been invented.

It was quite a different story with the first magnetic wire recorders. The electrical signal from a standard telephone transmitter went directly to a recording head where a small amount of the energy was caused to feebly magnetize the passing steel wire. On playback these weak magentic impressions generated correspondingly weak electrical signals that could be detected and identified by a single listener using earphones. This energy limitation was enough to keep magnetic recording from becoming a serious competitor to mechanical recording, but there were others. Wire speed constancy was poor, making it unsuitable for music, the wire ran at 7 feet per second, was expensive, required long rewinding times, duplicates could not be made, and threading was considerably more awkward than placing a record on a phonograph.

The "Telegraphone," as it was called, was recognized only as a dictation machine, and here too its use remained very limited.

In 1912 Dr. Lee De Forest, in attempting to record high-speed telegraph signals for later transcription at lower speed, applied one of his vacuum tubes to a Telegraphone in order to get enough energy to record the weak signals being received. This combination of tube and wire recorder, essential to the ultimate success of magnetic recording, was soon forgotten, and the wire recorder faltered and faded into obscurity around 1920, still plagued with serious limitations to its adaption.

Another opportunity for magnetic recording to emerge from mediocrity was missed a short time later. The background noise in such systems was always very high, caused principally by the use of a direct polarizing, or "bias," current superimposed on the audio signal fed to

the recording head. While developing a wire recorder for the U.S. Navy in 1921, two experimenters, W. L. Carlson and G. W. Carpenter, discovered that if a very-high-frequency alternating current was fed to the record head instead of the direct current previously mentioned, there was a great reduction in background noise during playback. Thus was born the concept of alternating-current or high-frequency bias. A patent was issued to them six years after the invention, in 1927. By that time very few experimenters indeed were the slightest bit interested in devoting time to development of magnetic recording.

One of the strongest influences to further eclipse magnetic recording was the introduction, in 1925, of electrical phonograph recording and reproduction by Bell Telephone Labs. It was soon commercially introduced by the Victor and Columbia companies in the United States and by HMV and Columbia in England. Within two years, out of this development came the talking motion picture. These systems were so advanced in their time that there did not seem any reason to tinker with magnetic systems.

There seems to have been only one man, in Germany, at this time who had the faith and was seriously interested in the development of magnetic recording. With his conviction he was able to persuade investors that they should organize the Telegraphie-Patent-Syndikat. This was Kurt Stille. His company developed apparatus and sold licenses to manufacture equipment. By 1929 they sold a license to Louis Blattner who developed a highly advanced machine that employed a steel ribbon instead of wire and was intended for use in broadcasting stations and motion picture sound recording. Its use was short lived in the motion picture business but it had better luck in broadcasting. The BBC, which installed a number of machines, reported that it was not suitable for music work because of speed inconstancy, but it was adequate for news bulletins or repetition of commentary recorded earlier in the day. The steel tape was 0.08 mm thick and ran at a speed of 150 cm per second. A half-hour program required a massive reel holding nearly 3 kilometers of tape. It, of course, employed direct-current bias and thereby suffered from limited dynamic range.

The Blattnerphone, as it was called, came to be used increasingly in the BBC domestic service but was particularly useful in its Empire service.

Blattner's design was taken over by the English Marconi Company, and a greatly improved version was introduced as the Marconi-Stille machine. The BBC found this to be much more satisfactory and started using such recorders in 1934. Their use continued through World War II. This was unquestionably the largest magnetic recorder ever designed for sound work. The spools on which the steel tape was wound were so massive that machines were scheduled in such manner that the reels did not require changing, material being held on a specific machine until it had been replayed on the air.

Kurt Stille also sold a license to Karl Bauer in the 1920s. Bauer started the Ekophone Company, which produced the Dailygraph in Germany. This machine was intended as a telephone and dictation recorder, and employed magazines which were easily interchanged. C. Lorenz, a large German communication firm, ultimately bought the business and redesigned the apparatus, renaming it the Textophone. As Hitler came into power, his organizations used ever increasing numbers of them after 1933. Lorenz then designed a heavy-duty machine for the German broadcasting service, employing steel ribbon. It was called the Stahltonmaschine, and it went into service in 1935.

In 1927 a very important concept came into being. Another German by the name of Pfleumer conducted tests with tapes of nonmagnetic materials such as paper or plastic, on which he coated a layer of magnetizable medium. This concept required the development of a new design for the recording and playback heads, leading to today's pattern of the so called "ring" head. Previously, in steel wire or steel tape the heads straddled the medium with one pole on each side.

Pfleumer's system was very attractive from the standpoint of material cost and weight and its easy editability, but it did not work very well at first. The particle size in the magnetic coating was very coarse so that the signal-to-noise ratio was inferior to other systems, which were poor enough as it was. The tape-handling mechanism left much to be desired. In 1931, however, the Allgemeine Elektrizitäts-Gesellschaft (A.E.G.) took over the work, concentrating on the electrical and mechanical design of the machine while turning over the development of tape to the large chemical organization of I. G. Farben.

By 1935 the system had been greatly improved, and it was first shown publicly as the "Magnetophon" at the German annual radio show in Berlin. Its performance left something to be desired, but it made a hit because of the inexpensive tape and the fact that recordings could be edited with scissors and cement.

Continuing efforts to develop the Magnetophon eventually brought its performance to a level comparable with the steel tape machines. What must have been a great day for Pfleumer, the A.E.G., and I. G. Farben developers of this apparatus occurred on November 19, 1936, when they were able to record a live orchestra for the first time with the newly improved machine. The London Philharmonic Orchestra was visiting Ludwigshaven and gave a concert at the Farben plant. A copy of the recording made on this occasion came to light in the 1970s, and copies of it have been widely distributed. It is heralded, justifiably, as the first significant music recording made on this type of tape. This is not to imply that its fidelity is in any way comparable to today's recordings. In listening to it, the peculiar distortion resulting from attempting to record at a level high enough to overcome the direct-current bias background noise is clearly evident. The Magnetophon still had a long way to go, although it was by now performing about the same as the earlier steel tape systems. The London Philharmonic tape demonstrates the point that no magnetic system, wire or tape, had yet performed with the fidelity of a good 78-r/min shellac disc pressing.

From all that we have revealed so far it might appear that the only significant work in magnetic recording had

been carried on by the Germans between the decline of the Telegraphone and the start of World War II. This was not so. Specialists in Japan and Bell Telephone Laboratories and the Brush Development Company in the United States were active as far back as the early 1930s. In 1937 Brush was demonstrating the "Soundmirror," an endless-loop machine containing enough steel tape to record for 1 minute. In the same year Bell Labs demonstrated their "Mirrophone," a similar endless-loop machine that gave excellent performance at the remarkably low speed of only 16 inches per second. It employed a ribbon of specially formulated tape, called "Vicalloy." Its use was predestined to be limited to telephone-company applications because the tape cost more than 1 dollar per foot.

During this period of development both the Japanese researchers and Bell Laboratories investigated the use of alternating-current bias. The first commercial use of the technique appears to have been in a machine which Bell displayed at the World's Fair in New York in 1939, again employing Vicalloy tape. A patent on alternating-current bias was granted to D. E. Wooldridge in 1941, and another was issued to Marvin Camras of Armour Research Foundation. In retrospect it seems strange that both of these patents did little more than harken back to the Carlson and Carpenter patent of 1927. The work of Camras and Lynn Holmes of Stromberg Carlson Company was directed to the use of high-speed steel wire, while Bell concentrated on Vicalloy.

The German broadcasting service, known as the "Rundfunk," having had much experience with steel tape systems, was intrigued by the Magnetophon and its use of cheap editable tape. Two of its engineers, Dr. Braunmuhl and Dr. Weber, undertook to improve the Magnetophon to make it fully suitable for broadcast service. While employing direct-current bias, the story goes, their recording amplifier suddenly broke into supersonic oscillation one day, and they were amazed to find on playback of the tape under test that it suddenly became amazingly quiet. Their subsequent investigations and hard work resulted in all the Rundfunk studios being ultimately outfitted with Magnetophons employing alternating-current bias and erasure. By this time Germany was at war, so the outside world heard nothing of the story of the high-performance Magnetophon.

Meanwhile developments by Camras at Armour in the United States resulted in a portable wire recorder of good performance, which found use by the United States armed forces for monitoring purposes. It employed alternating-current bias, but was far from a high-performance device. Wow and flutter were bad, it suffered from turn-to-turn printing as the wire lay against itself on the spools, and the wire traveled at 5 feet per second for a rather limited frequency response.

Like Armour, Brush Development Company concentrated on the use of wire early in the war period; but guided by Dr. S. J. Begun, who had previously been with Lorenz in Germany, interest was switched to the area of editable inexpensive tape. The objective in mind was to develop a machine of reasonable fidelity for military, and hopefully, for post-war home application. This work was particularly significant because it brought about the introduction of one of today's most important tape manufacturers to the field of magnetic recording.

In 1944 Brush addressed a letter to Minnesota Mining and Manufacturing Company, asking 3M to undertake the task of coating a carrier of plastic or paper with an iron oxide to Brush's specifications. Under Dr. W. W. Wetzel's guidance 3M produced the first practical tape in this country, enabling Brush to introduce their recorder, known as the "Soundmirror" model BK-401, in 1946.

The chain of events that led to the first use of professional-quality tape recording in this country has been detailed on numerous occasions by the writer. Suffice to say at this time that he was privileged to bring into the United States two obsolete-model Magnetophons (direct-current bias type), was able to upgrade them to the German broadcast quality level, and put them to work on Bing Crosby's radio show for master recording and editing in 1947. Prior to this, in October of 1946 he demonstrated their performance to Mr. A. M. Poniatoff, president of a small company that was anxious to get into some phase of professional-quality audio manufacturing, now that the war was over. This was Ampex Corporation. Mr. Poniatoff's enthusiasm resulted in Ampex designing and manufacturing the first professional audio tape recorder to gain acceptance in the United States.

Ampex' first model bore a resemblance to the Magnetophon from which it was derived, of course, but it was somewhat modified to take advantage of contemporary mechanical and electrical refinements. Its measured performance surpassed that of the German machines in several areas.

The first two Ampex machines were delivered to the writer in April 1948 and permitted the two Magnetophons which had produced 26 radio shows to go into much deserved retirement. Deliveries to the major radio networks, ABC, NBC, CBS, Mutual Don Lee, and others followed in short order. Mastering for phonograph records was obviously a natural and Decca, Capitol, Columbia, and RCA Victor quickly converted to tape.

The first "Chinese Copy" of the Magnetophon was actually Col. Richard Ranger's "Rangertone" introduced in 1947. Some initial design difficulties were promptly overcome and by 1949 it had found a fairly exclusive niche in the motion picture business, made possible by a clever synchronizing system which Col. Ranger developed. This permitted quarter inch tape to be run in synchronism with sprocketed film.

Magnacord was formed in 1946 and first made a quality wire recorder. The writer recalls hearing a demonstration of this machine and being impressed by its performance except for an objectionally high hiss level. This model, the SD-1 (for Super-Duper) was soon abandoned when it became obvious that tape was the preferred way to go. In May 1948 the first Magnacord tape model (the PT-6) was shown at the NAB convention in Los Angeles. Broadcasters everywhere were fully informed by now of the success of tape in the radio networks, but the price and size of machines such as the Ampex 200 had until now often killed their enthusiasm. The PT-6 was much smaller and

less expensive. Magnacord wrote $45 000 worth of business within three days.

A long awaited development by Fairchild appeared early in 1949. Taking advantage of recent tape developments it was able to give excellent performance at a speed of 15 inches per second where earlier entrants in the field had operated the tape at 30 inches per second. Fairchild also provided a novel system of synchronizing tape with film, and this was promptly put to work by CBS-TV to provide sound for its Kinescope recordings that were used for delayed TV broadcasts.

Other entries into the equipment business at the professional level included Presto, RCA, Concertone, and Amplifier Corporation of America. Finding themselves confronted with the reduced speed made possible by the tape developments of 3M, Audio, and others, Ampex, Ranger, and others who had followed the original German pattern soon made conversion kits for existing apparatus and set about to introduce new models whose primary speed was 15 inches per second.

While Ampex' model 200 was essentially for fixed installation, the new model 300 was much more compact. Its portable version, in two cases, could easily be handled by one person. Most significantly its price fell into an area that made it attractive to schools, radio stations, record companies, and serious amateurs. In a short while after its introduction in 1949 it became the standard of the industry in this country and was widely accepted overseas.

With regard to technical standards, it was recognized at the outset that operating levels, tape speeds, equalization, reel dimensions, tape width, and oxide characteristics would have to be agreed upon in this expanding industry. The 1949 NAB proposed that recording and reproducing standards for disc and magnetic tape contain a section with less than 350 words on the subject of magnetic recording. Within a year or two the subject was fully covered and well defined.

Various equipment manufacturers were soon to be found drifting into different areas of specialization. Presto, for example, found a ready market in the wired music services such as Muzak, taking the place of the earlier vertically cut transcription discs. Stancil-Hoffman designed apparatus to run at 18 inches per second, film speed, with the idea of providing sound for motion pictures, but Fairchild and Ranger also became widely accepted in this area. RCA machines, which were outwardly very similar to the Ampex 300, were mostly found within divisions of the company, and their manufacture was later discontinued.

In October 1946 Marvin Camras demonstrated sound from magnetically coated 35-mm film at the SMPE convention in Hollywood. The oxide had been spread on film base by Camras himself using an ordinary paint brush. The sound was excellent. This demonstration probably marked the beginning of earnest interest by the motion picture industry. The advantages magnetic recording offered over the existing optical methods were numerous and impressive: freedom from dependence on laboratories, immediate playback capability, permanence, relatively low cost, no critical adjustments compared to optical apparatus, reusability of the medium, ability to work in daylight, and its superior dynamic range which made noise reduction systems unnecessary. The principal suppliers of sound apparatus to the motion picture industry soon made magnetic systems available, and optical sound tracks remained common only for the convenience of release prints to be run in theaters.

In the United States the number of companies engaged in phonograph recording from the dawn of the phonograph into the 1950s could be counted on one's fingers. The number of radio stations was essentially static. This meant that after these industries were fully equipped with tape recorders there was a great slowing down of professional tape recorder sales. Some of the earlier manufacturers went out of the business altogether, but companies like Ampex shifted their attention to other lucrative areas of magnetic systems such as instrumentation and video tape recording. Here the opportunities for expansion seemed unlimited and possible sales unbounded. Professional audio was relegated to the back burner and allowed to simmer just hot enough to fill an occasional order. Even with management's coolness toward new developments, however, there was an occasional adaptation of standard apparatus to fill some new requirement. One of these was the introduction of two-track stereo recording on quarter-inch tape. Some single demonstration machines had been set up early in the game by Pfleumer and Weber in Germany and by Magnacord in 1948, but they were mostly novelties. In the early 1950s the prospect of providing stereo in the home through the medium of tape playback apparatus seemed promising since the phonograph record was strictly monophonic.

The quarter-inch two-track format was followed shortly by three-track half-inch systems. The use of half-inch tape assured that the track widths would provide slightly improved dynamic range with the flexibility of recording left and right orchestra channels, with soloist on the third channel, for post-recording mixing. This was really the start of the most common technique found in today's popular recording procedures.

From the time the long-playing record was introduced, efforts never creased to improve cutters, pickups, amplifiers, turntables, tone arms, styli, mastering discs, and the entire processing operation from coating the master to the final pressing. Within a few years the LP pressing was capable of quality, limited in some areas by the tape recording from which it was copied. Little was done, as has been pointed out, by the tape recorder manufacturer to improve his machines in this period. Tape manufacturers were not so apathetic, although the end results of much effort were relatively small improvements between 1948 and 1960. One attempt to ease the situation with regard to dynamic range by modifying the pre- and postequalization curves in the tape machine was introduced as the Ampex mastering equalization (AME). It was soon abandoned when it was found to be unworkable on certain types of music.

The first crack in the wall of professional tape recorder stagnation came in 1962, when a paper was given at an AES convention on a new tape having 4 to 6 dB lower

background noise. In many older machines the circuit noise was so high that the potential improvement of this tape could not be realized.

For the equipment manufacturers the time was ripe, in 1963, for a rebirth of interest in professional audio tape recorders. Video tape sales were tapering off, and government instrumentation requirements were slowing down. Some new studios were to be found here and there, and the apparatus in the older large organizations was becoming well worn. It was time to design new equipment. The day of the vacuum tube had passed some ten years earlier, but it took this renaissance to bring about the conversion to solid state.

By 1966 there were new studios springing up throughout the United States and Europe, and there was interesting new equipment to fill their requirements. Scully had always made only disc cutting lathes, but now entered the field with a high-quality tape machine of modern design at an attractive price. Ampex had redesigned its standard machine for better performance and improved eye appeal. The pattern was typical of others. One organization that had never made a professional audio recorder entered the field with a tight-loop tape drive mechanism derived from its experience in the instrumentation business. The electronic system that went with it was capable of a weighted noise performance of 76 dB. It met with immediate approval when it was described and demonstrated at the AES convention in Hollywood in 1964. The wide dynamic range was obtained at the expense of employing two tracks per channel, and while it received an enthusiastic welcome, it soon fell into eclipse because of the appearance of another noise-reduction system, the Dolby.

Ray Dolby's system met with immediate acceptance because it was applicable to existing machines, required only one track per channel, and was made up in external units that could be patched in or out of service as required. They performed beautifully from the start and are to be found everywhere today, which says that they must have been good to begin with. Dolby's system is a highly refined version of what was developed for radio telephone transmission in the 1930s in order to overcome the noise added to the signal during transmission. It was called at that time a "compander," since the dynamic range of the signal was compressed before transmission and inversely expanded at the receiving end, with the result that the transmission noise was greatly reduced. A compander system must follow some specific relationship of signal level to a degree of compression or expansion. Another system, following a different relationship than the Dolby system, has gained acceptance recently. This is the dbx system. Popularity of such devices continually points to the inherent tape noise limitation which even today plagues the professional tape recorder.

Tape manufacturers have been far from remiss in their concern for this limitation, however. As mentioned above, a 4 to 6 dB reduction in noise was achieved in 1962. This same manufacturer introduced a new tape in 1969 which provided a 3 dB higher operating level, and again in 1974 another 3 dB was added to the operating level. Some older machines are not capable of handling the additional level, but for those that can, the noise performance of the professional tape recorder is very good indeed. With the addition of a splendid compander system the performance is superb.

Another important feature of the professional tape recorder to come out of its 1966 renaissance was multiple-track recording. If one could record an orchestra in stereo on two tracks and add a soloist on the third, why not have the soloist come in later, listen to the orchestra tracks, and do his bit onto the third track. This necessitated an arrangement whereby the orchestra tracks could be heard from their record heads in order to have them in absolute time synchronism with the third track which was being recorded. Thus was born a powerful tool which has since been considered essential on all multitrack machines.

If three tracks provided greater flexibility, surely four would be better. But why stop at four? Within a year or two all manufacturers were making eight-track machines employing 1-inch tape. With such flexibility one could record the separate instruments of a group as they played a number in ensemble and later mix the parts together for the most agreeable balance, or the parts could be done one at a time and mixed later when they were all played in synchronism. It may be of interest to mention that in the case of Ampex, all they had to do was go back through their files and pull out the records of a job they did in the early 1950s for the novelty guitarist Les Paul. His multiple guitar records were sensational hits and were produced by recording a single guitar on one track after another on his specially built eight-track 1-inch tape recorder.

Multitrack recording added a great degree of flexibility to the tape recorder, but soon another degree was demanded by artists and producers.

It became imperative in certain operations to combine a number of tracks sometimes with simultaneous live input and to rerecord the mixed signals on a single previously unused track. This caused all manufacturers their full share of headaches.

It had never been necessary to shield record heads from the weak 60-Hz fields of motors and power transformers, nor had it been deemed desirable to make them with the very narrow gaps used in playback heads. When record heads had been used for monitoring in multitrack work, the frequency response was limited to about 6 kHz, and the background noise was high. This quality was perfectly acceptable for listening in earphones. This new requirement necessitated redesign of record heads and record circuitry to match them, adequate head shields, and high-performance preamplifiers, so that the measured performance of a record head used as a playback would match the performance of the normal playback head.

Standard electronic packages, made up for a single-track machine, were still small enough for two-track stereo configurations and were even squeezed into eight-track assemblies. Every manufacturer recognized that the inevitable could not long be delayed. Sixteen-track recorders would have to be made available since the nature of the recording business had moved drastically in the direction of multitrack flexibility.

One manufacturer, whose channel electronics assembly was considerably smaller than any other, converted to a card cage configuration, the compacted cage capable of holding electronics for all sixteen channels. Another, with initially smaller units, stacked them around and under the tape transport which, in order to accommodate the 2-inch tape required for sixteen tracks, employed components from their standard video recorder. To be sure, the completed assembly, all in gleaming stainless steel, closely resembled a mobile restaurant steam table. Ultimately, recognizing that 24 tracks could be spread adequately across two-inch tape, all manufacturers have compacted their electronics to permit reasonably sized machines with this configuration, and the 24-track configuration has become very popular. At this writing there have even been a few 32-track assemblies produced, but there are indications that requirements for more than 24-tracks can be more efficiently met by somewhat different techniques.

If absolute synchronism could be maintained between two 24-track machines, one would have the equivalent of a 48-track unit, yet with the ability to use either machine independently on other jobs at times when this number of tracks is not required. Such synchronizing methods are now available as an outgrowth of the following developments.

Television program production has fostered development of systems for interlocking film, video tape, and professional audio tape recorders. Recognizing that the problems of handling such dissimilar media efficiently could lead to enormous problems, a system has been developed wherein a magnetic track is set aside on each of the media for assignment to a specially recorded binary code, referenced to date and time of day that the recording was made. This is known as the SMPTE code, since it was formulated as a result of research by the Society of Motion Picture and Television Engineers. Operating through a computer system it allows an operator to automatically find a specific place in a recorded tape or film by causing the machine to run to it and "park" at the starting position desired. When several media are to be run in sync, they are all brought to the park position, and even though they may accelerate at different rates on the start command, the computer sees to it that they all pull into absolute synchronism. The flexibility this system provides for the present and its potential for the future are enormous.

Where the use of the SMPTE code is not yet justified, some handy tools have been devised to assist the operator in finding specific places in a reel of tape. These are generally based on counting the number of turns of a tape reel or idler wheel. One can set in a reference number and have the machine search until the count matches it, at which point the machine parks awaiting further instructions.

Cutting and splicing two-inch tape has proven to be impractical and expensive. The latest multitrack machines are now fitted with electronics which permit a performer to make corrections electronically by replacing imperfect musical phrases or spoken lines "on the fly" with completely inaudible effects at the start and end of the inserted segment.

It is somewhat curious that with the myriad developments and refinements that have gone into the professional audio tape recorder over the past 75 years, the method of handling the tape has followed the same basic path laid down by the Magnetophon in 1935. The tape is drawn off the supply reel, around a filtering idler, straight across the heads with a slight wrap on each one to assure contact, squeezed between the constant-speed capstan and a rubber pressure roller, and then released through a guide carried on a spring-loaded arm to the take up reel. There was only one memorable departure from this configuration in 1966, as mentioned earlier, when one manufacturer introduced a tight-loop drive system with differential capstan. The second break from convention occurred within the last year with the introduction of a drive which renders the capstan–pressure roller combination unnecessary.

When using the most recently developed tapes and making the most of attendant noise reduction systems, professional audio tape recorders seem to have reached the ultimate in analog audio signal recording. Have they reached the ultimate in audio signal recording?

Record Manufacturing: Making the Sound for Everyone

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INTRODUCTION: The reproduction of sound is universally credited to Thomas Alva Edison, but not until Emile Berliner's development of the disc did the manufacture of records have any chance at what we would define today as industry. Though the cylinder was a fine example of a crafted product of its day, it was the disc that allowed the record to be manufactured in ways that would yield sufficient product to reach a mass market. Later, at the turn of the century, Eldridge Johnson's improved processes turned a fledgling business into a serious industry. Though three quarters of a century have passed, we can readily recognize that the industry today is a refinement of Johnson's "prototype." It has, however, utilized the efforts of many individuals to bring its product along, continuously reducing the degrading effects of the manufacturing process.

With today's increased interest in the "ultimate" quality of records, we are also experiencing, in effect, an interest in virtuoso performance of the manufacturing arts. Though near superb quality can be obtained on a careful "mastering" basis for limited quantities, to get this quality to everyone who buys a record, we must provide the process reliability that only well designed automation can provide.

We have come a long way from the use of power devices to supplement muscle and crude cam timers to the replacement of the manual operation of valves. The fully automatic press, which found its roots in efforts of the late 1940s, has, however, taken a long time in making its mark as a means to quality improvement. The automatic press, coupled with a refined electroplating process and compound, will be providing a new level of quality for the marketplace.

DEMANDS ON THE REPLICATION PROCESS

When Berliner developed the disc, record manufacturing was freed from the need to trace the audio groove on each copy. In the replication process, however, proper attention must be paid to those physical parameters that define the groove in terms that can be read by the playback system.

In the 12-inch LP nearly one-half mile of groove is needed to produce a 30-minute program. To accomplish this, a groove density of approximately 300 lines per radial inch is required. Such a density limits the groove width to under 0.003 inch. Groove densities between 175 and 300 lines are found in practice as a function of program length, recording level, and frequencies encountered. Signal elements with amplitudes of less than 10 microinches (1/4 μm) can be encountered in practice, and the stylus is capable of reading them, though the recording level must be limited to prevent distortion.

$$\text{amplitude} = 0.025\ \lambda^2/\rho$$

where λ is the signal wavelength in the groove, ρ the radius at peak of the sine-wave curve, and min ρ is the stylus tip radius, that is, 0.0007 to 0.001 inch.

The perceptability of noise and groove degradation is essentially a function of physical size and frequency. It has been demonstrated that a change in level of 1 dB is barely perceptible to the ear, while an increase of 2 dB is only slightly noticeable. Accepting 2 dB as being perceptible, the perturbation in a "silent" groove would have the physical measurement $V = 10^{2/20} = 1.26$ cm/s and $A = V/11.3f$ where V is the rms transverse velocity and A the peak amplitude.

If the pertubation-produced frequency characteristic is 10 kHz, the amplitude would be on the order of 11 microinches.

It is further noted that the stereo groove has a tip radius of 0.0002 inch. Using a stylus with a tip radius of 0.0007 inch permits only a 0.0002-inch clearance at the groove bottom.

In recent years the development of the discrete four-channel (CD-4) record brought a new dimension to the sound. The system design, however, imposes the need for

additional precision in the manufacturing arts. With the carrier channels operating at frequencies between 20 000 and 45 000 Hz, wavelengths and significant amplitudes are one third of those experienced equivalently in stereo. This therefore causes defects in the 3-microinch size to become significant. It is further noted that the effective clearance between the stylus tip (Shibata) and the groove bottom is reduced by half to 0.0001 inch.

From the foregoing it is clear that the groove replication process of today must be an exercise in precision with process elements and an environment free from affecting degradations whose physical sizes are measured well into the submicron range. Fig. 1 shows examples of groove parameters.

MASTERING—SETTING THE SOUND COPY

Until the advent of magnetic tape recording, which was first used for record work in 1948, the master disc developed during the recording session was the direct physical link to the replication means and was vulnerable to the manufacturing process.

In the beginning, Berliner used a zinc disc with a fatty substance coating onto which was scratched the lateral recording line. The groove was then generated by etching in an acid bath, with the depth and width a function of the duration and strength of the acid solution. Recognizing the noise source presented by the etched groove, Johnson introduced recording by cutting the groove in wax, similarly to what was done by Bell and Tainter several years earlier in their improvement of the cylinder.

Berliner with his etched groove had introduced the method of developing a negative master by means of electroforming. To accomplish the use of the same replication method, Johnson developed a method of brushing the wax surface with powdered graphite to develop a conducting surface for the electroforming process. This process essentially remained intact until the wax was replaced by the lacquer in 1938.

The lacquer, though not impervious to damage, accomplished another milestone by providing greater durability and opportunity for noise improvement through process change. Though gold sputtering was introduced by Western Electric in 1930, it is interesting to note that Edison is credited by some with the use of gold sputtering in the mastering process around the turn of the century. Improvements in the lacquer disc had allowed the intoduction of "wet silvering" to produce the conducting surface for the subsequent electroforming operations. This process, similar to that used in the production of mirrors, is a chemical reduction of an ammoniacal silver. By the early 1950s this process was universally adopted by the major manufacturers.

Improved lacquer cutting techniques, notably the use of a heated cutting stylus and burnishing facets, have yielded groove surface finishes on the order of 0.5 microinches rms [1]. Such finishes, however, are not continuous in the tracing of the groove, as large horizontal displacements of the stylus will produce rougher surfaces. Impurities in the lacquer compound have been identified as the source of some of the "ridge" lines which run parallel with the groove. Stylus heat and lifting practice have also been identified as a cause of these ridges. Any residual debris on the stylus that could remain during a stylus lift will cause charring of the lacquer material, which will then produce the ridges on subsequent cutting.

These surface imperfections in the lacquer groove, though not significant of themselves, can appreciably affect subsequent processes. As an example, the silver may have greater affinity to the groove at the time the negative master and the lacquer are separated. A pullout of

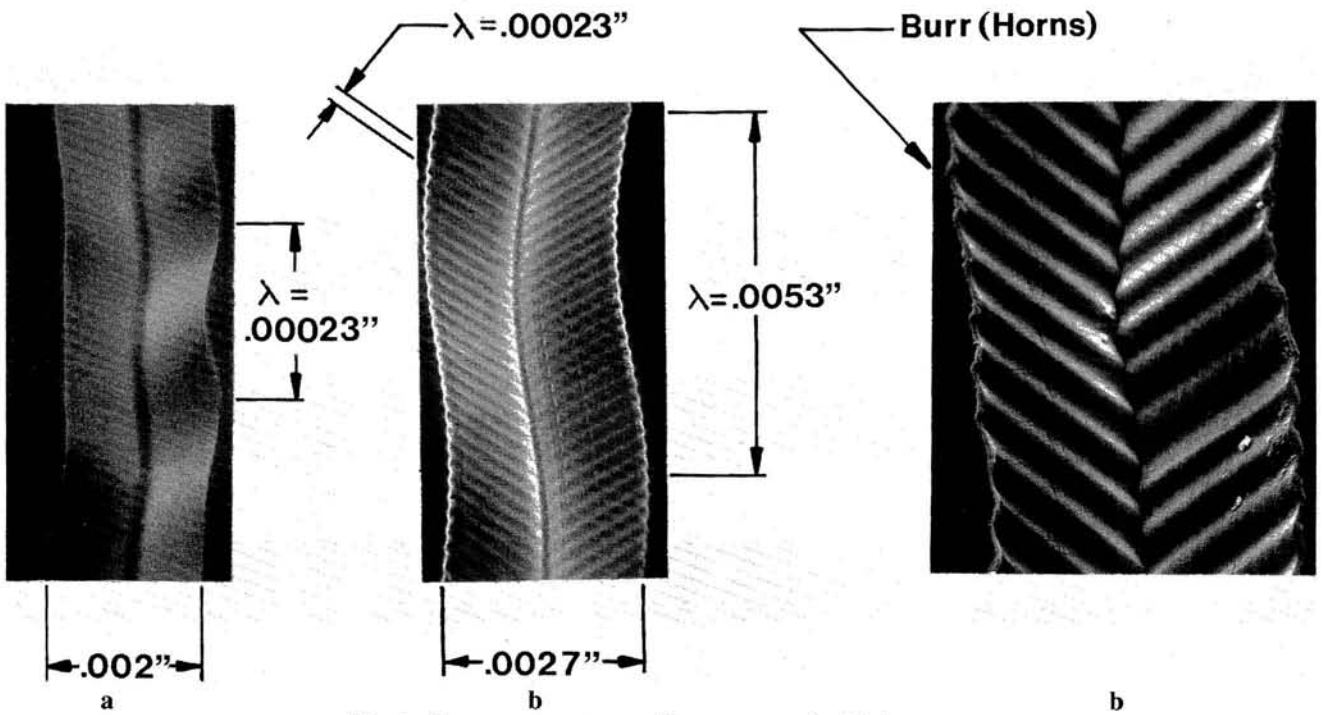

Fig. 1. Groove parameters. **a.** Stereo groove. **b.** CD-4 groove.

silver will produce a defect if the subsequent positive is generated from the silver-faced master. Surface roughness and ridges in the metal parts can cause problems in the release of the compound from the metal surface during pressing. At times the effect is accumulative with an exaggerated case where the compound sticking to the stamper groove results in a void.

At the present time much art still remains in the lacquer cutting process, and careful procedures are necessary to keep the cutting process clean.

MATRIX—TOOLING THE SOUND

The world of the audio groove is in dimensions outside the resolution capabilities of the unassisted eye. Those that work to reproduce this world very often do not have a direct means in the measurement of their success. This arrangement results in the development of many variations in the process arts and the recipes of their substances.

Processing with the Lacquer

Translation of the lacquer master to metal is performed by the process of electroforming. In preparation, the lacquer surface is cleaned and made electrically conductive by the chemical reduction of silver.

Since the lacquer material is highly plasticized, adequate pretreatment is required to eliminate the harmful effects possible by oils exuding out of its surface. Good practice allows for preconditioning in temperatures up to 100°F to assist in the removal of oils near the surface. Should such oils be on the surface or bleed out prior to completing the preplate that would set the shape of the groove, significant audible defects could result. Cleaning to remove the oil and debris that may have fallen onto the surface must be adequate, and since the success cannot be judged until several steps later, an optimum safe process must be chosen. Soaking in liquid detergent accompanied by careful gentle brushing is good practice. Harder or aged lacquers with less oils, however, could be adequately cleaned by soaking in a mild alkaline cleaner. Other practices such as precleaning with petroleum naphtha have been used by various processors. In the latter cases, extra care is required due to the hardening and possible crazing effect on the lacquer surface. After rinsing in deionized or distilled water, the lacquer is ready for silvering.

Temperature control, solution purity, solution control to prevent precipitation, and the process method are all important for the elimination of defects which could be introduced in this process step. The silvering solutions are formulated for an optimum temperature of application, and this can vary based upon the method of temperature control chosen. This is usually between 60 and 80°F but controlled within 5°F. Incomplete silvering (pin holes) and silver grain sizes affected by temperature result in potential noise elements. The silver deposit thickness is also critical. An optimum deposit of 3–4 microinches [1] provides for good coverage and consequent conductivity for electroforming. Deposits that are too thick can result in stress cracks which can translate into noise. Special machines have been developed for silvering lacquers to provide consistent control of the process. But whether the process is automatic or manually controlled, the design of the physical arrangement is important to the potential of noise. Any exhausting of overspray should be so arranged that ambient air is not passed over the surface of the part. Any atmospheric debris can cause defects. The initial discharge of silver and reducer should be away from the part to eliminate the potential of reduced "skins" from the nozzle tip being discharged onto the surface of the part. The design of the silvering enclosure should be such that drippings cannot collect above the surface of the part. The spray distribution should be such that all surfaces of the lacquer receive the optimum silver deposit. All surfaces that come in contact with the solutions, including the spray nozzles, should be chemically inert. Stainless steel or preferably plastic components are good choices.

The quality of the atomizing/propellant gas for the spray operation is also vital. Chemically clean compressed air usually provided from a system using a nonlubricated compressor and filtered to remove vapors and particles is essential. Some processors use chemically pure dry nitrogen as an excellent alternative.

The use of "final filters" to guard against errant precipitations and flow indicators for calibration is also good practice.

Immediately after silvering the lacquer is rinsed in deionized water and placed into a plating tank set up to interface with the delicate characteristics of the lacquer. Plating solution temperatures between 90 and 100°F are used to prevent deterioration of the lacquer. The solution is also carefully monitored and controlled for low stress and impurities. Stress in the electroplated metal is a possible source of echo, where the signal from a groove is mechanically impressed on the adjacent groove. Most notably, when this phenomenon occurs, the initial sound trace on a record can be heard faintly in the preceding "silent" groove. Excesses in stress levels, either compressive or tensile, can cause distortions or cracking of the silver surface which has low strength and poor adhesion to the lacquer surface. Where the stress has caused a void to open up, ticks will result in the sound track. The control of impurities is essential in this phase to allow for good control of stress. Due to the low plating temperatures and low current densities, the presence of impurities can make the control of stress unpredictable.

Prior to 1950, acid copper plating was used for electroforming operations. After that time Watts nickel plating was introduced to reduce surface noise by 5 dB. Because of the higher stress characteristics of this process, copper plating was used to build up the thickness of the parts after the groove was properly replicated in nickel. By the early 1960s most processors had converted to the lower stress sulfamate nickel process. This significantly lower stress process allowed for the full replication of all matrix parts in nickel and entirely eliminated copper plating. Bonuses were reaped in a reduced chance of metal contamination (copper is a serious contaminant in a nickel plating bath) and the reduction in the number of ticks previously experienced due to the higher stress process. In many cases the engravers, who were employed to repair such defects, were nearly out of business.

Preplating of the lacquer is carried out until a thickness of approximately 0.00075 inch is achieved. The preplated lacquer is then transferred to the regular process plating tanks where the bath temperatures are set between 130 and 145°F. This step takes advantage of allowable high current plating with consequent faster deposition rates, while maintaining the stress in good control. The thickness of the plating is raised to a total of 0.015 to 0.035 inch. After the plating is complete, the negative silver-faced master is separated from the lacquer. The separation method varies from the use of a circle shear to trim the edge of the combined parts to the use of a knife to cut through the preplate thickness if a rubber masking ring was used for the buildup plating. Physical separation is accomplished by "peeling" the metal master away from the lacquer. The thickness chosen for the metal master assists in keeping the bend at the interface between the two parts at a large enough radius to prevent distortion by overbending. Those interested in the process reliability of this operation have incorporated a vacuum fixture where separation takes place at a very large radius, almost perpendicular to the stationary part face. The separation between the two parts is further mechanically controlled to the point that the parts can be lifted out of the fixture without the potential of clashing.

Where ultimate quality is required, the lacquer is discarded after the first processing. The potential of damage in processing is too high to risk process reliability. Where a specified quality level or program increases the chance of success, lacquers are reprocessed.

Processing with the Master

Reproduction from the negative silver-faced master has many potential problems. The silver is very thin, soft, and therefore easily damaged. Industrial environments, where contaminants such as sulfides are present, cause corrosion of the silver. The potential of silver pullouts or loosening from the metal master somewhere in the thousands of feet of groove further adds to the problem. In the latter case, the few microinches of defect amplitude would not be directly significant in a stereo reproduction; however, in the pressing of the record such defects could lead to the pullouts of plastic that would be significant. It is further noted that in the processing of CD-4 grooves modulations of a few microinches are experienced in the FM carrier channels. Defects of that magnitude would therefore be significant.

Cleaning practices are also restrained because of the fragile silver. Processors using electrocleaning methods must resort to cathodic cleaning which could cause the migration of any impurities in the solution to the master surface. The use of anodic cleaning on the other hand would destroy the silver. The use of any brushing or wiping of the surface must be extremely cautious. In the separation of the metal master from the lacquer, quite frequently some of the lacquer material sticks to the silver. Removal of this material is essential if good parts are to be replicated. Cleaning of the silver-faced master therefore requires a routine cleaning with solvent.

The many problems associated with the silver-faced master has prompted processors wishing to provide the best quality reliability to chemically strip the silver prior to further processing. Many careful tests on stereo programs have demonstrated that removal of the silver of itself does not cause deterioration.

The life of a pressing master (stamper) averages approximately 2000 molding cycles. Due to this short life, it is necessary that the master be replicated to meet the requirements of usual production orders. The process takes two additional steps in metal replication to yield the pressing stamper. It is important to mention here that any deterioration in the "sound" because of the additional steps is due to process errors and/or contamination. The process itself need not cause significant deterioration, but the opportunity for errors does exist.

Plating the master proceeds in the same manner as described above, except that all the plating is done in the higher temperature plating bath. The main concerns in this replication are the control of stress. It is important that the resultant positive (mold-mother) be dimensionally stable for the several replications it will be used for. Though debris are to be eliminated as an overall policy, any such presence would be less critical in this step than in replicating from the lacquer or in the next step where the part to be copied has recessed grooves. The grooves offer a good place for the debris to collect. Common with all the electroforming steps, however, surface quality of the groove is important. In addition to the cleaning it is important that the surface of the part be properly passivated to allow separation later and wetted with plating solutions prior to switching on the plating current, as the surface quality could be impaired. The initial 10 minutes of plating is performed at low current densities (30–40 A/ft^2) and then raised to 150 or above. The upper limit on plating is a function of the individual process and will be discussed later. The resultant positive will be 0.020–0.035 inch thick and will be separated from the metal master as previously described.

Processing with the Positive

The positive at this point still carries the burrs ("horns") at the groove edges which were created in the lacquer cutting process. These burrs, if severe enough, will cause a molding defect called fractured groove. In effect, the burr, which would translate into a recess in the negative pressing stamper would accept a flow of plastic in the molding operation. When the plastic is frozen, the burr will tear loose frm the record and could cause damage to the level of stylus contact. Another result is that the burrs that were lesser would result in sharp projections of plastic at the groove edge and would promote scuffing of the disc surface. Now that the burr has been translated to metal in the positive, an opportunity is presented to remove it.

Careful polishng with pumice-impregnated cotton is usual. The technique must be such as to avoid scarifying the metal surface and packing debris in the groove. Adequate cleaning must follow to remove any residual debris. The process of removing the burrs has been a topic of research in the industy for many years. Many alternatives have been explored, but polishing still remains.

The metal positive also serves as a quality check point on the process. Since this replication of the lacquer can be played, it affords the best opportunity for checking on the process steps up to that point, including the lacquer cut.

Plating with clean solution is extremely important at all steps, but because the greatest plating activity is in generating stampers from metal positives, the control of solution debris is important. Plating solution is pumped directly to the surface of the part after passing through filters. These filters are composed of filter elements that are rated in themselves of controlling particle sizes between 6 and 10 microns. Coating of the elements with diatomaceous earth can further decrease the passed particle size to as low as 1/2 micron. The addition of "polishing" filters can reduce this further. The sources of debris include the ambient atmosphere, the equipment in the area, the operator, the anode material, and solution precipitates. The use of proper filters and the control of air distribution can limit the ambient-atmosphere particle size to approximately 1/5 micron. The equipment in the area must be designed and finished to ensure that it does not contribute contamination. Debris ordinarily caused by the operator usually can be handled if effective "skimming" is designed into the plating cell or covers are used to reduce this effect in the plating zone. The use of special clothing by operators could help further. The use of commercial anode material will cause debris, and some will even produce a sludge which must be isolated from the cathode. The use of anode bags or membranes and cell designs that promote sludge settling does help. In some cell designs the entire cathode area is isolated from the rest of the cell by a pervious membrane. The solution is pumped into this area to create in effect a positive pressure zone. The solution then leaves the cathode area through the membrane to effectively isolate the sludge. Precipitation of elements from the solution must be controlled by proper monitoring. Temperature control is also important where certain ingredients are in solution near saturation levels.

At this step, where the stamper is being generated, the physical dimensions of the plated part take on extra significance. The stamper whose thickness will be finalized at 0.007 to 0.010 inch requires that it be able to properly interface with the press molds. At stake are heat exchange characteristics that could create voids in the molding, product dimension and stability (warp), the life of the stamper itself, and even the life of the mold tooling which holds the stamper in place. Ideally for tooling purposes, the stamper thickness and taper should be held within 0.001 inch. The electrical field existing between two essentially flat fully submerged electrodes results in the (cathode) part receiving a tapered deposit from the center to the outer diameter. Attempts are made to eliminate the taper to provide another element of control in maintaining stamper thickness within the design parameters. In the 1950s plating equipment was being introduced that utilized a rotating spindle. Prior to that time the cathode parts were hung from horizontally reciprocating connection bars where the anode-to-cathode distance over the height of the part was not reliable. This variation then introduced a thickness difference along the circumference of the same radius from the center. The difference in heat transfer and part thickness that would occur in the more exaggerated cases made for moldings with voids and warp. The change to the rotating spindle provided a better opportunity of maintaining the same thickness along the same circumference. The use of the reciprocating connection rods was to dissipate the effect of the ion-poor boundary condition that would retard the plating process in a static arrangement. The rotating spindle also accomplishes the same function.

Further control of taper is accomplished in two ways. Processors using plating cells where the parts are fully submerged use dielectric baffles to rearrange the field in a way to result in an approximately flat part. Other processors utilize a plating unit where the rotating cathode spindles are arranged for partial immersion. In the latter case control of immersion to an optimum position yields parts flat within ± 0.0005 inch in production conditions. The total plating process is managed by ampere-hour meters to control the overall thickness of the part. Ammeters and voltmeters are also utilized as supplementary process indicators.

The speed at which plating can be applied is referred to in terms of amperes per square foot. It was mentioned earlier that the higher the plating bath temperature, the lower the average internal stress in the metal deposited. An upper limit, however, exists which is governed by the degradation limit of the plating solution constituents. For nickel sulfamate this temperature is above 160°F, and the by-products of degradation produce stress. It is further noted that internal stress increases with the current density, and above 100 A/ft^2 the relationship is essentially linear. The primary concern of stress in plating stampers is the control of premature separation between the positive and the stamper which would result in damaging stains, and the stability of the part for following operations. Solution temperature that can be safely maintained within the 160°F limit is therefore one of the constraints. Associated with this principle, at some level of current density, the anode begins to increase in temperature above the plating solution. This is a function of the anode conditions and the plating unit's ability to dissipate this heat. Above a current density of approximately 300 A/ft^2 circulation of solution through the anode material is required.

Another factor in plating speed is the electrical connection between the metal positive and the spindle. Increased current flow will heat up a marginal contact. Plating done above 300 A/ft^2 requires special provisions.

When the plating has been completed, the stamper is prepared for its interface with press tooling. Some roughness or nodules on the back side can be experienced, though they are minimal in a well maintained plating bath. An operation finishing the back side with abrasive cloth eliminates the potential of noise due to surface finish. Application of 250 grit is adequate for stereo processing, but a 500-grit finishing operation is required for CD-4 stampers to eliminate noticeable rumble. Eccentricity will introduce distortion, therefore careful centering of the

stamper is important. Optical methods focusing on the central "locked" groove can faithfully maintain runout within 0.003 inch by careful procedure. Blanking and forming operations complete the stamper–tooling interface. It is to be noted that all the equipment and fixtures must be designed and arranged in a way that reduces the potential handling damage. All the plating controls are not worth much if the operator clashes the exposed grooves on the edge of a die.

COMPOUND—THE SOUND SUBSTANCE

The materials from which records are made have varied broadly over the centenary of sound reproduction. From Edison's tinfoil to today's vinyl compounds, the motivations for use have varied among the proof of a function, the improvement of quality, play wear life, cost, and taking advantage of related developments. During the history of record manufacturing, two materials stand out because of the duration of their use. Each in its own way was the optimization of a technology step. The filled shellac compounds served during the 50-year period that was dictated by wear life with heavy pickups. The development of low tracking for pickups, which began to appear in the 1930s, heralded a new era of sound quality. After the dust settled, vinyl, or rather the copolymer of vinyl and vinyl acetate, emerged as the base material and has been on the scene for the last 30 years (see [2]).

Requirements on Compound

Quality and moldability are the two terms generally used in connection with compound. Though the two terms are from what appears at times to be opposing vantage points, they nevertheless are parallel goals in compound considerations.

Moldability to the processor initially means the ability to mold, within the capabilities of his equipment, and a resultant disc without unfill (air marks) together with good release from the stampers. Second, the considerations of appearance (no stains) and finally sound quality round out the general evaluation criteria. In recent years new methods of study have been utilized to meet these criteria on an optimum basis [3]. Studies of melt viscosity and elasticity have improved the resolution of material answers where before only cause and effect were known. This work has resulted in the optimum control of melt viscosity, molding voids, warpage, and noise as related to compound. Specific accomplishments include the design of a compound that can meet noise and wear life requirements of discrete four-channel records (CD-4) [4] and a compound that optimized cycle speed for use with automatic presses.

The Process Effect

The philosophy considered in the design of optimim compound requires interaction between material ingredients and the process. For several years extruders have been used in conjunction with the presses as a means of plasticizing the record compound. The initial equipment design utilized a piston to force the compound through a steam-heated cylinder. In the cylinder another means such as a steam-heated "torpedo" was arranged to reduce the flowing material cross section to achieve complete plastication. Such an extruder requires precompounded material because of poor dispersion characteristics and has the disadvantages of entrapping a quantity of air with the material. Extra process care is required to reduce the potential of the trapped air from causing blisters in the finished record. This extruder, however, has the advantages of fast plastication and the ability to provide lower melt temperatures. Further development introduced the screw extruder onto the scene. This equipment greatly improved the ability for dispersion and reduced the bubble size of the entrapped air. It, however, had the disadvantages of a higher discharge melt temperature due to the large amount of mechanical work imparted into the material and less control of melt volume until volumetric control was developed. The improved dispersion characteristic, however, allowed the development of "dry-blend" technology, where the compound ingredients are not previously plasticized before the extruder at the press. In the dry-blend process reliable success is attained only if the minor formulation ingredients coat the individual resin particles. This requirement, achieved in a high-shear blender, is important since separation of the ingredients can take place in handling if the mix composition is not intimate. The ability to utilize dry blend along with automation improvements in compound had the impact of significantly reducing material cost and the potential of contamination.

Following on the rheological studies previously mentioned, material improvements often were found to need preplastication. The use of liquid ingredients, or the inclusion of minor ingredients at volumes beyond the ability of the resin particles to accept and hold, proved to be a limitation of the dry-blend system. Further analysis indicated that to optimize cycle speed by the reduction of melt temperature required a pelletized precompounded material. Studies indicate that melt temperature can be lowered by approximately 10°F by using a pelletized version of the same optimum material. The conclusion today is that the optimum process for a quality compound is one where the ingredients are optimally dispersed in a high-shear blender, then plasticated in a means where a filtering screen arrangement can be used and where pellets attain a near spherical shape. At this time only a twin-screw extruder with face cut pelletizing can meet all the requirements.

Compound Design

Today's optimum compound is designed for the most favorable melt viscosity at the lowest melt temperature possible. All molding process cycles are directly affected by the cyclic temperature differential experienced in the mold. Every incremental reduction directly affects the potential cycle time. The effective melting point (glass transition temperature) can also be significant at the other end of the scale.

Elimination of molding voids (unfill, air marks) is accomplished by the dependence on some of the resin

particles remaining discrete. In terms that are measurable, the discrete particles' lower melt elasticity will improve the flow ability of the melt. The discrete particles, however, must be sufficiently gelated to form a homogeneous material at the surface of the record, at least to the depth that can be "read" by the stylus, or noise will be experienced. The latter requirement also involves the choice of ingredients that do not melt in the compound. Nonplastic materials must of necessity then be of sufficiently small size to meet the 2-dB requirement as previously discussed. The stylus will surely find such particles in much the same way that pebbles under a rubber mat could be felt when stepped on.

Warpage is affected by the pressing process, its related components, and the elastic properties of the compound materials. Elasticity studies of various record materials indicate variations in the residual elasticity in test specimens that can only be explained by differences in the materials. Correlation of product tests with respect to warpage have been achieved. Today's optimum compound is designed to reduce the material elastic effects as far as practical.

Finally, the entire compound process, starting with the manufacture of the various ingredients, should be performed and handled in clean and closed systems as far as practical. Should damaging particles be introduced which could scratch the tip of the stamper groove ridge to a depth of 0.0002 inch, on stereo and 0.0001 inch on CD-4, the stylus will read noise. Further, if the scratch is in the stylus track, damage in the magnitude of 10 microinches in stereo or 3 microinches in CD-4 will be significant.

MOLDING—MAKING SOUND COPIES

The basic method used to mold phonograph records has not changed much since Berliner started to manufacture discs prior to the turn of the century. During the years, however, improvements in materials, controls, and equipment have accounted for continuing progress of quality and economy in the record industry.

Brief History of the Press and Its Automation

The basic equipment required for molding is a press, and three basic types are recalled from the days preceding automation. Those early presses were chosen or optimized for interface with an operator. Since the operator was required to load material in and remove records from the mold, the main requirement was provision for optimum access to the mold. The first type, a mechanical press, achieved this by providing optimum opening between the two parallel press platens. This press was so arranged that the major part of platen travel could be performed quickly and the final pressing position slowly but with optimum mechanical advantage. The second type, a fixed-head hydraulic press, was arranged with a hinged mold that could be moved in and out of the press with a minimum movement of the platens. When out of the press, the mold would be hinged open for good operator access. The third type is a hinged-top platen press (swing-leaf) with a counterweight to assist operation of the platen. The hinge pins were in the back, two posts and latches are arranged for the front two posts. This hydraulic press also required only a minimum movement of the force platen.

Paralleling the developments in record fidelity (and the consequent sales increases) were the industry's efforts toward automating the basic recording-molding process. The forerunner attempts in the late 1930s involved incorporating air cylinders and timer controls in press operations. This reduced the need for muscle in opening and closing presses, and also provided more uniform control of the molding cycle, previously performed by manual valves. Several other elements of the press operation became individually powered during the 1940s. These efforts, coupled with the introduction of plastic record compounds in the later 1940s, set the stage for the first automatic press. The product of the day were 7-inch 45-r/min records, and the time frame was the late 1940s through the mid 50s. Two different molding methods were developed in independent investigations. In the first the newly developed piston-type extruder was married with the hydraulic swing-leaf press then being used for manual pressing. The automation involved the substitution of mechanisms for operator duties, and it would not take much imagination to see how it could be converted to manual operation if it did not work. This successful design served for a good number of years, and it probably was not coincidental that many other first attempts appeared to be quite similar as the processors' interest in automatic presses grew. The second development path went in the direction of injection molding, then a relatively new process to the halls of manufacturing. A successful higher molding yield resulted, but operations previously performed at the press in compression molding were now relegated to separate centralized operations. The process had an inherent problem in fully molding the groove primarily at the intersection between the groove and the land. Proper process controls, however, could effectively keep this unmolded area from encroaching on the stylus track of the fairly large sized 45-r/min groove. In any event, the process did have some economic advantages, and its use expanded in the industry.

By the latter 1950s the 12-inch record began to be the major seller, and automation efforts were directed to that new product line. Evaluations conducted by several technical organizations in the industry concluded that compression molding was still the only viable method for producing the larger sized record. Automation efforts began to proliferate, and the results of most turned out to be compromises far from what could be expected in terms of process reliability. Improved second and even third generations taking advantage of what was learned from the past yielded significant improvements with respect to quality reliability in the 1970s.

MOLDING PROCESS REVIEW

Compression Molding

Compression molding is the oldest record-molding technology and records have been made by this method at least as long as disc records have been made. The modern-day automatic press coordinates the molding with

a series of preparatory and finishing operations to effectively replace all the old cyclic manual functions. Fig. 2 shows the four steps in compression-molding records.

In the first step of the process, vinyl record compound is prepared for "flowability" by extrusion. The quantity required to mold each record controls the cyclic operation of the extruder. At the exit of the extruder, the plastic (300–325°F) is shaped into a form to facilitate handling into the press. At this step labels are also singulated (individually separated from the stack of labels). The plastic form and labels are then transferred to the press to begin the second step of the process.

Compression molding with the plastic placed in the center of the mold provides a systematic means of expelling the air from the cavity between the mold havles. We are, howevec molding more than a disc. There are grooves that are at right angles to the flow of material, and the material has some elasticity. Proper heating of the molds is necessary to eliminate minute pockets of air that could produce voids in the finished records. In practice it has been found necessary to heat the molds at least 15°F hotter than the plastic. This softens the plastic at its interface with the stamper. Properly executed records made with specially designed compounds do not have any sound penalty caused by voids.

Compression molding also requires more material than is used in the record. It is necessary to flow a certain amount of material out of the cavity in order to allow for thickness variations inherent with the process and eliminate sink marks and air voids near the outside diameter of the record. In practice, approximately 25% of the compound placed into the mold cavity is squeezed out at the outer diameter in the form of flash. Once the plastic has filled the cavity, cooling is necessary to complete the rigid product.

After the mold has been sufficiently cooled, the press is opened and the molded record with flash is transferred to the edging station for the third step of the process. There the flash is trimmed and the record is prepared for transfer to the stacking station. The flash trimmed from the record is reprocessed for use as record material.

At step four, stacking, an auxiliary operation is introduced to provide a flat reference spacer if more than 25 records accumulate. Several factors, which are not consistent, can cause slight variations from flatness in the records. Since a drooping semicooled record gravitates toward a solid reference point supporting it, a growing stack of records would "settle," accumulating record-thickness variations, and eventually reach an out-of-tolerance condition. Hence the need for spacers. At this station the record can be inserted into a packaging sleeve if the process is sufficiently free from random faults to allow statistical inspection techniques.

The normal cycle time experienced in the record industry for compression molding 12-inch records is 30 seconds. Some successful developments have yielded 20-second cycles. Analysis of all the elements involved indicates that an optimum cycle of 16 seconds is possible.

Injection–Compression Molding

This process is in effect the utilization of an injection molding machine to compression mold records. The essential difference is that the plastic (record load) is formed directly between the parted mold halves rather than externally and then transferred to the mold. The use of the injection machine in this way was pursued in the late 1960s and became a contending process in the early 70s. Such equipment is now in use for molding both 7-inch and 12-inch records. A typical cycle of this interesting marriage of injection machine, handling mechanisms, and compression molding technology follows.

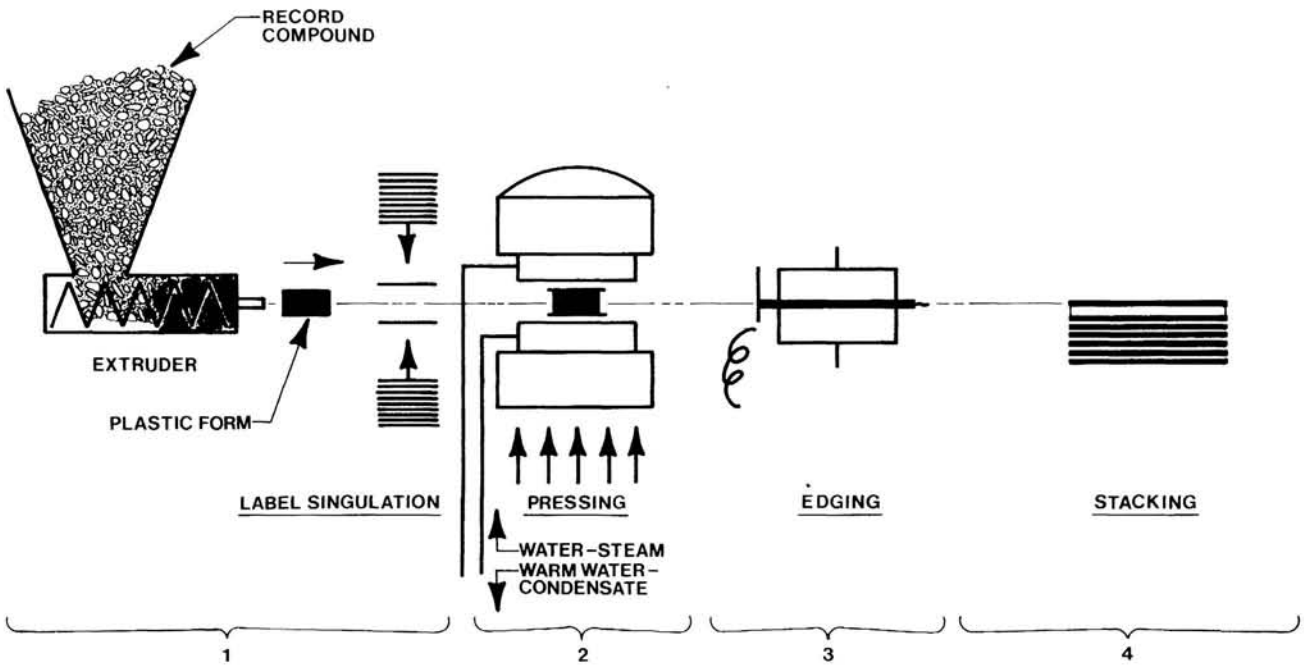

Fig. 2. The four steps of compression molding records.

1) Concurrently with the mold curing cycles, the material is plasticized by action of the injection unit screw, and labels for the next record are picked up by the label insertion mechanism.

2) At the completion of the curing cycle, the movable platen (clamp) opens, the previous record is picked up and removed, and the labels are placed on center with the respective mold halves and held there by vacuum.

3) Upon retraction of the label mechanism, the clamp is partically closed to a 5/16-inch opening, and the injection unit pushes the plastic load into the center of the mold (Fig. 3**a**). Prior to this point steam was introduced into the mold to raise its temperature to the process maximum.

4) The clamp advances at high pressure until the resistance experienced in displacing the material balances the clamp force. At this point flash has been formed as the excess material is squeezed out of the cavity (Fig. 3**b**). The fluid passing through the mold is changed from steam to water at a point in the cycle determined by time.

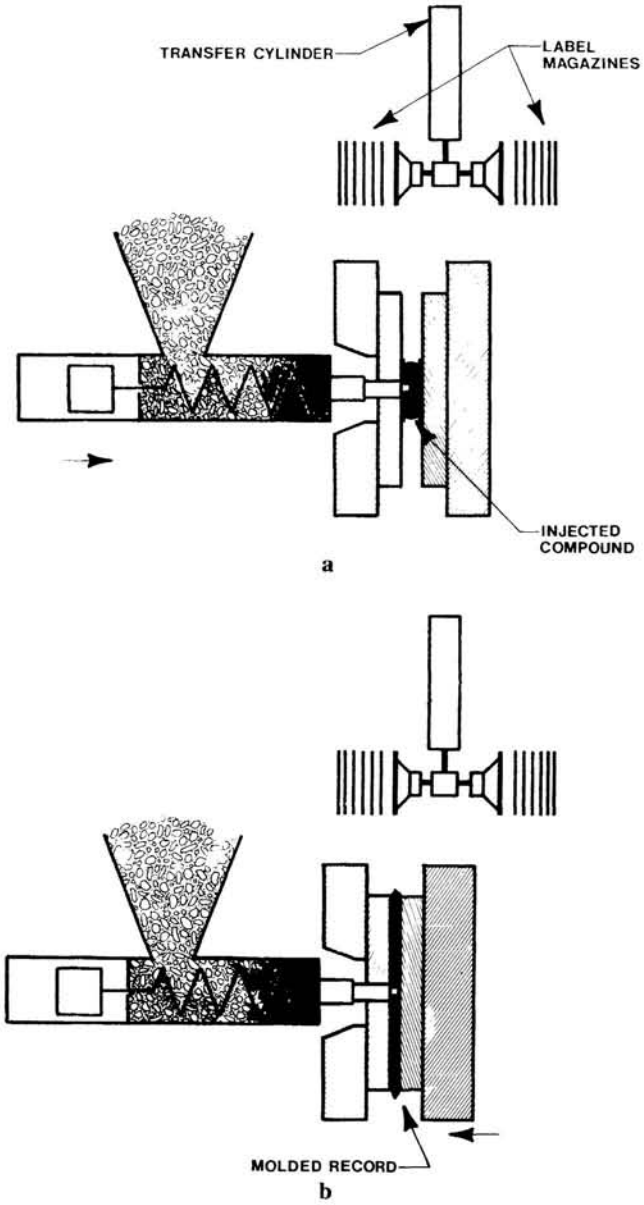

Fig. 3. Injection-compression molding. **a**. Injection phase. **b**. Molding phase.

5) After the record has been cooled to a rigid form, the clamp is opened and the record removed by a pickup and transported to an edging station to remove the flash. In the case of 7-inch records, punching of the large center hole is also performed following the edging operation.

6) At this point the record is either stacked or dropped into an envelope, then stacked.

Current process examples are known to use molding cycles between 13 and 16½ seconds for 7-inch records and 24 to 30 seconds for 12-inch records.

Injection Molding

Approximately half the 7-inch records produced in the United States and Europe are molded by the injection process. In the United States these are all molded in styrene; Europe's product is vinyl. The first large-scale production using this method can be traced to installations made in the early 1950s. Many attempts have also been made in the industry to injection-mold 12-inch audio records, but no practical process has been developed to date.

The injection process requires the exertion of large forces, and, as a consequence, larger equipment is required. Injection pressures on the order of 12 000 lb/in^2 are required to push the plastic into a closed mold, where air in the cavity is displaced by the material through normal venting methods. Should this force be applied to the full projected area of a 12-inch record while the plastic is still fluid, it would require a clamping force in excess of 600 tons to keep it from being forced open. Special techniques using vacuum-cavity evacuation and a profile-controlled injection phase may make the process technically feasible, but the equipment required would still be large, especially when compared to the 100–140-ton clamping forces required in compression molding.

Manufacturing 7-inch records, however, has adapted well to injection molding, since the physical characteristics of the product are compatible with the process. The material is plasticized to a very fluid state in the injection unit. Melt temperatures 50°F higher than the compression process are used, so heat-sensitive materials (such as vinyl) require a much higher performing stabilization additive to withstand process conditions. The molding is performed by pushing the material into the mold cavity after the mold halves have been fully closed. The mold is maintained at a constant temperature (on the order of 90–125°F), determined by specific process parameters. Various channeling designs are used in the industry for heat exchange; these are directly related to the cycle time. The air from the cavity is forced out through very thin vents (less than 0.001 inch wide). This small size is necessary to produce a "flashless" record. Though the cavity is filled to the pressing master (stamper) clamp rings and injection pressures as high as 15 000 lb/in^2 are used, a significant amount of air is left in the cavity. The high injection pressure and rate, coupled with the cool molds tend, however, to orient this trapped air into a virtually continuous void. This void results in a radius at the meeting line between the land and groove of the record. If this radius is controlled, and the grooves are not

too small, no consequence to the playback quality is experienced.

Current technology uses two or three stacked cavities per mold with a center ejector pin for separating the sprue (material remaining in the injection manifold). Some processes introduce labels into the mold, while others apply labels after molding. The state of the art produces cycle times between 12 and 21 seconds; cycles as fast as 8 seconds are known to be possible.

REQUIREMENTS FOR AN AUTOMATIC PRESS

The development of an automatic record press is an exercise in many of the engineering arts. To be truly valid, the result of such work must extend beyond initial success but must be capable of maintaining the reliability goal for as long as its technology is relevant. To achieve this level of accomplishment, the equipment must be designed to meet the following base guidelines.

1) The design of the automatic press shall be such that proper performance with respect to product quality shall be inherent with each function. The occurrence of random faults inherent with a mechanism design will not be acceptable.

2) The interface between man and machine shall be such that all manual elements can be performed easily and quickly without special skill, but with confidence. Adequate clearances and task method required shall be such that would allow maximum practical protection to pressing masters (stampers) and labels during manual loading in the machine. Safety will underlie all elements.

3) The system logic shall be such that trouble shooting can be performed in an easily followed procedure and that the occurrence of a fault would be monitored and prevented from causing a catastrophic machine failure. All control components shall be easily replaced (without a high possibility of a fault being generated by such replacement), to allow for trouble shooting by substitution and a quick return to the production mode.

4) All components and composite mechanisms shall be sufficiently durable to withstand the rigors of the production mode without unreasonable deterioration.

5) The appearance of the equipment would be pleasing and can be maintained with reasonable housekeeping practices.

Fig. 4 shows examples of equipment which has achieved a large measure of ideal.

CONCLUSION

In the foregoing we have shown the degree of sophistication required to engage in the manufacturing arts of reproducing audio grooves. Though the art required in the many process steps cannot be avoided, nonetheless steady progress has been made in improving the resolution and process reliability in the manufacture of the record. Today much of the technology exists which could provide for the replication of sound without significant deterioration by the manufacturing process and in ways that would preclude the occurrence of random faults. From the technical view we are hopeful that it can be put to use. Perhaps the psychology of premium regard for perfection that seems to be coming forward in this centennial year of sound will bear the seeds of motivation.

ACKNOWLEDGMENT

The author wishes to express his appreciation to RCA Records Division and Operations Engineering Manager, J. M. Frische, for permission to publish this paper. Special thanks to J. F. Wells for his review and suggestions and to the Audio Engineering Society for the opportunity.

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Fig. 4. Automatic compression molding.

Record Materials

Part I: Chemical Technology in the Edison Recording Industry

LEAH S. BURT

Edison National Historical Site, West Orange, NJ

Guest Editor's Note

Before the Use of Vinyl: Hardly any time had passed after the phonograph had been invented until the question arose of the most appropriate material upon which to record sound for distribution to the market. That question has not been left unconsidered at any time from that day in 1877 to this. During that time, there have been some fairly well-defined periods.

The first of these periods has to be the tinfoil period which lasted until about 1888, during which the principal activity was with the Edison exposition model of the tinfoil phonograph being shown at fairs and expositions. About 600 of these models were built. Some of them had a handy little drawer built into the base in which the tinfoil blanks were stored. Probably the most successful of these exposition models was that one exhibited and demonstrated at the Chicago Exposition. An agent named Douglas made $3000 for himself and $30 000 for Edison. Even so, the tinfoil record revealed itself to be entirely unsatisfactory as a permanent medium. It is at this point that the story of the search for the right material and the right process for manufacturing records begins in the account by Leah S. Burt.

Warren Rex Isom

On July 18, 1877, while working on the speaking telegraph Edison came to the realization that voice vibrations impinging on a diaphragm were of such intensity that they could be made to do mechanical work: "Just tried experiment with a diaphragm having an embossing point and held against paraffin paper moving rapidly. The speaking vibrations are indented nicely and there's no doubt that I shall be able to store up and reproduce automatically at any future time the human voice perfectly" [1].

Edison's most ingenious invention, the phonograph, was completed on December 4, 1877 by Swiss machinist John Kruesi and British draftsman Charles Batchelor from an exceedingly crude sketch dated November 29, 1877 drawn by Edison himself. No one can doubt the expertise needed to bring such a bare sketch into fruition, with Kruesi performing the machining and Batchelor constructing the phonets. As outlined in Fig. 1, the first recordings were made on pliable sheets of tinfoil [2].

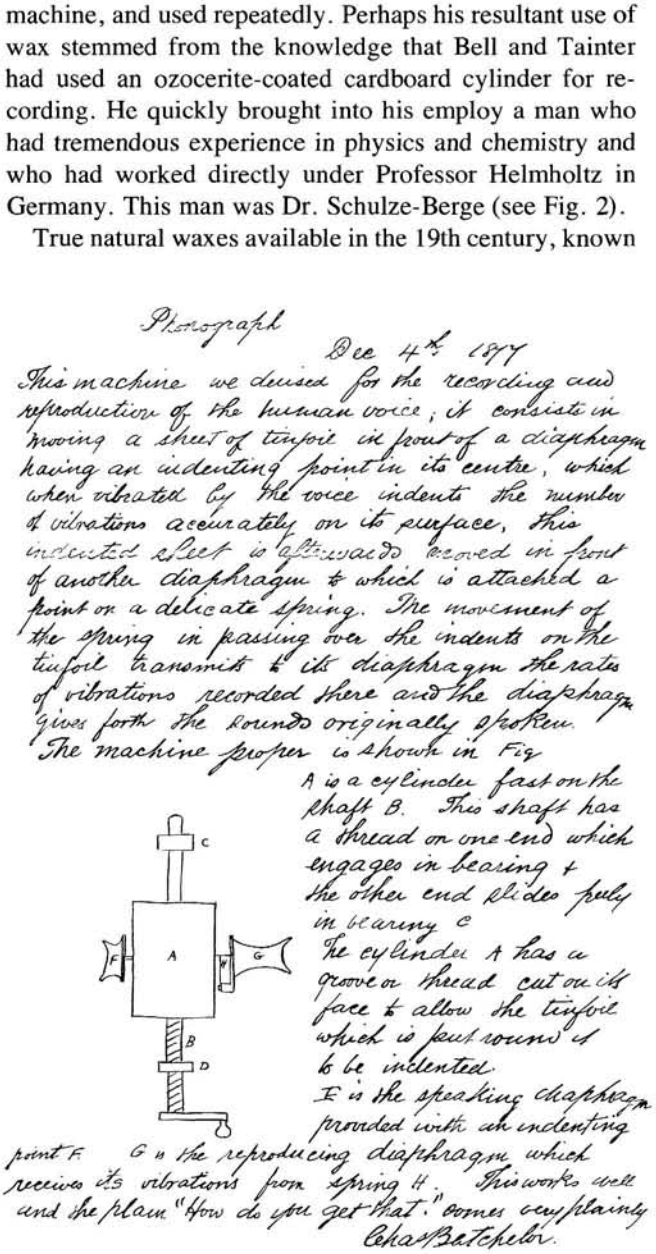
Charles Batchelor states that there were many discussions between Edison and himself "of what we should do to make money out of the phonograph in the future, and amongst other uses he frequently talked to me of a duplicating machine that should automatically reproduce from a backed-up tin foil from the phonograph a duplicate that could be sold cheap to the public" [3].

It soon became apparent that an instrument using a pliable strip as a record could never become practically successful. Every attempt at reproduction tended to smooth out and obliterate the sound record. Another serious defect was its lack of recording capacity, necessitating frequent changes of the foil, which consumed much time and required considerable skill in adjusting it properly to the cylinder. Even if it were possible to make a record sufficiently accurate for practical purposes, in pliable sheets, such a sheet could not be removed from the cylinder on which it was made without deforming the indentations [4].

After a respite of ten years, Edison again tackled the thorny problem of making records for his now "perfected phonograph." He knew he must devise a method and apparatus whereby records could be made in a rigid or self-sustaining cylinder, available for immediate reproduction, and which could be transported, placed on another machine, and used repeatedly. Perhaps his resultant use of wax stemmed from the knowledge that Bell and Tainter had used an ozocerite-coated cardboard cylinder for recording. He quickly brought into his employ a man who had tremendous experience in physics and chemistry and who had worked directly under Professor Helmholtz in Germany. This man was Dr. Schulze-Berge (see Fig. 2).

True natural waxes available in the 19th century, known to be esters of both a high-molecular weight fatty acid and an alcohol, were beeswax, carnauba, montan wax, and spermaceti. The mineral wax, ozocerite, associated with coal deposits, is not a true wax, but is designated a wax because its physical properties closely resemble those of beeswax.

Edison chose to use both carnauba and ozocerite for his wax cylinder masters in the 1888 period, for both these waxes took the preliminary gold-plating well [5]. His caveat dated Oct. 21, 1887 for making multiple copies of phonograms, as cylinder records were called in those days, outlines the procedure: "The cylinder is placed in a vacuous chamber containing two electrodes of gold or other unoxidizable metal and an arc being formed by bringing the points together and seperating (sic) the same. The electric current causes the metal of the points to be vaporized and this is deposited in a perfect manner over



Phonograph

Dec 4th 1877

This machine we devised for the recording and reproduction of the human voice; it consists in moving a sheet of tinfoil in front of a diaphragm having an indenting point in its centre, which when vibrated by the voice indents the number & vibrations accurately on its surface, this indented sheet is afterwards moved in front of another diaphragm to which is attached a point on a delicate spring. The movement of the spring in passing over the indents on the tinfoil transmits to its diaphragm the rates of vibrations recorded there and the diaphragm gives forth the sounds originally spoken.

The machine proper is shown in Fig

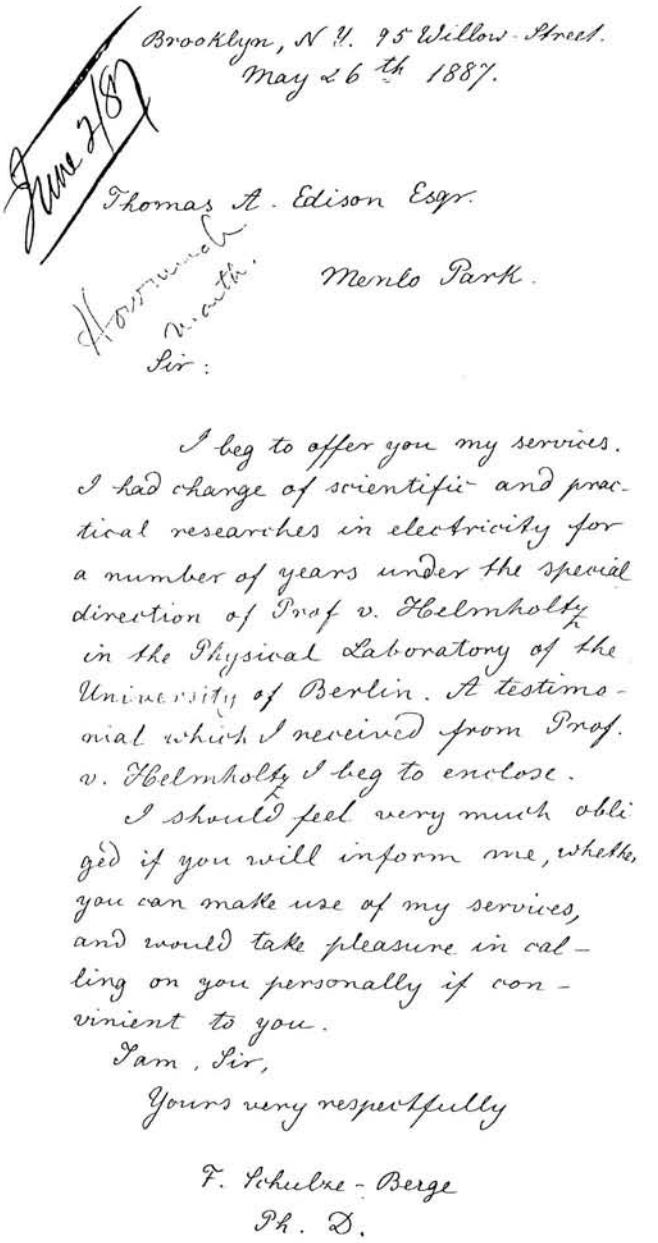
A is a cylinder fast on the shaft B. This shaft has a thread on one end which engages in bearing + the other end slides freely in bearing C

The cylinder A has a groove or thread cut on its face to allow the tinfoil which is put round it to be indented.

E is the speaking diaphragm provided with an indenting point F. G is the reproducing diaphragm which receives its vibrations from spring H. This works well and the plan "How do you get that." comes very plainly

Chas Batchelor.

Fig. 1. Entry in Charles Batchelor's notebook, December 4, 1877, describing the fabrication of the original phonograph [2].



Brooklyn, N.Y. 95 Willow Street.
May 26th 1887.

June 2/87

Thomas A. Edison Esqr.

Menlo Park.

Sir:

I beg to offer you my services. I had charge of scientific and practical researches in electricity for a number of years under the special direction of Prof v. Helmholtz in the Physical Laboratory of the University of Berlin. A testimonial which I received from Prof. v. Helmholtz I beg to enclose.

I should feel very much obliged if you will inform me, whether you can make use of my services, and would take pleasure in calling on you personally if convinient to you.

I am, Sir,

Yours very respectfully

F. Schulze-Berge
Ph. D.

Fig. 2. Letter from Dr. Schulze-Berge to Thomas A. Edison. Note Edison's comment: "How much math?"

the whole of the exposed surface of the cylinder. The latter if necessary is rotated while being deposited on in the vacuum. Thus the nonconducting surface is perfectly coated with a conducting surface; it is then placed in a plating bath, the deposit being increased to one-quarter inch with copper, nickel, etc., in the usual manner.'' [6] (See Fig. 3.) The wax master was separated from the Cu/Ni master mould utilizing the difference in coefficients of thermal expansion between the wax and metal.

Subsequent moulded cylinder records used a stearic acid/ceresin/carnauba mixture. By 1903 the proportions were:

$Na_2CO_3 \cdot 10\ H_2O$	12.9%
NaOH	.6%
Al	.2%
Stearic acid	60.1%
Carnauba	12.8%
Lamp black	.5%
Ceresin	12.8%

And the procedure for obtaining the wax-base mother liquor was as follows: Recrystallized sodium carbonate ($Na_2CO_3 \cdot 10\ H_2O$) was melted in an iron vessel with water and 98% pure sodium hydroxide (NaOH). Upon liquefaction pieces of 20/1000 sheet aluminum were added, and the hot solution filtered through canvas. Stearic acid, with a melting point of 136°F, was brought to a temperature of 240°F; at which point the previous solution was added as rapidly as possible without boiling over. At a temperature of 360°F, purified #3 Sierra carnauba wax and the best grade lamp black were added; the temperature raised to 450°F and held till foaming subsided, at which time the ceresin (145°F melting point) was added. The wax mixture was brought to a congealing point at 290°F with the addition of stearic acid [6]. Plating processes are shown in Figs. 4–8.

In October, 1912 Edison introduced the unbreakable 4-minute Blue Amberol cylinders: wax composition cylinders were now no longer necessary. From October 1 all cylinder machines except the Gem, Fireside, and

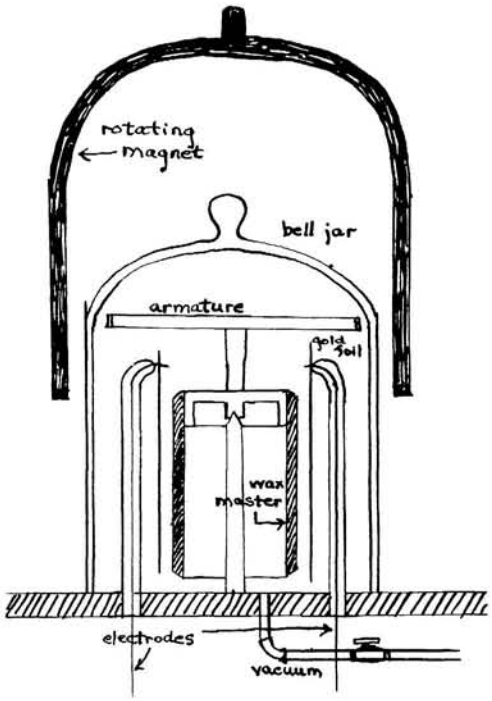


Fig. 3. Diagram of apparatus for gold-plating cylinder wax masters. The technique of plating by vacuum deposition of electrically evaporated metal is commonly referred to as ''spluttering''—gold spluttering in this instance.

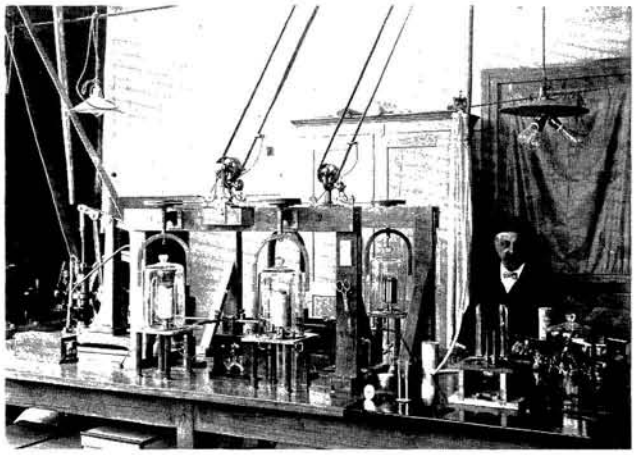


Fig. 4. Gold-plating of master wax cylinders. Berlin manufactory for Edison records. Note the one gold-plated cylinder beneath the bell jar and the rotating horseshoe magnet.

Fig. 5. Gold-plating: Edison Paris factory.

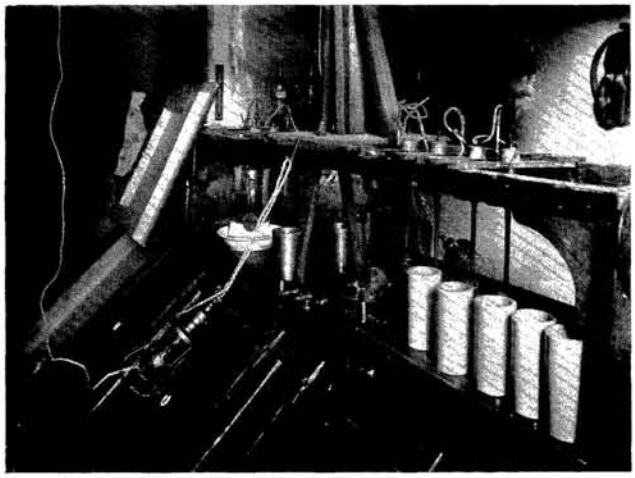


Fig. 6. Copperplating: Edison Paris factory.

Standard were to be equipped with the new Diamond reproducer needed to play the Blue Amberol cylinders, rather than the old sapphire stylus which had been so satisfactory for the wax cylinders. The new Blue Amberol cylinder (Fig. 9) was made from purchased celluloid tubing 4 feet long. The various steps in manufacturing are as follows:

1) Tubes stretched to proper diameter,
2) Dipped in blue aniline-based dye; deep blue, 20 minutes; proper blue, 10 minutes; let dry 2 or 3 hours,
3) Seasoned for 14 to 18 days,
4) Cut into record blank lengths,
5) Blanks slipped into molds and sent to steam press to be printed,
6) Record inspected,
7) Record backed with a core of plaster of paris,
8) Dried in oven at 150°F for 10 to 12 hours,
9) Reamed to fit mandrel,
10) Dipped in oil and benzene,
11) Title, etc., filled in with whiting on records,
12) Washed, boxed, and labelled.

Four men could print 10 000 records per day. Presses were run in batteries of 10, one printer for each battery, and one man for loading. It took one minute to press a record with steam and 5 minutes to set by air cooling.

Fig. 7. Temporary nickel-plating bath: Berlin factory.

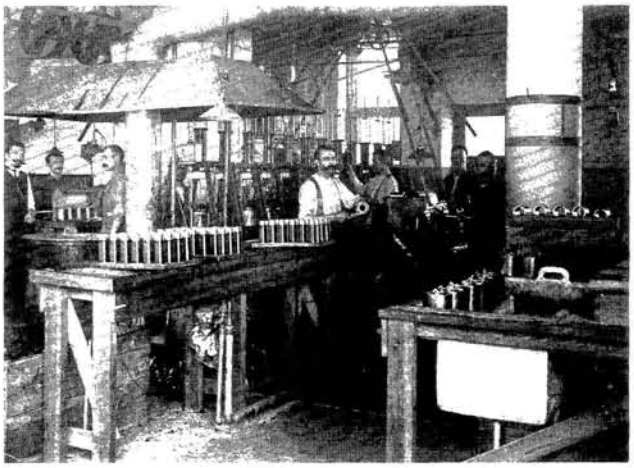


Fig. 8. Moulding room: Edison Berlin factory.

Celluloid, the first synthetically-produced plastic, was discovered as early as 1869 by J. W. and I. S. Hyatt of Albany, New York, and Newark, New Jersey. Edison obtained his supply of celluloid from the Hyatt Brothers' company, the Celluloid Manufacturing Company, 45-47 Mechanic Street, Newark.

That same year, 1912, saw the introduction of the first disc record into the Edison recording industry. This commercial Diamond Disc, as it was called, was almost unbreakable, one-quarter inch thick, but still carried the hill-and-dale configuration. At the New York Recording Studio, recording was done on a wax master of the same composition as before, only this time it was in the shape of a disc. During the 1912 period, successive manufacturing operations were carried on at West Orange, New Jersey, with the preliminary plating being either graphite or gold.

The steps in the making of a diamond disc record were as follows:

1) From the New York Studio a messenger brought the wax master, suspended by cork wedges in a flat tin can and sealed with adhesive tape, usually on the evening of the day it was recorded, to West Orange.
2) Scriber worked recorded number into wax for identification. (Fig. 10 shows Edison's numbering schedule.)
3) Wax master was then graphited with purified graphite (Dixon 097) on outer edge and labeled by hand with a piece of sheep's wool.
4) Wax master was then placed in graphiting machine where the rest of surface was covered with graphite mechanically with the aid of a silk brush.
5) Graphited wax master was copperplated while rotating semi-submerged in a $CuSO_4$/sulfuric acid plating bath for 4 to 5 hours, the advantage of the half-submerged state being to keep the bubbles broken.

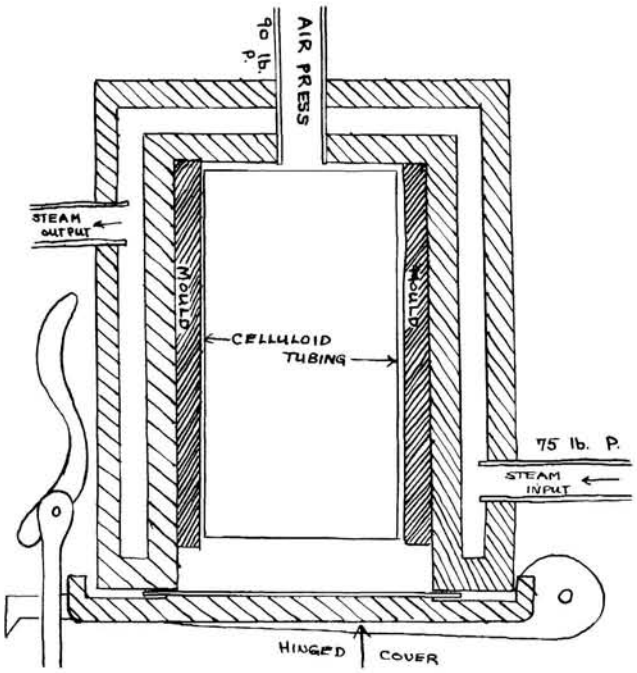


Fig. 9. Blue amberol cylinder mould.

6) It was placed completely submerged in fast Cu-plating bath.
7) The plated assembly was turned on a lathe till line of demarcation between wax and copper was visible, then was stripped from the wax. Backed with rubber to prevent plating on back.
8) The plating was electro-cleaned with concentrated Na_2SO_4 solution, made slightly alkaline with NaOH, and immersed in "8-4" solution for 2 minutes till dull and bronze-colored.
9) It was then placed in Ni-plating bath for 2 hours and in Cu-plating bath to make nickel-faced copper female master mold.

The nickel face was much tougher than the copper face on the master. In successive steps, using the same plating procedures, working molds were finally produced. Each Cu master could produce 10 females. Each female could eventually produce at least a dozen working molds, from which the condensite records were manufactured. The submaster print was usually made of cheesecloth (Snowflake brand)—backed with celluloid, applied to a powder blank for approval or disapproval by the music committee.

The term "powder blank" was applied to the core of the laminated disc record. Ordinarily, the procedure was to take the precisely flat preformed and prepared disc blank and, in the case of approval pressings, apply the celluloid surface material, as previously noted. A phenol resin bonding agent was used on the blank to secure the celluloid and cheesecloth. The assembly was placed in the press and bonded together under the pressure and heat required for pressing the music grooves of the working mold (stamper) into the surface of the disc. In the case of pressings for commercial use, the surface of the blank was uniformly covered with a powder made by finely grinding the hard and brittle shellac compound. Then the assembly was placed in the press and the powder fused to become the music groove surface of the record. But in the Edison manufacturing procedure, the powder blank saw no powder. Instead, it was uniformly coated with the Edison condensite varnish, which was liquid and thermosetting. It could not be applied in a powder form. The varnish-coated core was cured in the press to form the hard and long-wearing playing surface for the Edison Diamond Disc. It is a curious thing that even though varnish was used for the coating and not powder, the blank was nevertheless called the "powder blank." A great deal of knowledge and understanding is hidden behind the jargon of the trades and professions; particularly in the record industry.

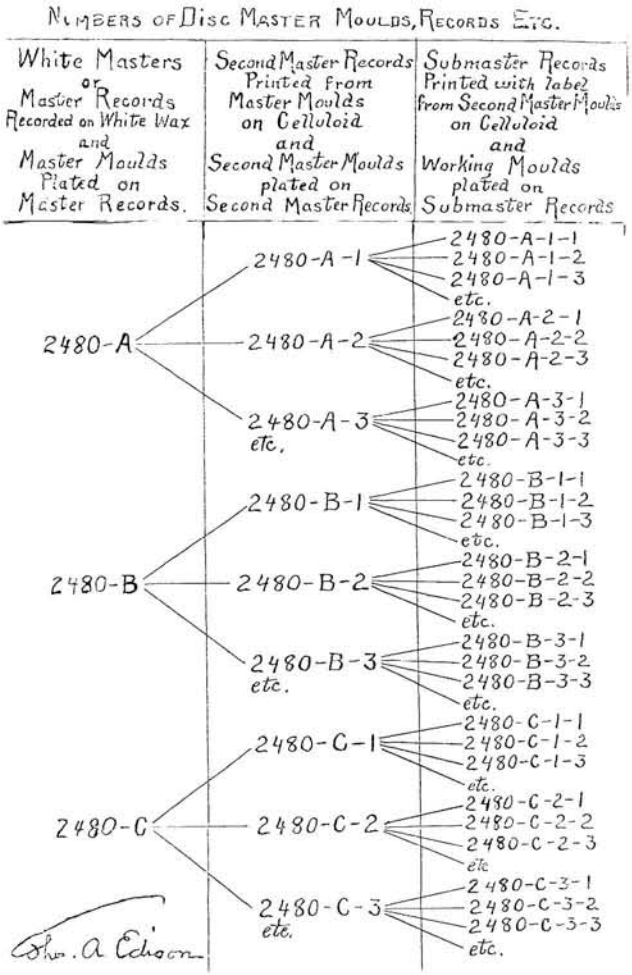


Fig. 10. Edison's handwritten schedule of identification of masters, second masters and submasters.

Powder blanks, used in the molding of the final commercial record, were of a wood flour/lampblack/phenol-resin/denatured alcohol/"6-4" composition. The spruce wood flour, ground to pass through a 30-mesh wire screening, was purchased in bales either from E.I. duPont de Nemours & Co. or Union Wood Flour Company, Glens Falls, New York. The varnish, with which the powder blanks were coated and into which the sound grooves were imprinted, was made essentially of "Shino", phenol, paraphenylindiamine, "6-4", penta chlora phenol, denatured alcohol, phenol resin, and sandarac.

Demand for a lighter-weight record to meet the competition from Victor and Columbia stimulated the Edison Company to produce in 1927 the lateral-cut or Needle record. This was a signal departure from the wood flour base medium, in that the new records were now made from greenstone or epidote, crushed to pass through a 200-mesh screen, cotton flock, shellac, and carbon black. Unlike their predecessor, the Edison Diamond Disc, the Needle records were extremely brittle and had an unwelcome tendency to warp.

In October 1929, the Edison Company curtailed all record manufacturing operations, leaving the field of making recordings wide open to competitors.

FORMULAS USED IN RECORD MANUFACTURING

8/4 Solution:

8 gals. distilled water
400 cc. of 5% solution of selenious acid

Selenious Acid:

25 lbs. selenium gray powder (B. F. Drakenfeld Co.)
14 liters commercial HNO_3

High Speed Nickel Plating Solution:

430 g. $NiSO_4 \cdot 6\ H_2O$/liter
6 cc. glacial acetic acid/liter
pH: 6-6.2

High Speed Copper Plating Solution:

350 g. $CuSO_4$. 5 H_2O/liter
32 cc sulfuric acid/liter
s.g. at 34°C. = 1.25

Wax Master Copper Plating Solution:

250 g. $CuSO_4$. 5 H_2O/liter
24 cc. sulfuric acid/liter

Master Wax Cleaner:

20 parts benzol
10 parts denatured alcohol
½ part glacial acetic acid

Solution for Taking Copper or Gold off the Face of a Record:

3500 cc. H_2O
100 cc. 15% KCN
50 cc. 4% H_2O_2

Formula for Blueing Amberols:

60 parts denatured alcohol
40 parts water
10 parts acetone
2 parts methyl blue BB (Heller & Merz)

Solution for Sticking Celluloid to Powder Blank:

100 g. phenol resin
7.5 g. 6/4
500 g. denatured alcohol

Powder for Diamond Disc Commercial Blank:

100 lbs. wood flour
2 lbs. lampblack
25 lbs. phenol resin
45 lbs. denatured alcohol
472 g. 6/4 (hexamethylene tetramine)

Phenol Resin:

1050 lbs. phenol
609 lbs. formaldehyde

Regular Varnish:

5. g. phenol
2 g. paraphenylindiamine
7.9 g. 6/4
4 g. pentachloraphenol
145 g. denatured alcohol
100 g. phenol resin
sandarac (resin from the African sandarac tree)
''Shino'' (Pb resinate)

Filler for Disc Record Numbers:

egg albumen
ZnO
water

Formula for Needle or Lateral-cut Edison records:

1.25 g. gas black
1.5 g. cotton flock
30.75 g. 200-mesh epidote
5.5 g. orange shellac
11.0 g. garnet shellac

REFERENCES

All reference material listed below is in the Archives at the Edison National Historic Site.

[1] Loose Edison laboratory notebook sheets in Document File.

[2] Loose Batchelor laboratory notes, Batchelor Collection.

[3] Testimony of Charles Batchelor, American Graphophone vs. U.S. Phonograph Company, et al. in equity on Patent 341,287.

[4] Testimony of Charles S. Tainter, American Graphophone vs. U.S. Phonograph Company, et al. in equity on Patent 341,287.

[5] Dr. Schulze-Berge's laboratory notebooks, 1888-90.

[6] Edison's handwritten caveat, dated October 21, 1887.

Record Materials

Part II: Evolution of the Disc Talking Machine

WARREN REX ISOM

RCA (retired)

THE FIRST GREAT AND IMPORTANT STEP

The second general period in the development of materials for recordings and records is the wax period, which began around 1887 with the Bell and Tainter patent covering the cutting of a groove in wax. For recordings, wax was used until the coming of lacquers in the 1940s; for records, its limitations were recognized almost instantly. For recording, wax was almost ideal. Its textureless and structureless composition introduced no spurious reactions to the motion of the cutting stylus. Its hardness was directly under the control of temperature; its freedom from impurities under the control of filtering; its cost was reasonable; and its sound qualities excellent. All of these characteristics were applicable to a material for records but records required one characteristic that was not important for recording: durability. As the demand for loudness grew, the inadequacy of wax became more and more limiting. In the period when sound power of a phonograph came directly from the record, wax could not deliver. However, it filled the gap until compositions could take over about the turn of the century.

Emil Berliner took a grand technical detour before he reached the use of wax for original recordings. In March or April of 1887, he started to develop an etching process by making a lateral tracing of the sound waves through an acid resisting and opaque film upon paper, polished metal surface, or glass. In November 1887, he had progressed to the point where the recording was on glass, covered with a film of amorphous ink. It was transferred to a photographic negative from which a pattern was exposed onto a polished zinc plate light sensitized with bichromated albumen. After preparation, the plate was put in an etching bath of nitric acid. The results were more than promising and he continued. A number of the electrotyped stampers could be made from the etching.

On March 30, 1888 he was in the library of his patent attorneys when he read in a book by Theodor Schwartz on the telephon, mikrophon, and radiophon, a description of Charles Cros's disclosure of the phonograph. The process it described was almost identical to the one he had developed. Berliner was advised that the Cros disclosure was an abandoned experiment and was of no value as a patent. Berliner continued his work on the process and had it ready to release for manufacture by 1892. Records were stamped from vulcanite by matrices made by electrotyping from the acid-etched originals.

Other problems came with production. The acid etching process did not behave as expected. The acid spread in all directions in the zinc from the smooth surface line in the wax. This resulted in excessive surface noise. It was not acceptable as a commercial solution to the mass production problem. Consequently, work continued in search of a solution. It was only natural to turn to the use of wax for original recordings, cutting the groove in the wax, and then electroplating a matrix from it.

Bell and Tainter as well as Edison had been active in the field and there was some question as to the patent situation. When 1896 came around, Eldridge Johnson, the manufacturing machinist from Camden, New Jersey, who had been a supplier of parts and assemblies to Berliner, was working on the problem, also. Later, Mr. Johnson as the leader of the recording industry, evaluated his solution. "It changed the Gramophone or disc Talking Machine from a scientific toy to a commercial article of great value. *It was the first and most important step in the evolution of the disc talking machine.*" He simply described it as: 1) "a lateral cut recording in a flat wax-like disc; 2) a very fine electrotyped matrix of this recording; 3) multiple male 'stampers' made from the master matrix." He and his assistants melted candles in pie pans; then for more precision they used a cake plate. Candles

were not good enough, so they melted Edison wax cylinders. They worked under lock and key and patented nothing until August 16, 1898, when he filed. This was the beginning of a long involvement that finally was cleared before the Victor Company went into operation in 1902. Wax was established as the recording material until the coming of lacquer in the 1940s and until that time and even after, the Johnson solution to the problem has been used by all disc record manufacturers. Only the material for the originals was changed in the 40s.

Hard rubber sometimes called vulcanite had its faults as a material for buttons and particularly for records: Uneven shrinkage in cooling caused violent warping, entrapped gas produced blisters, hard particles gave loud ticks and pops, and the coarseness of its structure produced a roar. In terms of signal-to-noise ratio, the best probably did not exceed 6 dB and the average was very near unity. The comparative quiet of the wax cylinder records made the Berliner people conscious of their number one fault. When Fred Gaisberg in 1895 heard that the Newark Durminoid Company was successfully making buttons with a substitute for hard rubber, he looked into the situation and found that a shellac compound was the material. Sample pressings from the material were amazingly superior to the hard rubber variety. The composition was patented; it was compounded from shellac, lampblack, byritis, and cotton flock.

At Least 100 000 Plus Limestone

The switch to shellac came fast, but it did take a few years, till around 1900. The improvement in signal-to-noise alone mandated the change. Great as it was comparatively speaking, it was actually very poor by present standards. After all of the improvements in record manufacturing technology that took place in the next 40 years, including the technical advances in recording resulting from the heated styli and electrical recording, the best signal-to-noise ratio never exceeded 32 dB; 28 dB was a high average performance. Nevertheless, shellac was the medium for recorded music for nearly half a century.

The new material reduced some of the crudeness of the manufacturing processes. A virgin formula (formula not using "scrap"—reground flash and returned unsold records) in percentages read as follows:

Shellac	13.6170%	a mixture of orange and garnet
Vinsol	8.7234	a low melting point molding modifier
Congo Gum	.9219	a somewhat flexible binder
White Filler	37.4469	powdered Indiana limestone
Red Filler	37.4469	powdered red Pennsylvania slate
Carbon Black	1.3475	colorant for appearance
Zine Stearate	.4964	lubricant for mold release
	100.0000%	

When thoroughly mixed in their dry state, these ingredients produced virgin material which was stored separately and used as the principal ingredient for a working formula. 470-pound batches were the rule.

The working formula normally included 25% scrap. The scrap had to be revitalized and to do this, 1% of the weight of the scrap in shellac was added as well as another 1% of vinsol. These additions increased the weight of the scrap by 2% which was subtracted from the weight of the virgin material required. For the typical 470-pound batch of working formula, the 25% of scrap weighed 117.5 pounds plus 1.2 pounds of added shellac and 1.2 pounds of added vinsol which have a total weight of 119.4 pounds of revitalized scrap. Therefore, the 470-pound batch would require 470 minus 119.4 pounds = 350.6 pounds of virgin material. To control the ratio of the ingredients to an accuracy of approximately 0.5% illustrates a tightness of process control unexpected in a formula of this kind. Even so, wide variations in the quality of the records made from the shellac compound continued to exist. However, tight control was necessary in order to curtail the aura of black magic associated with shellac compounds. To control the mixes, then, while futile in many instances, was the only hope of obtaining uniform quality of the shellac records.

The largest element of uncertainity in the process was the condition of the shellac itself. Often it was loaded with impurities such as grass, weeds, gravel, plain dirt, and it seemed, anything else that would add weight to the shipment. However, to understand something of the nature of the material is to realize that more was demanded of the product than it was able to provide. Shellac is a composite word—a combination of shell and lac. "Lac" is a Hindu word meaning 100 000 (one is tempted to add "at least"). The word is used also by the Hindus as the name of a insect that infests the kusum, ber, ghout, palas, and other trees in India, Burma, and Siam. This insect is called "lac" because one is never seen alone but always in company with at least 100 000 others. Myriads of these insects blanket twigs and small succulent branches of the host trees. During the part of their life cycle in which we are interested, they draw sap from the trees, process it through their digestive systems and secrete it so that it becomes an attached protective shell for both the individual insect during the remainder of its life and for the unhatched eggs that are left behind. The shells are never quite as large as a grain of wheat but similar in shape. It is these shells that are the raw shellac.

The shells of the lac insect are variously harvested twice a year depending on many factors relating to the region, the host trees, the color of the shells, and the intended end use of the product. Some harvesting techniques are painstaking and selective; others are gross and ravenous. The most common technique of the latter method is to scrape the encrusted shells from the twigs and branches. In the 30s and 40s, records were the greatest use for shellac. As the supply became more limited during World War II, the tendency must have been to scrape harder and harder, and to recover more and more of that which fell to the ground. Eventually the supply of shellac became so

pitifully small that much was used which otherwise would have been rejected. Even though it had been a boom to records as the replacement for hard rubber with at least 25 dB better signal-to-noise ratio, at the time of its greatest need in the middle 40s, its quality proved to be woefully inadequate.

In the meantime, however, it was probably the most appropriate material available. Other facets of the recording industry were so far from the present state of the art that to relate past practice is to risk credibility. First of all, the sound power obtained from a recording came directly from the record itself. This meant that the record surface had to do a great deal of work upon the stylus and pickup diaphragm. This required a record groove six thousandths of an inch wide to support the several ounces of stylus force it took to flex the diaphragm in accord with the sound recorded in the groove. For the stylus to reproduce the sound most faithfully, it was best that it fit the groove exactly. To bring this about an abrasive additive was put in the record compound.

Looking at the basic shellac record compound formula again, it is seen that there were two principal ingredients: 13.5% shellac and 75% filler plus about 12% other materials. Limestone, finely ground, was found to be a good filler since it was smooth sounding and cheap. Red slate flour from Allentown, Pennsylvania also was inexpensive but not so quiet and a great deal more abrasive. A little experimentation revealed that mixing white limestone flour half-and-half with red slate flour gave the abrasiveness sought and the smoothness of sound properties required in a filler for the compound. The fact that red slate flour was used gave credence to the rumor that records were made from ground bricks. How abrasive were these records? Jukebox operators changed steel needles after 1000 plays. The needles removed were invariably worn to the exact profile of the record groove.

Limestone as a filler for records may have contributed to the State of Indiana becoming for a while the center of the record manufacturing industry in America—if not, of the world. For several reasons, RCA Victor saw fit to move some of its record production facilities to Indianapolis, starting in 1939. No surprise was involved but the advantages of being near the source of the best filler for the records and near the center of the population of the country showed up larger than was expected on the bottom line of the balance sheet. Other record companies, particularly Columbia, for the same and other reasons, also located near the limestone and the population center and, for a time, about 75% of the material for American records was quarried in Indiana.

Almost any amount of scrap could be—and was—used in the shellac compound. Batch mixing charts gave the weights for each of the ingredients for the compound, using from 20% to 70% scrap in 5% steps. The use of scrap was advantageous from every point of view, particularly since it was revitalized by the addition of virgin shellac and of molding modifier. The reworking of the scrap portion of the new compound made that part of the compound better than it was originally and, in addition, accelerated the fusion of the whole mix in the banbury. In fact, it was general practice to leave a "tail" in the banbury mixer to start fusion in the next batch.

The word scrap was stretched in its meaning in the record factories to include the dust from the factory dust collector. While this always caused those who were quality conscious to cringe a bit, no real harm was ever found to result from this practice. Not so, though, with regard to the labels on the returned unsold records. The labels were ground with the records, and the large pieces of paper were screened out. True, the paper that was left was no worse than the bark from the trees or dirt from the tropical groves. It did, however, add to it.

The worst aspect of the use of scrap was its psychological effect. Scrap is synonymous with trash, discard or junk. Boxes labelled "scrap" around the presses, in the warehouses, and wherever invited their use for the disposition of waste material. It was not uncommon for the scrap to include soft drink bottles, litter, pieces of masonry, or other unwanted material, all of which were ground up together and mixed in with the next batch of compound. Years of dedicated attention to changing the labels on the scrap boxes to read "used compound" and to label the waste cans "waste" or "trash" was wasted effort. The present day energy-saving emphasis upon recycling has given respect to boxes labelled "compound for recycling." This will continue at least until the new editions of dictionaries re-define recycle as scrap.

Shellac records were difficult to mold, particularly in the days when there were no automatic controls. The tolerances were narrower than the human sensors used for controlling the process were accurate. Presses opened too soon created a record that could not be removed without tearing and one left too long would crack in the press. Because abrasive compound was used, extruders could not be used. The biscuit-steamtable technique of preheating the shellac record preform before it was put in the press was another instance where the human sensibilities based on sight and feel were not adequate to avoid variations in the quality of the output. This was reflected in the variation of force needed to close the press. The stampers were built to withstand this spread between maximum and minimum force. Copper stampers 20 mils thick (0.020 inch), nickeled and chromed, were soldered to a sixteenth inch steel backing plate for strength before mounting in the press. In those days, it took 22 hours to copperplate a stamper.

The shellac record was brittle even as it came from the press. This very often caused the center hole to chip away, among other things. One solution to this problem was to mold an oversized centerhole in the record to be covered by a star label which, in effect, bushed the hole to size when the four or five star points extending over the center hole were folded inward as the record was placed on the turntable. Another solution was to champer the center hole of the record to provide some angular freedom when the record was removed from the press.

The largest deficiency of the shellac record was its surface noise. There was no way to reduce it to today's level. However, the surface noise was a partial blessing for it masked many of the other faults. Shellac records

were full of blisters and unfilled grooves which produced ticks and pops in the sound. The hard particles from the impurities in the raw shellac, from the trash in the scrap and from thermal decomposition of the uncontrolled fusing of the ingredients all were present. A shellac record without surface noise to mask these faults would have been intolerable.

Because the shellac record was brittle, finishing the edge of the record was somewhat of a problem. The early procedure was to place the record between round wooden finishing blocks and to use sandpaper by hand as the first step. Then the edge was polished with a cloth impregnated with paraffin and dampened with a solvent. A later technique employed a lathe on which up to 10 records were spindled and finished at the same time. From this, with the coming of vinyl records, the next step was to the individual lathe (trimmer) at each pressing station.

The brittleness of the shellac record put a great burden upon handling, packaging and shipping. Capitol Records used wooden boxes for shipping as did other companies.

First of the Laminates

Back in 1906, Columbia found itself troubled by the success of its competitors. In spite of the best it could do technically with its Twentieth Century Graphophone cylinder machine, Edison was taking the business. Commercially, Victor, with its lavish advertising of its artists exclusively on the Victor label, left little for Columbia to relish. It was that year that the great Italian inventor of wireless telegraphy, Giulemino Marconi, paid a visit to The American Graphophone Co. plant at Bridgeport. He was retained to make a thorough study of sound recording and reproducing techniques. It might also be added that the study was quick: by July, Columbia had announced the new Marconi Velvet-Tone record. This was a thin flexible laminated record with a paper core and a plastic face or faces. The thin records were pressed in the same machines as the standard records and with the same stampers. Their advantage was that the amount of surface material that carried the music grooves could be and was exceedingly small because it needed to be only a few thousandths of an inch thick to contain the grooves. This record design reduced the amount of high quality plastic needed by a factor approaching ten, which made it possible to use only the very best. Surface noise, and ticks and pops were reduced, the product was less fragile, and had less weight. Unfortunately, Velvet-Tone did not help Columbia's position a great deal because their competitors were not taking the business only because of record quality.

The importance of this type of record was to come later. The manufacturing technique was to use a craft paper core cut to approximate record size. After the core was carefully flattened and dried, it was covered with compound dust to a thin uniform thickness. The dust was powdered shellac compound. The core was often referred to as the "powder blank." The dust-coated core was put in an oven and the dust fused to the core or blank. For two-sided records, the operation was repeated for the other side. To press the record, the record blank and the labels, were placed in the press, with the standard stampers, and the press was closed. This technique produced the ultimate in quality for shellac records.

The laminated record has made several appearances in the history of sound recording, always in a slightly different form. Its next appearance was as the Edison Diamond Disc in 1912/13.

For the next 15 years this Edison disc was the highest quality record in the world, and today could still be a candidate for the world title of top quality. The "powder blank" of the Diamond Disc was manufactured with a thickness of approximately one-quarter inch, precisely flat, and from a durable compound, as reviewed in the preceding section. The condensite varnish surface undoubtedly is the most durable known to the industry. It had to be to support the unmercifully great unit pressure of the 0.0075-inch tip radius diamond stylus with a force of nearly nine ounces. When Edison went to a groove pitch of 450 for a 40-minute record (20 minutes per side) at 80 r/min in 1927, he used this Diamond Disc as the medium. This Diamond Disc record was 10 inches in diameter and weighed 440 grams or just under 1 pound. This fact may be the event that has related record weight with record quality in the minds of the American consumer even after the Diamond Disc has been removed from the market for nearly 50 years.

The laminated record turned up in another form, first in 1929 and several times since, as a picture record. The "powder blank" or core of the record is printed with the artwork in color, if desired. In one version, the core is sandwiched between two clear plastic sheets cut to size and inserted into the record press to be fused together while the music grooves are being formed. In another version, clear vinyl compound is powdered by cryogenic grinding and substituted for the powdered standard compound regularly used in laminated records. These descriptions are indications of the techniques involved. A great deal of additional know-how is needed before a satisfactory product can be assured. Picture records have never been an important factor in the market. However, in the late 40s, several million were sold as children's records, carrying pictures of the performing Mother Goose or nursery rhyme character.

Columbia returned to the laminated record in 1922, this time with a coarser compound for the "powder core" that was bonded between two discs of craft paper. The coming of electrical recording in 1925 with its better frequency response made the better surface of the laminated records much more noticeable. When the Edison lateral cut "needle" record was issued for a short time starting in 1927, it was of this type of laminated construction. In the early 30s when records were hanging on for dear life in the marketplace, the Durium Products Corporation of New York introduced the "Hit of the Week" record at the newstands for 15¢ each. This was a single-sided coated craftboard record. After being on the shelf for 45 years, it is only slightly warped dome-shaped. This was about the time (1934-1935) that Decca came into the American market with the biggest personalities in popular music at 35¢ a record. The Velvet-Tone style of a laminated record gave Columbia the opportunity to successfully compete

for the ten-cent store record market. Columbia really made a triple-play with its laminated record. Not only did it give the company the inside of the ten-cent store trade, but it used the 1922 version to sustain the quality of its classical repertoire recordings of the Columbia Broadcasting Company Orchestra under Howard Barlow. The technical superiority of this record, at 50¢, lifted Columbia to a new height with popular music, because these records worked best with the new jukeboxes and the new record changers. The third play was not planned. World War II cut off the supply of shellac. The laminated record meant that Columbia's need for the material was much less critical than was that of the other record companies. It gave Columbia a record quality advantage during the war period which may have been a key factor, if not the key factor, that established Columbia Records with an enduring reputation for quality. This was in spite of the one sour note that is always heard in times of sweetness and light: One popular changer was the best delaminater of Columbia records ever invented.

THE SECOND MOST IMPORTANT STEP

A number of things had conspired against shellac even before its last days. Union Carbide had announced a vinyl resin in the 1930s that proved to be ideal for record compound. It also proved to be compatible with all of the record making equipment in the factories. Vinyl compound was as near a one-to-one replacement for shellac that one could wish. This fact practically eliminated the attitude against making a change that is anchored to the vested interest in maintaining the status quo. It also facilitated research and development programs based on the use of vinyl and really made it possible to make special runs of records using vinyl in the same factory that used shellac.

Consequently, special uses were made of vinyl for critical records. Western Electric began to use vinyl for transcriptions for radio stations; RCA did the same. Muzak used vinyl for its music services, and with the coming of the war years, RCA pressed unbreakable vinyl records for the armed forces. The "V" records, as they were called, could arrive at their final destination by parachute without breakage.

As the war years came to a close, RCA smarted under the record quality situation and had to do something about it. A way had to be found to associate RCA with the best in record quality. With shellac prices up about 10 to one, the time had come. Red Seal 12-inch records would be released optionally on transparent cherry-red vinyl starting in 1946. These records vividly demonstrated just how beautiful recorded sound could be. The one sour note was the objection to the increase in price for these special quality records. One enterprising music department manager of a great retail store, realizing that the magnitude of the advancement in sound quality should not go unnoticed, fitted up the grand showcase window of the store located along the north side of a principal downtown street with pyramids of the brilliant red records arranged about the window on glass display stands. On the day of the announcement, at ten o'clock in the morning when the store opened, the curtains were drawn back and the display, with its glorious red records radiant in the sunlight, announced a new day in records. By noon every record in the sun had tightly drooped itself down and around the display stand. Lesson number 1: Do not store in sunlight.

The leadership of the quest for a better record material can certainly be disputed but RCA had embarked upon an active program and carried it forward with the first public commitment to the new material. This was in harmony with the public and official predictions of the company made during the war that there would be better and more costly new materials for records, new pick-ups and new players. Other record companies were also working.

A large portion of the leadership credit must go to the successful supplier of the material, Union Carbide. Union Carbide had a new product and had found a ready place for its use. No record company failed to get the full story of all the advantages of this new material for records backed up by a guaranteed supply of the material when it was needed. Fulfilling those two obligations to consumers is the essence of commercial leadership. Union Carbide was the first with success. This always gives special notice, historically.

The importance of the new material for the record industry can not be overemphasized. Every advance in the art of record making from this point on piggy-backed on this development: high fidelity, fine-groove, stereo, quadraphony, and some yet to come.

The impact of the new record material was varied. Some changes had to be made, including elimination of old habits and some new rules had to be learned. The greatest effect was the establishment of the record as the strongest link in the chain of events that was responsible for recorded sound. For the next 25 years (until 1970), no other component of the recorded sound system could claim the excellence of performance of the record. The record became the world's most precise mass produced consumer product. A slight calculation verifies this statement. On one side of an LP record is a 20-minute recording that has full response to 10 kHz. Twenty minutes equals 12 000 seconds. With 10 000 sonic events per second, the record contains 12 000 000 events per side or nearly 25 000 000 for both sides. Since it is stereo, the numbers double—they are 24×10^6 and 5×10^7. This is not a rigorous analysis; it is only an indication of the detail involved in record manufacturing.

Since about 1970, pickups have become much more sensitive and amplifiers have almost unlimited frequency response. The burden of excellence of performance is again back with the record. For instance, discrete four-channel recordings need good response at 45 kHz. For simplicity, if this is regarded as 50 kHz, then a 20-minute CD-4 record has 60 000 000 events recorded per side—doubled for stereo gives 12×10^7; redoubled for four-channel, 24×10^7. There are approximately 75 square inches of music groove area. This means that the pickup stylus must be able to identify by reproduction, 3 200 000 sonic events per square inch, (5000/mm^2) or one per mesh on a 1789×1789 screen. This all indicates that sometime

in the future there may be a change in the method of recording on the vinyl disc using video disc techniques or further refinement of the material.

The vinyl material is a product of the plastics industry and its production is completely under process control. This has brought about a degree of uniformity of physical characteristics from batch to batch that could not be achieved with shellac. This control has progressively become more and more complete as instrumentation has been developed and applied to almost every aspect of the physical characteristics of the material. This has resulted in a refinement of product and a straight-line improvement in record quality. That this will continue to be the situation depends upon the direction that audio recording takes in the future. Video disc techniques offer bandwidth support from the same record material for whatever turn in direction audio might take, including digital recordings.

The selection of copolymer resins as the basis for the record material to succeed shellac was more fortuitous than planned, for no one could have foreseen how completely it would satisfy the requirements for more than thirty years to come.

This evaluation names the selection of vinyl resins as the successor to shellac for record material as *the second most important step in the evolution of the disc talking machine*. The first was the Johnson Recording Process. The third great and important step in the evolution of the disc talking machine is the replacement of wax with lacquer as the material for original recordings.

THE THIRD MOST IMPORTANT STEP

Forty or fifty years is a good life for an industrial process. Such a life did the Johnson Recording Process enjoy from about 1896 to about 1946. When wax was selected as the material for original recordings, it was regarded as ideal. At the time it was such an improvement over anything else that could be done, that everybody was happy. As time went on and production of records grew larger and larger, shortcomings began to appear.

The first of these, of course, was that the wax had poor physical properties. It was particularly sensitive to temperature. While this gave a measure of control over the hardness of the wax, conversely, it meant that the temperature had to be under control at all times. These and other nuisance requirements were not important—they had been lived with for more than forty years.

Not so for the important complaint that became more and more damaging as production increased. The wax and the gold-spluttered coating had an affinity for each other and in time, an amalgamation would take place which always varied in the most awkward manner. From that time on, it was impossible to clean the master recording. Wax particles would cling to the gold so that it was impossible to plate molds from the original without including these particles under the plating to raise the noise level of the pressings. With shellac records some of this noise was masked by the imperfections. But with vinyl, every speck of gold gave notice of its presence when the record was played.

A solution of nitro cellulose resin and plasticizers, fillers, lubricants, and dye was found to give spectacular results in comparison with the wax originals. This solution was lacquer and it was used to coat either aluminum or glass blanks. Again, as with the vinyl record compound, many of the characteristics of the material came under control for the first time and much of the variation from batch to batch and from lacquer to lacquer was eliminated.

In use, the lacquer was silvered which avoided outgasing during plating and which permitted cleaning between platings when required.

Another advantage was that for the first time, an original could be played back, if done with the utmost skill and care. A lacquer could be independently evaluated. Numbers could be applied to the results produced under defined conditions. With the original wax and shellac process, a 30-dB signal-to-noise record was hard to produce, almost impossible. With lacquers and vinyls, 55-dB to 60-dB records were reached and an average within 5 dB of the best was maintained.

As a matter of fact, 60-dB lacquers were about the best that could be done. However, every lacquer processor working under favorable conditions has measured lacquers at least 10 dB better.

There is no question that the replacement of wax with lacquer as the material for original recording in the Johnson Recording Process is the third most important step in the evolution of the disc talking machine. But notice, only the material changed; the process remained the same. The fourth most important step in the evolution of the disc talking machine was the introduction of magnetic recording for original recording as is detailed by Mr. Mullin in a previous paper in this issue.

The technical detail of the use of vinyl compound in record making is a monument to the cooperation of the record industry with the plastic industry—the supplier with the manufacturer. There is nothing unique about this situation. The extent of the involvement of one with the other can never be understood until some idea is given of the amount of tailoring which must be done on the raw material by the supplier. This is done well by Mr. S. K. Khanna in the treatise on "Vinyl Compound for the Phonographic Industry." And from this an insight can be gained of the most intensive and extensive materials research program that has been cooperatively conducted by supplier and manufacturer for the past thirty years.

Record Materials

Part III: Vinyl Compound for the Phonographic Industry

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The phonograph record business is a volatile business. A popular disc today is often an unsaleable commodity next month. In the past 25 years, however, technological changes in the industry have been quite dramatic. New recording techniques, new record speeds, the improvement in the playback systems, and the introduction of quadraphonic sound have produced some new thinking and development work in the raw materials used in producing discs.

In the early 1940s the majority of records had a 10-inch diameter with 78 r/min playback speed. The material used consisted of slate and limestone fillers with shellac, a naturally polymerized plastic, as a binder. The presence of the mineral fillers precluded its use for the production of longer-playing records because background noise became unacceptable owing to the imperfections of molding. The use of thermoplastics became very desirable and a polyvinyl chloride (PVC) based material was considered.

The PVC homopolymer material was too stiff in the melt form and the gramophone record industry was unwilling to change the basic molding process for capital cost reasons and any new material had to fit in with the established procedures.

Practically all currently produced 12-inch long playing records are compression molded of vinyl chloride vinyl acetate copolymer. Other materials, such as modified polystyrenes have been used for injection molding of 7-inch, 45-r/min discs.

CHEMISTRY OF VINYL PLASTICS

The raw material used for the manufacture of PVC is vinyl chloride monomer. The vinyl monomer is derived from petroleum products by cracking hydrocarbons, such as naptha, to ethylene and acetylene.

Previously, the production of vinyl chloride monomer consisted of two basic techniques: 1) acetylene plus hydrochloric acid to produce vinyl chloride directly; and 2) ethylene plus chlorine to produce ethylene dichloride, followed by cracking to yield vinyl chloride and hydrochloric acid.

The relatively new process called oxychlorination has become very popular to produce vinyl chloride economically. This monomer can also be synthesized from coal and agricultural products.

Vinyl acetate which is copolymerized with vinyl chloride to make the plastic flow easier is obtained by reacting acetic acid with acetylene.

These monomers should be free from such impurities as acetylene, iron, hydrochloric acid, oxygen, water, acetaldehyde, etc., which affect the quality of the resin and resin particle size and distribution.

POLYMERIZATION PROCESSES

PVC was first produced commercially in Germany in the 1930s. Four basic processes may be utilized for polymerizing PVC. 1) suspension polymerization: this process employs water as the continuous phase, with monomers dispersed by means of suspending agents. Most of the copolymers used in the record industry are suspension-polymerized; 2) emulsion polymerization; 3) bulk or mass polymerization; and 4) solution process.

The polymerization (making of the resin) is carried out in large capacity stainless steel reactors. Reactors are jacketed for initial heat-up and cooling during the course

of polymerization. Monomer-soluble initiators such as peroxide are used at a polymerization temperature of 120-130°C. The molecular weight of the resin is a function of the polymerization temperature. Suspending agents and, in some cases, emulsifying agents are used to control the resin particle size and shape. The nature of the particles for PVC/PVA copolymers is shown in Fig. 1.

The polymerization of PVC is to some extent a batch process. There have been some new technologies in the market where some elements of continuous process have been used. The two-stage bulk polymerization process used by Pechiney-St. Gobain is worth mentioning here.

CHARACTERISTICS OF PVC COPOLYMER RESINS USED IN THE RECORD INDUSTRY

The important properties of resin used in the record industry are the following:

1) Molecular weight: This is the most important consideration in selecting a copolymer since it greatly affects both processing and end use properties of the disc. See Fig. 2 for the effect of molecular weight on the melt viscosity of the resin. As the molecular weight of the polymer increases the melt viscosity increases making the melt stiffer and slower to flow.

2) Acetate content: This is the second important property of a copolymer. The primary function of the presence of acetate in a resin is to act as an internal plasticizer. As the amount of acetate level increases, the melt viscosity decreases and thus the compound flows easier. The effect of the amount of acetate level on the melt viscosity can be seen in Fig. 3.

3) Dry flow: This is employed as a measure of the ease of handling the powder resin.

4) Gels (Fish Eyes): These are large resin particles which have not been completely fused during processing. These may be observed as small spots on a disc and produce objectionable sound quality in the form of "ticks and pops."

5) Percent volatiles (heat loss): This is a measure of

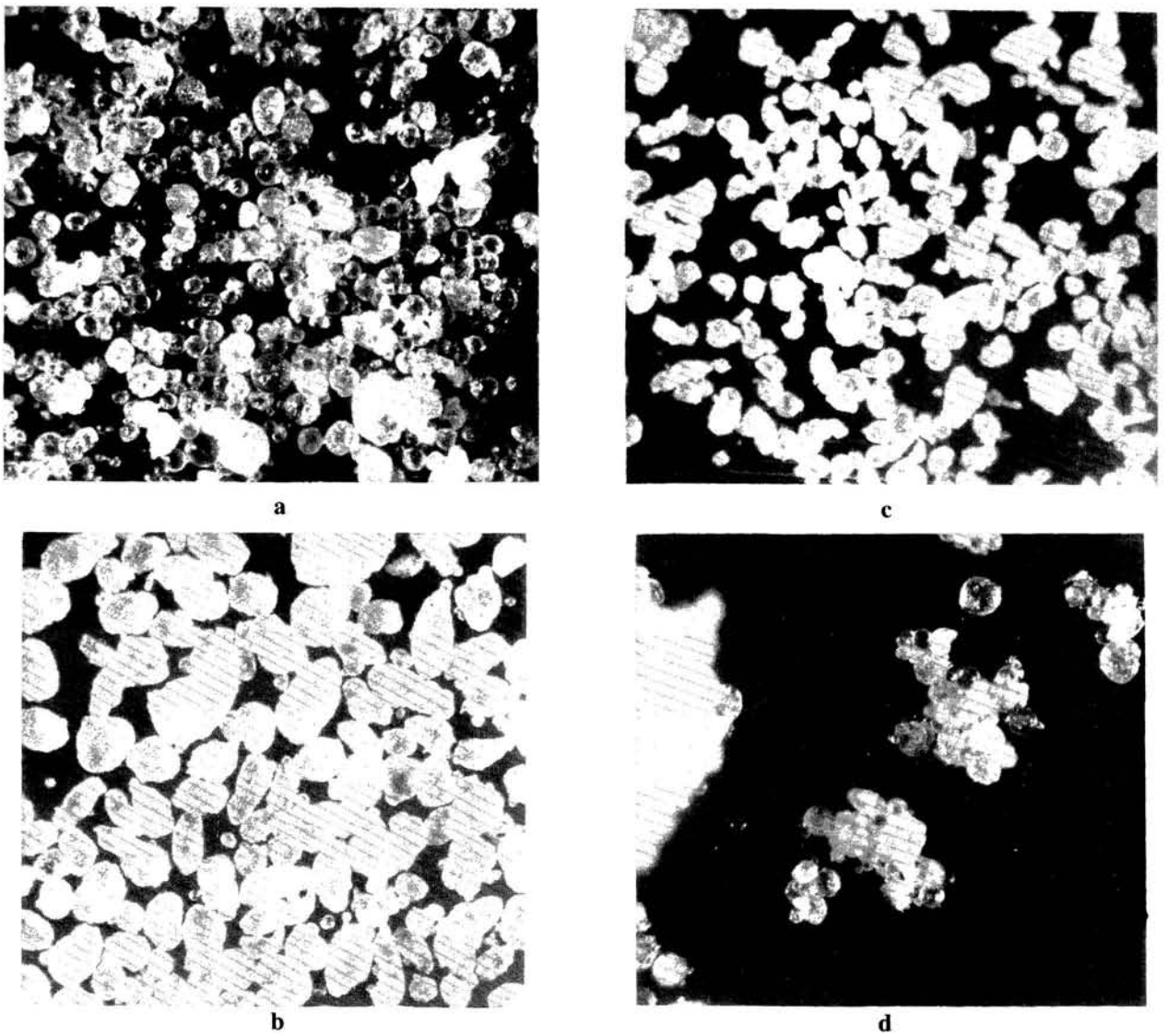

Fig. 1. Photomicrographs of PVC homo- and copolymer suspension resin particles. **a.** and **b.** Copolymers of 15% acetate produced under different polymerization conditions. **c.** PVC homopolymer low molecular weight. **d.** Copolymer glassy bead example of agglomeration.

volatile components which generally consist of water and unreacted monomer. Too high heat loss content can give rise to blisters and stains in the finished discs.

6) Heat stability: The inherent stability of vinyl resins is known to vary, causing differences in the requirement for stabilizers. A preferred way to determine the thermal properties of the resin is the dynamic stability test, using an Instron capillary rheometer. The extrudates surface, coloration changes and any changes in melt viscosity due to thermal degradation of the resin can be characterized and are shown in Figs. 4 and 5.

7) Processing characteristics: Some rheological instruments may be used to characterize the processibility of the copolymers. The use of a capillary-type viscometer for determining the melt flow properties of the resins is important. The use of other devices such as a rheovibron and mechanical spectrometer provide excellent correlation with elasticity problems (warpage) and shear-related differences.

8) Contamination: The contaminants such as burnt resin particles and foreign material are checked very carefully since these contaminants can produce inferior quality discs and can damage the stampers also.

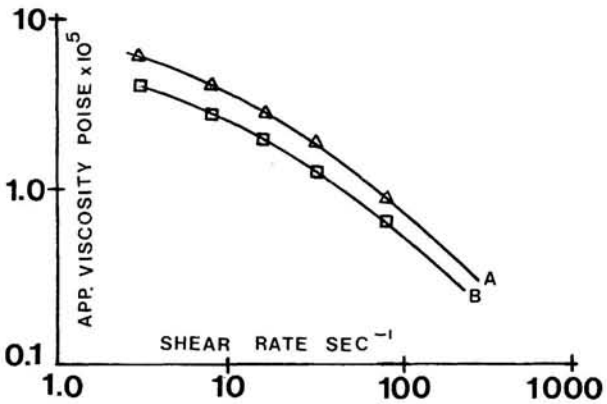

Fig. 2. Apparent viscosity vs shear rate at 141° C for copolymers containing 12.5% acetate with different molecular weight. A [η] 0.272. B 0.241 specific viscosity.

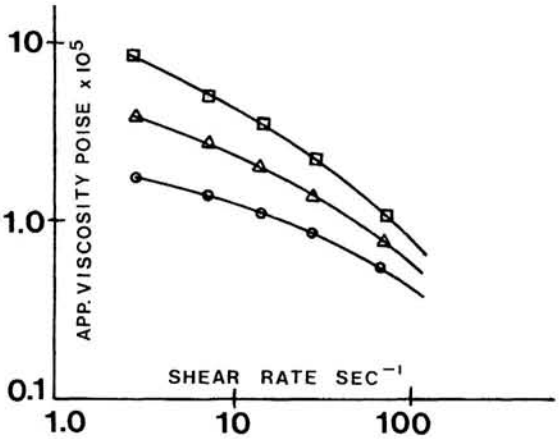

Fig. 3. Apparent viscosity vs shear rate at 141° C for copolymers of [η] 0.241 viscosity with vinyl acetate content: (□) 6.5% (Δ) 12.5% (○) 17.2%.

COMPOUNDING

A few resins are useful in their natural form and do not need much mixing with other materials. Vinyl resins are not among these few polymers. The PVC resin has very poor heat stability and processibility. To improve these properties, other additives are mixed or compounded to improve and enhance these properties and, thereby, make them more useful for a variety of applications. The process by which ingredients are intimately mixed together into a nearly homogeneous mass is known as compounding. Because of the nature of both the resin and other ingredients, compounding requires a wide range of mixing, fluxing equipment and different range of mixing operations and conditions (see Fig. 6 for good dispersion material in a molded disc).

There have been various mixing theories described in the literature [1], [2], and, at RCA the compounding technology for the manufacturing of the CD-4 quad compound has been patented [3].

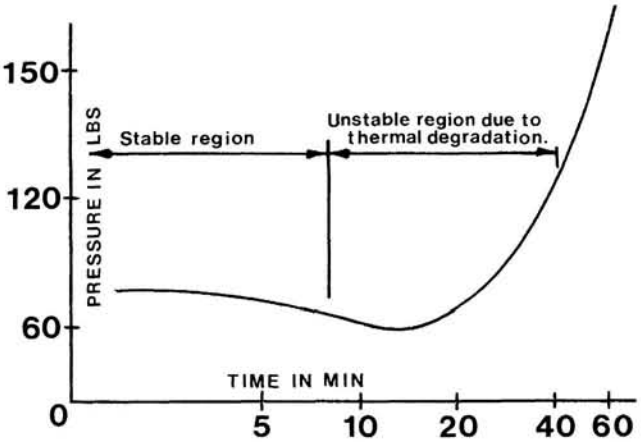

Fig. 4. A typical thermal stability curve for a 15% acetate copolymer at 150° C using 1% stabilizer.

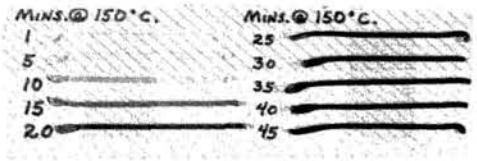

Fig. 5. Extrudates collected at different extrusion times at 150° C using Instron capillary rheometer at 7.5 sec^{-1} shear rate.

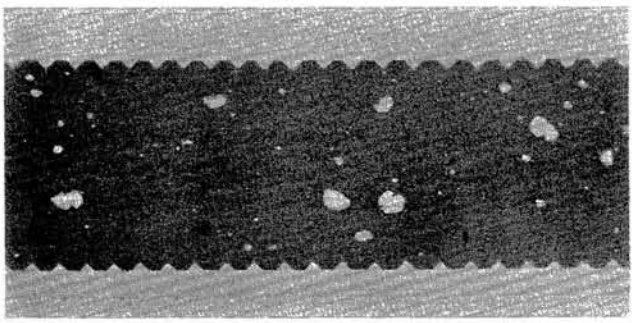

Fig. 6. Microtomed section of a disc showing partially fluxed secondary resin and distribution of carbon black particles. ×36

The compounding process may be performed continuously or in a batch and can be divided into two major classifications: a) dry blending, where the compound used on the press floor is in powder form: b) fluxed compounding, where the material is melted through a plasticizing mixer or by the extrusion process to result in a granular form. The processing cycle used for compounding in the record industry is shown in Fig. 7.

COMPOUND DESIGN FOR GRAMOPHONE DISC APPLICATIONS

Variables which come into play in the design of a record compound are shown in the following formulation variables.

Resins

1) Selection of Resins: Resin selection is very important with respect to effects of such properties as melt viscosity, melt elasticity, nature of the particle size and structure and contaminants in the form of polymerization agents. It has been demonstrated [4] that PVC/PVA copolymers with similar molecular weight and percent acetate level could have different processing properties due to the difference in molecular structure of the copolymer produced under different polymerization conditions.

Stabilizers

1) Control of the thermal stability of the compound.

2) Sound characteristics, certain type stabilizers contribute to noise.

3) Lubricating and compatibility effects during processing of compounds.

Colorant

Selection of carbon black with ideal particle size and distribution. Certain types of carbon black dispersed more uniformly and also hid more of the plate-out problems than other types.

Fillers

Types of fillers, their selection and effect on compounding, visco-elastic properties and sound properties are very critical. The fillers should not be used to cheapen the compound but they should improve some of the visco-elastic properties which improve the quality of the discs.

Special Additives

1) Lubricants.
2) Modifiers.
3) Plasticizers.
4) Antistatic agents.

All of the above special ingredients have tremendous bearing on the fluxing, flow and dynamic properties of the record compounds. These additives are very effective in changing the above-mentioned properties and need very special blending and compounding conditions in order to be used successfully.

Historically, the compounding of vinyl record formulations has been treated more as an art than a science in the record industry. The above formulation variables describe the complex nature of compounding and the selection of materials. Various compounding steps need very careful study in developing a record compound. The increasing number of quality-conscious persons and new audio technologies such as quadraphonic and, to some extent, video applications have demanded some basic research in the field of material science.

Flow is one of the most important properties of a plastic compound intended in the manufacture of phonograph records. The earlier works of Dyer [5] and Coleman [6] have stressed the importance of the flow properties in designing compounds and resins for the record industry. Melt elasticity and the dynamic properties of molded specimens have also been shown to be important to the dimensional stability of the completed product. These latter properties as well as a proposed rheological model for compression molding of discs are explained in [7] and [8].

The phonograph disc is an extremely critical application of plastic molding. Molding defects and dimensional stability find their way into degrading the audio properties. With the introduction of automatic presses, additional incentive exists for decreasing molding cycles. All of these elements require the control of the rheological properties to optimize the performance of compound.

FUTURE TRENDS FOR MATERIAL FOR THE PHONOGRAPH INDUSTRY

The use of fillers has not been completely evaluated for use in the record formulations. Preliminary lab work has indicated that good stereo discs can be molded from compound containing fillers without sound penalty. We need to evaluate fillers, modifiers, new stabilizers and lubricant systems in order to further develop improved compounds. We should also look seriously to the

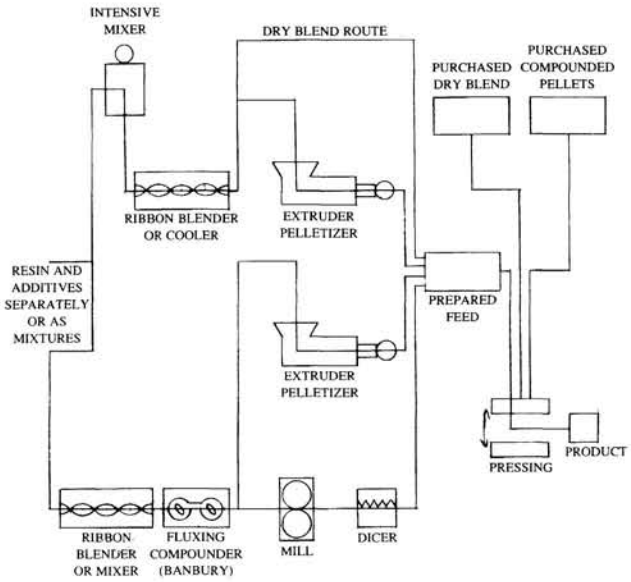

Fig. 7. Gramophone compound processing cycle.

homopolymer resins and see if we can alloy these polymers during compounding to improve their flow properties so that these materials can be processed in the existing pressing plants.

Additional work could be structured to optimize materials for use with the injection molding process. A systematic review of material alternatives in relation to the process and rheological studies could provide an optimum material for at least 7-inch discs. Alternative material studies are also considered important. Such studies could make the record industry less vulnerable to the future material shortages, which could happen, since these materials are petroleum-based products.

ACKNOWLEDGMENTS

The author acknowledges the fruitful discussion with J. C. Ruda in regard to the preparation of this article.

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THE HIGH-FIDELITY PHONOGRAPH TRANSDUCER*

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High fidelity began in earnest with the adoption to the phonograph of electrical transduction and amplification. Phonograph pickups had been patented as early as 1918, nevertheless, they do not appear to have become widely used until the late 20s and the early 30s, at which time measurement procedures and improved understanding of stylus-groove relationships provided a basis for high fidelity developments that followed. The renaissance of the phonograph after the depression of the 30s was spearheaded by the development of the Bimorph Rochelle salt crystal element and the invention of the lever-type pickup which allowed the stylus bearing loads to be reduced by half an order of magnitude. Crystal pickups were dominant until the 50s when they began to be displaced by barium titanate and lead zirconium titanate ceramics, with the piezoelectric principle in various forms being successively adapted to the LP record in 1948 and the stereo record in 1958. The renaissance of the magnetic pickup was presaged by the development of an ultralight moving conductor reproducer during the 30s and followed by the wide adoption of the variable reluctance principle after World War II. A quantum drop in stylus bearing forces again occurred with the introduction of the moving magnet pickup in 1957 which was modified for use with the stereo disc in 1960. Fidelity was further improved with the introduction of bi-radial styli for audio-frequency records and of pyramidal and Shibata styli for ultrasonic carrier-type discs. An indispensable pickup element, the pickup arm has undergone considerable improvements with the better understanding of the optimum arm geometry which has resulted in virtual elimination of tracking error inherent in pivoted arms. In a cogent manner, side thrust caused by the stylus-arm friction has been compensated with simple spring or weight mechanisms. For high-fidelity performance it is essential that the arm be properly damped. Two damping arrangements are described and their characteristics analyzed. Pickup equalization circuits are briefly treated. Among the problem areas still in need of improvement are a continuing lowering of stylus bearing forces; protection of stylus against damage; improved arm damping techniques; control of vertical stylus tracking angles; and reduction of stylus/groove resonances.

INTRODUCTION: To analyze the evolution of the high-fidelity phonograph transducer (more familiarly known as the pickup) as an isolated phenomenon, is difficult, perhaps even impossible. The purpose of the pickup is to perform a specific function—to translate record groove modulations into electrical signals. The electrical performance of the pickup must correspond with the characteristics of the record, and the study and measurement of the groove-pickup interactions constitute a discipline in itself. The pickup comprises a transducer proper, or "cartridge," mounted in an arm and the coupling between the mechanical impedances of these two elements affects the system performance. Sound modulations of the record groove are transmitted to the pickup via a stylus, thus the stylus-groove relationships must be taken into account (no less than three doctoral theses have been written in this area over the past several decades with the final chapter probably yet to be written). Thus, while attempting to follow the principal theme of this paper, it will be necessary to explore these related aspects of phonograph technology to gain a thorough understanding of phonograph transducers.

THE ORTHOPHONIC TRANSDUCER

Thomas Alva Edison applied for a patent for the phonograph in 1877 [1]. Its key innovation was a mechano-acoustical transducer for transforming mechanical groove modulations into audible sounds. During the ensuing decades, the phonograph became the beneficiary of many inventions and improvements, most of them of the type which stem from the minds and rules of thumb of creative practical men. Also in 1877, Lord Rayleigh published his monumental *Theory of Sound* [2] and began its chapter on Electrical Vibrations with the assertion:

* Dedicated to the memory of Alan Dower Blumlein

"The introduction of the telephone into practical use, and the numerous applications to scientific experiment of which it admits, brings the subject of alternating currents within the scope of Acoustics, and impose upon us the obligation of shewing how the general principles expounded in this work may best be brought to bear upon the problems presenting themselves."

Rayleigh then proceeded to lay down the foundation for analysis of alternating electrical circuits in terms of acoustical theories. Half a century later, through the efforts of Webster [3] and Kennelly [4], the concept of electrical impedance repaid this debt to acoustics through the technique of equivalent circuit analysis [5]. One of its most successful applications was in 1926, the Orthophonic phonograph reproducer of Maxfield and Harrison [6].

The Orthophonic reproducer was a colossal achievement which stands out as one of the first steps in the direction of high-fidelity sound reproduction. Nevertheless, Maxfield and Harrison were handicapped by attempting to carry water on both shoulders, so to speak, i.e., to provide uniform, broadband sound reproduction and, at the same time, to extract maximum energy from the groove modulation. The development of the electrical pickup, or electromechanical transducer, for disc reproduction allowed the phonograph designer to separate the variables of efficiency and bandwidth. Thus, high-fidelity can be said to have begun in earnest with the adaption to the phonograph of electrical transduction and amplification.

ELECTRICAL SOUND REPRODUCTION

The concept of electrical reproduction of groove modulation, of course, predates the work of Maxfield and Harrison. Many such concepts are to be found exclusively in the patent literature to which we shall make frequent references.

An early patent on an electromechanical phonograph transducer, invented by Henry C. Egerton and assigned to Western Electric Company, was filed on February 1, 1918 and issued as Patent No. 1,284,623 on November 12 of that year. Egerton's first claim seems to anticipate many modern magnetic phonograph transducers:

"An acoustic device comprising a member adapted to be secured to a phonograph for movement therewith relative to the phonograph record, a supporting member secured to said first member and movable perpendicularly to the direction of cut of the record, a magnet carried by said supporting member, a coil associated with said magnet, an armature carried by said supporting member and mounted for rocking movement relative to said magnet and a stylus carried directly by said armature adapted to engage the record."

In 1921, H B. Wier filed a patent application on Sound Recording and Reproduction Apparatus, also assigned to Western Electric Company, for electromechanical binaural recording and reproduction, which was issued in 1924 as U. S. Patent No. 1,508,432. Wier provides the options of engraving two grooves on two synchronized cylinders, or as a bifilar arrangement on a single cylinder. It is not known if Wier's idea was ever widely used; nevertheless, it is indicative of early interest in improving spatial fidelity of recorded sound.

In the Historical Context section of his book, *Electroacoustics*, F. V. Hunt [7] asserts that the earliest all-electric phonograph to become commercially available was the Brunswick Panatrope marketed (probably in the late 20s) by the Brunswick-Balke Collender Company, but the details of its pickup are not given. It can be stated, however, that most of the early electrical pickups with which this author is familiar were little more than small magnetic transducers of the type used in loudspeakers or earphones in which a stylus holder replaced the drive-rod coupler. The usual arrangement is shown in Fig. 1. The typical stylus bearing force of such a pickup was 4 oz (114 g). This type of pickup appears to have been developed by E. W. Kellogg, around 1927 [71].

Another example of early electrical phonograph transducer designs may be seen in the U.S. Patent 1,855,150 filed in 1928, issued to W. B. Jones in 1932, who appears to have been one of the first to combine orthogonal lateral and vertical modulations in a disc and independent orthogonal transducer axes in a pickup—possibly the first practical stereophonic pickups ever devised. And, in his now famous British Patent 394,325, filed in 1931 and issued in 1933 A. D. Blumlein of EMI in the United Kingdom describes a cutter and a pickup for the 45°-45° modulation in a stereo record groove, presaging the introduction of the modern stereodisc a quarter of a century later.

PERFORMANCE CRITERIA

To develop the high-fidelity pickup, it was necessary first to devise the means of measuring its performance. Attempts were made during the 30s to provide electromechanical drivers[1] for this purpose; it was soon realized, however, that meaningful measurements would require the use of a record with precisely known modulation characteristics.

Among the first to be concerned with modulation measurements were Buchmann and Meyer [8] who, in 1930, noted that reflections from the grooves of a distant point source of light produce a luminous pattern whose width b along the groove can be related to the maximum lateral velocity u and the angular velocity of the record $n = 2\pi$ r/s by the equation $u = \pi n b$. Buchmann and

[1] The author built such a driver comprising 2 × 1 × 1/4-inch (51 × 25 × 6-mm) expander Rochelle salt crystals in the late 30s. Its amplitude of motion, however, was insufficient to adequately simulate disc performance.

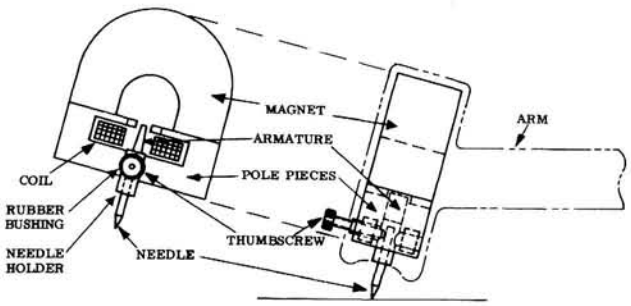


Fig. 1. Typical magnetic pickup (circa 1930).

Meyer thought that it was sufficient for the width b to be small compared with the distance D between the eye of the observer and the point at which b is measured. This, however, turned out not to be the case [9]; a more accurate expression is

$$u = \pi n b_o (1 - kr/D), \quad \text{for the outer pattern} \tag{1}$$

or

$$u = \pi n b_i (1 + kr/D), \quad \text{for the inner pattern,} \tag{2}$$

where b_o is the width of the outer pattern (the one farthest away from the source of light), b_i is the width of the inner pattern (the one nearest to the source of light), r is the radial distance from the record center to the point at which b is measured, and $k = 1/(1 + \cos \beta)$ where β is the angle of reflection of light from the record. For the common case where β approaches 90°, $k = 1$.

For the monophonic case, the maximum lateral modulation velocity is given simply by the equation:

$$u = 2\pi n \, (b_o b_i)/(b_o + b_i). \tag{3}$$

With continuing progress of the recording arts, it became necessary to use light patterns to measure modulation levels at the upper audio frequencies. Thus, another problem was noted: light reflections from the short wavelengths give rise to diffraction and interference patterns introducing an uncertainty in the measurements. By utilizing the mathematical relationships governing the formulation of diffraction and interference it was possible to increase the accuracy of calibrations and to extend the frequency of measurements to the upper audio frequencies [10].

Indirect techniques for record calibration also were developed. Among the most successful is the variable turntable method, where, by using single-frequency cuts, and by choosing properly various modulation wavelengths and rotational rates, response calibration of the record over the full range of frequencies can be obtained [11], [12].

Once a test record has been calibrated, the pickups can be measured thereon simply by playing the appropriate frequency bands and noting the output voltage, at the same time observing the waveform on the oscilloscope for signs of mistracking or distortion. For many years this work was performed by a laborious point-by-point measurement until the advent of a glide-tone test record synchronized to a conventional curve tracer [13].

STYLUS/GROOVE INTERACTIONS

The pickup stylus which has been identified as the element which transmits groove modulations to the transducer plays a critical role in the design of phonograph pickups. The groove is a V-shaped trough (Fig. 2) with a rounded bottom and with walls generally at a 90° included angle. In the earlier 78-r/min records, the groove had an average width of 0.006 inches (0.015 cm) with a bottom radius of 0.0025 inches (0.0065 cm) while the present-day 33⅓-r/min LP groove (Microgroove) has an average width of 2.2 to 3.2 mil (0.005 to 0.008 cm) and a bottom radius of 0.00025 inches (0.00065 cm). It should be noted that, at least in theory, the stylus is supported by the sidewalls and does not touch bottom. Therefore, the stylus bearing force F_v results in two reaction forces 0.707 F_v at the sidewalls causing a slight groove-wall deformation, which will be discussed later.

Electrical pickups used with 78-r/min records during the 30s were equipped with the same type of stylus, or needle, as used with the earlier acoustical sound boxes. A large number of needle designs were produced employing an unbelievable variety of shapes and materials, ranging from cactus to tungsten carbide. The common needle (Fig. 3**a**) was made of steel. It was ⅝ to ¾ inches (15 to 19 mm) long and $^1/_{32}$ to $^1/_{16}$ inches (0.79 to 1.56 mm) in diameter, and had a cylindrical-conical shape terminating in a polished spherical tip (obtained by tumbling a large number of sharply ground needles in a small barrel together with fine abrasive powder until the desired radius was developed). Conventionally, the tip radius was 0.003 inches (0.0075 cm). The package in which steel needles were sold usually carried an admonition about changing the needle after each play. Little attention was paid to this notice because of the inconvenience and the cost it involved. Furthermore, the quality of sound reproduction did not seem to be much affected by a few repeated plays. Eventually, however, the needle developed large enough "flats" at the points of contact with the groove wall to produce distortion [14].

The necessity of frequently changing the steel styli resulted in a significant preoccupation during the 30s with the problem of producing a permanent stylus. One ingeni-

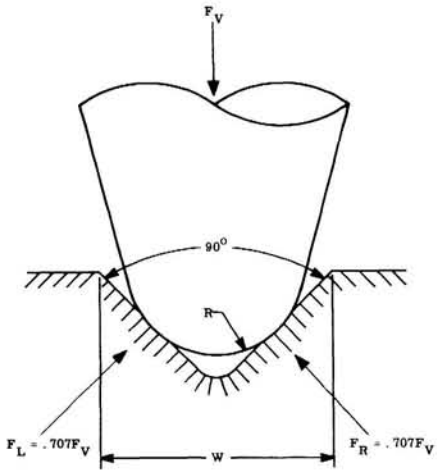


Fig. 2. Typical cross section of record groove with stylus supported by groove walls.

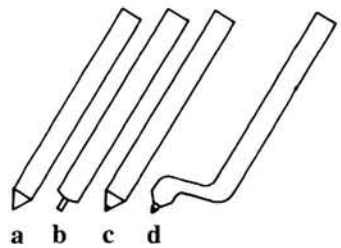


Fig. 3. A few varieties of phonograph needles used in the 1930s: **a**. common steel needle; **b**. needle with tungsten wire tip; **c**. needle with osmium tip; **d**. anti-chatter needle with sapphire tip.

ous approach which can be traced to the early part of the century was a stylus with a short length of 0.004-inch (0.01-cm) diameter tungsten wire at the end of its shank (Fig. 3**b**). The intent was to provide a constant cross section to the groove as the wire wore out. But, instead, the wire broke easily and this product never became widely used. As a next effort, a number of manufacturers began to produce styli tipped with sintered rare earth alloys, principally compounds of osmium (Fig. 3**c**). These could be used a few dozen times before needing replacement. Then, the popularization of synthetic sapphire during the late 30s gave to the industry a plentiful supply of uniform gem rods resulting in a wide availability of sapphire stylus tips which increased the lifespan of the needle by another order of magnitude [15]. Unfortunately, the early gem-tipped styli installed in the relatively heavy pickups caused accelerated record wear despite attempts to provide shock absorbing compliance in the stylus shanks, as shown in Fig. 3**d**. Also, the interaction between the stylus and the disc produced considerable chatter. A composite stylus developed by the author, which combined lateral stiffness with vertical compliance to protect the gem against breakage and to diminish chatter, is shown in Fig. 4 [16]. Styli with shock-absorbing nylon "knees" also were popularly used [17].

The development of pickups requiring stylus bearing weights of 20 grams or less during the early 40s and the further lowering of this number to 6 grams for use with fine-grooved LP and 45-r/min records in 1948 [18], greatly helped to increase the demand for sapphire-tipped styli. Diamond-tipped styli also were popularly marketed for use in pickups intended for the specialist and high-fidelity trade. Today diamond-tipped styli are *de rigueur* except in the lowest cost disc reproducers.

TRACING FUNCTION

Until the mid-30s, little serious thought appears to have been given to the microcosm which exists between the stylus tip and the groove wall. Pickup designers appeared to be happy if the stylus merely stayed in the groove. Then, in 1936, during the tri-centenary festivals at Harvard University, a young professor of physics, Frederick V. (Ted) Hunt, was given the task of making phonograph recordings of the entire proceedings. Those of us today who, on a moment's notice, think nothing of taping any and all sounds, have no idea of the difficulties which Hunt's task entailed. He wrote of interacting with Assistant Professor F. C. Packard of the Public Speaking Department, who he said, " has been making use of the art of instantaneous voice recording in connection with the training of students' voices" and described the available equipment which included a disc recorder capable of embossing sound on "soft aluminum discs, an inexpensive material, but one which leaves much to be desired from the standpoint of surface noise and frequency fidelity." Hunt also wrote of "a relatively new type of record material, the coated disc," continuing, "these discs are prepared by applying to thin aluminum discs a very thin coating of cellulose lacquer (chiefly cellulose nitrate) to which one or more plasticizers have been added. The results obtainable with these coated discs were so satisfactory that plans were immediately made to record virtually the entire tri-centenary proceedings on this new material."[19].

This experience, interacting with Hunt's fertile mind, started a most fruitful chain of advances in the art of disc recording. Hunt at once recognized that the soft lacquer disc could not be played without damage with the then available heavy pickups. With the help of a graduate student, Jack Pierce, he proceeded to design a pickup, the HP6A (Fig. 5), capable of tracking at 5-gram stylus bearing weight, a tenfold reduction from the contemporary practice of that time. The HP6A comprised a single-turn loop of thin phosphor bronze ribbon lying within a concentrated transverse magnetic field provided by two magnetic rods at either side of the loop. To the outer, closed, end of the loop is attached the base of a conical shell of aluminum whose apex bears a sapphire stylus. A couple of 90° twists in the loop provided a structure whose tip is quite rigid for lateral displacements in the plane of the loop, but which is flexible in torsion and reasonably

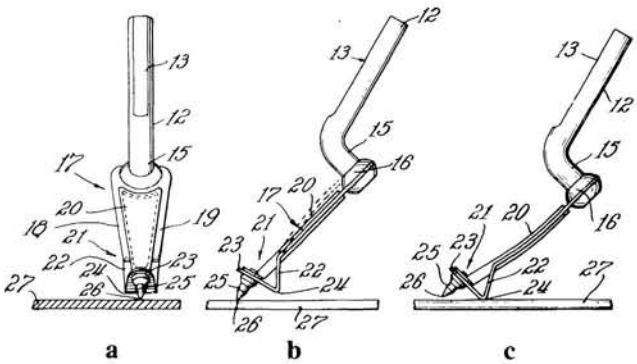


Fig. 4. A front view **a**. and side view **b**. of a jewel-tipped phonograph needle with damped shock absorbing spring to protect the stylus and to diminish chatter, and method of protecting stylus against excessive loads **c**. (*From U.S. Patent 2,455,913*)

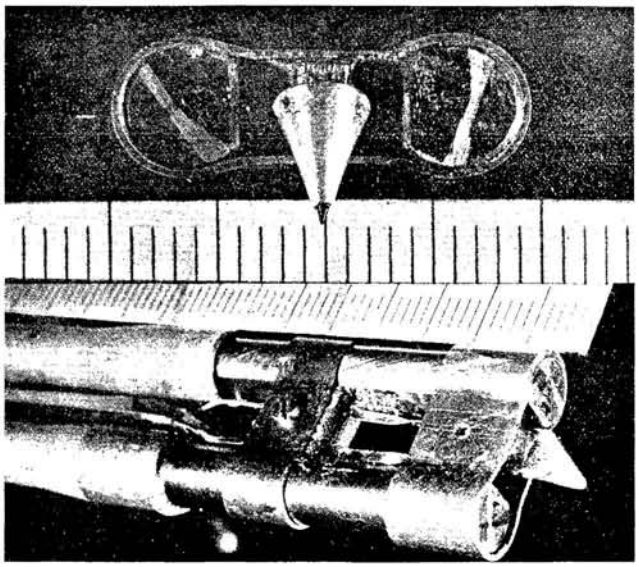


Fig. 5. Head-on and quartering views of the HP6A reproducer. (The small-scale divisions are millimeters in each case.) *(Reprinted from Electronics, March 1938; Copyright McGraw-Hill, Inc., 1938. All rights reserved.)*

flexible for vertical displacements. This pickup was used by Ted, not only to play the tri-centenary records, but also to provide experimental verification to the theories which he and his students were to evolve [20].

One of these theories, developed in Jack Pierce's doctoral thesis, dealt with the problem of tracing the groove modulation. Tracing is simply explained by reference to Fig. 6. While scanning the modulation shown by the solid sinusoid, the curve actually traversed by the center of a spherical tip is the distorted curve shown in broken line. Hunt called this curve a "poid." (It is said that this is an abbreviation of its initial name "Pierce-oid".) The poid may be shown to contain even and odd harmonic components [21]. Because with lateral monophonic recording the modulations associated with the two groove walls are complementary, the even harmonics are cancelled, leaving untouched the third and higher odd mode harmonics.This at once put to rest the arguments going on for the previous half-century about the relative merits of the lateral versus the vertical modulation. The even-order harmonics, however, add up in the vertical plane, resulting in a vertical modulation component in monophonic recording which corresponds to the so-called "pinch" effect. This had led Hunt and Pierce to the then startling conclusion that an ideal reproducer for laterally-cut records must embody sufficient vertical flexibility to enable the stylus to execute the vertical motion faithfully, and also that the reproducer had to be supported by the side walls of the groove. The above two precepts have remained the guideposts of all high-fidelity pickup designs to this very day.

It should be noted that in the same article, Pierce and Hunt project a 12-inch (0.3-m) diameter, 33-r/min record that would provide a playing time of 17 to 19 minutes using a ¾-mil (0.0019 cm) tip-radius stylus. These figures, calculated in 1938, came very close to the parameters employed in the modern LP records introduced a decade later [18].

In a further study, W. D. Lewis and Hunt refined the Pierce-Hunt theory by computing the harmonic and intermodulation distortions caused by tracing the groove modulation with a stylus of an arbitrary shape [22]. For a spherical stylus and single side-wall modulation (i.e. modulation normal to the groove wall, which is most significant for the modern stereo disc) the second and third harmonic distortion component terms D_2 and D_3, based on a velocity responsive pickup turn out to be

$$D_2 = (\tfrac{1}{2})kakR \tag{4}$$

$$D_3 = (\tfrac{3}{8})[kakR]^2 \tag{5}$$

where k is $2\pi/\lambda$, λ is the wavelength of the recorded modulation, a the displacement amplitude of the recorded modulation and R the stylus radius.

The previous theories were based on the assumption that the groove wall is rigid. In reality, however, the groove wall is deformable, this resulting in considerable kinematic and kinetic complications which play a key role in the design of phonograph pickups. The way this problem has been sorted out is as follows: the displacement of a sphere of radius R and "infinite" hardness penetrating an elastic plane of Young's modulus E as a result of a force F is given by the Hertz equation

$$\delta = 0.825\left[\frac{F^2}{E_0^2 R}\right]^{1/3} \tag{6}$$

and the resulting mechanical compliance is

$$C = \mathrm{d}\delta/\mathrm{d}F = 0.550[E_0^2 FR]^{-1/3} \tag{7}$$

where $E_0 = E/(1 - \nu^2)$ and ν is Poisson's ratio, usually 1/3.

As applied to a spherical stylus resting in the groove, the resulting stylus-groove compliance C_G is somewhat greater than C because the normal groove-wall force is only $0.707\,F_v$, and it is given by the equation

$$C_G = \Delta z/\Delta F = 0.617[E_0^2 F_v R]^{-1/3} \tag{8}$$

where z is the displacement caused by application of a force F and F_v is the vertical stylus bearing force. It can be shown that C_G is uniform in all directions in a plane perpendicular to the groove.

Because of the stylus-groove compliance, the actual stylus motion differs from the geometrically predicted motion, especially at higher frequencies where stylus-groove resonances are apt to occur. A proximate study of these differences was conducted in the early 40s by Kornei [23], but a more definitive investigation was performed by Miller at Harvard in 1950 [24]. Miller's thesis makes two points:

1) There is a mechanical resonance between the stylus mass and the groove compliance at a resonance frequency f_r

$$f_r = 0.203(E_0^2 F_v R)^{1/6}/m^{1/2} \tag{9}$$

where m is the effective stylus mass, and

2) there exists a cutoff frequency f_c at which the pickup output rapidly falls off, regardless of the modulation amplitude,

$$f_c = 0.482\, v(F_v R/E_0)^{-1/3} \tag{10}$$

where v is the linear groove speed.

James V. White, the last of Ted's doctoral students, formulated a new nonlinear theory that accounted for geometrical and deformational nonlinerarities [25], [26].

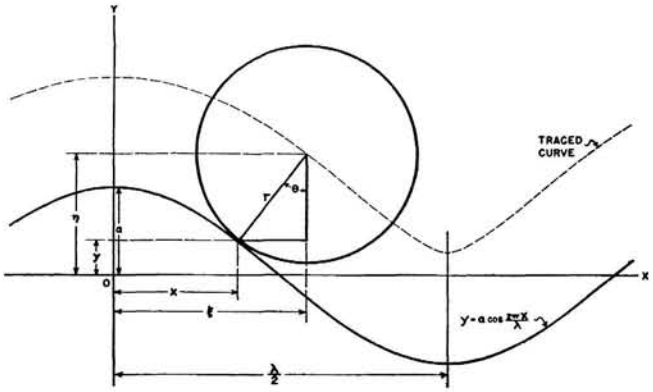


Fig. 6. Stylus tip (represented by a sphere) scanning the groove; coordinates and nomenclature for the harmonic analysis of the curve (poid) traced by the center of the sphere sliding or rolling along a cosine curve are shown.

He avoided the use of Hertz's theory by using his measured groove impedance data [27] to model the dynamics of the groove deformation. The geometrical nonlinearities and scanning effects were modeled so that the theory would be consistent with measured frequency responses at both long and short wavelengths [44], [45]. Predictions of nonlinear distortion based on his theory compared favorably with experimental results reported by Woodward and Werner [46] on difference-tone distortion.

When resonances between the stylus and the groove compliance occur, they often are of significant magnitude. One approach toward damping the stylus groove resonance without increasing the stylus-point impedance was proposed by this writer [28].

On the other hand, the stylus-groove resonance frequency in pickups intended for reproduction of carrier-type quadraphonic records is often placed at the carrier frequency (i.e. 30 kHz) to facilitate the detection of the carrier.

Before closing the discussion on modulation tracing, which in a large measure reflects the contribution of Ted Hunt and his students, two phases of unfinished business he began deserve mention. Hunt bore a conviction that below a critical interface pressure between the stylus and the record materials, wear would totally cease. Furthermore, he opined that the stylus-groove resonance frequency might become shock-excited by random groove surface roughness, causing an increase in surface noise [29]. As an outgrowth of this thesis, he produced a rationale for proportioning pickup characteristics in an optimal manner [30]. Only time will tell if the prophesies suggested by these writings—his last papers on phonograph technology before his death in 1972—will surface in the future advances of the phonograph arts.

It would be incomplete to end this section without making reference to the contributions of Corrington [31], Kantrowitz [32], Shiga [33], and Cooper [34] to the sum total of the phonograph reproduction theory.

PICKUP SPECIFICATIONS

One of the primary requirements of a phonograph pickup is to scan the groove continuously, i.e. its stylus must remain constantly in contact with the groove walls while the record is being played. A number of factors conspire to endanger this objective. The record may be sufficiently warped to cause the pickup to leave the surface of the record; or the arm pivots may exhibit excessive friction; or modulation may be sufficiently great to cause the stylus to lose contact with the groove walls or even to skip the groove. Setting aside the gross effects we consider the scanning force relationship resulting from groove modulation.

Pickup stylus tip impedance can be thought of as being composed of three parameters: stylus mechanical compliance C_s, mechanical resistance R_m, and mass M, all being referred to the stylus tip. Compliance comes into play principally at low frequencies, where modulation amplitude is large. An instantaneous modulation amplitude a deflecting a stylus having a compliance C_s produces a reaction force $F = a/C_s$. Assuming, for example, that lateral modulation produces a force F_H whose amplitude is equal to that of F_v, it is seen from the vector diagrams in Figs. 2 and 7 that a resultant unbalanced force $-F_H$ has two components, one of which tends to reduce F_L to zero causing the stylus to move away (in this example) from the left groove wall, which will cause the stylus to skip to the next groove or to remain rattling in the groove.[2] Since lateral peak amplitudes of 0.005 cm often occur with modern recordings, and a one-gram stylus bearing load target (equivalent to $F_v = 980$ dyn) is now considered a minimum acceptable criterion, the lateral stylus compliance should be no less than 0.005/980 equals approximately 5×10^{-6} cm/dyn. Applying to this number a safety factor of 3 to 1 (which stems from Ted Hunt's analysis [30]) suggests that an appropriate value for the lateral pickup compliance is 15×10^{-6} cm/dyn, a value often used with modern pickups.

Mechanical resistance comes into play at mid-frequencies where velocity tends to predominate. Velocities as high as 30 cm/s are not infrequently encountered, suggesting that the stylus tip mechanical resistance should not exceed 980/30 = 33 cgs mechanical ohms, or again, with the safety factor of 3 to 1, a figure closer to 10 cgs mechanical ohms is considered acceptable. (This figure is some 2.5 orders of magnitude smaller than that set as a target by Maxfield and Harrison in 1925!)

And, lastly, to provide for accelerations of 1000 g units and more found in modern recordings, the effective stylus mass should not exceed 1 milligram; preferably, it should be considerably smaller. Assuming $R = 0.7$ mil (1.8×10^{-3} cm), $E_0 = 3.7 \times 10^{10}$, $m = 0.001$ gram, and $F_v =$ 1 gram (980 dyn) stylus/groove resonance $f_r = 23.6$ kHz is obtained which is typical of high-fidelity pickups. Stylus/groove resonance can be measured readily with a sweep record such as the STR-120 which provides a sweep frequency range of 500 Hz to 50 kHz.

It should be noted that even if an LP record is recorded to its innermost groove diameter, 4.75 inches (12 cm), which corresponds to a linear velocity v at 33⅓ r/min of 21 cm/s, and substituting this v (as well as the aforementioned values of F_v, R, and E_0) into Eq. (10) results in a

[2] It should be added that the skipping and, in general, low-frequency tracking problem is a complex matter which often involves low-frequency arm resonance and damping, which generally cannot be predicted from compliance measurements alone.

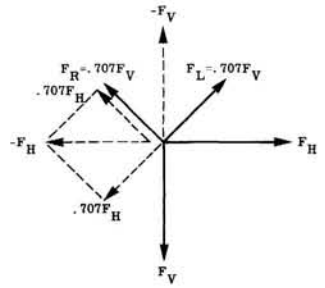


Fig. 7. Vector diagram illustrating a condition which causes the stylus to lose contact with one groove wall, producing distortion or rattle.

cutoff frequency f_c of 28 kHz. Thus a modern phonograph pickup playing an LP record is potentially capable of full high-fidelity frequency range reproduction over all of its playing surface.

A measurement of the dynamical compliance and resistance of phonograph pickups can be performed conveniently using a simple apparatus in which a suspended mass is driven by an electromagnet connected to a variable frequency oscillator. The resonance frequency and resonant rise of the stylus-mass system can be related to the pickup parameters [36]. Compliance can also be measured by noting the resonant rise when playing a glide-tone record such as the STR-120 (which also provides a 10 to 500-Hz range) in an arm of known mass. The stylus-tip mass usually is calculated directly from the mechanical constants of the pickup, or estimated from experimental determinations of F_r, using Eq. (8).

A most important set of pickup parameters is that dealing with the pickup's ability to translate mechanical motions into electrical energy. Typically, it is desired that pickups employing piezoelectric transducers—which are displacement responsive—should have a uniform voltage sensitivity as a function of frequency (flat frequency response) on a displacement amplitude basis, while those employing electromagnetic (moving armature, moving magnet, or moving coil) transducers should have a flat frequency response on a velocity basis. Electrical compensation is added to take into account the frequency characteristics of the recording system, albeit in the lowest cost pickups, mechanical resonance sometimes is expected to furnish a part of the desired compensation. In modern practice, piezoelectric pickups are expected to have a sensitivity of the order of 0.5 to 1 volt, and electromagnetic pickups a sensitivity of 0.005 to 0.010 volts when reproducing a 1000-Hz lateral modulation of 5 cm/s.

A further specification for stereophonic pickup is channel separation or independence between the left and right channels, which, in modern pickups, is expected to exceed 20 dB over the full range of audio frequencies (with pickups for carrier-type quadraphonic records, good separation is required to 45 kHz). Response and separation are measured by using a suitable stereophonic test record [12].

STYLI FOR HIGH FIDELITY PICKUPS

The pickup tips used in early needles or styli almost always were spherical. Nevertheless, even the early experiments recognized the merits of aspherical styli tips. For a given profile normal to the groove, an aspherical tip is able to scan a narrower window along the modulation length than an equivalent spherical tip. As examples, in April 1907, F. Petmecky was granted U. S. Pat. No. 849,425 on a pyramidal stylus which scanned the groove with its opposite pair of sharp edges. In November of the same year, S. Levine received U. S. Pat No. 870,300 on a stylus having the shape of the quill of a pen. And in December 1913, J. W. Owen patented an elliptical stylus and used it to scan the groove with the stylus oriented either transversely or lengthwise (U.S. Pat. No. 1,080,924). No wonder more than one modern stylus tip designer was caused to cry out: "The ancients have stolen my invention"[7]. This, nevertheless, does not diminish the merit of the painstaking craftsmanship which provided the modern high-fidelity pickup with a variety of extraordinarily precise styli of diverse shapes intended for different needs.

The introduction of the LP record in 1948 with its lowered groove velocity caused the pickup designers at once to drop the stylus radius from 3 to 1 mil (75 to 25 μm). The advent of stereo in 1958 introduced a further complication: each groove wall modulation in effect is a hill-and-dale modulation without the benefit of the even-harmonic cancellation provided by the laterally modulated monophonic disc. In order to keep the tracing distortion of stereo records within reasonable bounds, the stereo stylus-tip radius was at once diminished to 0.7 mil (18 μm) as shown in Fig. 8**a**. Radii lower than 0.7 mil were also tried but they were found to run into the danger of touching the groove bottom with consequent mistracking.

In an attempt to further decrease the scanning window, a 0.4 × 0.7-mil (10 × 18-μm) elliptical, or biradial, stylus gained considerable popularity (Fig. 8**b**) retained to this day. For even more precise scanning, a nude diamond was developed, using a square-section diamond sliver capable of being oriented along favorable crystallographic axes and lapped to a 0.2 × 0.7-mil (5 × 18-μm) elliptical shape (Fig. 8**c**). Finally, to reach the ultrasonic modulations of carrier-type discs, a nude diamond with Shibata tip is used (Fig. 8**d**). The Shibata tip, like the older pyramidal tip, features a near-line contact with the groove wall, providing excellent resolution. On the other hand, both of these types must be carefully oriented with respect to all three axes (this is a problem with some record changers) and must be properly shaped along the groove profile to avoid touching bottom.

PIEZOELECTRIC PICKUPS

During the early 30s, the Great Depression, combined with the novelty of radio, had driven phonograph sales down to an all-time low. By the mid 30s, however, the country was recovering from the depression, radio's newness had begun to wear off, and music lovers everywhere were demanding greater freedom of choice for the music heard in their homes. The renaissance of the phonograph had begun.

Three innovations helped to satisfy this demand: 1) the progress made by popularly priced amplifiers and

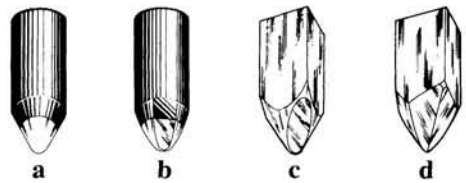


Fig. 8. Perspective view of modern styli. **a.** 0.7 mil conical bonded diamond; **b.** 0.4 × 0.7 mil elliptical bonded diamond; **c.** 0.2 × 0.7 mil elliptical square-shank nude diamond; **d.** Shibata square-shank nude diamond. *(Courtesy Audio-Technica)*

loudspeakers due to the development of radio; 2) the invention of the rubber-puck, rim-driven, mass-production turntable which, in an effective and inexpensive manner, provided speed stability by coupling the kinetic energy of an 1800-r/min motor into a relatively light turntable mass; and 3) the development of the Rochelle salt bimorph crystal transducer by Sawyer [37] which found ready use in low-cost pickups.

The Rochelle salt crystal is grown from a solution into a large, clear polyhedral body which is sawed into 1/32-inch, or thinner, slabs. The slabs, in turn, are sliced into approximately ¾ × ¼-inch (19 × 6-mm) elements assembled in pairs with suitable electrodes to take off the electric charge stemming from the application of bending or twisting stress. The crystal pickup is simple and inexpensive, is not subject to the influence of magnetic fields, provides a relatively wide-band frequency response, has a relatively high-output voltage, and offers an ideal impedance match to a vacuum tube amplifier. On the other hand, Rochelle salt has hygroscopic properties and has to be carefully moisture-sealed to ensure continuing operation, especially in humid climates—and it promptly loses its piezoelectric properties and dissolves in its water of crystallization above 120° F (49° C). Despite its environmental difficulties, the popularity of the Rochelle salt pickup reached far and wide, and it dominated the home phonograph market for the ensuing quarter of a century until the advent of the much sturdier piezoelectric ceramic transducer which, in its turn, was succeeded by the much superior modern variable reluctance and moving magnet pickups which are well matched to transistor amplifiers.

A representative crystal pickup of 1937 vintage is shown in Fig. 9. A twister Rochelle salt bimorph crystal is used, clamped in a phenolic case between two firm back-support pads. Its front end is driven through a soft rubber coupler surrounded by a biforcated drive unit. The elasticity of the coupler furnishes the compliance needed to allow the stylus to remain in the groove with a 2-oz (57-gram) stylus bearing force. The compliance of the rubber is some 25 times greater than the compliance of the crystal. With a typical 78-r/min record, this pickup produced an average output of 1 to 2 volts; the source impedance was equivalent to 500 to 800 pF, adequate for driving the first audio stage of a typical 1937 receiver.

The equivalent circuit in Fig. 9**c** suggests at once that this early pickup is quite inefficient: Most of the modulation velocity u finds its way as u_r into the rubber coupler, and only a small portion, u_c, enters the crystal, where it is instrumental in producing output voltage. This analysis leads at once to the idea of a much improved lever pickup.

THE LEVER PICKUP

Shown in Fig. 10**a** and 10**b** [38], the front-end mass is reduced as much as possible through the use of a drive-unit made of aluminum or magnesium rod which has a paddle drive member in place of the bifurcated end. The lever, made of a stamped and formed metal strip, produces a torque leverage of approximately 5:1, thus increasing the effective crystal compliance by a ratio of 25:1. The coupler pad between the paddle and the lever ends is sufficiently stiff to avoid significant compression loss.

In the equivalent circuit in Fig. 10**c**, the lever is depicted as an ideal transformer of 5:1 ratio which matches the mechanical impedance of the crystal to the groove. This lever-type pickup and its numerous subsequent variants was instrumental eventually in reducing the stylus bearing weights of the piezoelectric pickup by nearly an order of magnitude—down to 5 to 6 grams—without too great a reduction in sensitivity, just in time to make the crystal pickup usable with the LP record which was announced shortly after the development of the pickup.

A significantly improved material, barium titanate in tetragonal polycrystalline state, was developed by R. B. Gray [39], who applied for a patent on a pickup using this

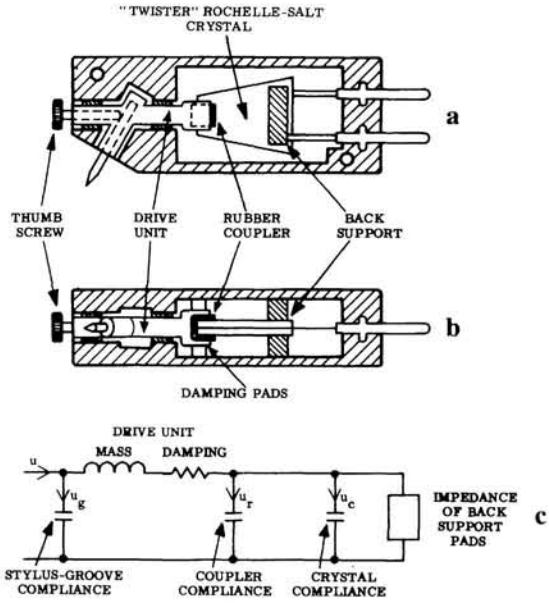


Fig. 9. Early Rochelle salt crystal pickup (circa 1937): **a.**, **b.**, cross-sectional views; **c.** equivalent circuit.

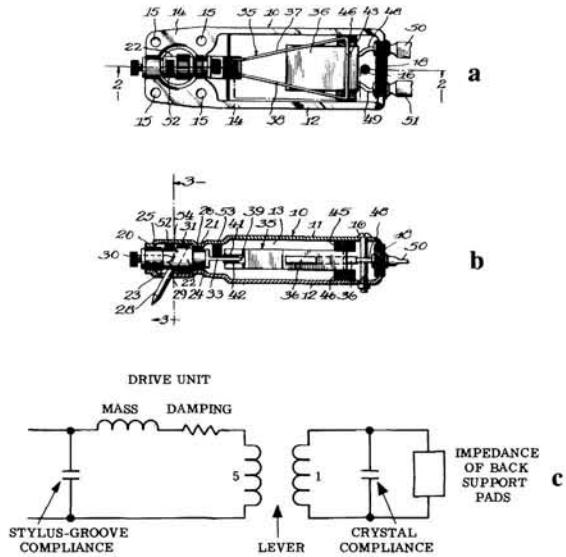


Fig. 10. Lever-type crystal pickup: **a.** plan view; **b.** vertical cross section (*From U.S. Patent 2,486,009*); **c.** equivalent circuit.

material in September 1946. The piezoelectric material is first made into a thick paste which is slip cast into a thin sheet perhaps 10 mil (250 μm) thick and fired at appropriate temperature to form a thin ceramic body. The ceramic strip is sliced into wafers approximately $\frac{1}{2} \times \frac{1}{16}$ inch (13 × 1.6 mm) assembled in pairs and provided with silver-paste electrodes. As a last step, the element is subjected to a high potential which produces in it permanent polarization. In May 1949, Koren [40] described a pickup using barium titanate; Gray's patent was issued in November of the same year. Barium titanate, however, was stiff, heavy, and had low specific capacitance and piezoelectric activity. The development of lead zirconium titanate by the U.S. National Bureau of Standards [41] gave to the industry a vastly improved ceramic material which rivaled the qualities of Rochelle salt and soon displaced it in all but the very cheapest pickups.

DUAL PURPOSE PICKUPS

Space does not permit us to depict all the ingenious crystal and ceramic structures developed by pickup designers for use in mass-production home phonographs; however, the solutions of the problem posed by the introduction of the LP record, which required a 1-mil (25-μm) radius stylus in addition to the 3-mil (75-μm) radius stylus used for 78-r/min records, deserves at least a brief mention. One approach attempted by some investigators (including, alas, this writer) was to try new stylus shapes; some with intermediate-size radii, others with wide-angle conical shapes bearing on the edges of the groove-land intersection [42], and still others with truncated conical shapes which spanned the bottom radii of the conventional coarse groove and LP groove [43]. These makeshift devices, mercifully, soon gave way to pickups with two styli, the proper one being brought into operation by some form of mechanical action. An example of this was a two-stylus turnover pickup developed by this writer [47] which in its time gained considerable popularity but was handicapped by requiring that the mass of both styli be moved at all times. Another was a two-stylus pickup in which the proper one was brought into position by means of a cam, a rather complex mechanism which, however, permitted the groove modulation to move only one stylus at a time, thus providing improved performance [49]. Still another was an ingenious pickup developed by Korn et al [48] which had a single dual-stylus needle, the proper one being brought into position by turning the stylus (installed in an L-shaped handle) 180° (which, however, still bore the mass of two styli).

STEREO PIEZOELECTRIC PICKUPS

A new set of problems arose with the commercial introduction of the stereo disc in 1958. Two piezoelectric elements were required and, again, ingenuity was needed to bring them into operation with maximum effectiveness. Two pickups soon became available which deserve mention: A crankshaft-type pickup invented by Bachman in 1957 [50] is depicted in Fig. 11. Two ceramic elements are mounted in a vertical plane, as shown in Fig. 11**a** driven, as illustrated in plan view in Fig. 11**b** by a special stylus holder supported on a three-point orthogonal-suspension. This simple and highly leveraged mechanical structure is efficient and has good frequency response. Another pickup developed by this author and his collaborators, A. L. DiMattia, E. Kaulins, and G. Sioles, has an interesting antecedent. In 1955, we noted that the pickup stylus bearing forces on the average had been dropping over some four previous decades, roughly according to a straight line in semilogarithmic coordinates (Fig. 12) and by simple extrapolation, we conjectured that the two-gram area would be reached by 1956 [51]. As observed by D. Gabor [52], one cannot foretell the future but he can invent it and, indeed, predictions often tend to act as a spur to the workers in the field. By 1962, magnetic pickups operating in the 1- to 2-gram area were already available, but most home phonographs still worked with 6-gram piezoelectric pickups, which, to us, was an untenable situation. The time for a low-cost 2-gram cartridge was clearly at hand.

The 2-gram pickup was first described at the 14th Convention of the Audio Engineering Society on October 16, 1962 [53]. It is shown in Fig, 13. Two lead zirconate

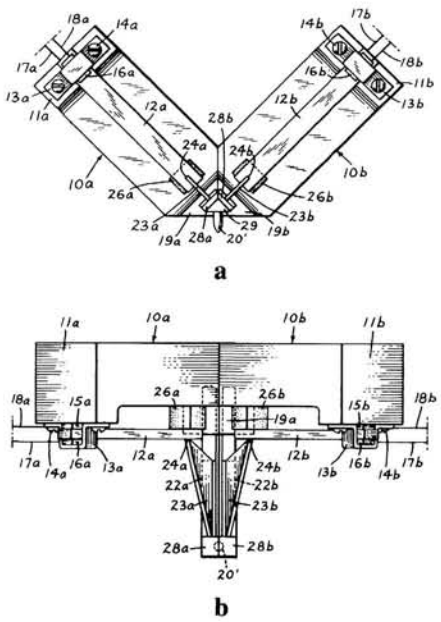


Fig. 11. Crank-type pickup: **a**. elevation; **b**. plan view. *(From U.S. Patent 3,055,989)*

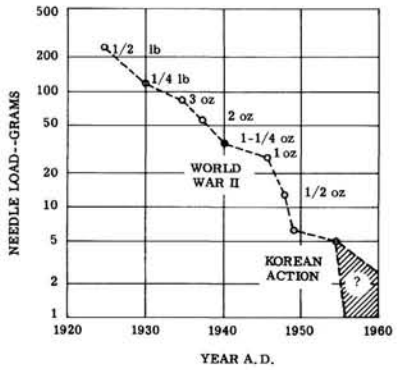


Fig. 12. Progression of needle loads with time.

titanate ceramic elements are clamped in quadrature for translation of the signals from the corresponding stereo record grooves as shown in Fig. 13**a**. The ends of the elements carry an elastomer coupler as shown in Fig. 13**b**, which is driven by a light stylus whose fulcrum is located a short distance behind the coupler, thus providing a lever ratio of approximately 5 to 1. Two styli are used, one for 78-r/min and another for 33⅓- and 45-r/min records. The fulcri are located in a box-like holder shown in Fig. 13**c** from whence they are allowed to pivot rather freely (to avoid loss). The whole assembly in cross section is shown in 13**d**. The stylus change is accomplished by depressing the knob, turning it 180° to permit the desired stylus to fall into operating position, and allowing the knob to snap back into position.

The mechanical parameters of the pickup, referred to the stylus tip, are $C_s = 6 \times 10^{-6}$ cm/dyn; and the effective mass at the stylus tip is 1.5 mgs, adequate for 2-gram tracking. The output voltage is 0.35 volts at 1 kHz for an rms velocity per channel of 3.54 cm/s, and the source impedance is equivalent to 400 pF per channel capacitor.

The arm in which this pickup operates embodies another interesting design innovation, shown in schematic cross section in Fig. 14. Intended for use in a record changer, the automatic lift mechanism dictates that the horizontal pivot be placed behind the vertical pivot so that a rod passing through the vertical pivot can lift the arm at the end of play. The mass of the counterweight and arm acting on the back pivot gives rise to a torque around the vertical pivot increasing its frictional force beyond that which is acceptable for 2-gram tracking. By using a combination of counterweight and arm spring, the balance of torques is achieved so that the vertical moment around the horizontal pivot is reduced to zero, allowing the arm to track the record with perfect freedom. The pickup cartridge, in turn, is floated in the arm in such a manner that a vertical force inadvertently applied allows the cartridge to recede within the arm, preventing damage to the stylus and record.

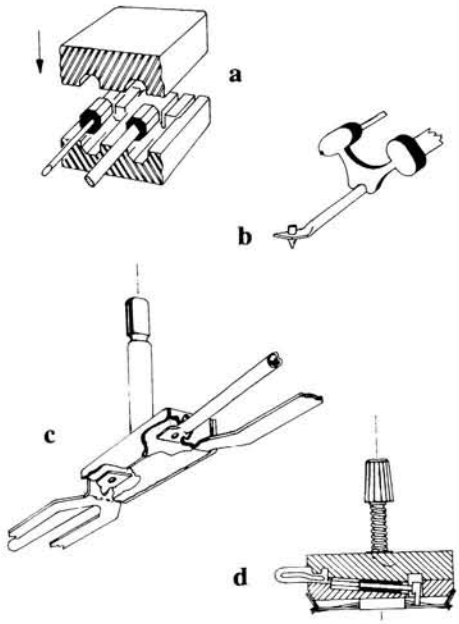


Fig. 13. Components and cross-sectional view of 2-gram stereo ceramic pickup cartridge: **a**. ceramic element holder; **b**. elastomer stylus coupler; **c**. box-like stylus holder; **d**. cross-sectional view of the pickup.

Before leaving piezoelectric pickups, at least a mention should be made of a class of single-element stereo-ceramic transducers in which the polycrystalline piezoelectric material in its unfired state is extruded in the form of a tube, approximately $^1/_{16}$ inches (0.16 cm) in diameter and which, after firing, is provided with four striped electrodes in an orthogonal arrangement, suitably polarized by application of a high potential to the electrodes, and then cut into rods of the desired length—usually ½ to ¾ inches (1.3 to 1.9 cm). Equipped with a stylus, this Multimorph transducer is capable of producing two output signals responsive to stereo groove modulations. Because the sensitivity and the channel separation of this transducer is difficult to control and its mass tends to be on the high side, its use has been limited to the lower cost pickups.

MAGNETIC PICKUPS

Despite its apparent simplicity, the piezoelectric lever pickup is a relatively complex device. Consisting of a stylus which also is a lever, a coupler, one or two transducer elements, damping pads, clamping pads, and, often, a measured amount of damping grease, all of which interact and influence its performance, this pickup can hardly be expected to provide the truly flat response demanded by high-fidelity enthusiasts. On the other hand, it is difficult to imagine a transducer which is simpler than a magnetic pickup. The armature is pivoted at, or near, one end and carries a stylus at the other end. Thus, the possibility of spurious resonances or of things going out of adjustment is minimized and truly high-fidelity performance becomes possible.

During the years following the development of the Hunt-Pierce HP 6A pickup—which no doubt inspired pickup designers to give a second look to the electromagnetic translation principle—a number of magnetic pickups were devised and described. The first one to become widely used and highly regarded was the variable reluctance pickup by W. S. Bachman [54]. Depicted in Fig. 15**a** in vertical cross section and Fig. 15**b** in plan view, this pickup consists of a case carrying two coils in a hum-bucking arrangement, wound around magnetic pole

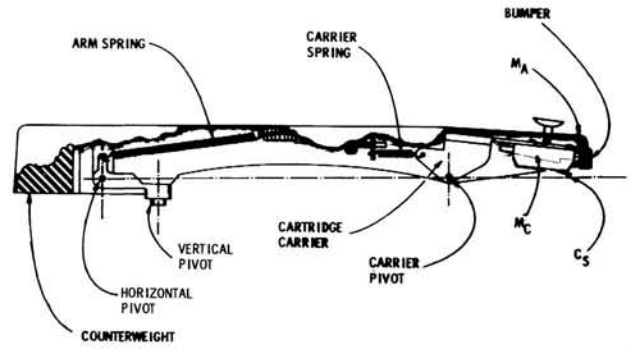


Fig. 14. Schematic representation of the tone arm design.

pieces which protrude downwardly of the case, and an armature/stylus member made of a strip of soft magnetic material which, at one end, is fastened to a post which also is the polarizing magnet, and at the other, carries a jewel tip. The armature has a twist near its base which allows it to move both in the horizontal and vertical modes, and it is centrally damped with a small piece of cellulose nitrate plastic (Viscaloid). An important feature of this design is that in the record playing mode, the tip end of the stylus is constrained to move exactly in response to the groove modulation, resulting in faithful reproduction. This pickup operated at 20 grams stylus bearing weight prior to the introduction of the microgroove record, whereupon it was lightened to approximately 6 grams. Its output was 10 mV for a modulation velocity of 5 cm.

Another magnetic pickup which gained significant popularity after World War II was designed and produced by N. Pickering [55]. It had an armature/stylus member oscillating within a single coil inside a magnetic structure. The structure provided a shielding effect, which was needed since the coil did not have a hum-bucking feature.

MOVING MAGNET PICKUP

Hum is the great enemy of magnetic pickups, especially those used with high-fidelity reproduction equipment which has good loudspeaker response at hum frequencies. Magnetic armatures extending outside the pickup tend to become hum antennas, foiling the coil shields and hum-bucking arrangements. Furthermore, the relatively large magnetic structure with its ample cross section of iron needed to carry the flux from a polarizing magnet adds mass to the pickup, which tends to become bulky and heavy.

By devising a moving-magnet pickup, in which the traditional roles of armature and magnet were reversed, it became possible to lower the 6-gram stylus bearing force (popularly used in the mid 50s) by almost an order of magnitude [56]. As we see in Fig. 16, the moving magnet pickup comprises pole pieces **8** and **8a** which carry two coils in a hum-bucking arrangement. The magnet **5** which extends perpendicularly to the paper, is polarized transversely (i.e., in a direction parallel with the coils) and vibrated around its axis perpendicularly to the paper in response to the oscillation of an extremely small and light crankshaft **6**, equipped at its end with a stylus **7**. The crankshaft is offset with respect to the major axis of the pickup to provide a most favorable tracking angle relationship, as will be described in a subsequent section. It will be noticed that the magnetic structure has a discontinuity **10** at its back end, which is designed to provide equal reluctance to that contributed by the magnet **5** and the gaps **4** at its front end. The purpose of this precaution is to achieve good magnetic balance which helps hum-bucking for magnetic fields arriving from any direction.

The transducer element is encapsulated in a plastic case, shown in Fig. 17**a** and 17**b** in plan view and elevation, respectively. It is seen that the magnet pivots in an elastomeric bearing **15** which allows it to be easily inserted and withdrawn for the purpose of changing the stylus in case of damage or wear. The whole structure is potted in a plastic compound and provided with shielding members **31**, **32**, and **33** which further reduce the possibility of hum induction to negligible proportions.

The moving magnet pickup was the first in which one-gram stylus bearing forces were achieved in a practical, commercial device. But, it appeared in the marketplace in 1957, only one year prior to the introduction of the sterophonic disc record and, therefore, soon had to be redesigned for stereophonic performance. Nevertheless, its tracking capability had set a new standard which has not been exceeded to this very day.

THE MOVING MAGNET STEREO PICKUP

Credit for the development of the moving magnet stereo pickup belongs to this writer's former associates at Shure Brothers, Messrs. Gunter and Anderson, who brought to successful fruition an earlier collaborative effort in which we all participated [57], [58]. The basic structure for the stereophonic moving magnet pickup is shown in Fig. 18, and it will be noted that it is very similar in principle to the monophonic moving magnet pickup. Four magnetic pole pieces and a corresponding number of coils are provided in a cooperative hum-bucking, pair-wise relationship, the flat ends of the pole pieces forming a common gap. A magnet polarized lengthwise of the structure **17** is supported within a gap for angular vibration substantially about a point intermediate to the poles of the magnet. The vibrations of the magnet along the corresponding axis result in the generation of signals in the appropriate pair of

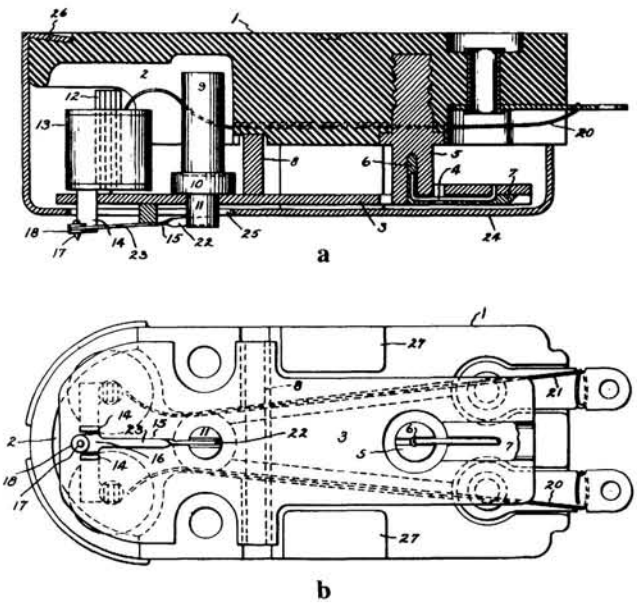


Fig. 15. Variable reluctance pickup: **a**. sectional side elevation; **b**. bottom plan view.

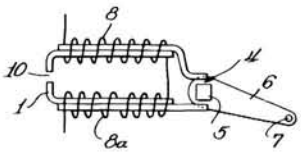


Fig. 16. Moving magnet monophonic pickup, schematic view. *(From U.S. Patent 3,055,988)*

coils. While the structure in Fig. 18 is of vertical-lateral variety, the patent [57] also covers the 45°-45° case. A late commercial embodiment of this pickup in much improved and refined form appears in Fig. 19. Laminated pole pieces are used to diminish eddy currents. A tubular stylus bar is coupled to the magnet with the aid of a dynamic control lever—a light and stiff metallic member which raises the resonance and contributes to the damping of the stylus/magnet assembly [70].

A variation of the moving magnet principle was developed by P. E. Pritchard [59], who uses a soft iron armature which is magnetized by induction from a permanent magnet, external of the stylus.

Another interesting moving magnet structure is that developed by Audio Technica whose dual magnet stylus/magnet assembly is shown in Fig. 20**a** and a cutaway view of the cartridge in Fig. 20**b**. The moving element has two magnets in a quadrature relationship. Thus, when the stylus oscillates in response to a left-channel modulation, the right-channel magnet rotates around its axis, adding a minimum amount of mass to the moving structure. Likewise, when the stylus oscillates in response to the right-channel modulation, the left magnet rotates around its axis, contributing a minimum mass to the moving structure. Through this arrangement the total effective mass of the moving structure referred to the stylus tip is diminished, this being extremely important for adequate ultrasonic performance required with carrier-type records.

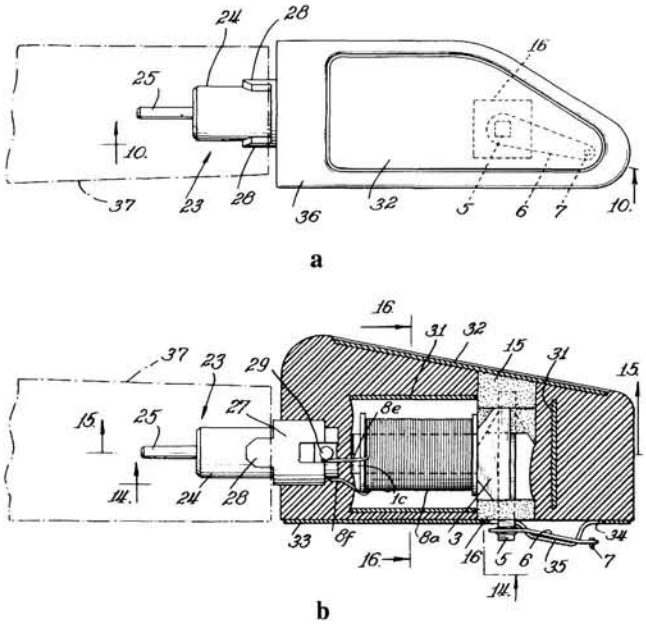


Fig. 17. Moving magnet monophonic pickup: **a**. plan view; **b**. elevation. *(From U.S. Patent 3,055,988)*

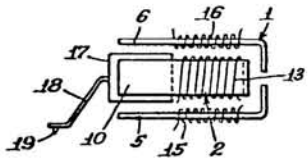


Fig. 18. Basic concept, moving magnet stereophonic pickup. *(From Canadian Patent 723,749)*

The availability of newer high-performance magnetic material has now made it also possible to design excellent small moving-armature magnetic pickups. Moving-coil pickups also have been devised and they are highly regarded for their excellent performance, but because of their low output voltage, they require the use of a transformer or a special low-noise preamplifier.

TRACKING ANGLES IN PHONOGRAPH REPRODUCTION

For as many years as this writer has been engaged professionally in the field of sound recording and reproduction—40 at this writing—there has been an uneasy awareness on the part of phonograph designers of the differential angle between the tangent to the groove at the point of contact with the stylus and the projection of the stylus on the record surface. During the 30s, the principal concern with this so-called tracking error (more accurately, *lateral* tracking error) was not the possible generation of distortion but assumed record wear. The wear theory stemmed from the belief that the flats developed in the steel styli after but a few plays of the record would be reground continuously with the changing tracking error, resulting in accelerated erosion of the groove walls. This led to the development by this writer of a pickup in which the tracking angle error, as previously defined, was diminished by repositioning the stylus by appropriate displacement and twisting. This development was described in February 1937 [60], and resulted in a commercially successful product. But, the aforementioned description received a prompt rebuttal from Benjamin Olney [61], who asserted that what mattered was not the "criterion . . . generally given, which stipulates that the projection of the needle upon the record surface shall be tangent to the groove," but, rather, the more appropriate criterion of the "projection upon the record surface of the axis about which the needle vibrates." He added, however, that based on experiments he performed there was no perceptible difference in the quality of sound or wear for records played with the conventional straight arms or those designed to diminish tracking errors. He calculated the distortion caused by tracking error and concluded that "ordinary amounts of tracking error are negligible in their practical effect."

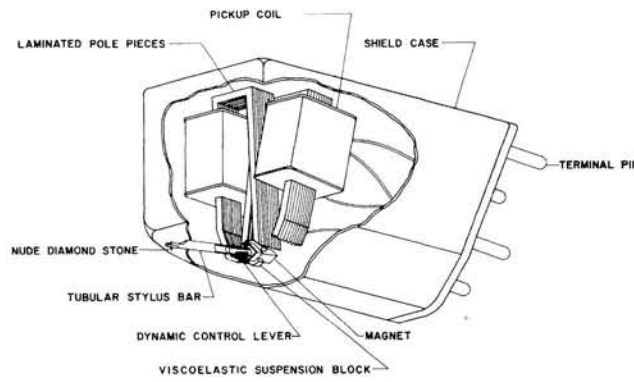


Fig. 19. Refined commercial version of moving magnet stereophonic pickup. *(Courtesy Shure Brothers, Inc.)*

It should be noted that Olney's proposed definition of tracking error is incomplete. It would fail, for example, if applied to the monophonic moving magnet pickup described in a previous section in which the axis about which the transducer vibrates is normal to the record, and tracking error is reduced by a predetermined torsional bias. Thus, in this author's view, a more general definition is: the angle between the tangent to the unmodulated groove at the point of contact with the stylus and the normal to the free stylus motion at the same point. This is the definition we use in the remainder of this paper.

We were not prepared to accept Olney's characterization of tracking error as inconsequential because it appeared obvious to us that the trends in high fidelity phonograph reproduction would necessitate more careful attention to fidelity than was afforded by the phonograph design practice used at the time.

This led us to a study of distortion and geometrical relationships between a pivoted arm and the rotating record which, because of preoccupation with the onset of World War II, was delayed until the closing years of the war [62]. Meanwhile, independently, H. G. Baerwald, using a different rationale which, nevertheless, is based on solid mathematical grounds, came to an essentially identical set of conclusions which he published in 1941 [63].

The geometrical construction in Fig. 21 illustrates the concepts we describe. The straight line from the vertical pivot arm to the stylus tip defines the arm length l. The minimum distance from the stylus-tip arc to the center is known as the overhang D. D is positive if the arc passes beyond the center of the record, thus $l - D = d$, the record center-to-pivot distance. The angle between l and the tangent to the unmodulated groove at the point of stylus-tip contact at radius r is known as the tracking angle ϕ. ϕ is readily calculated from the law of cosines.

$$r^2 + l^2 - 2rl\cos(90 - \phi) = d^2 \tag{11}$$

or

$$r^2 + l^2 - 2rl\sin\phi = (l - D)^2. \tag{11'}$$

Solving for ϕ,

$$\phi = \arcsin((r^2 + 2lD - D^2)/2rl). \tag{12}$$

Eq. (12) is precise in every respect but does not lend itself to simple manipulation. It turns out, however, to be quite satisfactory to assume that the sine of the angle is equal to the angle, and at the same time to neglect D^2 within the parentheses. With these assumptions, Eq. (12) takes on the following form:

$$\phi = ((r/2l) + (D/r)), \text{ radians} \tag{13}$$

a b

Fig. 20. **a**. Audio-Technica dual stylus magnet assembly and **b**. pickup cartridge, cutaway view. *(Courtesy Audio-Technica)*

or

$$\phi = 57.3((r/2l) + (D/r)), \text{ degrees.} \tag{13'}$$

It is shown in [62] (and portrayed in Fig. 21) that by choosing a suitable value of positive overhang D, for an arm of given length l, the tracking angle ϕ becomes relatively uniform throughout a range of groove radii r_1 and r_2. The line p is the tangent to the groove. By rotating or offsetting the cartridge (which is assumed normal to the free stylus trajectory) through a suitable angle β, the tracking error $\alpha = \phi - \beta$ is reduced to a relatively small value. Assuming that proportionately greater error is tolerable at longer wavelengths, what becomes important is not the absolute value of the angle α, but rather the quotient α/r. By analysis of Eq. (13) it has been shown [62] that the optimum arm geometry is obtained when the overhang D is

$$D = \frac{r_1^2}{l\left[1/4\left(1 + \frac{r_1}{r_2}\right)^2 + \frac{r_1}{r_2}\right]} \tag{14}$$

and the offset angle β is

$$\beta = \frac{57.3\, r_1\left(1 + \frac{r_1}{r_2}\right)}{l\left[1/4\left(1 + \frac{r_1}{r_2}\right)^2 + \frac{r_1}{r_2}\right]}, \text{ degrees} \tag{15}$$

where r_1 and r_2 are the minimum and the maximum groove radii, respectively.

With 33⅓-r/min records, the accepted limits for r_1 and r_2 are 2⅜ (60 mm) and 5¾ (147 mm) inches; however, 2¼-inch (57-mm) radii sometimes are approached.

In dealing with tracking angles there exists also the

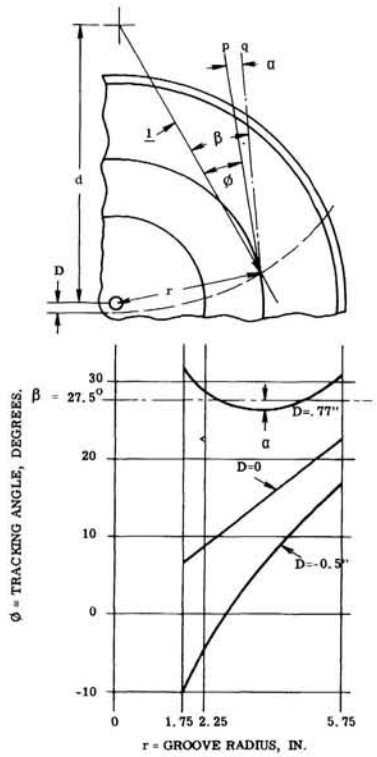


Fig. 21. Tracking angle relationships for 7½-inch arm.

converse problem—how best to place with respect to a turntable an existing arm having a predetermined length l and offset angle β? This problem also has been solved [64] as follows.

If an existing arm having length l and offset angle β is to be placed with respect to a record of groove radii r_1 and r_2 to produce the least distortion possible, the corresponding overhang D (or underhang $-D$) may be determined by finding β_o and β_i and then using Eq. (18) if $\beta = \beta \leqq \beta_i$, Eq. (19) if $\beta_i < \beta < \beta_o$ and Eq. (20) if $\beta \geqq \beta_o$.

$$\beta_o = \frac{r_1\left(1 + \frac{r_1}{r_2}\right)}{l\left[1/4\left(1 + \frac{r_1}{r_2}\right)^2 + \frac{r_1}{r_2}\right]} \tag{16}$$

$$\beta_i = \frac{1}{l\left[\left(\frac{1}{r_1} + \frac{1}{r_2}\right) - \frac{r_1}{2}\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right)\right]} \tag{17}$$

$$D = \frac{\beta\left(\frac{1}{r_1} + \frac{1}{r_2}\right) - \frac{1}{l}}{\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right)} \tag{18}$$

$$D = \frac{r_2}{2}\left(\frac{r_2}{l} - \beta\right) \times \left[\left(1 + \frac{\beta^2}{\left(\frac{r_2}{l} - \beta\right)^2}\right)^{1/2} - 1\right] \tag{19}$$

$$D = \frac{r_1}{2}\left(\beta - \frac{r_1}{l}\right) \times \left[\left(1 + \frac{\beta^2}{\left(\beta - \frac{r_1}{l}\right)^2}\right)^{1/2} + 1\right]. \tag{20}$$

ERRORLESS TRACKING

A number of arm arrangements have been devised to eliminate tracking error completely by equipping the pivoted arm with a cam or linkage arrangement which provides a more accurate tangential correction than is possible with a simple pivoted arm. Also, a number of mechanisms have been developed which transport the pickup cartridge tangentially of the groove along a radius, to simulate the action of a recording lathe. Most of these embody a servo mechanism to overcome friction. This attempt to achieve tracking perfection entails complications and expenses which, in the opinion of this writer, are out of proportion to the benefits obtained, except where the greatest of precision is desired.

A properly installed optimally-shaped pivoted arm maintains the horizontal tracking error within less than 1° per inch of radial distance from the record center. This is a lesser error than the user's ability to install a cartridge in a typical arm. Thus, greater accuracy in the transport usually is a non-essential feature.

VERTICAL TRACKING ANGLES

One of the most cogent arguments for untrammeled scientific research is that it produces, at times, wholly unexpected and beneficial results. Such was the nature of an investigation into the transient response and intermodulation between stereo pickups and records we conducted in 1962. This task necessitated recording a vertical square-wave modulation on a disc record, which on a velocity basis, comprises a series of triangular segments. Because of the cutter geometry, we were led to expect that the resulting wave would resemble a line of sarcophagi; but, instead, the wave was a series of isosceles triangles. This led us to conclude that there existed longitudinal elasticity in the cutter mechanism or in the body of the lacquer with the result that the recorded vertical modulation angle was significantly lower than the geometrical cutter angle, as had previously been assumed [65]. Also, an analysis of the pickups available at the time revealed that they had relatively high vertical tracking angles producing significant tracking errors, resulting in the generation of considerable harmonic and intermodulation distortion [66].

These experiments led to remedial action on the part of record and pickup manufacturers. In contemporary technology, records made with modern stereocutters maintain the vertical modulation angles at 15° to 18°. Recent measurements on current high-fidelity pickups suggest that the vertical tracking angles, in general, are maintained between 17° and 19°, with an occasional unit exhibiting an angle up to 25°. Record changers usually add up to 5° to 7° to the vertical tracking angle when the lowest records are played. Vertical tracking errors are difficult to detect by visual inspection and constant vigilance is needed to prevent them from creeping into the records and pickups.

The vertical tracking angle of a pickup can be measured dynamically with a vertically modulated test record containing predominantly a single tone, with second harmonic component added in graduated steps in successive bands. As the pickup plays these bands, it is found that lowest distortion occurs when the band corresponding with the vertical pickup tracking angle is played. One such record is the STR 160.

ARM DYNAMICS

The dynamic system consisting of a phonograph record and the associated pickup has a tendency to enter a resonant condition at low frequency. This resonance has caused a problem to pickup designers for years—especially since the introduction of stereophonic records and pickups in 1958.

In its simplest form, the pickup consists of an arm provided with a transducer at one end and pivots, and perhaps a counterweight, at the other. The transducer has a stylus, bearing against the sidewalls of the groove, which follows the groove modulation. The arm pivots are intended to accommodate the gross lateral motions of the groove as it spirals toward the center of the record, as well as to take up the vertical motions caused by warped records, etc.

The stylus and its mounting within the transducer form a spring, which customarily is measured at the stylus tip, defining a stylus compliance, C_s. The moment of inertia of the arm and its counterweight about the pivot divided by

the square of the pivot-stylus distance defines the arm mass, L_a. The arm mass and stylus compliance enter into a resonant condition commonly known as arm resonance, which in practice occurs below 100 Hz.

The dynamical constants of the pickup at low frequency are shown by an equivalent circuit in Fig. 22. Because symmetry is assumed, a single circuit will suffice for any mode of translation—lateral, vertical, or 45°-45°. The modulation velocity I_m is spent in deforming the stylus spring and in causing the motion of the arm mass. A bit of reflection will convince us that the transducer velocity I_t, which is related to the velocity of motion of the stylus tip relative to the arm mass, is precisely represented by the current through C_s. It will be noted that we neglected to include the groove-wall compliance and the stylus-tip mass, as they are not important at low frequency. A convenient way of measuring I_t in the equivalent circuit is by inserting a small resistor, R_s, in series with C_s and measuring the voltage drop, E_t.

Let us consider the case in which a velocity-responsive pickup is used to reproduce a constant-velocity test record. The transfer function is obtained by applying a constant current I_m to the circuit and plotting I_t (i.e., E_t) as a function of frequency. The form of the resultant is shown in the graph in Fig. 22. The low-frequency response is seen to extend from the lowest usable frequency f_l, below which the response drops rapidly to an intermediate frequency f_i where an asymptotic condition is reached. Between these points one finds the arm resonance f_a.

VISCOUS ARM DAMPING

Among the first to deal effectively with the problem of arm resonance was W. C. Bachman [67]. Bachman's arm damping was in the form of silicone fluid between two hemispherical surfaces. In schematic cross section this arm is shown in Fig. 23, together with its equivalent circuit. The circuit constants given are only examples, and may be scaled as needed. The damping appears as a series arm resistance R_a. The response-versus-frequency characteristic of the pickup is shown with R_a as a variable parameter. It is seen that even relatively modest values of damping cause a significant reduction in the resonant rise. To damp out the resonant rise so that it does not exceed, say, 2 dB, a 3000-ohm resistor is required. This proves to be no disadvantage as far as the high-frequency response is concerned, since the modulation velocity is effectively shunted into the transducer compliance C_s, which has an impedance diminishing with frequency. It will be noted from the graph that for large values of damping the response to extremely low frequencies is augmented. Normally, the record itself is quite free of spurious low-frequency lateral vibrations, but is prone to vertical vibrations caused by rumble and warp. Therefore, in practice, an intermediate amount of damping is used to avoid increasing the subaudible response.

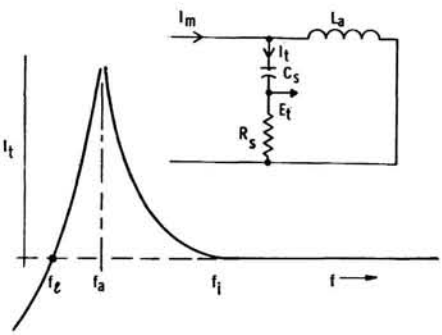


Fig. 22. Simplified equivalent circuit of a phonograph pickup at low frequency and the resulting frequency characteristic.

DYNAMIC DAMPING

With diminishing stylus forces it became desirable to obtain an effective arm damping without interposing any drag between the arm and the motorboard. A successful attempt in this direction for a monophonic pickup arm was described in 1957 [68]. The damping is composed of a leaf spring and elastomer compound interposed between the arm and its counterweight. While a significant decrease of the undamped resonant rise was obtained, the design was not optimized for stereo performance. An improved design will be projected below that also takes cognizance of stereophonic operation [69].

Referring to Fig. 24, we assume that the arm, including the cartridge and the counterweight, has an effective mass

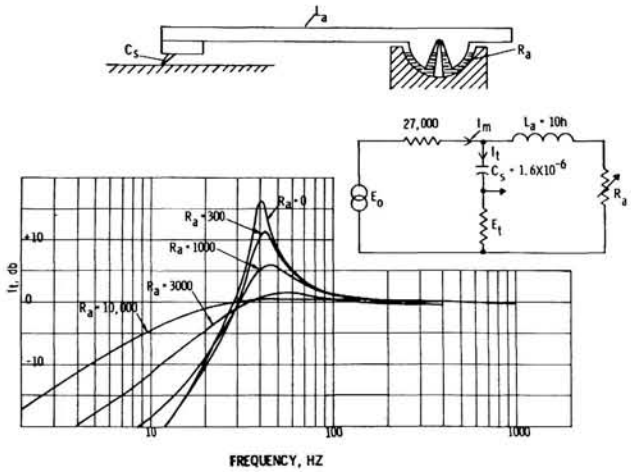
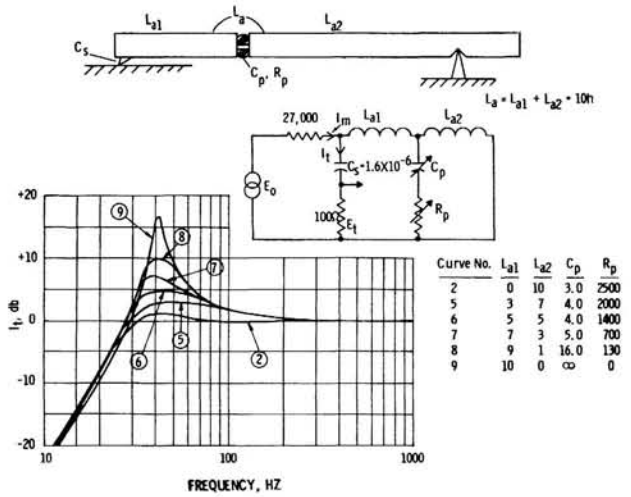


Fig. 23. Viscous arm damping.



Curve No.	L_{a1}	L_{a2}	C_p	R_p
2	0	10	3.0	2500
5	3	7	4.0	2000
6	5	5	4.0	1400
7	7	3	5.0	700
8	9	1	16.0	130
9	10	0	∞	0

Fig. 24. Dynamic arm damping.

L_a which is subdivided into two portions, namely L_{a1}, associated with the cartridge, and L_{a2} associated with the arm proper and the counterweight. The two portions are coupled through a damped spring, symmetrical in the axis of the arm, which defines a compliance C_p in all directions, and is provided with viscous damping defining a resistance R_p. The resistance may be composed of a viscous fluid or a visco-elastic semisolid. As an example, we assume a stylus compliance of 1.6×10^{-6} cm/dyn and an effective total arm mass of 10 grams. Next, we select various combinations of $L_{a1} + L_{a2} = 10$, e.g., 10 and 0; 9 and 1; etc., and for each combination, find the C_p and R_p which produce an optimum response.

The results are summarized by the graph in Fig. 24. We find that an optimum flat response is obtained when the mass associated with the cartridge, L_{a1}, approaches zero while that associated with the arm and counterweight, L_{a2}, is 100 percent which in this instance is equal to 10 grams. Optimum response is obtained when the arm coupling compliance C_p is 3.0×10^{-6} cm/dyn and R_p is 2500 ohms. With this choice of constants, the response is flat down to the cutoff frequency f_1, rapidly diminishing below. One would expect this condition to result in an optimum arm design for proper damping and rumble rejection. Again, these circuit constants are given only by the way of example, and they may be scaled as needed.

DYNAMIC DAMPING OF PIEZOELECTRIC PICKUPS

At this time, we can settle an old-standing debt to the piezoelectric pickups popularly used in home phonographs. It has been observed that some of these pickups, which track well at all frequencies, do not exhibit arm resonance even when not provided with special arm damping. This seeming anomaly is easy to explain in the light of the foregoing theory. Fig. 25 shows the front view and cross section along a line **A-A** of a piezoelectric pickup, together with its equivalent circuit. The stylus drives the transducer through a lever of ratio n. The transducer compliance proper is shown at C_s, which corresponds to the piezoelectric element compliance and includes the coupler and stylus lever compliance, and is shunted by the series combination of the compliance C_p and resistance R_p of the mounting pads and damping grease. It is interesting to note that when mounted solidly to a simple arm of mass L_m, this pickup provides the

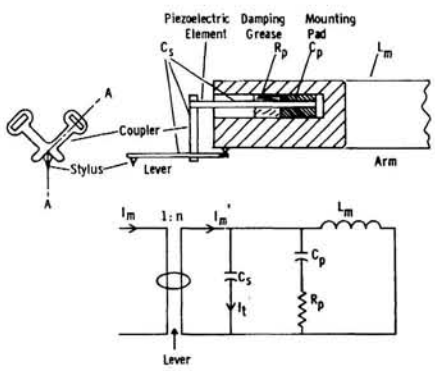


Fig. 25. Dynamic damping of piezoelectric pickups.

dynamic configuration needed for damping the structure in an ideal manner, and response corresponding to Curve 2 in Fig. 24 is attainable. In the piezoelectric pickup of Fig. 13, this result, to a great measure, has been achieved. It is hoped that with a better understanding of the theory of dynamic damping, pickup designers will be able to furnish improved pickups for home phonographs as well as for the component market.

BIAS COMPENSATOR

A stylus tracking the groove with a vertical force F_V is subjected to a fractional force μF_V (where μ is the coefficient of friction) which is counterbalanced by tension generated in the arm and a side thrust borne by the inner groove wall [62]. A simple force diagram readily proves that the magnitude of the side thrust is $\mu F \tan \phi$, where ϕ is the tracking angle.

Referring to Fig. 21, it is noted that when a pivoted arm is mounted with an optimum overhang D (Eq. 14) [in the example given for a 7½-inch (190-mm) arm, $D = 0.77$ inch (19.6 mm)], ϕ is very nearly constant between the playing radii for the 33⅓-r/min 12-inch (0.3-m) disc, and it approximately equals 27.5°. Since tan 27.5° = 0.52, the side thrust (or "bias," as it is frequently called) in this case is $0.52\mu F_V$. Let μ be 0.25, which is typical; thus, the bias force borne by the inner groove wall is approximately $0.13F_V$. The above calculation demonstrates that in many cases the bias force can be neglected without serious effect upon pickup performance. For optimum performance, the bias force should be compensated. Fortunately, because bias force in a properly shaped and mounted arm remains essentially uniform throughout the playing surface of the record, compensation can be done very simply with a constant tension spring or counterweight. An example of this is the SME arm shown in Fig. 26 in which the antiskating bias force is controlled by a fine thread tied to a notched rod protruding behind the pivot. The thread passes through a pulley and ends in a small weight which applies a constant antiskating force to the rod. The loop can be moved along the notches to adjust the bias force.

Some people attempt to set the antiskating mechanism by allowing the pickup to play a blank record (without grooves) and adjusting the antiskating device until the arm stops exhibiting centrifugal or centripetal tendency. This is an incorrect procedure. Referring to Fig. 2, it is noted that the vertical stylus bearing force is borne by two components, each of which is $0.707\ F_V$ with corresponding frictional forces at each groove wall. The sum total of these two forces is greater than that of the single F_V acting on a blank record. A better procedure, therefore, is to follow the manufacturer's instructions for adjusting the antiskating compensator.

EQUALIZATION CIRCUITS

A survey of the phonograph pickup art would be incomplete without at least a brief treatment of the electrical equalization procedures. This closes the circle and brings us back to the opening sections of this paper.

It would appear that Maxfield and Harrison [6] were the

first to provide flat response from recording through reproduction in a phonograph. The throat acoustic impedance of the horn they used, at least to the first approximation, defined an acoustic resistance down to the cutoff point which in their design was 115 Hz. During the resistive interval, the horn radiated a constant acoustic power into the listening area for constant volume velocity applied to the throat. An efficient transformation of the stylus-tip velocity into acoustic-volume velocity required that the disc-modulation velocity be a constant with frequency.

Maxfield and Harrison predicted that electrical reproduction would allow the record to be cut with a characteristic other than "uniform velocity sensitiveness," with the reproduction characteristic adjusted by electrical means to be inverse of the characteristic of the record. They argued against this approach, however, because of concern that there would be excessive modulation amplitude at low frequency or that the radius of curvature of modulation at high frequency would become too small for proper scanning by the stylus tip. Therefore, in the orthophonic system they settled for a frequency response which was flat on a velocity basis from 200 Hz to 4000 Hz, dropping at 6 dB per octave below and above these limits.

The concerns of Maxfield and Harrison about amplitude and curvature limitations turned out to be only partially justified in the light of subsequent studies of the nature of power versus frequency distribution for orchestral music published by Sivian, Dunn, and White in 1931 [72]. Because sound power tends to drop at the lowest and the highest extremes of the audio frequency range, it becomes possible to pre-emphasize both the bass and the treble registers during the recording phase. In the light of the abrasiveness and resulting severe random noise produced by the shellac records used prior to the adoption of vinylite in the late 1940s,[3] there was a strong tendency on the part of record manufacturers to enhance the recorded high-frequency signal and to count on a compensatory reduction of pickup response by the user to reduce surface noise. A survey conducted by this writer in 1945 [73] revealed that the frequency characteristic used by the individual record manufacturers was either a closely guarded secret or was adjusted for each particular record until it sounded "good" on some arbitrary playback system. The situation, indeed, was greatly in need of standardization.

Unquestionably, improvements in the accuracy of modulation measurements [8]–[11] contributed to the feasibility of standardizing the frequency characteristics of records. With standardization efforts gaining momentum, various record manufacturers and professional organizations promoted their own ideas about the optimum response characteristics [74]. Some high-fidelity equipment was even provided with a multiplicity of adjustments that made it possible for the user to select among a variety of the competing curves. At last, in the early 50s the Recording Industry Association of America (RIAA) published a standard characteristic which was adopted by the record industry. It was defined as follows: [75]

> "The R.I.A.A. Standard Disc Phonograph Record Characteristic curve is specified as the algebraic sum of the ordinates of three individual curves which conform to the admittance of the following three networks expressed in dB:
>
> A. A parallel L/R network having a time constant of 3180 microseconds.
>
> B. A series RC network having a time constant of 318 microseconds.
>
> C. A parallel RC network having a time constant of 75 microseconds."

For both the displacement-responsive (i.e. piezoelectric) and the velocity-responsive (i.e. magnetic) pickups, equalization networks for conforming with the inverse RIAA curve can be obtained with simple configurations of two resistors and two capacitors as shown in Fig. 27**a** and **b** respectively. In the case of the piezoelectric pickups, one of the capacitors can conveniently become the capacitance of the piezoelectric element C_1 (including the capacitance of the cable connecting the pickup to the

[3] Typically, the so-called "shellac" records were made of up to 80 percent mineral filler (mainly calcium carbonate or slate flour ground to 325 mesh), up to 5 percent lubricants, gums, and coloring (mainly zinc sterate and carbon black), and up to 20 percent shellac used as binder.

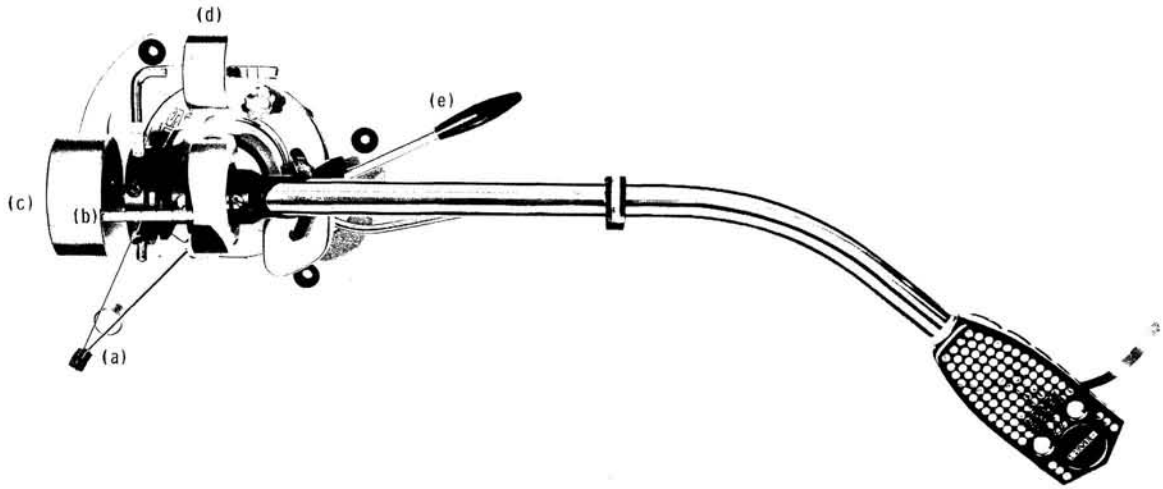


Fig. 26. SME arm: **a.** antiskating bias weight; **b.** notched rod for adjusting bias; **c.** coarse counterweight; **d.** fine stylus bearing weight adjustment; **e.** arm lifter. *(Courtesy SME LIMITED)*

amplifier), and one of the resistive elements can conveniently become the volume-control potentiometer R_3.

The relationships are as follows [76]:

$$R_3 = 750 \times 10^{-6}/C_1 \quad \text{ohms} \tag{21}$$

$$R_2 = R_3/6.88 \quad \text{ohms} \tag{22}$$

$$C_2 = 2.92\, C_1 \quad \text{farads} \tag{23}$$

Using an approach similar to that of reference [76], it is not difficult to show that for a velocity-responsive pickup, if one chooses an arbitrary resistance R_1, the remaining three values are calculated as follows:

$$C_3 = 750 \times 10^{-6}/R_1 \quad \text{farads} \tag{24}$$

$$R_2 = R_1/6.88 \quad \text{ohms} \tag{25}$$

$$C_2 = 2187 \times 10^{-6}/R_1 \quad \text{farads} \tag{26}$$

The network in Fig. 27**b** usually follows an amplifying stage.

Recent studies of the power vs frequency distribution in recorded music [77] and the surface noise power distribution and modulation limits of vinylite 33⅓-r/min records [78] have suggested that it should be possible to diminish the pre-emphasis in recordings above 3500 Hz and to appropriately diminish the attenuation of high frequency in the reproduction of 33⅓-r/min discs, thereby potentially gaining greater recording-channel capacity and freedom from distortion. In view of the universal acceptance of the RIAA standard, however, this would not appear to be a practical option for conventional phonograph apparatus.

CONCLUSION

The evolution of the electromechanical phonograph transducer exhibits a consistent and outstanding series of practical and theoretical contributions ranging from the development of improved transducer materials to the generation of the most advanced theories of surface interactions. The objective in each case was to achieve an improved, simpler, more practical, more durable product, and constantly to achieve higher fidelity of sound reproduction. This remarkable history of product development over six decades rivals that of other great industries, such as the automobile or airplane.

We can look forward to further improvements. There is no reason to anticipate that the chart in Fig. 12, after having flattened for the past 10 to 15 years, will not resume its downward trend. The stylus is still too readily damaged by mishandling—an almost indestructible stylus assembly needs yet to be devised. Too many high-priced arms are not adequately damped—they exhibit resonances in the infrasonic area whereby floor vibrations due to walking, etc., cause the woofer cone to be driven into a nonlinear range resulting in intermodulation distortion (albeit, recently this writer saw one notable exception where the cartridge mount was connected to the arm with a damped coupling as in Fig. 24, thereby effectively eliminating arm resonance). The vertical tracking angles of pickups need better control. Stylus resonances at present occurring just beyond audibility could stand some attention as they may be contributing to surface noise, as predicted by Hunt.

Each time the disc record and the pickup have been challenged by other recording media, they were able to come out ahead stronger than ever. The new generation of pickup designers need not suffer from a lack of goals to achieve.

ACKNOWLEDGMENT

The author acknowledges with gratitude the assistance of various pickup manufacturers who have furnished illustrations of their products for use in this article, and regrets that it was not possible to include all of them. The assistance of Lee Gunter, Jr., of Shure Brothers, Inc., who provided some of the patent information, and of James V. White of CBS Technology Center, who helped to assemble the material related to stylus/groove interaction is gratefully acknowledged.

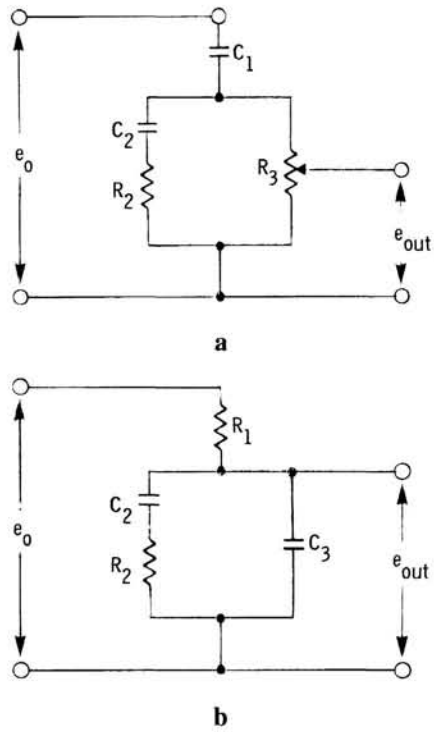


Fig. 27. Equalization circuits for **a**. displacement-responsive (piezoelectric) pickups and **b**. velocity-responsive (magnetic) pickups.

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Record Changers, Turntables, and Tone Arms—A Brief Technical History

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Some of the highlights in the development of record changers and turntables since the early 1920s are recounted. Electric motors, drives, and change mechanisms are discussed in some detail along with important features of tone arms. The present state of the art is summarized, and the paper concludes with a prediction of future development.

Scientific American, October 1, 1921:

"Fifteen to One Hundred Phonograph Records without a Stop

The latest novelty in the phonographic field is a machine that handles its records automatically, and continues playing one record after another until the supply is exhausted. Indeed, as many as one hundred records may be played without a break and without attention of any kind.

The device which makes this automatic operation possible is shown in the accompanying illustration.[1] A batch of records is placed on the turn-table of the phonograph, and all but one record are raised by hand and held in place by the arms or fingers mounted on the pillars on either side of the turntable, as shown. When a record is through playing, the tone arm automatically lifts and falls back, whereupon a new record is deposited on the turntable. It is said that the record is carefully dropped in place, with no danger of breakage. The tone arm is then brought into position with the stylus in the first groove, and the record begins playing. By extending the pillars upwards and mounting more arms or fingers on them, the capacity of the machine can be increased up to one hundred records. Obviously, an electric motor drive must be employed for the phonograph so as to do away with the manual rewinding."

[1] Not shown here.

INTRODUCTION: When Rex Isom, president of the Audio Engineering Society, called in January of this year to ask me to write this paper, I was naturally very flattered and readily accepted. The assignment was to review the history, tell about the present, and forecast the future of changers, turntables, and tone arms for home phonographs. The project did not seem to be too difficult until I started searching for historical references. Discovering suitable material has proved to be quite a task.

To trace technical history properly requires finding a great deal of detailed information. According to *Scientific American,* the history of changers dates back to at least 1921, and, of course, the turntable and tone arm go back to the original Berliner mechanism (1887). Literally hundreds of companies have been involved in providing thousands of designs. The patent file on these products is voluminous. Technical articles are available to some degree, but in a wide variety of publications. Company sales and technical literature could be helpful, but are not easy to locate.

We first considered a chronological approach, that is, trying to identify the date and company or individual who introduced each major improvement. That did not prove to be practical within a reasonable time framework. After attempting that approach it was decided (possibly as a pure

rationalization) that the exact determination of dates and those responsible is not really as important as recounting the principles involved. The bulk of the paper, therefore, will emphasize important features and principles. Where it was possible to ascertain dates, they have been included.

We reviewed all pertinent material in the *Journals* of the Audio Engineering Society, the Acoustical Society of America, and the Institute of Electrical and Electronics Engineers and its predecessors. There were some fine articles, but not nearly enough to provide a historical perspective. That was obviously not the way to attack the problem. Since it appeared that help was needed, we sent off a batch of letters to friends around the world asking for information. We eventually received replies from over thirty people. The responses proved to be extremely useful, both in providing answers to specific questions and in telling us where to go to find technical information.

Another approach was to employ the services of Brian Sinofsky of our Development Laboratory to do a literature search. Brian combed the depths of all the major libraries in the Chicago area and did a superb job of uncovering a wealth of information. The type of data we were seeking was often found in dead storage, and it took considerable effort to dig much of it out.

Some very useful facts are found in *From Tinfoil to Stereo* by Oliver Reed and Walter Welch [9]. It was not until we entered into this project that we fully appreciated the marvelously detailed and complete job these men did in preparing that classic book.

Lee Gunter of our Company was kind enough to review the American patent literature on tone arms and provided examples of many interesting patents. We have not, however, attempted in any way to offer a detailed review of the enormous patent literature that is available throughout the world.

At the time of this writing, pertinent material is still coming in, and we fear that important contributions may be omitted because of the need to meet the deadline for publication. If that turns out to be the case, we will be glad to provide a sequel at a later date. We will also welcome comments and added information from the readers.

Most of the material in this paper is documented somewhere in the bibliography. Wherever possible, we have tried to obtain more than one source on a given subject. In some cases we were not able to document the document, so to speak, and we only hope for the veracity of the source. Names of people and companies are included for older developments, but we have minimized giving company names in the present era to prevent, as far as possible, the injection of commercialism.

PROCESS OF TECHNICAL EVOLUTION: MOTORS AND DRIVE MECHANISMS

The romantic view of technical development is in terms of great inventions and giant steps. Practicing engineers know that technological development is much more prosaic. It is a process of continual improvement in small, sometimes imperceptible steps. Often we discover a cyclic movement where ideas that were discarded long ago are resurrected, made to work, and come to the forefront of the technology. Concepts developed as far as the existing technology would allow are replaced by better ideas, but then reemerge at a later date when new materials or new conditions allow the resolution of earlier problems.

Looking back into the history of record changers, we find an excellent example of that thesis in the development of electric motors and drive mechanisms. In perusing the advertising copy of the current hi-fi magazines, one finds that the top-quality turntables and changers either employ a direct-drive motor or are belt driven. Who introduced these modern developments, and when?

A picture of the first belt-driven turntable may be found on page 122 of *From Tinfoil to Stereo,* which shows Emile Berliner's original Gramophone with its hand crank and belt drive. The belt may not be quite as refined as in today's models, but it was probably chosen for many of the same reasons.

Electric motors were used in the phonograph industry in some of the earliest designs. You will find in that same book a photograph of one of Edison's cylinder units driven by a dc motor and dated 1887.

An early direct-drive system appeared in 1921. C. I. Hall, in "The Induction Disc Phonograph Motor" [46], describes in detail the performance characteristics and advantages of a direct-drive phonograph motor. To quote from *Scientific American,* May 14, 1921:

"Something New in Phonograph Motors

> An engineer in the large electric works at Fort Wayne, Ind., Chester I. Hall, has developed a motor to be used on phonographs, which meets all the requirements and which presents several interesting and novel features in design and operation.
>
> The motor is a small induction motor, somewhat similar to those used as the motive power of induction watt-hour meters. It consists of a rotating element fastened to the shaft of the turntable and running between two field coils. The rotor is formed of a ring of copper of about 6 inches inside diameter, and about 1½ inches wide, supported from the main shaft by a cast aluminum spider.
>
> The rotor revolves through a shifting magnetic field produced by field coils wound on laminated magnetic circuits. Thus, since the revolving element is directly fastened to the main turntable shaft, all necessity for high speed gearing, belting or friction drive is entirely eliminated. The lower bracket supports a governor which is geared to the main shaft by a worm gear.
>
> It was found quite difficult to eliminate the noise caused by the magnetic hum, due to the sixty-cycle circuit, but this was accomplished by a proper design of the supporting brackets and spider, as well as by the elimination of vibration in the motorboard itself.
>
> The simple construction, few moving parts—two only, as a matter of fact—the absence of sliding contacts and the small amount of power consumed in bearing friction, all combine to give the motor a life that is probably limited only by the life of the insulation.
>
> If the claims made for this phonograph motor are substantiated in actual practice, it appears that this invention marks a distinct step forward in the phonograph art. Heretofore it has been well-nigh impossible to obtain a truly silent mechanical or electric motor, due to the fact that the high speed driving element has had to be geared down to the 78 turns, more or less, of the turntable."

(There is reference to a dc direct-drive motor in *Popular Mechanics,* April 1917 [45], but we have not as yet determined the manufacturer.)

At the time of the introduction of the induction disc motor in 1921, the universal or commutator-type ac–dc motor was quite popular. The advantage of the universal motor was that it could operate from either ac or dc power, the latter being fairly common at that time. Also, the motor could be used on either 110 or 220 volts with only the adjustment of a series resistor. Its major disadvantages were a high mechanical and electrical noise level and the necessity for a mechanical governor to maintain constant speed.

Electrical noise was of no consequence in the day of acoustic reproduction systems; but mechanical noise created a problem, and the ac induction motor offered an advantage in that regard. During the 1920s, the induction motor achieved a position of major importance. Of the various varieties available, the shaded-pole type became the most popular and indeed has continued in popularity to this day because of its simplicity and relatively low cost.

A common form of drive mechanism employed a worm gear between the motor and turntable. Those drives generally incorporated a flyball governor and were used with induction as well as universal motors. General Industries' "Green Flyer" was a popular product using that design. Garrard in the late 1920s and early 1930s entered the electric-motor-drive field with their model ED, which was a universal motor that employed a belt drive to the turntable along with a centrifugal-type governor [3].

Another direct-drive motor, the Garrard model 201, was introduced in the late 1920s. To quote E. W. Mortimer [13],

> "This was a split-phase induction motor with a 6 in. diameter stator on to which was assembled 30 separate coils. The rotor, which ran at turntable speed (78 r.p.m.), revolved around the outside of the stator acting as a flywheel to smooth out speed variations in addition to driving the turntable. The speed of the rotor was governor controlled and the speed could be varied over a very wide range."

A major step forward came in 1938 with the introduction by the Alliance Manufacturing Company of the idler-wheel, puck, or rim drive as it is variously called. The idler wheel offered advantages in both simplicity and performance and was instrumental in leading to the demise of the gear drives. It should be noted parenthetically that emphasis must be placed on cost in the home phonograph. The idler wheel is not necessarily superior to the gear drive if the cost consideration is ignored. Indeed, Thorens offered top-quality gear drives on record changers well into the 1950s.

By the end of the 1940s, the two- and four-pole shaded-pole motor using an idler wheel was far and away the most popular drive mechanism for turntables and record changers. That type of drive continued to be most popular through the 1950s; however, the introduction of 33- and 45-r/min and later stereo discs created a need for better drive systems. The improvement in quality of reproduction required reducing rumble, wow, flutter, and electrically induced noise.

While synchronous motors had been employed for many years, the need for such motors increased with the advancement in fidelity of the playback system. At least three types of synchronous motors were in use; namely, reluctance, hysteresis, and permanent magnet. By the end of the 1950s and early 1960s, small slow-speed synchronous timing motors were incorporated in turntables. One significant product that helped popularize such motors was the AR turntable. The design principles of that product are described in an excellent article by Villchur [44].

A forerunner of future events appeared in the *AES Journal,* June 1958 [41]. The articles describes a drive by Fairchild using a hysteresis motor powered by an oscillator with speed controlled by the frequency of the oscillator. That unit used a belt drive and claimed a speed accuracy of $\pm 0.3\%$. The system was not dependent on power-line frequency

A variation on the belt drive system appeared in the late 1950s when Thorens introduced a drive incorporating a combination belt and idler wheel. That combination offers the advantage of the belt for good mechanical noise isolation and simple speed change with the idler wheel.

By the early 1960s, the direct drive was practically nonexistent in the home phonograph. Having rediscovered Emile Berliner's original concept, the industry was moving back to belt drives. The idler wheel was still the most popular driving mechanism, and gear drives were a thing of the past along with universal motors and mechanical governors. In vogue were the two- and four-pole shaded-pole induction motor and the permanent-magnet and hysteresis-type synchronous motor.

In the mid 1960s the first closed-loop electronically controlled turntables began to appear. The AES Preprint "Development of the Sony TTS-3000 Turntable" [38] describes a turntable employing a 300-r/min dc motor as part of a servo system employing a tone generator on the motor shaft for feedback. The governor was back again in the form of an electronic feedback control system! Somewhat later Thorens introduced the TD125 turntable employing a slow-speed ac motor driven from a stable ac source mounted beneath the turntable. Both systems use belt drives.

The direct drive returned once again with the introduction of slow-speed brushless dc motors used in a servo loop. A Letter to the Editor in the June, 1970, issue of the *AES Journal,* entitled, "A New Direct-Drive Phono Motor" [48], describes a brushless dc motor which has the rotor outside the stator. Today several types of direct-drive motors, ac and dc, are employed in both single-play and automatic turntables as well as higher priced record changers.

One major advantage of the closed-loop and oscillator-driven systems is that they are independent of line frequency. Conceptually, the older types of drives were not that much different in that a mechanical servo (flyball governor) was used to control the speed; however, the difference in technology and the results achieved are pretty obvious.

Today both the direct and belt drives are popular and appear in many of the top-quality record changers and

turntables. There is apparently a healthy disagreement as to which is the better approach.

PRESENT-DAY SPECIFICATIONS

We surveyed the specifications of 34 popular turntables and record changers available at this time. The results are summarized in Table I and will give some idea of the state of the art in 1977.

We have gone from belts to gears to direct drive to idler wheel and now back to belts and direct drives. What will come next? If our past experience of cycles in development holds true, we may be seeing gear drives again. Electric motors in phonographs started out as dc, changed to induction types, then synchronous, and now again to dc. Where we go next is hard to predict, but there will probably be a lot more said comparing the merits of synchronous and dc drives.

CHANGE MECHANISMS

Some of the best sources of information on record changers are the service manuals produced by John F. Rider [29] and by Howard Sams [28]. The Rider book entitled, *Automatic Record Changers and Recorders,* was published in 1941. Sams started publishing his manuals in 1947.[2] A thorough review of all the mechanisms described in those manuals would take months, but if one is inclined in that direction it is most enjoyable reading. The dedication of the Rider manual is worth quoting: "Dedicated to the RADIO SERVICEMAN who through no fault of his own now is surrounded with pawls and cams and gears."

In Chapter 3 of the book Rider describes four types of changer mechanisms, including the drop, ejector or throwoff, turnover, and combination drop–ejector types. I would add a fifth type as a subheading, which we will describe later in elaborating on the drop-type mechanism.

To quote Rider,

> "By drop type is meant a mechanism whereby the stack of records is supported on two or more oscillating shelves, which are capable of slicing off the bottom record, which then slides down the spindle to the turntable . . . The majority of the automatic record changers sold during the past few years are of this type.
>
> Another type of automatic record changer is known as the "ejector or throwoff" wherein the record is actually pushed off the turntable into a sort of hopper where the used stack is formed . . . For example, the stack of records instead of being located upon shelves above the turntable, are located upon the turntable. The spindle is movable in that it can slide down into the assembly below the turntable to the extent necessary to permit the approach of the ejector arm and its contact with the top record already played. This means that the spindle recedes the amount equal to the thickness of the record, thus permitting the ejector arm to slide off to the top record, but the remaining records are held in place by that portion of the spindle projecting above the turntable.
>
> Another type of record changer is known as the "turn-over" which is typified by some of the Capehart units. In this interesting arrangement the records to be played—there can be twenty of them at a time—are stacked horizontally in a hopper. When a record is to be played, this stack turns up on end and when in a diagonal position, the bottom record slides out upon the turntable.
>
> A recent development in automatic record changers is that device which is a combination of the ejector and drop types and is a double-side player. This is saying quite a lot and means that the placement of the record upon the rotating turntable is by means of a drop from record shelves. The ejection of the record after both sides have been played is by ejection into a hopper, although the mechanism is different from that previously described. In this unit, the entire turntable assembly is upon a swivel which tilts, as shown in Fig. 1,[3] so as to permit the record to slide off onto a recess chamber after both its sides have been played."

That was the view in 1941. Let us go back another two decades to see how the technology had progressed. The first mention (1921) we found of a record changer for discs was still in the days of acoustic recording and playback. The modern era of phonograph reproduction was ushered in by Maxfield and Harrison with their paper, "Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research," presented to the AIEE in February of 1926 [84]. The first all-electric phonograph produced commercially for home use was the Brunswick Panatrope which appeared in 1927. Record-changing mechanisms for the home were offered with acoustic phonographs as early as 1926 [18]. In the late 1920s electrical phonographs with record changers were offered by such companies as RCA, Brunswick, Majestic, and EMI. The Capehart changer, which did just about everything, including turning the records over and playing mixed sizes, was introduced in 1931 [2].

A major step forward in reducing the cost of changers for the average user was the drop-type mechanism. To quote Rider [29, author's foreword], "In fact, it is possible to credit the revival of phonograph record sales and interest in such records to the successful development of a simple record changer."

An example of such a changer, produced in 1932, was the Garrard RC1. The RC1 used three platforms that supported the records directly above the turntable. During the change cycle, blades were inserted between the bottom record and the one above, allowing the lower record to drop while holding the remainder of the stack. A later model, known as the RC1A, played mixed 10 and 12 inch records and according to Garrard was the first drop-type changer to automatically select the record by size. That type of mechanism was popular through the 1930s and 1940s.

By 1940, changer mechanisms that stacked the records above the turntable were the dominant type. The article, "Automatic Record Changers," in the February, 1942, issue of *Electronics* [17], describes the state of the art as of that day.

There were at least three two-side players available, offered by Capehart, Garrard, and RCA. Both the Capehart and Garrard changers turned the record over and

[2] We owe a debt of gratitude to Roy Poulton of Shure Electronics in England for supplying a copy of the Rider manual and to Roy Parr of the VM Corporation for lending us a complete shopping bag full of the Sams manuals.

[3] Not shown here.

played the second side before moving on to the next record. The RCA changer described earlier as a combination ejector and drop type used a turntable about the size of the record label and employed a tone arm with two cartridges. After playing the top side, the turntable reversed its direction of rotation and the bottom side was played with the other cartridge. After the second side was played, the turntable was tilted and the record slipped off into a storage compartment.

In reviewing the designs of the two side changers, one must marvel at the mechanical genius that went into their development. One might gain as much enjoyment from watching them operate as from listening to the results.

According to the 1942 *Electronics* article, all single-side changers on the American market at that time stacked the records horizontally above the turntable. The major differences were the methods of supporting the records and dropping one record at a time. One popular design was the drop type similar in concept to the Garrard RC1, using two or three platforms. Another widely used method of supporting the records was with an offset spindle and a single support on the side. A pusher mechanism in the side support was used to move the bottom record onto the turntable. That type of mechanism was employed into the 1960s, while the double-platform system disappeared earlier. Rider's book also shows a Galvin Manufacturing Company (Motorola) design which utilized a push rod and record trigger release within the spindle in conjunction with a passive side support. Improved variations of that technique are used in many of the popular changers of today.

THE CHANGE TO LP

Howard Sams' *Automatic Record Service Manual*, vol. 2, 1948 [28], must be considered a classic in the historical archives. In that volume we find the first of the 33 r/min record players. Also, there is the first reference we have been able to find outside the patent literature to the so-called "umbrella-type" spindle assembly, which is so popular today.

The Farnsworth model P72 and P73 changers were equipped with a center spindle for supporting the records without a side platform. During the change cycle, a rubber sleeve expanded to hold all the records but the bottom one. As the cycle progressed, a support was withdrawn into the spindle assembly, allowing the bottom record to drop to the turntable. The Silvertone 101.761-2 employed a similar mechanism. Later C. G. McProud in *Audio,* August 1954 [26], reported on the "Magic Wand" Miracord as being the first of that type of change mechanism. We should mention that a great deal of development on this type of change mechanism took place in Europe (for example, [22]–[25]).

The VM models 402D and 400D, vintage 1948, employed a lift-and-push-off mechanism within the spindle. Unlike the Motorola unit described previously, the VM changer was able to play mixed 10- and 12-inch records. It also played both 33- and 78-r/min records using a turnover-type cartridge arrangement.

The hectic pace at which manufacturers converted to 33⅓ r/min is evidenced in several of the changer designs described in the 1948 manual. Both Admiral and Philco, for example, showed record changers with two arms, employing a manually operable arm for the 33⅓ r/min records.

1949 saw the introduction of the RCA 45-r/min record and changer. An excellent article on that system entitled "A Record Changer and Record of Complimentary Design" [19], appeared in the *RCA Review* in June 1949. The paper describes the changer mechanism and goes into detail to explain RCA's rationale for selecting 45 r/min.

WHERE NEXT WITH CHANGE MECHANISMS?

By 1949 the basic concepts for the change mechanisms used in today's home phonograph had been introduced. A detailed accounting of the present mechanisms would describe myriads of improvements, which in total have undoubtedly combined to provide a major advancement. Forecasting is normally a matter of extrapolating from the past, and when the past has been conceptually unchanged for almost three decades, it is difficult to foretell the future. If the theory of cycles in development holds true, we may once again see the two-side player. Whether such a device would be commercially practical is open to

Table I. Survey of 34 turntables and changer.

Type of Drive	Quantity	Type of Motor	Quantity
Idler	11	Induction	6
Belt	15	Synchronous	18
Direct	8	Direct current	10

Claimed Specifications*	Minimum	Maximum	Specification	Quantity
Wow	0.01%	0.14%	rms	23
	0.04%	0.15%	DIN 45507	6
Flutter	0.01%	0.1 %	rms	20
	0.04%	0.15%	DIN 45507	6
Rumble	−50 dB	−48 dB	DIN A	5
	−70 dB	−50 dB	DIN B	17
	−60 dB	−45 dB	JIS	2
	−70 dB	−35 dB	NAB	9

* Specifications that did not call out a recognized standard are omitted.

question, but just think of the interesting engineering problems, and would it not be enjoyable once again to have a record changer we could watch rather than ignore?

FEATURES AND IMPROVEMENT IN PERFORMANCE

The emphasis we have placed on drive systems and change mechanisms could lead to an erroneous impression of the development of changers and turntables. While those parts of the system have been improved and perfected to a significant degree, there are many other features and functions that have contributed equally to the great advancement in product performance. We do not have the space to go into detail on all those things, but we must mention some of the important items.

1) The means for lowering the arm to the table gently and with very little possibility of damaging the record have been improved significantly over the years.

2) Cuing devices have been perfected to bring the stylus back to the same groove time after time. These devices are provided with damping so that the arm will drop slowly to prevent any possibility of record damage.

3) Antiskating devices provide accurate adjustment of skating force compensation.

4) Friction in both the horizontal and vertical motion tone-arm bearings has been reduced significantly. Torsional problems formerly encountered in bringing the leads out of the tone arm have been resolved.

5) Automation of control functions has evolved. By the end of the 1950s two types of system were dominant, the changer and the manual. It was generally considered necessary to employ a turntable and manual tone arm in order to achieve ideal playback performance for true high-fidelity purposes. During the 1960s turntable–tone arm combinations began to achieve a greater degree of popularity. At this date these combinations are offered with varying degrees of automation, ranging from completely manual units to ones that automatically shut off at the end of the record, units that shut off and return the tone arm to the rest, and finally automatic turntables that take the tone arm through the complete cycle at the push of a button.

6) Electronic programming of control functions has been introduced. The most recent advancements provide features such as advance selection of the number of replays of a single record and selection of the desired bands which the user wishes to play. Remote control of preprogrammed functions is also offered.

7) A variety of both mechanical and electronic speed adjustment and speed selection controls have been made available.

TONE ARMS

B. B. Bauer suggested that one of the major contributions to the tone-arm art was the analysis and solution of the various geometrical problems associated with tone arms. We would certainly agree. One of the earliest mathematical analyses of arms was by Percy Wilson and appeared in *The Gramophone* in 1924 [82]. To quote from Wilson's paper, "British Contributions to Audio during the Past 50 Years" [10], "His mathematical proof in 1924 that tracking error would be reduced to less than 2° and the consequent distortion to not more than 2% by the 'overlap and offset' method established a standard technique in Britain before the last war, but only made an impact in America after 1945, when B. B. Bauer published a different sort of analysis which led to the same result." Nevertheless, Bauer's paper [73] was widely circulated and helped disseminate some of the ground rules for the design of arms for offset angle and overhang.

Surprisingly, finding historical references on tone arms in the technical literature has been less productive than on changers and turntables. To provide some historical perspective, we have selected a few items from the U.S. Patent files.

J. H. Elfering in 1907 assigned to the Victor Talking Machine Company Patent 855761, which was a true articulated arm mechanism that provided close to linear tracking. As one might imagine, the files are filled with variations on schemes for that type of arm.

An early mechanism for tracking force adjustment with a spring appeared in 1917 in Patent 1243854 by J. Matson. Mr. Matson points out that his invention is for the purpose of "counter balancing any excess weight of the tone arm causing undue pressure of the stylus upon the record." He later goes on to say, "The proper adjustment of the weight or pressure of the stylus upon the record to the character of the record is essential and that a poor reproduction results from either too great or too little weight or pressure of the stylus upon the record."

A unipivot tone arm is shown in Patent 1,353,061 by A. R. Spicacci (1920). It should be remembered that Mr. Spicacci had some significant problems in creating his design. Rather than bringing a few fine wires through the pivot, he had to provide an acoustic tube for the sound to pass through. Percy Wilson advised that the first unipivot arm in Britain for electrical reproduction was made by Cosmocord about 1930.

I do not want to bore you with patent numbers, but before going on to other matters, Patent 1,468,455 by W. H. Bristol, issued in 1923, is worth mentioning. Figures 3 and 6 of that patent are recreated here in Fig. 1. One interesting aspect of the patent is that Mr. Bristol refers to his pickups as electrical transmitters some four years before the introduction of the Brunswick Pantrope (although work had been done on electrical reproduction in England as early as 1919). The more interesting aspect of the patent is the use of two pickups for time-delayed reproduction. Also, one of the arms is offset and probably for the right reason.

The point of these examples is that many of the basic concepts in tone arms were developed a long time ago.

DEVELOPMENTS IN THE 1930s AND 1940s

Tone arms in the early 1930s were rather massive affairs by today's standards. According to E. W. Mortimer [13] the 1933 vintage pickup required a needle force of 4 ounces (1120 millinewtons) to play a record. Mortimer goes on to say that this was considered an achievement, as the previous sound boxes required a force of at least 6

ounces (1680 millinewtons).

By the end of the 1930s, changer manufacturers were claiming tracking forces in the range of 1½ to 1¾ ounces (420 to 490 millinewtons). A major change came with the introduction of the long-playing record in 1948. By the early 1950s, electronic distributor catalogs were advertising tone arms and pickups for tracking forces in the range of 6–8 grams (60–80 millinewtons). By the end of the 1950s, claims in the order of 1 gram (10 millinewtons) were common, and by the middle 1960s they were achieved with what might today be considered reasonably good fidelity. Tracking force specifications remain in that range at this time.

In recounting the history of the phonograph, one cannot overlook the monumental work of Frederick Hunt [1]. While his effort was primarily in the area of pickups and distortion analysis, his studies of record wear certainly relate to tone arms, particularly with regard to his commentary on reducing tracking force. The article, "The Rational Design of Phonograph Pickups" [88], remains a classic to this day.

THE ADVENT OF THE SEPARATE TONE ARM

In the 1950s we began to see the popularization of separate tone arms for the hi-fi enthusiast. The variety of designs found in the catalogs indicates that people were thinking about the right things and were struggling to obtain the proper materials and find the right devices to achieve the desired solutions. To do justice to all the designs offered during that period would require a separate article. We will touch on just a few.

In England, Burne-Jones offered a twin shaft articulated arm [59]. Worden later made an arm in which the offset correction was produced by the movement of one shaft inside another [56]. In the United States, arms with rear pivots for horizontal motion and pivots toward the front of the arm for vertical motion seemed to be of interest. Such arms were offered by Pickering, GE, and Shure, to name a few. Incidentally, that concept was not particularly new. Acoustic phonographs employing tone arms with a front vertical pivot were available in the early 1900s. An advantage at that time was to simplify changing the needle.

Viscous damping was used in the Grey tone arm, which employed a unipivot along with a hemispherical cup containing a viscous fluid [63]. Arms with compliantly mounted balancing weights to provide dynamic damping were also offered [55].

By the late 1950s and after the introduction of stereo, the tone-arm designer really had to consider the finer details. With tracking forces in the order of 1 gram, bearing friction had to be minimized. Highly compliant styli required tone-arm mass be reduced to optimize low-frequency resonance. Attention had to be paid, not only to offset angle and overhang, but to tone arm height, lateral balance, and skating force.

Percy Wilson in an article in *The Gramophone* [12] discussing skating force stated, "I drew attention to it in a note published in the March, 1925, issue." He went on to say, "It is intriguing to note that whilst we were only 20 years ahead of America in the matter of 'needle-track-allignment,' we were 40 years ahead in reference to 'skating force!'" At the October 1960 meeting of the AES, Alexandrovich described a tone arm by Fairchild that incorporated antiskating compensation [53].

SME in England did a great deal to popularize the significance of skating force. They chose to provide antiskating compensation by hanging a little weight on a nylon thread at the rear of the tone arm. The weight piqued the curiosity of potential users and created a great deal of interest. Subsequently we have seen antiskating compensation provided in most top-quality tone arms and changers, with a variety of elegant solutions being offered using magnetic forces and springs, as well as balance weights.

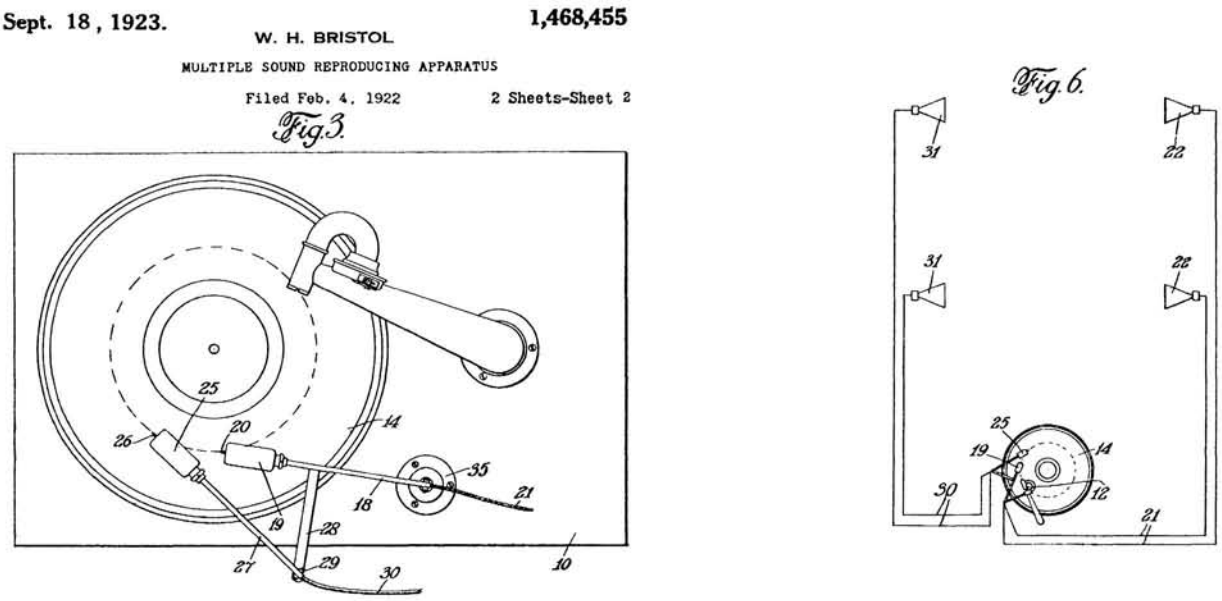

Fig. 1. Figs. 3 and 6 of Patent 1,468,455

Possibly the simplest solution may be achieved by tilting the horizontal pivot to a suitable angle. For some reason that concept has not become popular in spite of its apparent simplicity.

1960 AND ON

In recent years there have been many additions to the variety of tone arms available to the home user. Rabco produced the first commercially successful linear tracking servo-controlled arm. Linear tracking arms of several varieties are now available. These arms have the advantage of eliminating both lateral tracking error and skating force. Garrard introduced the first articulated arms in changers which provide near-zero lateral tracking angle error, but require antiskating compensation.

The damping of tone arms has been developed to the point where a highly sophisticated dynamic damping mechanism is available as part of the counter balance (Dual). Tracking force adjustments accurate to within a tenth of a gram, using springs or weights, are found in better quality arms. A variety of cuing mechanisms, height adjustments, vertical tracking angle adjustments, and other features abound.

THE FUTURE

Forecasting is a dangerous occupation as any meteorologist or economist must admit. Nevertheless, Mr. Isom has asked us to contemplate the future, and we shall make an attempt.

As for tone arms, we cannot invoke the cyclic theory. Apparently, we haven't finished the first cycle as yet. The trend seems to be toward lower mass, which makes a good deal of sense with today's high-compliance cartridges. How low the mass will go is another question which is intimately related to phono cartridge development.

Improvements will be made toward eliminating noise on records. In spite of the claims and protestations of the advertising people, nobody makes a record-playing system today that does not wear the record to some degree and create some noise in the form of pops and clicks and, ultimately, a continuous wideband background noise. While records can be played hundreds of times with little change in the frequency response, pops and clicks and user irritation eventually occur.

The electrostatic attraction of the tone arm by the records in the stack above the turntable is a problem that ought to be and probably will be solved. Also, improvements in the shock mounting of changers and turntables are on their way and should be developed to a high state of sophistication in the next few years. Such a development is not only important in eliminating acoustic and mechanical feedback, but can significantly improve the quality of low-frequency reproduction.

Electronic programming and control of automatic turntables and changers will undoubtedly become popular. We have just entered the era of integrated circuits and microprocessors. As these products become more sophisticated and less expensive, they will most probably find their way into lower cost changers and turntables.

And, finally, let us make a prediction of which we are quite certain. We will continue to see improvements in the state of our art a little bit at a time. Features and quality, which are now found only in the top-priced products, will be found in those of lower price. As the user is educated, his demands will increase. Those demands will be met.

ACKNOWLEDGMENT

In addition to those who have already been cited, we want to give special thanks to Bert Stone and Don Fairbairn of Shure Brothers Incorporated for digging through their old files and providing some choice bits of history. In spite of his infirmity, Percy Wilson was kind enough to write us three letters which, in our industry, is tantamount to receiving a chapter of the Bible signed by the author. C. G. McProud offered many valuable suggestions. To those and the others too numerous to mention, we express our deep appreciation and regret only that we did not have the time nor energy to write the book this subject could easily fill.

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Electronic Home Music Reproducing Equipment

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The search for amplification and control of recorded and transmitted music over the last 100 years has progressed from mechanical amplifiers to tube amplifiers to solid-state equipment. The AM radio, the record player, the FM receiver, and the tape recorder have supplemented the acoustical phonograph and the telephone. An incomplete summary of important developments in the past is presented along with challenges for the future.

Home music reproduction began when Bell invented the telephone in 1876 and Edison invented the phonograph in 1877. Instruments were manufactured soon thereafter and leased or sold to the public. Yet the listener had very little control over the reproduction and the volume of sound, the tone quality being predetermined by the manufacturer of the phonograph and record or by the telephone company and its equipment.

A great deal of effort went into various means to increase the volume or to be able to hear sounds from a greater distance. There was need for an amplifier, and various inventors devised methods that seemed to solve the problem.

Edison [1] coupled a telephone transmitter to the armature of a telegraph relay in 1877. Hughes [2], writing "on the physical action of the microphone," described the accidental discovery of the "howling telephone" when he placed both the transmitter and the receiver on a wooden sounding board, thereby having found something which provided a "relay" for the human voice in telephony. Numerous other inventors improved upon this electromechanical amplifier, notably H.W. Shreeve [3] of the Western Electric Company. The Shreeve repeater was reliable enough to qualify for commercial telephone service in toll telephone circuits (New York–Chicago 1904) and even saw service in the first transcontinental telephone service [4] inaugurated on January 25, 1915. The compact size and relatively modest power needs of the electromechanical repeater caused it to be used for 20 years more as a hearing-aid amplifier [5, pp. 64–69].

C.A. Parsons of London, England, inventor of the Auxetophone, marketed in 1907 a phonograph where the playback stylus vibration caused a valve to modulate a stream of compressed air which was fed to a reproducing horn [6]. Capable of great volume, but always having a background hiss, the modulated air stream loudspeaker is still with us today as the only means of amplification capable of producing extremely high sound pressure levels.

All these methods had the common problem described in these days as "inertia." We now recognize that the moving mass in all those devices was relatively high, and an increase in high-frequency response required an increase in driving power, which was just not available. Equalization of frequency response was possible only by empirical means.

Even radio broadcasting existed in the preelectronic days. In 1902 Pickard succeeded in transmitting intelligible speech by radio, using an 8–10-kHz spark transmitter as source and a carbon microphone in the antenna lead as a modulator [5, p. 39]. Successful broadcasting of speech and music was conducted by Fessenden [7] at Brant Rock, Massachusetts, on December 24, 1906, using a 1-kW 50-kHz alternator built by the General Electric Company under the direction of E. F. W. Alexanderson. Modulation was accomplished by a watercooled carbon microphone in

the antenna ground lead. Clear reception was obtained at many locations, including ships at sea. In the following years an increasing number of transmitters were built, some of them arc transmitters. One essential tool in these stations was a mallet, used to free the carbon granules in the microphone when they had become stuck by overheating [9].

It is probable that not only electrolytic detectors were used for reception, but also the first solid-state detectors [8], the first crystal detector having been invented by Pickard in 1906. It consisted of a silicon crystal and a catwhisker. Dunwoody's detector of about the same time consisted of a carborundum crystal clamped between two brass holders. Most likely a Marconi magnetic detector would be used, connected in series with a set of magnetic headphones. These receiving sets eventually became known as crystal sets and became very popular.

The remainder of the receiving system [9] would consist of a long-wire antenna, a ground, a cylindrical antenna loading coil connected between the antenna and the main tuning coil which was connected to ground. A third coil, connected between the headphone–detector combination, was arranged so that its coupling to the main tuning coil could be varied by sliding one cylindrical coil into the other. As an alternate, pancake-shaped coils were used, variable coupling being accomplished by moving one coil with respect to the other. Tuning of each coil was accomplished by selecting one of several taps with a tap switch. All coils were large, 4–8 inches in diameter. A popular form for home construction of coils was the Quaker Oatmeal box.

The increasing number of "wireless" transmitters for various communication purposes roused popular interest in radio, and thousands of amateurs, or "hams," listened to these transmissions with their crystal sets. Operating such a set was an art, first tuning it to the station, then probing with the catwhisker, a sharp metal wire, for a sensitive spot on the unstable crystal, then retuning, reprobing, etc.

In 1883 Edison discovered current flow in vacuum while seeking the cause of blackening in lamps. This led to the invention of the vacuum diode, the "valve," by Fleming in 1904 [10]. This valve was not very popular because of the need for an additional rheostat to control heating of the filament, which burned out quickly. Furthermore it was not as sensitive as the crystal detector.

In 1906 DeForest [11] added the control grid to the Fleming diode, thereby making it a triode vacuum tube which he called Audion, and the modern age of electronics was born. The "inertialess" amplifier had been discovered.

The DeForest triode saw immediate application in radio reception as a detector superior to all other types, requiring a filament battery and a rheostat and a plate battery which could be tapped to various voltages. The early Audions were highly nonuniform and had a very poor vacuum. Probable life as a detector was 20 to 30 hours, and the filament could be expected to burn out in less than 50 hours. As late as 1915, DeForest [12] could not predict whether the anode current would go up or down when a signal was impressed—each tube was different. However, starting in 1912, both the General Electric Company and the Western Electric Company had learned to make uniform well evacuated tubes [13].

The triode tube was not only capable of detecting radio signals, but it was able to amplify audio signals as well. In 1912 the Federal Telegraph Company [14] demonstrated to the U.S. Navy the first commercial cascade audio frequency amplifier (Fig. 1). Containing three DeForest Audions, tests made at that time indicated that the amplifier increased the received signal in intensity by 120 times.

Other research with tubes continued throughout the pre-World War I period [15]. Almost simultaneously four inventors (DeForest, Armstrong, and Langmuir in the United States and Meissner in Germany) independently discovered (in the 1911–1912 period) the increased receiver sensitivity produced when a portion of the output signal was fed back to the input of a triode so as to effectively increase the input. The regenerative circuit (Fig. 2) made it possible to receive transatlantic signals in the heart of a city using relatively small antennas, heretofore impossible. The commercial importance was immediately realized, and extensive patent litigation ensued, which was not resolved until the United States Supreme Court settled in DeForest's favor in 1934.

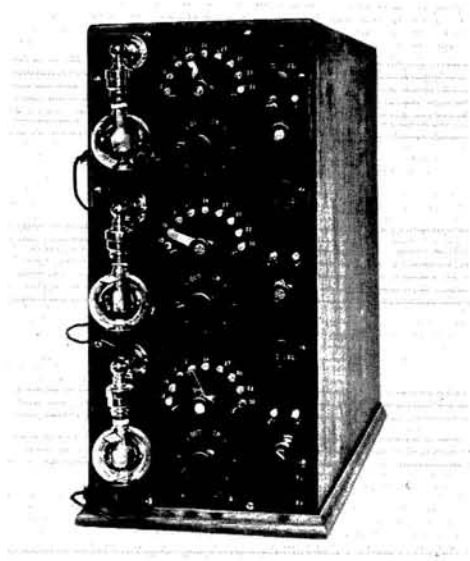


Fig. 1. Three-stage DeForest Audion amplifier. *(Courtesy ITT)*

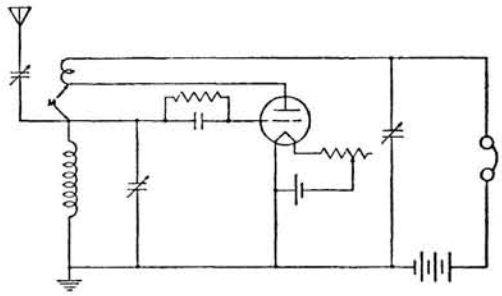


Fig. 2. Armstrong regenerative circuit. [From *Proc. IRE*, Swinyard, W., vol. 50, p. 794 (May 1962)].

The triode tube could also amplify high-frequency radio signals; however, its grid-plate capacitance was relatively high, and stable amplification was difficult to obtain until Hazeltine [16] invented the neutrodyne circuit in 1918. Here a current obtained from the plate circuit was fed back into the grid circuit in the proper magnitude and phase to balance out, or neutralize, the grid-plate capacitance inside the tube, thereby preventing oscillation and achieving stability.

Regenerative radio receivers reached the peak of their popularity in 1922 and continued as a low-cost receiver for many years thereafter. As late as 1940 a consortium of manufacturers in Germany produced an ac–dc low-cost radio[1] containing two tubes, one triode–pentode as regenerative detector—power amplifier, and one power rectifier.

The triode tube could also oscillate at radio frequencies and van der Bijl [17] of the Western Electric Company discovered that the improved triodes of 1913 had a square-law characteristic curve. He utilized the variable slope to produce a modulated wave by applying a small high-frequency signal and a relatively large modulating signal voltage to the grid of the tube. The ATT Company transmitter, constructed according to this principle at the Naval Station in Arlington, Virginia, in 1915, employed 500 tubes in parallel as class-A amplifiers and was heard as far away as Paris and Honolulu.

Soon thereafter various amateurs not satisfied with receiving signals decided also to transmit signals. The laws of the United States in 1920 specified these wavelengths [18]:

High power stations	over 1600 meters
Navy	600 to 1600 meters
Ship stations	300, 450, 600 meters
Amateurs	below 200 meters

One of these amateurs, Dr. Frank Conrad [19] of East Pittsburgh, Pennsylvania, built his amateur wireless station in 1916, obtaining call letters 8XK for it. In 1920 he converted his station to radio telephony and put on a two-hour program Wednesday and Saturday night. His programs proved to be so popular that the supply of crystal sets in the local department store was soon sold out.

On October 27, 1920, Conrad's station became the first in the world to be licensed as a commercial station. It began broadcasting with a power of 100 watts, using call letters KDKA on November 2.

In 1920 only one broadcast authorization was granted. The next year 30 authorizations were given, assigned to the wavelengths of 360 m or 833 kHz and 485 m or 619 kHz. In 1922, 639 stations were authorized, in 1923, 239, and in 1924, 286. The additional wavelength authorized was 400 m or 750 kHz. In 1924 the entire band between 550 and 1351 kHz was allocated to the broadcasters in the United States by the United States Department of Commerce. The functions of allocation and enforcement were taken over by the Federal Radio Commission in 1927, whose functions were transferred to the Federal Communications Commission in 1934. On August 28, 1922 at 5:15 p.m. WEAF, New York, broadcasted the first commercially sponsored program [20] (Queensborough Corporation, a real estate organization). The first chain broadcast on January 4, 1923, featured a telephone tieup between WEAF, New York, and WNAC, Boston.

A few years later, radio broadcasting networks were organized: November 1, 1926, the National Broadcasting Company with WEAF and WJZ as key stations, and September 18, 1927, the Columbia Broadcasting System went on the air with a basic network of 16 stations.

In Europe radio broadcasting progressed under much stricter government control; the stations were generally operated by the post office departments of the various countries. For example, the first German broadcast station [21] went on the air in 1923. In 1928 the "final" number of AM broadcast stations in Europe was reached by international agreement with spacings every 9 kHz. From that time until the end of World War II the number of stations remained constant, and only the transmitter power increased.

The result of these diverging philosophies was that American sets ended up with dials marked only in wavelength or frequency while European sets featured larger dials with the transmitter's location marked prominently.

The direction of the radio receiver industry focused from its beginnings on increased performance and operating convenience. Until 1927 all receivers used filament-type triodes [13], the filament A and plate B supply voltages generally supplied by batteries. The early triodes used the tungsten filament as the cathode without additional coating. To achieve electron emission, the filament had to be operated at white heat. Western Electric coated the filaments with barium oxide and other oxides, enabling tube operation with the filament heated only to red heat. Of these tubes, the Western Electric VT-1 tube was perhaps best known. During the beginning years of broadcasting, the tube types 200, 201, and 202 high-vacuum triodes with tungsten filaments were available.

In 1923 the broadcast receiver business was flourishing, crystal sets and regenerative sets providing most sales [8]. The most famous sets were the Westinghouse Radiola, the Clapp-Eastham, and the Grebe. Each of these receivers had one detector and two stages of audio amplification. These sets received ship signals on 600 m (500 kHz), the broadcast frequencies of 485 m (619 kHz) and 360 m (833 kHz), and the "hams" on the short-wave band 200–250 m (1200–1500 kHz). The frequency range of all "medium-wave" broadcast receivers has changed only slightly since that time.

The neutrodyne [16] circuit was developed into a receiver in 1922 (Fig. 3). This was a three-tube reflex receiver [8] in which the tubes acted both as a neutralized radio-frequency amplifier and as an audio amplifier. The same circuit, but as a five-tube set with a separate audio amplifier, was placed on the market in 1923 by Freed-Eisemann. In both sets, volume was adjusted by varying the filament voltage.

[1] "Der Kleinempfänger" (DKE).

In 1924 neutrodyne receivers were selling by the hundreds of thousands and continued to sell until the screen grid tube in 1928 (Fig. 4) with its low grid-plate capacitance made unidirectional amplification possible without need for neutralization.

Neutralization of triode radio-frequency amplifiers permitted stable stage gains of about 15 dB and also permitted the ganging of tuning of the various stages. Early receivers used variable-inductance tuning or variometers [9], the receivers of 1923 and later using variable-capacitor tuning with its better reproducibility. Popular tubes of that era were the GE type 99 and 101A triodes and the Westinghouse type WD-11 [13].

True single-knob operation of a radio was made possible by the invention of the automatic volume control circuit by Wheeler in 1926 [22]. Here a diode rectified the radio-frequency signal, fed the audio-frequency signal to the audio amplifiers, and a proportional negative-bias voltage to the radio-frequency amplifiers, thereby reducing gain. The first such set, the Philco [23] model 95, appeared with the new indirectly heated tubes. It contained two type 24 tetrode tuned radio-frequency amplifiers, one type 24 untuned radio-frequency amplifier, one type 27 triode audio amplifier, and two type 45 triodes as push–pull power amplifiers with a type 80 rectifier. 50 dB of automatic volume control was achieved. By 1932 practically every receiver on the market used automatic volume control.

A common idea is often conceived by a number of people working independently because the time is ripe for that idea. In 1912 Fessenden [15] discovered the principle of heterodyning whereby two radio-frequency signals could be combined to produce an audio-frequency beat note. Fessenden used an arc source as his local oscillator to receive unmodulated radio-frequency signals. Prior to this, all detectors had acted as valves controlling a direct current in response to the received signal.

Many inventors worked on the applications of heterodyning, with Armstrong [15] finally obtaining the superheterodyne patent in 1920 (Fig. 5). Here the radio-frequency signal and a local oscillator signal were combined in a converter (or mixer or "first" detector) to produce the heterodyned beat frequency or intermediate frequency, then amplified with fixed tuned intermediate-frequency amplifiers until finally demodulated by the detector (or "second" detector). High and constant receiver selectivity could thus be obtained with the intermediate frequency lower than the signal frequency.

The first publicly sold superheterodyne receivers were made by the General Electric Company [8] in 1924 using the Radiola brand name. The circuit used six UV 199 triodes as reflexed untuned radio-frequency stage and intermediate-frequency stage, a self-oscillating converter stage, a second neutralized intermediate-frequency stage, a detector, and two audio stages, and the set had a built-in loop antenna. The console model included a horn loudspeaker. The second harmonic of the oscillator frequency was used to prevent interaction or pulling between the signal and oscillator circuits.

The intermediate frequency was set at 42 kHz to enable the then available triodes (amplification factor about 6.6) to be used. Later superheterodynes used an intermediate frequency of 175 kHz and operated with the fundamental oscillator frequency. By 1930 superheterodynes began to take over and were in universal use in 1932. In Europe [21] the superheterodyne receiver started in about 1930, and in 1939 it was reported that 73% of the receivers were "superhets," the remainder tuned-radio-frequency sets. In 1938 the standards committee of the Radio Manufacturers Association (RMA) agreed on an intermediate frequency of 455 kHz, while in Europe 468 kHz became popular. Other frequencies such as 262 kHz and even 1600 kHz in Europe enjoyed some temporary popularity.

In the mid 1920s a popular triode, such as the 01A, had a retail price of $9.00 [13], equivalent to about $50–$100

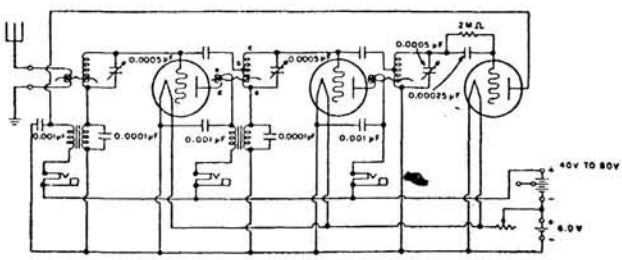
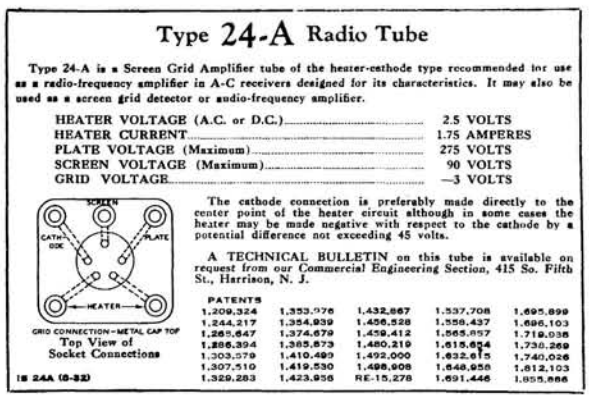


Fig. 3. Hazeltine Neutrodyne circuit (reflex receiver). [From *Proc. IRE,* Swinyard, W., vol. 50, p. 795, (May 1962)]



Type 24-A Radio Tube

Type 24-A is a Screen Grid Amplifier tube of the heater-cathode type recommended for use as a radio-frequency amplifier in A-C receivers designed for its characteristics. It may also be used as a screen grid detector or audio-frequency amplifier.

HEATER VOLTAGE (A.C. or D.C.)	2.5 VOLTS
HEATER CURRENT	1.75 AMPERES
PLATE VOLTAGE (Maximum)	275 VOLTS
SCREEN VOLTAGE (Maximum)	90 VOLTS
GRID VOLTAGE	−3 VOLTS

SCREEN, CATHODE, PLATE, HEATER

GRID CONNECTION—METAL CAP TOP

Top View of Socket Connections

The cathode connection is preferably made directly to the center point of the heater circuit although in some cases the heater may be made negative with respect to the cathode by a potential difference not exceeding 45 volts.

A TECHNICAL BULLETIN on this tube is available on request from our Commercial Engineering Section, 415 So. Fifth St., Harrison, N. J.

PATENTS

1,209,324	1,353,976	1,432,867	1,537,708	1,695,899
1,244,217	1,354,939	1,456,528	1,558,437	1,696,103
1,265,647	1,374,679	1,459,412	1,565,857	1,719,038
1,286,394	1,385,673	1,480,219	1,615,624	1,730,269
1,303,579	1,410,493	1,492,000	1,622,615	1,740,026
1,307,510	1,419,530	1,498,908	1,648,958	1,812,103
1,329,283	1,423,956	RE-15,278	1,691,446	1,855,886

IS 24A (6-32)

Fig. 4. Data sheet once packed with every tube. *(Courtesy RCA)*

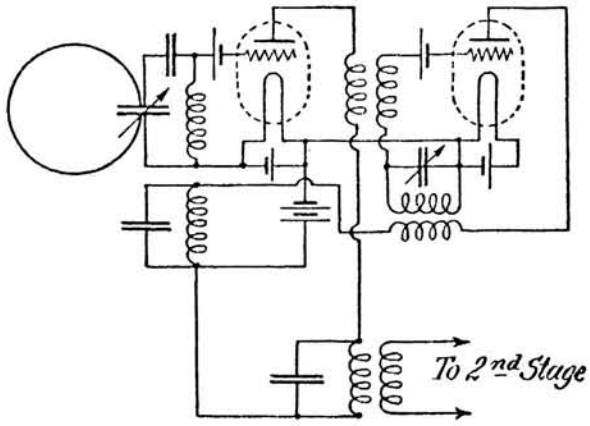


Fig. 5. Basic superheterodyne second-harmonic circuit [From *Proc. IRE,* Swinyard, W., vol. 50, p. 796 (May 1962)]

at today's prices. All sorts of ingenious tricks were devised to minimize tube count, while maximizing performance.

The most popular trick of minimizing tube count in radio receivers of the 1920s was "reflexing." It is not known who discovered that a tube could amplify signals not only in one frequency range but in several frequency ranges simultaneously. Consequently many receivers, particularly neutrodyne receivers, were designed in which the same tube acted both as a radio-frequency amplifier and as an audio amplifier. The earliest superheterodynes also made use of reflexing as shown above.

Unfortunately all reflex receivers [24] had the common failing of interaction (later known as intermodulation) between the two signals because of tube nonlinearity. This resulted in such side effects as the inability to tune the volume to zero, even though no more desired audio-frequency signal passed through the stage.

Reflex circuits disappeared as soon as tubes became less expensive than the additional circuit complexity entailed, approximately in the early 1930s in the United States and in the mid-1930s in Europe.

During the years around 1920 another circuit appeared which today has an important influence on all reproduction of music. Previously when attempting to boost power, output tubes in parallel would be used. Later it was discovered that a larger power increase could also be obtained with two tubes operating in push–pull, that is, when one tube had an increasing signal, the other had a decreasing signal, causing one of the plate circuits to "push" current into the load while the other tube proceeded to "pull." Since driving signals of opposite phase were required to result in an output signal of opposite phase, both input or driving transformers and output transformers were required.

Beginning in the 1930s driving transformers were eliminated with the advent of indirectly heated tubes, to reoccur when high-power tube amplifiers were designed and again when transistors were used in audio circuits around 1960. Not until complementary NPN and PNP transistors became available did both output and input transformers become obsolete in home audio equipment.

Push–pull circuits not only had lower distortion than "single-ended" circuits (even harmonics generated in the output stage tend to cancel), but also output transformers did not suffer from saturation problems by the direct idling current, thereby extending low-frequency response. Furthermore, the circuit had low sensitivity to power-supply hum. It is now the universal output circuit.

The first attempted "loudspeaking" radio resulted in horns attached to telephone receivers [8]. This soon proved to be unsatisfactory. The moving-armature loudspeaker was the next popular reproducer. Balanced-armature receivers, because of their simplicity of construction, survived in the United States until the 1930s and in Europe until about 1940 in a German two-tube receiver, the DKE model.

In 1925 Rice and Kellogg [25] of the General Electric Company described the moving-coil loudspeaker with first use in the Radiola model 104 in 1926, which also included a 1-watt amplifier. At a price of $250 this model also provided power for the Radiola 28 superheterodyne receiver, which became the first batteryless radio receiver.

Prior to the early 1920s power amplifiers were probably quite small because Rice and Kellogg first had to build their own amplifier in order to test the concept of their loudspeaker. In 1923 Green and Maxfield [26] described public address systems, and in 1924 Martin and Fletcher [27] described high-quality transmission and reproduction of speech and music.

The state-of-the-art commercial power amplifiers of 1926 were the Western Electric [28] amplifiers employing directly heated 205-D triode tubes, operating single-ended and in push–pull and delivering 2.5 and 10 watts, respectively. These amplifiers were used successfully into the 1930s in movie theaters for sound reproduction of talking pictures, generally in conjunction with highly efficient horn loudspeakers of "theater-size" dimensions.

The desire to be able to play music louder than was possible before led to a type of competition which took its name from the automobile trade, the "horsepower race." A powerful receiver of 1925, using the new "low-mu" triodes and a B battery eliminator generally had less than ½ watt output [13]. While the 1926 Radiola model 104 was capable of 1 watt output, a typical 1929 "high-performance" set used the new oxide filament low-mu power triode type 45 capable of 1 to 3 watts (single-ended or push–pull) to the loudspeakers. Contributing to this increased output was the advent of indirectly heated tubes, such as the type 27 triode and the type 24 screen grid tube, which permitted a receiver to be operated directly of the one power line without hum introduced in the cathode circuit, the oxide-coated tubular metal cathode enclosing the heater and shielding the tube elements from its hum field.

The search for higher power prior to 1930 took two basically different routes which later combined. In Europe engineers at Philips [29] discovered that the high-current low-voltage knee of the zero-grid bias curve of a tetrode or pentode permitted a larger audio power output to be obtained from such a tube than that available from a triode optimized for the same heater. This led to the development of pentode power tubes (with an oxide coated filament) which appeared first around 1930.

In the United States Barton [30] described the class-B amplifier in 1931. A class-A amplifier is one in which the output tube (or other device) conducts throughout the signal input cycle. In a class-B amplifier one tube conducts for one half-cycle while the other conducts for the other half.

Barton's class-B circuit permitted the power of amplifiers to be increased beyond what was considered possible by the mere addition of a power output tube. A further power increase caused by increased peak plate currents was made possible by increasing the grid voltage drive to positive instantaneous voltages, while maintaining the output tube bias voltage, the C-battery, at a fixed voltage rather than that determined by cathode resistor voltage drop. Up to that time the use of a positive grid signal was equivalent to entering a forbidden region. With

tube types then available output powers approaching more than 10 watts were soon achieved, the driver amplifiers providing the peak grid current.

In 1935 both paths converged as the indirectly heated beam-power tetrode [31] became available. Performing like a pentode, but with greater available low-voltage current, this tube, the 6L6, was originally manufactured with a metal envelope. Later on it became available with various glass envelopes and capable of 6.5 watt power output (single-ended) to 24 watts (class-AB push–pull, no grid current with cathode bias) to 60 watts (class-AB push–pull with grid current). This tube became the standard high-power audio-amplifier tube used in designs rated between 20 and 50 watts appearing as late as the 1960s.

When electrically recorded phonograph records were described by Maxfield and Harrison [32] in 1926, along with their improved acoustic reproducer, the electric phonograph pickup had already been invented. The Western Electric 4A pickup [28] was used for the reproduction of the talking picture sound recorded on 16-inch 33⅓-r/min records according to the Vitaphone method first demonstrated publicly in early 1927.

The improved acoustic phonograph, the Orthophonic Victrola [5] of 1926, only one year later had an all-electric phonograph rival, the Brunswick Panatrope, produced by the Brunswick-Balke-Collender Company aided by engineers from RCA, General Electric, and Westinghouse. Soon other all-electric phonographs and radio–phonograph combinations appeared, with the effect that the acoustic phonograph was virtually displaced in the United States in 1930 by the all-electric radio–phonograph combinations. Acoustic phonographs continued to be produced for ten more years in Europe and as portable instruments worldwide.

The electric phonograph pickup of the years starting with about 1927 was the magnetic pickup, which had a balanced armature using a horseshoe magnet. The output was a good fraction of 1 volt, and the upper frequency limited by a resonance was between 2½ and 4 kHz. Using replaceable "needles," the tracking force was several ounces.

The connection of such pickups to the radio circuits of the 1920s and 1930s was governed principally by the desire to obtain enough amplification, since the output from a pickup was less than that of a high-level detector. Little effort was made to properly equalize a pickup response, since each recording company had its own, often secret, recording curve, each manufacturer striving for its own distinctive sound. The radio-phonograph engineers had to make the best of such a situation, which was complicated by the fact that economic considerations did not permit an additional phono preamplifier tube for the receiver and switches were often unreliable. One of the common solutions was to use one of the intermediate frequency amplifier tubes as a preamplifier [33] for the pickup, choosing the values of the high-frequency bypass components so as to provide for some equalization. This also simplified the switching to a simple disabling of amplification ahead of that stage.

The engineer's life was made a little easier when Sawyer [34] in 1931 described the bimorph Rochelle salt transducer, which became known as the crystal pickup. These pickups, first produced by the Brush Development Company, were comparatively light in weight, requiring only 1 or 2 ounces of tracking force, had an available "permanent" stylus, and produced an output of up to 2 volts when loaded by a grid leak resistor while having constant-amplitude characteristics. This meant less gain and less equalization required than before, and the popular low-cost connection was between the grid of the output tube and ground. Perhaps a million radios had such a "phono" jack connection, and an untold number of electric phonograph attachments contained such a pickup and a simple motor-driven turntable.

Radios and radio–phonographs of the 1930s had magnetic loudspeakers only in the lowest models and electrodynamic loudspeakers in almost all others. The Radio industry [8], having converted from battery-operated receivers to B battery eliminators (Philadelphia Storage Battery Company, 1924), to A battery eliminators (same company soon thereafter), to the radio with integral A and B eliminators (Zenith, 1926), to ac filament tubes (1926), also converted to power-line operation of the loudspeaker. The magnetic field of the typical electrodynamic loudspeaker was a wound coil, a choke, which could be used to filter the rectified high voltage (or B+ voltage) required by the circuit.

It worked, but the loudspeaker emitted a humming sound caused by imperfect filtering. Pridham [35] of Magnavox invented the hum-bucking coil in 1929 which consisted of a few turns of wire wound beside the field coil and connected in series with the voice coil in such a fashion to minimize hum.

Since filter capacitors were expensive, often unreliable, and as electrolytic capacitors with a liquid electrolyte often sensitive to orientation, marginal power supply filtering was the rule rather than the exception of the 1930s. Other ingenious hum-reducing tricks were used. They included partial filtering of hum in the grid circuit, adjusted in such amplitude and phase to cancel hum in the plate circuit (Rechnitzer [36] of Telefunken, 1928), or the use of tapped filter chokes (McLennan [37], International General Electric, 1931), or the adjustment of the operating voltages of one tube in a push–pull circuit to minimize hum. Hum in earlier low current stages was often adequately suppressed by additional filtering.

The beginning uses of light-weight magnetic pickups (General Electric [38], 1948) focused on another source of hum—leakage current from the heater to the cathode and hum coupling from the filament into the cathode and grid circuits. The solution was to use the cathode type tubes with a filtered direct-current filament supply. Scott [39] (model 210 A, 1947) used two 12.6-volt 150-mA preamplifier tubes with filaments connected in series as the cathode resistor of the 6L6 push–pull power amplifier. Not until transistors and integrated circuits permitted small assemblies, have equivalent input hum levels reached any significantly lower value.

Volume controls, or high-impedance potentiometers

made from pressed graphite or carbon, became available in about 1925 and were used as volume controls in all power-line operated radios manufactured, with the exception of regenerative sets. Long-distance telephone circuits, as shown in a 1919 patent issued to T. B. Wier [40] of Western Electric, used a volume control along with a filter which removed high-frequency noise.

Tone controls are another matter: no clear record of achievement exists here. To this date, tone controls are a boon or a bane, panacea or pandemonium. The compiler of the *Radiotron Designers Handbook* [24, pp. 635–678] writes, "Tone control is a controversial subject with very strong conflicting views held by many competent authorities." To this day these words are true; however, many forms of tone control fall under the general heading of equalization or correction of frequency response of program material intentionally preequalized according to some standard. For example, the equalizer circuits used to compensate for the RIAA characteristic of records, or the NAB characteristic of certain tape recordings are not tone controls in the conventional sense, although they at one time fell into the "controversial" category.

However, the user-adjustable controls affecting tone quality are contested. For the purist no tone controls are desirable, "flat response" is the ideal.

Historically, tone controls started as low-pass filters, usually switched as a passive filter (that is, not containing amplifiers) designed to remove high-frequency noise; similarly bass boost filters are really a simple R-C low-pass filter having finite, limited attenuation at high frequencies. Such switch type controls were described by Scroggie [41] in 1932. The result was that radio consoles [24] of the 1930s all the way into the 1960s had a series of switches which controlled tone quality. Such a "quality switch" usually varied in complexity in proportion to the quality level of the set. A series of interlocked push-button switches that might also vary the selectivity of the set were often labeled poetically "orchestra," "jazz," "alto," "tenor," "distant," and many other titles. There was often justified suspicion that none of the switch positions in certain sets resulted in flat response. Starting in the late 1930s certain of these switch positions changed the frequency response by changing resistor–capacitor networks in the feedback loop of the power output stage.

One early pioneer in tone control circuitry is Aceves [42] who in 1930 and 1931 applied for patents granted in 1934 using inductors and capacitors as tone control in conjunction with an amplifier.

Continuous tone controls appeared first in the late 1930s, mostly as a high-frequency RC filter. This control is still with us as a "tone" control in simple radios or tape or record players and is generally "flat" in its extreme position. A variation of it is a tone control which attenuates bass in one extreme position ("speech"), treble in the other extreme, and has relatively flat response in the middle ("music").

In the years following World War II, a number of tone control circuits appeared which were able to attenuate the response progressively less as the control was advanced, had a flat response position, and then a progressively larger boost with further advance of control setting. Separate controls for bass and treble were provided, and these are still with us in essentially unchanged function.

Originally most of these bass and treble controls were passive, the repeatability of frequency response dependent upon the accuracy of attenuation of the potentiometer. Others sought to have separate boost, flat, and attenuate networks and attempted to use the tone control as a fader control between those networks [39]. Finally, P. J. Baxandall [43] developed the negative-feedback tone control in 1952, a circuit which combined a continuous bass control with a continuous treble control having input, output, and amplifier input terminals, and a common high-gain amplifier connected between the amplifier input and output terminals of both controls. This circuit gained rapid acceptance because of its simplicity and is in almost universal use today, providing unity gain in the "flat response" position, rather than an insertion loss required to be larger than the maximum desired boost.

Radio and radio–phonograph designers of the late 1920s discovered that their sets sounded "thin" at low volume. Jacobs [44] in 1930 applied for a patent for a volume control in which the bass frequencies are attenuated less than high frequencies at low control settings. His loudness control, or compensated volume control, is still with us today.

Any broadcast or recording medium always suffers from the combination of finite bandwidth and finite signal-to-noise ratio. Improved broadcasting or recording media show improved numbers, but the same types of limits still exist. A large number of schemes have been invented over the years to make the ear believe that the received or reproduced signal is improved over the unprocessed version. One of the most successful is preemphasis, where certain frequencies are boosted in transmission and then attenuated along with noise upon reproduction.

Ever since the advent of broadcasting and recording, the engineers have attempted to make maximum use of the medium. Adjusting modulation level or "riding gain" is a standard method. The compressor for records dates back to 1927 when Mitchell [45] (Columbia Records) varied sensitivity of the electrodynamic record cutter with a rectified audio signal.

The expander, at the other end of the music reproduction chain, dates back to 1931 when Cook [46] (United Research Corporation) invented the volume expander, consisting of variable-gain tubes receiving a rectified and filtered gain control signal in proportion to the input signal. Thus loud music passages could be reproduced even louder.

The problems of compression and expansion are still with us today. First, if the two are not matched, unnatural reproduction can exist. In particular, reference levels have to be maintained carefully. Second, since compressors and expanders obtain their control signal from a rectified and filtered program signal, there is a delay between cause and effect. For example, a compressor may show temporary overshoot of output, and an expander may show periods of high gain with high noise reproduction after a program peak has passed. Swishing noises and thumping

noises may be heard.

Etzrodt [47] (Siemens and Halske) proposed in 1932 that the control signal of a compressor for use by a matching expander be transmitted along with the compressed program material.

Other complete closed-loop schemes involve the splitting of the audio-frequency bands into multiple frequency ranges, compression and expansion after transmittal and then recombination, as invented by Hammond [48] in 1931. Barney [49] (Bell Telephone Laboratories) proposed a two-frequency-band scheme in 1942. The most successful of these schemes is still with us today, the frequency selective compressor–expander scheme by Dolby [50] (1965). Here multiple-frequency-range compression and expansion using the diode voltage–current law as basis over a limited volume range in multiple-frequency ranges have proven successful in many recordings and broadcasts.

All the automatic noise-reducing schemes referred to above are closed systems, that is, the program material is processed prior and after recording or transmission. Other schemes tried to obtain the most "listenable" signal from whatever the program might be.

In 1930 W. Van B. Roberts [51] (RCA) applied the automatic volume control bias voltage to a one-tube audio amplifier stage. The tube's grid-plate capacitance reduced frequency response for weak signals (or no AVC) and permitted a wider range for stronger signals.

After many other futile tries by others, H. H. Scott [52] introduced his dynamic noise suppressor in 1946. Scott realized that the effective bandwidth of the human ear varies with reproduced signal level, and that a lesser bandwidth is acceptable for low-volume signals. Reduction of bandwidth at low and high frequencies was sensed by the absence of program material in the high bass and low treble regions, respectively, and effected by reactance tubes. Scott's Dynaural noise suppressor was successful until the beginning of stereophonic records in 1957 and was used to process many 78-r/min in master recordings into long-playing records. Burwen's [53] noise-reducing system, adjusted to wide-dynamic-range program material as available today, has been able to remove the swishing problems of earlier systems by nonlinear processing.

Circuit theory advanced over the years. Although Ohm's law dates back to 1827 and Kirchoff's laws to 1845, complex quantities in electrical engineering were only vulgarized by Steinmetz in 1894.

Prior to 1932 it was thought by all scientiests that no more than 6 dB feedback could be applied to any device [54]. They reasoned that negative feedback behaved similar to positive feedback, where any more than 6 dB caused oscillation. In 1932 Nyquist proved his stability criterion, which was experimentally confirmed by Peterson in 1934. The advantages of negative feedback were systemically discussed by Black [55] in 1934, and the relations of amplitude and phase were clarified by Bode in 1940. Not until about 1945 were most of the fundamental feedback concepts made known [56].

It is, therefore, not surprising that most electronic equipment prior to 1945 contained little or no feedback. This may be the cause of published arguments in the trade press until the late 1950s about the sound of triode amplifiers and pentode amplifiers. The difference in internal impedance and distortion between designs using moderate amounts of feedback can account for the argued differences. However, these arguments have now been settled, or rather overshadowed, by arguments over tube sound and transistor sound. Today arguments about distortion, its nature, definition, audibility, and measurement persist. From some of the arguments advanced, this subject will not be resolved soon.

Feedback amplifiers for music reproduction became available soon after World War II [39]. Prior to this, adjustments to amplifiers were made only after an exhaustive graphical analysis of published tube characteristics [57]. Distortion-measuring equipment during that time consisted of wave analyzers (or selective voltmeters) which had to be tuned to each harmonic. State-of-the-art oscillators produced less than 1-percent distortion.

The situation changes rapidly thereafter. In 1949 McIntosh and Gow [58] described a new 50-watt amplifier which had a then unheard-of guarantee of less than 1% distortion at full power over the entire audio range between 20 and 20 000 Hz, and less than ¼% distortion at midfrequencies. This performance was accomplished using a bifilar wound driver transformer and a bifilar wound output transformer in a common feedback loop. This model cost nearly $300 with amplifier and power supply on separate chassis and set a new standard for high-fidelity music reproduction.

The tape recorder, the Magnetophon, which was brought to the United States from Germany as one of the spoils of war, was used in the transcribed Bing Crosby broadcasts of 1946. The popular tape recorder, the Brush "Soundmirror," used black iron oxide paperbacked type 100 tape by the Minnesota Mining and Manufacturing Company, soon to be followed by "acetate" plastic tape with a red iron oxide, type 110. In 1947 General Electric released the variable-reluctance pickup [59] with an available accessory preamplifier, containing one 6SC7 high-mu dual triode. In 1948 Columbia Records [60] introduced long-playing records, followed in 1949 by RCA's 45-r/min record [61].

In 1949 it was also possible to make stereophonic tape recordings by using two half-channel recording heads "staggered" by mounting space normally required by the full-track recording and playback heads [65].

The consumer electronics industry tried valiantly to keep pace with all these new developments. In 1935 the ac–dc radio had been the latest development, and in 1939, 1.4-volt miniature tubes permitted portable battery-operated sets which led to the 1946 Belmont pocket radio [8].

In the late 1940s the music lover could choose from several makes of equipment, the electronics built on a chassis with tubes and capacitors and transformers sticking up and the controls out front behind a spaced flat panel. When desired, it could be installed into a piece of furniture by doing cabinet work. Loudspeakers came as bare "chassis" or in a cabinet styled for "professional"

use. Interconnections were left to the user's dexterity. Separate power supplies for the field windings of electrodynamic loudspeakers were no longer required, the high-flux Alnico permanent magnet systems took the place of electromagnets.

In the late 1940s loudspeakers for home music reproduction were relatively efficient, and the average separate amplifier had an output of 10 watts. Toward the end of the 1950s the benefit of wider and smoother frequency response of the "low-efficiency" bookshelf loudspeaker was compensated by an increase in amplifier power to an average of perhaps 20 watts. In the 1950s stereo records and stereophonic broadcasting necessitated two channels, each averaging perhaps 20 watt output, or a total of 40 watts. Today, to reproduce higher peak sound levels seems to indicate an average of 4×20 watts or 2×40 watts, or 80 watts. Already, amplifiers of several hundred watts per channel exist.

Statistically, a power output increase of about 3 dB per decade cannot continue at this pace. The consequences of home-type amplifiers by the turn of the century having output power ratings in the kilowatt per channel range provide quite a stimulus to a fertile imagination.

Amplifier quality has also improved over the years. If total harmonic distortion over the total audio frequency range is used as one measure, halving of distortion every decade seems to have occurred with the average now around ½ percent.

The improvements in phonograph pickups, resulting in wider frequency response and lower tracking force, have also resulted in lower output voltages. If reference recording levels of 3.5 cm/s per channel at 1000 Hz or 5 cm/s lateral modulation are used as a "medium loud" signal, the pickup output levels have decreased at an irregular rate of 3 to 6 dB per decade. As a result, the gain of amplifiers measured between the phono input and the loudspeaker output has increased by more than 6 dB per decade. It is to the credit of the amplifier designers that the signal-to-noise ratio has not been degraded but has actually improved.

Fortunately there were several major developments which made all this possible. Electronic engineers in the tube era were often frustrated by the singularity of the tube—electron flow is always from the cathode to the other elements—they wanted a device with current flow in the opposite direction to be able to devise a better push–pull circuit or a better direct coupled circuit.

Although few realized it at the time, the solution was described in 1948 by Bardeen and Brattain [63] of Bell Telephone Laboratories. The germanium point contact transistor of 1950 was a fragile device, prone to oscillate, yet it amplified and did not require heater power. Just three years after the original announcement, Shockley's work on the theoretical aspects of p-n junctions resulted in the development of the (germanium) junction transistor in 1951 by Shockley [64] and his coworkers at Bell Telephone Laboratories.

Soon other manufacturers produced transistors for commercial use. In November of 1952 the *Proceedings of Institute of Radio Engineers* was a special issue on transistors. The then current transistor manufacturers advertised their products. Federated Semiconductor Company (sales agents for Germanium Products Corporation), Transistor Products, RCA, and Raytheon advertised products, the latter company achieving fame with the CK 721 and CK 722 germanium junction transistors introduced a few months later. These types were used by many an engineer who wanted to learn about these new devices.

The same issue also had a theoretical paper by Shockley describing "a unipolar field-effect transistor," a device that was yet to be made.

The first consumer application of transistors was in hearing-aid amplifiers, which up to the early 1950s contained usually three subminiature vacuum tubes as amplifiers.

In 1954 Regency marketed the first transistorized radio. The 1957 Radio Shack catalog [65] lists DeWald, Hallicrafters, Regency, and "Famous Make" transistor radios at about three times the price of ac–dc tube radios.

The same catalog also shows the first transistorized high-fidelity product, a three-transistor preamplifier for microphone or magnetic pickup produced by the Fisher Radio Corporation.

The first transistor high-fidelity amplifiers were produced in 1961 by Transistronics [66], the model TEC S 15. A matching tuner, model TEC 15 MPx, was also offered. In the following years a number of companies offered transistorized music reproduction equipment.

The use of more rugged transistors helped the engineers to design more reliable equipment. The author was at that time successful in analyzing the demands on performance of output transistors and devising circuits which would provide protection against excessive dissipation [67]. Since that time, protection of amplifiers by electronic means other than fuses has become standard for all high-power transistor circuits.

In 1959 Kilby [68] of Texas Instruments described a solid-state circuit in which all elements (transistors, diodes, resistors, and capacitors) were made by standard semiconductor processes. This first integrated circuit became the forerunner of all the integrated circuits used by the millions in computers, calculators, and many other applications. Soon thereafter Noyce [69] of Fairchild Semiconductor developed the planar semiconductor process which permitted isolated function of these parts. Originally devised as a means to decrease space requirements, to increase reliability by eliminating human error, and decrease manufacturing costs (all achieved), the integrated circuit manufacturers also achieved devices which were closely matched to each other. Because of this matching and more particularly from understanding the nature of semiconductor behavior, linear integrated circuits became possible. Widlar [70] of Fairchild Semiconductor in 1965 succeeded in devising the μA709 operational amplifier, an integrated circuit which has spawned all operational amplifiers used today, from instrumentation to music reproduction. Of the latter, the first commercial use of operational amplifiers as equalized preamplifiers by Scott in 1969 resulted in reduced noise and improved circuit stability.

During the 1930s the Loewe Company [71] in Germany

offered a series of radios which contained an early form of integrated circuit, two or three vacuum tube sections along with resistors, and capacitors inside a common evacuated glass envelope.

The successful transistorized designs had both signal source and load under complete control of the designer. The first transistorized record playing system, the KLH model 11, introduced in 1962, used 12 germanium transistors (Fig. 6). Packaged in a three-piece suitcase (at a retail price of under $200) and soon emulated by others, this model became the successful forerunner of today's compact music systems.

After having worked with many improvements over standard amplitude modulation systems in radio transmission systems, Armstrong in 1936 demonstrated his FM broadcasting system before the Federal Communications Commission [20]. The demonstrated superior fidelity and signal-to-noise ratio coupled with the wider bandwidth requirement resulted in the construction of experimental 50-kW FM broadcast stations in 1938, Armstrong's in Alpine, New Jersey and Shepard's on Mt. Wachusett, Massachusetts. Two years later the Federal Communications Commission (FCC) set standards and authorized FM broadcasting on 40 channels in the 41–45-MHz band. A number of stations started broadcasting, and FM receivers became available. However, World War II interferred with all this, and in 1945 the FCC moved FM broadcasting to 88–108 MHz, the "new" FM band, allowing for 100 channels. Unfortunately most of the program material was identical to that supplied, either by records or the network line, to the AM station owned by the same broadcast license holder.

Although Armstrong had specified frequency modulation, not too many engineers realized that frequency modulation might be caused by incidental phase modulation due to multipath. In 1948 Arguimbau and Granlund [72] demonstrated the need for fast limiting and a wide-band detector to suppress distortion and to capture interferring signals. The model 310A Scott [73] tuner was the first FM tuner making use of these requirements.

Fig. 6. Compact phonograph. *(Courtesy KLH)*

In 1953 Armstrong [20] demonstrated before the FCC a system of FM broadcasting which permitted two independent programs to be broadcast by the same FM station without mutual interference. The second program, modulated on a subcarrier (which in turn modulates the FM station carrier) resulted not in stereo directly, but in background music broadcasting by the subsidiary communication authorization (SCA), granted by the FCC in 1955. Previous to this date, background music had been provided, since 1935, using leased telephone lines.

Normally of limited fidelity to provide "canned music" to factories and stores, the idea of two signals on one station itself stimulated interest in stereophonic broadcasting.

Stereophonic music transmission [74] dates back to 1881 when music from the Paris opera was transmitted by two telephones to a remote location.

In the 1930s Bell Telephone Laboratories [75] demonstrated stereophonic music transmission and reproduction and Blumlein [76] showed a method of recording stereophonic information on a phonograph record. In 1957 the method of orthogonal stereophonic recording, the left channel on the inner groove wall of a record and the right channel on the outer wall, was adopted. Some radio stations began to broadcast stereo signals, usually the left channel on FM and the right channel on AM. Stereophonic recordings became popular very quickly.

Realizing the need for a common volume control, Scott in 1958 released a short-lived piece of equipment called the Stereodapter, controlling two "monophonic" amplifiers.

Shortly thereafter (in 1958) stereophonic music reproduction equipment became available, the record player initially being restricted to a pickup made by ELAC of Germany. Soon other makes began to appear.

After hearings and field tests conducted by the National Stereophonic Radio Committee, the FCC chose in 1961 a system which allowed stereophonic broadcasting [77]. Again the author was successful in designing equipment [78] which could receive these stereophonic broadcasts while excluding the simultaneous broadcast of background music.

Today stereophonic broadcasting is a normal source of program material for home listening. Similarly, tape recordings (since 1947, available prerecorded in stereo since about 1956) and most particularly tape cartridges [79] (since 1965) (recorded for reproduction of music in automobiles) and tape cassettes [80] (since 1966) along with stereophonic records are the sources of music for the home listener.

The radio, once the major source of home entertainment, still exists in ever-increasing numbers, selling at an average of 45 million radios per year over the last 10 years in the United States alone [81]. Table radios and clock radios for the home and portable radios and auto radios for the home-away-from-home comprise the bulk of the production. Because of the price competition, very few manufacturers have followed the lead of KLH (Fig. 7)

who in 1960 introduced a table model radio (model 8) which was capable of flat acoustic frequency response of all but the bottom octave of FM broadcast limits.

Radio–phonograph consoles, once the prestige music reproducers in the home, have been declining in the recent few years, giving way to high-fidelity components, which have been rising in popularity ever since their introduction in the years following World War II.

Home music reproduction has had the benefit of the almost regular introduction of a new service or a new convenience. In the last 30 years came the magnetic tape recorder, the long-playing record, the "component" amplifier, the high-quality tuner, background music via FM, prerecorded tapes, stereophonic records, stereophonic broadcasting, the automobile tape cartridge, and the tape cassette.

The introduction in 1970 of four-channel sound is still in the undecided stage because several incompatible systems exist. There are systems which mix four channels into two channels for recording and broadcasting, the original material in part recoverable by a mixing and automatic fading technique. There are systems which are two-channel and where stereophonic material is enhanced by additional delays and reverberation. Then there are systems which transmit and record four channels using subsidiary modulation techniques. Finally, there are systems of using multiple tape tracks. Some additional systems have been proposed for FM broadcasting.[2]

At this time the solution is not clear, and sales of four-channel equipment and recordings have been a disappointment to many. The quadraphonic broadcasting proposals have been analyzed and tested and are now in the hands of the FCC for further testing and possible decision. Not until there is an easily available source of low-cost program material to the average nontechnical consumer will four-channel sound become popular.

Before this happens, there is another service which might entice the public: when stereophonic broadcasting was proposed prior to 1960, there were several methods of FM broadcasting, other for TV broadcasting, and others for AM broadcasting. Interest in AM stereophonic broadcasting has reawakened, with committee meetings[3] currently (March 1977) going on and field tests scheduled for midyear. Perhaps a new service will result from this effort.

In the 100 years since the introduction of the phonograph, the attempt has been to bring the stage or the concert hall into the home. Success has been remarkable, but not complete. Fidelity has been improved and multiple channels were used for greater realism. The listening room always had its own contributing acoustics, not the least of which is the transmission of sound in both directions through walls and doors and windows. The resulting restriction of the dynamic range, and the inability to use a very large number of channels have resulted in less than perfect sound. The use of headphones has largely removed the sound transmission problem, but has introduced new problems, the restriction of movement of the wearer of headphones, his discomfort, and the lack of feedback on the acoustic image while the listener moves his head. The first two problems seem to be problems which may be resolved. The latter is a problem for the future: how to have two recorded channels of program material for the two ears and how to present them to the mobile listener, presenting him a stationary music image, predetermined by the record. The listener will then be the determining part of the feedback loop. Furthermore, how will multiple listeners be accommodated, perhaps without headphones? Also, how can multiple program desires be handled without interference to each other? Here loudspeakers with nearby electronically controlled sound absorption may provide the answer.

All of these ideas, when in the process of development, will result in new challenges which then may be overcome.

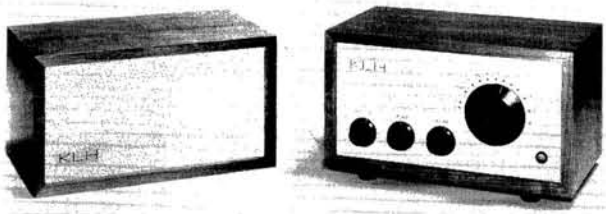


Fig. 7. Compact radio. *(Courtesy KLH)*

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Home Music Reproducing Equipment Performance and Styling

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The Magnavox Company, Fort Wayne, IN

Performance and styling are principal purchasing incentives. Anticipated good performance is the primary inducement, but appearance must conform to home decorating patterns and current life styles. A review of past changes in performance and styling, an analysis of some reasons for changing, and an appraisal of today's status should enable us to forecast tomorrow's changes more accurately.

INTRODUCTION: Musical entertainment in most homes did not change for more than thirty years after Edison invented the phonograph in 1877. They continued to play "Oh Promise Me" on the Packard Orchestral Parlor Organ and join in singing. Their music box gave an automated original performance.

A product for the consumer market will not sell unless the performance and appearance appeal to customers. Novelty may attract a few initially, but early phonographs were too expensive for most homes, did not work very well, and would not fit into parlors.

Edison's serendipitous invention was not intended for musical reproduction and had problems as a talking machine. A critic said it was a burlesque or parody of the voice. Some consonants were entirely lost and others could be confused. Sibilants were heard only in the middle of words.

The early hard-rubber Gramophone records were stamped with an etched zinc master. The etching process gave noisy grooves, and record ridges flattened quickly. The resulting sound was described as the sound of escaping steam, the rumbling of a horseless carriage, and the braying of a wild ass.

A change to shellac and powdered limestone records helped, but a critic still said the blasting noises interfered with the music, it sounded only a fifth of a cornet's tones, and its appearance was not impressive. Using wax masters radically improved the tone and noise, "dropping the hiss to a hush." Noise and record wear were reduced further when a new metal tone arm freed the reproducer from the large metal horn's weight. There were still defects, but futher improvements would soon make records last longer, sound louder, and have a more natural tone.

Most wives refused to have a phonograph in the house until after 1906. The gears and spring were hidden, but the rotating turntable, the tone arm, and the huge horn were too ugly.

A Victrola with an enclosed turntable and horn was introduced in 1906. Its piano-finished mahogany console was 4 feet high and had a lift lid. The horn pointed down. Its $200 price, about $1600 in today's dollars, was too high for many homes. Most of us can see in our mind's eye the prewar Victrola upright golden oak or dark mahogany consoles with its square lines with corner posts, squared-dome lid, and shutters or doors over the front horn opening.

Home decoration had changed from the neorococo through a neogothic period with huge square lines and multicolor inlays to the prewar Turkish corner of Moorish lines. Columbia made Grafonolas to fit into many decorating plans.

Added competition and a 1913 dance craze started a sales boom that lasted until deflation hit in 1920. More than two million phonographs were sold in 1919, many with very expensive cabinets. Some Vocalians were $2000, more than a year's wages for many workers. Most

buyers were more interested in matching Windsor oak furniture.

1920s sales slump became a real depression in 1921. Workers switched back from silk shirts to cotton. Some phonograph prospects bought player pianos instead. Victrola cabinets still looked like 1906, and there had been little improvement in performance for years.

Phonograph sales dropped further with the 1922 radio boom. Many were listening to the latest music with no expense for records. A few hybrid models appeared, called phonograph radios. Radio's sound was not very good, but it gave critics a basis for comparison and the phonograph lost. Its 168-Hz to 2-kHz range missed bass notes and overtones, giving a metallic quality or tinny vibration to orchestral music. The 1¼- to 1¾-minute recording time made overfast tempos the rule. Pianos often sounded like banjos.

A 1924 flat-top Victrola had a space for the customer to insert a radio. Brunswick phonographs included Radiola radios. Others followed.

Electrical recording started in 1925 with a 100-Hz to 5 kHz range. The Orthophonic Victrola (see Fig. 3 of "Emile Berliner, Eldridge Johnson, and the Victor Talking Machine Company," this issue) had a better horn, but it still had an acoustic reproducer. Electrical recordings did not sound right on acoustic phonographs, giving a squeaky tone with exaggerated sibilants according to one critic. Another said it was like a window to the concert hall.

Brunswick's 1926 Panatrope had the first all-electric radio phonograph combination, styled much like the uprights. Victor's all-electric Electrola arrived a little later. Their first record-changing phonograph was introduced in 1927.

Phonograph production stopped with the 1929 crash and depression, never to recover as a separate product line. A few phonograph-only consoles were built by radio manufacturers around World War II and a few more when stereo records were introduced. Except for these and portables, they appeared only in radio-phonograph combinations.

RADIO

The radio years started in 1923 or later for most homes, but pioneers listened to broadcast music much earlier. Home builders of early receivers could hear Fessenden's broadcasts in 1906, and several stations were broadcasting by 1912.

Receiver fidelity was still poor, limited by the audio transformers and the horn speakers, but the transmitted music was the latest from Broadway and Tin Pan Alley.

Stations were owned by newspapers, hotels, and large stores for prestige value. Some call letters were WGN for World's Greatest Newspaper and WLS for World's Largest Store. Some slogans were The Nation's Station and The Voice of Dixie. Direct advertising was ruled out, so artists and orchestras took names like the Gold Dust Twins and A & P Gypsies so that they could be paid.

WBBM started jazz broadcasts in 1924, soon followed by others. WLS started the National Barn Dance and WSM had mountain music. KFKB was supported by Dr. Brinkley's goat gland lectures, but became the most popular station with hymns, banjos, accordians, and the College of the Air. There were better receivers to listen to the better programs, all "good-neighbor nonradiating." Most were multidial neutrodynes, some were superhetrodynes, with one superdyne.

Reception was frequently a group activity. Neighbors would gather on silent night. If the signal was too weak for the loudspeaker, several earphones could be connected and split so that six at a time could hear with one ear. Popcorn and cider were passed while they listened to Harry Snodgrass play "The Prisoner's Song" from a real prison. They listened until he played his theme at "Three O'Clock in the Morning."

COMPETITION FOR LISTENERS

All of this added up to competition between the radio and the phonograph for listeners. The radio had the real advantage of presence; it was "live." However, this advantage was not to last forever.

Radios were accepted as part of home decoration. Some stylists were following authentic period details as closely as the mechanics could permit. Some were expensive. A Zenith 10-tube high boy sold for $800. In 1920, DeForest Radio had one model for $1450. In 1926 a Zenith 10-tube Spanish-styled console sold for $2500; the same in Chinese motif was $1700; with Italian dominance, $1250; done in "English" it was $800; but as an American colonial deluxe console, it cost $650. However, the price range for the period between 1920 and 1930 was from $50 to $200 for 90% of the product offered. Most styling was neoclassic, as shown in Fig. 1, often called the waterfall period. The top front and the sides were rounded. Fake inlays and highly figured panels were generously used, even zebra wood. Philco started their own "Hollywood-Massive" designs and Majestic used neogothic with molded imitation carving. Zenith and Midwest featured huge round dials. Chairside cabinets were introduced in 1936 and continued for thirty years. There were a few cabinets with period lines.

Materials were in short supply after World War II, but anything that could be built would sell. Large consoles with very small chassis were common in 1946, about the last year for console radios. Table radios and radio–phonographs gave maximum return on material usage. Many combinations still looked like radio consoles with baffle areas that hinged down or tilted out for access to changers that moved out with the baffles or slid out on drawer glides. Most consoles provided for record storage, usually hidden behind hinged panels.

After 1947 much radio-phonograph styling followed a pattern initiated by Magnavox and Capehart. It was a chest on very short legs with the front roughly divided into quarters. The top doors swung out or were fastened together and tilted down for access to the radio and changer. One bottom quarter usually opened for record storage, with the other quarter fixed in place for the speaker baffle. The bottom sections usually framed grille cloth covered by gold or brown wire mesh. Several

choices of finish were common, often including blonde and ebony. Period styling was suggested by leg shape, door pull design, and an occasional gallery rail. A few manufacturers stayed with prewar radio console lines, and a few authentically styled Hepplewhite and Duncan-Phyfe cabinets were made. There were no other major styling changes until stereo in 1958.

Audio Fidelity made sample stereo records in 1958 with train sounds and music by the Dukes of Dixieland. Dealers had stereo phonographs and radio-phonographs by the time stereo records were on sale. Most of these had two cabinets. The second cabinet usually included record storage as well as the loudspeaker for the added channel. Some were phono-only models.

Some stereo models had new styling, a long low console with sliding glass lids having a marble finish in colors to complement the cabinet finish. Performance was also adequate with 15-inch woofers and horn tweeters. Several consoles in those years had ultramodern lines, blonde or ebony with large gold pulls.

One small phono-only stereo console in 1959 had the woofers mounted in the ends of the cabinet so that the middle and low frequencies would be reflected from the sidewalls of the listening room. This increased the separation and spatial effect, allowing the use of smaller self-contained stereo consoles. The principle is now used by several high-fidelity speaker unit manufacturers.

The early solid-state or "transistorized" amplifiers had serious reliability problems and many hybrid units were built using both transistors and tubes, often with Nuvistors in the tuners. A successful all-solid-state stereo phonograph was mass-produced in 1961. It was a small table model with self-contained loudspeakers mounted at an angle for better separation.

An all-solid-state radio-phonograph with stereo FM, a 100-watt amplifier, heavy woofers, and horn tweeters was first produced in 1961. When shown, its sound filled a large New York theater with a capacity audience. Acceptance was good despite a high price because of sound that other consoles could not match. This series had large and heavy cabinets.

Fig. 1. 1936 neoclassic radio-phonograph.

Styling followed the trend to Danish modern in the mid-sixties with very long and low boxes on various types of legs. One served as a coffee table with both fixed and sliding top panels. Such long boxes lasted until 1969 with variations in legs and trim, sometimes with a gallery rail.

Serious shortages of wood for both solids and veneers have handicapped styling since 1970. Most cabinets now use pressed wood materials where possible with a rolled-grain finish or covered with wood-grained vinyl. Complete cabinet sections are often molded of plastics that can be finished like wood. The molds are expensive, inhibiting frequent changes. Authentic styling is often impossible and many follow only "period influences."

Many customers have objected to compromised styling, and several quite authentic specialty models have been produced since 1972, including breakfronts, dry sinks, Queen Anne chests, spice chests, drum tables, drop front desks, and antique work benches.

A few manufacturers captured a large part of the console market in the seventies by installing low-performance imported equipment in low-quality cabinets that were also imported or made here by the assembler. Some are imitation fireplaces or usable as bars, but most are in very long consoles with heavily decorated plastic sections. Most of these are sold at low prices in discount stores where there is little opportunity to judge performance or inspect the cabinet for quality problems.

This group of manufacturers started claiming high power outputs a few years ago, using such terms as IPP for instantaneous peak-to-peak power, a purely imaginary figure, much larger than the actual output. They dropped all reference to power output after the FTC required a standard rating method.

Starting in the early sixties a few manufacturers packaged regular console equipment in separate wooden cabinets; tuners, amplifiers, record changers, and loudspeakers. These were sold to customers who wanted the flexibility of separate components but did not want to pay for high-performance units. Several customers also liked buying prematched groups or systems. Some items were combined, and increased sales allowed better tooling and cabinet styling. Such products are now classed as modular or compact systems and are offered in a wide range of prices, with appearance and performance varying with the price.

HIGH FIDELITY

One of the first known uses of the term was by Philco when they called their 1934 model 200X a high-fidelity radio, true for that time. The hi-fi boom began with the LP record in 1949 and loud rock in 1955, and mostly started with college students. They went to audio fairs or read *Audio* and saw components they could buy or build and combine to give them the sound quality they wanted. This

demand had been anticipated by several engineers and scientists who were also unhappy with radio's progress. After World War II they started to design and build higher performance equipment. Even operating independently, each one's progress helped the others.

Several things helped the hi-fi boom: LP records, loud rock music, electronic instruments with frequencies difficult to reproduce, stereo records, stereo FM, the Beatles, protest music, and disco.

Component styling is not intended to match home decoration, but to appeal to the customer as an individual item. Components from one manufacturer usually have the same styling. There have been several trends; the wedge look, the white look, the black look, and the instrument look. Some have been repeated.

Four-channel equipment was introduced and heavily promoted in the early seventies, but has never sold as well as expected. It took ten years for stereo to be accepted in the marketplace, but four-channel has some special problems. Wives object to the rear loudspeakers and the additional, hard-to-hide wiring required for them, to the furniture rearrangement thought to be necessary for best listening, and to the added cost. These objections are stronger for new homes with smaller rooms and floors that frustrate concealed wiring.

TODAY

Superfidelity would be a better term for the expensive high-performance equipment available to the audiophile now. The reproduced program is often better than the recording or transmission.

The differences between competing units are no longer possible to detect by the most acute human senses. Many can deliver sound levels above the threshold of pain with distortions too small for the ear to detect. Frequency ranges exceed the limits of hearing.

More features are available than ever before and at moderate cost. Lower priced models have recently been added by major manufacturers to broaden their sales base. Some of these outperform expensive equipment produced a few years ago.

Styling variations are available to satisfy almost every customer. This is also true of compact and modular system styling. The equipment shown in Fig. 2 was from a period with fewer variations.

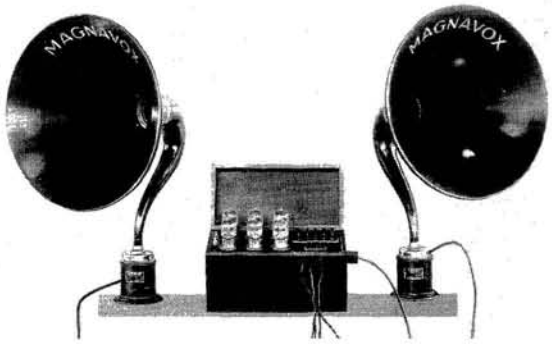

Fig. 2. 1920 two-channel audio with three-stage amplifier.

New compact systems were introduced this year with low profiles, much like components made in Denmark. This may be a new trend for system styling.

There are still low-priced modular systems for sale, often with unknown brand names. Their styling attracts attention when displayed on shelves in discount stores where sales assistance is minimal. So much of their cost is allotted to appearance that little is left for performance. Most are sold without demonstration.

Fortunately for the future of home music reproduction, the trend is toward higher priced systems, with more features and better performance. Some new modular systems and consoles now perform as well as the lower priced components. The dividing line between high- and low-performance units has blurred even more by new "matched component systems" that look like modular systems.

Home music centers were reintroduced this year and seem to be well accepted. They look like modular equipment permanently mounted on shelf units or in cabinets that resemble open front consoles. Most of the equipment has been styled for a studio control desk effect, often with extra controls to help the illusion.

One of the better new consoles also looks like a control desk when its fold-down double door is opened. To illustrate product recycling, Fig. 3 shows a 1941 version of a home music center in an Adam Secretary console.

TOMORROW

The scheduled introduction of pulse code modulated (PCM) recording next June will surely change other digital recording projects from "hold" to "crash." The PCM unit will be shown as a Betamax accessory for recording and playback of high-quality audio. An 80-dB dynamic range is claimed which means noiseless reproduction and

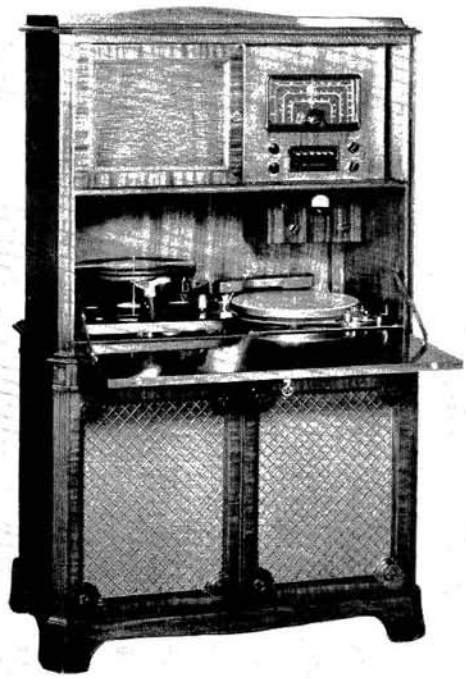

Fig. 3. 1941 Adam Secretary music center.

less demand for compander and noise reducer systems. Prerecorded tapes with good video and PCM audio may follow.

Video disc players and an initial catalog of discs should also be available soon. These can provide good pictures and sound with more flexibility in playing. The discs are expected to cost less than prerecorded tapes.

A successful marriage of home video and audio equipment seems likely now that good performance on both is possible with a single player. Popular records of the future will permit both watching and listening to the performer. Early movie jukeboxes were popular but could not be supported with software.

It is also likely that this video/audio (vaudio?) center will contain a microprocessor for interactive games, lessons, and creative activities.

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Great Music for All and for All Occasions.....

by WARREN REX ISOM

The first music was produced when the first man realized that he enjoyed the sound of his own voice; the first group was formed when he and a few of his companions learned that it was more enjoyable when they combined their vocal sounds in what was little more than accidental unison, *a cappella*. They found that banging on a hollow stump—the world's first musical instrument—added excitement and attracted cautious but curious interest from those within earreach. So, musical entertainment was launched and the first seeds of the recording industry were planted.

The recording industry is based upon the universal interest in music that has existed from the beginning of time. As with the interest in sports, it is a self-perpetuating one that is spontaneous and self-rewarding. Involvement in sports is as natural as exercise is necessary, particularly in the sedentary lifestyle of today that is enveloping so much of the world. But both interests have evolved to the point where they are now organized and promoted, and different forms of each are competing for participants and spectators.

Extensive enjoyment of music comes only with organization and direction. The early churches and religious organizations were dependent upon the existence of musical participation, both actual and spiritual, by their members. A great part of their resources and energies was devoted to the development of music for religion, including the instruments, the choirs, and the symbolism of musical prayers. The recognition of music as part of the total entity of the organization was also made by nations, kingdoms, dukedoms, principalities, local civic clubs or lodges, and patriotic organizations as well as practically all military units composed of 100 men or more.

The musical comedy called the *Music Man* tells the story of the establishment of boys bands in the many River City(s) of the United States. But this is not where the interest in music begins. Very early the toddler is introduced to the enjoyment of the simple sounds of nursery tunes; later, in elementary school, the student is encouraged to understand the structure of music, and to participate in the playing of rudimentary instruments. This is soon followed by group activity bent on ultimately qualifying the student for the school band. The school is the crux of the success story of the interest in music in the U.S. It has its counterpart in most of the other countries of the world.

The high school band does more for the maturing of interest of students in music than the Little League does for baseball. Conservatively estimated, there are 40 000 high school bands in the U.S. This could mean that on any given Saturday during the football season, "Hail, Hail, to Old Notre Dame" is tootled by hordes of high school students scattered over the country, four million strong. The rate of recruitment is about one million per year because that number graduates every year; some to college and university bands, to rock groups, army units, dance bands, but all—almost without exception—to a lasting interest in music.

The interest in music at college level continues high. A few years ago, this group was asked to list their choices of professions and careers. Eighty-five percent indicated that a career in music was second only to their fields of concentration. So long as this degree of interest continues, it is expressed by attending campus musical events and by buying the latest releases of their peers who have made the grade, and of those artists who have made the grade with their peers. This reaction to the records currently offered is repeated by all of the most active buyers; namely, they buy what they personally like and what their peers like. They do this for about 8 years—throughout high school and college. During this time, some of them may buy as many as a thousand records, but a significant percentage will buy more than 500 records. Then, after college, the buying continues for another 4 or 5 years at an unabated rate. This group is continuously replenished by new members graduating into it year after year. This accounts for the overwhelming popularity of pop records.

With classical records, the situation is different in at least two respects. First, for those who enjoy this type of music, it is a world that has reached perfection and permanency, not one of dynamics and change. Because of this a record library of 50 albums can be more satisfying to the classical music listener for a lifetime than one of 1000 albums to the popular music devotee for a year. Much of the library of popular records can lose its appeal when the next release is available, and the larger the number of popular releases, the less the time span of interest in each.

The result of all of this is that the classical record buyer has 50 years in which to amass a library of 50 records for an average of one per year over the entire buying period; the buyer of popular records gathers ten times as many records in a fifth of the time. This brief review, which uses

figures of the right proportions if not of exactness, explains the great effort that is required to sell classical records in sufficient quantities to be profitable. The sad effect is that if a great effort is mounted on behalf of a worthwhile selection, it does not insure success. On the other hand, the same investment in the promotion of a popular release practically insures success and a larger return. The amazing thing is that in the recording industry today classical records are even released. In the early 1900s, before the first demand for classical records (including opera) had been met, even provisionally, the Victor Company advertised three opera stars and only one popular artist, along with the following disclaimer and explanation: "Our business is just the other way." They meant that promotion efforts in behalf of popular records is nine times more productive than that for classical records.

Recorded music is the adjunct to so many other business and human activities that within the industry itself there are few competitors, but many associates. Records for the home do not compete with recordings for the car; in fact, it seems, that there is little or no conflict between records and tapes for the home. The tape recording business has been very largely a business within a business; its sales have been in addition to record sales, not instead of. The single record supplements the long playing album. The radio industry is a great ally of the record business; so is the jukebox, the movies, the theater, and the dining room.

There are so many uses of recorded music that the demand for it grows at an accelerating rate and the industry which produces it has been thought to be depression-proof. It is used as auditory wallpaper; that is, to make a pleasant sound environment that would otherwise be drab, monotonous, and bare. It has been used to dispel loneliness and to withdraw from reality. When people refer to "our song" it is a happy reminder. Folk ballads also engender sympathetic empathy. "Music to _____ by" eases the tedium and enhances the joys of everyday life. Music is used to show off audio prowess and as a symbol of affluence; it allows mastery of one's moods and the enjoyment of sweet sounds. Music inspires men to their greatest effort, be it a football team's response to their bands playing ". . . shall win overall . . ." or the Scots army rallying to Wellington's Highland Pipers to win the Battle of Waterloo.

The record industry is great because people enjoy recorded music. But its appreciation does not stop with human beings; animals too, are lulled by its tones. It was Arion of Sicily who in 600 BC was rescued by an appreciative dolphin after his song for his life failed to stop pirates from throwing him overboard. We know that music was used to increase milk production from cows. We also know that the Greek Orpheus charmed plants, even trees, with the music from his lyre. "Music to grow plants by" will only add yet another to a long list of uses for recorded music.

The Graphic Arts and the Record Industry

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It should be no surprise that record packaging, as part of a field as volatile and creative as the record industry, has been the chameleon that it has through the 100 years of recorded sound. The distance between the packaging of a Berliner disc—an unmarked, grey paper sleeve—and 1971's "Chicago Live at Carnegie Hall"—four long-playing records in cardboard sleeves, boxed, with two posters and a full-color booklet included—suggests not only that changes have occurred, but that those changes have been revolutionary as often as evolutionary, and that the graphic arts have had as great an impact on the growth of record and tape sales as any other single factor.

The importance of the graphics work involved in any record today is pointed up by the anxiety its design often entails. Artists and managers measure their importance to a record company by the amount of control they have over album covers. Marketing managers complain that a bizarre design camouflages the artist's name, or that a suggestive cover may keep it out of the racks of such retail giants as Sears Roebuck. Promotion personnel leave sales meetings muttering that a better cover would have created more interest in the record at radio stations.

Are they exaggerating the importance of careful packaging? Sales figures, the record company's all-important bottom line, assert that they are not. Certainly radio airplay, word of mouth, the means by which the consumer hears something he likes are at the core of record and tape sales, but time after time the buyer has shown that he does judge the "book" by its cover. Store owners know how important impulse buying can be, how often the customer who comes in for one record will have another catch his eye. In large part that impulse sale or multiple purchase has been made possible by record packages encouraging browsing, and by record departments designed to foster such shopping.

Things have not always been so convenient for the record shopper though, and the days when one bought a record by catalog number, from shelves behind a counter, are not so far away. Even today, the merchandising of eight-track and cassette tapes seems to be experiencing the same growing pains that records went through in the first half of this century. Record packaging and graphics have come far, and the lessons a century of development can teach say much about how those techniques have built record sales.

Emile Berliner cut his first flat record discs in 1887. His American competitors, Thomas Alva Edison and others, put their money in cylinders, 2 and 4½ inches in diameter, wax-coated at first, later molded of Amberol or other materials. Had the cylinder won out in the battle for consumer preference, record packaging today might resemble that of soup cans, but fortunately for art directors at labels everywhere, the disc finally won a struggle that lasted more than three decades. Edison conceded a change was coming when he introduced his own disc in 1913, but his sales people continued to argue the sound fidelity and price virtues of the cylinder until its production was stopped in 1929.

Berliner's phonograph discs, made initially of vulcanized rubber and then (in 1897) of shellac, a quarter-inch thick and recorded on only one side, could hardly have been packaged less imaginatively. Just the idea of recorded sound, in those early years, was sufficient novelty to make the records sell. Who needed graphics?

Grey kraft paper bags or envelopes, just wide enough to contain the discs, usually 10 but sometimes 7 inches in diameter, were the humble forebearers of modern record jackets. Before 1900 phonograph records began to bear round paper labels in the center of the disc, identifying the selection and the artists, and almost immediately a hole of like diameter was cut in the side of the envelope to let the label show through.

The center labels, generally silver ink on black paper undistinguished by typographic novelty or eyecatching design, remained essentially unchanged until 1901, when the Gramophone Company in Europe brought out a series

of 10-inch recordings by Chaliapin and the other stars of the Russian Imperial Opera. These were set apart by their red labels, and were marketed as Red Label records. In 1903 several Red Label releases were issued on 12-inch discs for longer playing time, and naturally the envelopes grew with them.

When Nellie Melba agreed to let the Gramophone Company press and distribute her privately recorded singing in 1904, she stipulated that her records be distinguished by labels printed on mauve paper, beginning a tradition of artist control over packaging that has resulted in some of the most beautiful and elaborately designed jackets—and many of the most expensive headaches—the record industry has seen.

Technical advancements in pressing methods brought thinner and thinner shellac discs. Early in the new century Odeon in Europe, followed quickly by Columbia in the United States, began to manufacture records with grooves on both sides, and therefore with twice the playing time. Two sides meant two labels, and two round holes in the same plain record envelope.

Not only were such paper sleeves unaesthetic, however, they did little to protect the vulnerable discs from dirt, heat, and moisture. Records warped in shipment from the factory were commonplace, the envelopes providing no mechanical support.

Manufacturers hit upon "record albums," patterned closely after the popular and novel photo albums of the day and frequently made by the same firms, as a solution. Both were someone's idea of what a finely bound book might look like. Typically, a "record album" for either 10- or 12-inch discs consisted of a leatherette cover, decoratively stamped on the spine like a bookbinding, and containing as many as 12 kraft paper pockets, each with holes in the center. The record owner could thus flip through his collection in a binder which also offered some protection against dirt and warpage. Record companies also began providing glassine or paper inner sleeves, also with holes cut out over the label area, for use inside the album pockets.

Companies limited their orchestral or individual performances in those days to what would fit on one or two sides of a 10- or 12-inch disc. Like feature films on television today, operas and symphonies suffered drastic cuts to fit the playing time of the record. Sensing a market for longer works, Odeon in 1909 brought out a four-disc package of Tchaikovsky's "Nutcracker Suite," complete on eight sides, packaged in an album specially designed for the records. The great success with which the package met led other companies to release two-, three-, or four-disc sets of other classical favorites.

Not much separated these specialized albums from their leatherette-covered predecessors. The spine and front of the album were now stamped with the title, composer, and performer of the work. The accommodation of full length operas or orchestral performances eventually resulted in sets of as many as 20 records contained in three albums.

While sound quality improved remarkably during the teens and twenties, with electric recording techniques replacing acoustic ones, packaging stagnated. Some companies had adopted blue, yellow, or other colored center labels for their records, but the outer sleeve was still most often of the same unmarked brown or grey kraft paper.

The merchandising of records lagged along with packaging. Retail outlets "displayed" their wares stacked flat or on edge, on shelves of pigeonholes protected by a counter. A customer wishing to buy a record would consult one of many catalogs listing popular and classical releases, then ask a clerk for the disc. Phonographs on the counter, and in later years semiprivate "listening booths," helped the customer decide on his purchase. Browsing and impulse buying could be done only through catalogs, almost never through studying the discs or albums themselves.

Depression, tight budgets at record companies, and then, with World War II, shellac shortages and War Production Board restrictions, made innovations in record packaging and design almost impossible. Then in 1943 the company that eventually became Ivy Hill Communications approached Jack Kapp of Decca Records with a suggestion: instead of simply stamping the album cover with lettering, the company said, why not substitute a full-color design, printed on paper, and pasted on the cover? To carry the idea further, it was suggested that the inside front cover and the back cover could be printed with pictures of the artists, notes on the performance or the work, or other information of likely interest to the buyer.

After some initial reluctance, Decca bought the idea and released copies of "Desert Song" with covers using two-color printing techniques. Later that year, Decca's original cast recording of "Oklahoma," in an album with an illustrated cover, met with sales of almost a million and a half copies, and the record industry was sold on the new idea.

The printing methods that effected this revolution had been developing steadily since the nineteenth century. Throughout this time, photographic and typographical innovations had streamlined a basic process that has, at its core, remained unchanged. Mechanical improvements in the presses themselves have made an enormous difference: where Ivy Hill could print perhaps 2000 sheets per hour 30 years ago, today we can print 8000. The number of different inks at our disposal has increased. Chemical changes have made the inks more scuff and dirt resistant.

At its most basic, a four-color print of a given design today begins with the taking of four photographs of the design, each through a different filter—yellow, black, red, and blue are standard, although any color could be used. Each negative is transferred to a printing plate, with each of the four plates then inked with a different color. Blank paper or board is then passed across each plate until all four colors have been printed.

Modern plants generally print up to six colors in one operation. The ink on sheets coming off the press contains chemical agents that air-dry it in a few hours, after which the imprinted cover is cut, folded, and glued. Remarkable as such a modern operation would seem to a printer of 50 years ago, the elements of the process are now as they have been for most of this century.

With a picture permanently established on its cover, the

record album itself now began to metamorphose. In the mid-forties changeover from shellac to vinyl records reduced the weight of each disc by as much as 85 percent, and with the advent of the "unbreakable" record, less protection was required of the album jacket. With shipping costs plummeting, record companies were also freer to experiment with their packaging.

For Frank Luther's 1946 reading of "Tubby the Tuba," Decca asked Ivy Hill for a special package for children. The firm devised a boxboard construction consisting of a pocket and a foldover flap, die cut and glued, and instead of printing the design on paper for mounting on the jacket, successfully attempted to print the picture directly on the board, running flat sheets through the printing press, making this 78 the industry's first such package.

In 1950 the Record Company of America (not to be confused with RCA) was promoting a very-low-price disc line to department stores, and Eli Oberstein of that company asked Ivy Hill for the "cheapest record jacket ever" to go with it. Modifying the "Tubby the Tuba" design, Ivy Hill printed a series of standard 7- and 12-inch record jackets in four colors directly on clay-coated chipboard. The printed jackets were also die cut, folded, and glued, then imprinted with individual titles for each particular record.

Recording techniques now fueled the development of new graphic styles and packaging forms. In June 1948 Columbia introduced its breakthrough, the 12-inch 33⅓-r/min long-playing record. With microgrooved vinyl allowing 23 minutes of playing time per side, the need for multirecord sets for longer works was largely eliminated.

To contain this new type of recording, the Columbia art staff, Bob Jones and Alex Steinweiss, created a new package consisting of a printed cover sheet pasted onto 24-point chipboard. This mounting operation, and the forming of the laminated board into a record jacket, was begun by a Brooklyn, New York, manufacturer of folding cartons, Imperial Paper Box Company. Without an inside front cover upon which to print, Imperial printed the black-and-white liner notes on the back of the package, creating what is still the conventional single-record jacket.

Rather than placing the new long-playing records directly into the cardboard jackets, manufacturers put their products first into protective white paper inner sleeves, initially glassine-lined, with the familiar holes in both sides.

For recordings that still required two records, manufacturers introduced double covers and double liners, both usually printed in full color, laminated to chipboard, and forming jackets with a pocket in each leaf. These four-panel jackets were sometimes used just for single records, purely for promotional impact, with the unneeded pocket "frozen" shut with glue.

These single- and double-record jackets became far easier and less expensive to manufacture than the cumbersome albums they replaced. This permitted record companies to invest in better art work and printing without raising costs beyond reason. Creative art directors soon turned the record cover into an art form, and illustrators sought out this new and lucrative market for their talents.

Meanwhile across town, as it were, RCA introduced its own new recording configuration. The company chose a lightweight 7-inch vinylite disc, playable at 45 r/min, to compete with the LP. The smaller, lighter disc held as much sound material as a 12-inch 78 r/min disc.

In search of something superior to the brown kraft sleeve to help sell the new 45s, Ivy Hill introduced first a two-color 7-inch sleeve on white stock, followed soon by a four-color sleeve printed on coated "slick" paper. Sales of 45s in the new packages responded dramatically. Both universal sleeves and selection-oriented individual 45 packages were made.

Yet another packaging innovation took shape to accommodate those selections requiring more than one 45. This new double-record album generally had full-color printing on the front and back covers, and one, two, or four colors on the inside spread containing notes and illustrations.

Only two years after the introduction of the 45, in 1950, RCA announced it would also begin pressing LPs, and with most manufacturers producing both configurations, the battle between the two ended, leaving the 78 as the only casualty. Convinced that the LP would eventually dominate the market place, Ivy Hill and a German manufacturer developed new high-speed machinery to produce more rapidly the standard 12-inch paper inner sleeves, now printed on offset paper in one or two colors, then cut, folded, and glued automatically.

This new technique made it possible for the record company to list on the inner sleeve additional selections by the same artist, or other records of the same label. Ivy Hill technicians developed the means of reducing and reproducing album art in color or black and white on the sleeve to stimulate sales of other discs sold by the record company. For the center label, the firm innovated running inks of all colors, so the label was no longer restricted to a silver imprint on one-color stock. Ivy Hill also perfected the technology to print record labels in full color without blistering or peeling under the heat and pressure of the record press.

Stereo, and the decision to simultaneously release most records in both monaural and stereophonic versions, created new packaging problems, one of which Ivy Hill solved with a new jacket which read "monaural" at the bottom and "stereo" at the top. As the marketplace demanded, the jacket fabricator trimmed off one or the other to suit his needs. When "compatible stereo" emerged as the sole configuration in the late sixties, the way was clear for a resumption of direct printing on board (which had been tested several times since "Tubby the Tuba"), and the present era of graphic design and packaging of records had begun.

One need only look at the differences between a record store in 1940 and that same outlet in 1970 to understand the merchandising revolution which full-color printing on record jackets created. Jukeboxes and radio stations that featured records instead of live music had made the listening booth obsolete. Merchants recognized that there was more to a record sale than sound, that an eye-catching design or a pretty face worked for record covers just as it

did for any other product. Records crawled out of their cubbyholes and into racks and tabletop bins that invited casual browsing.

The modern record store, then, often resembles a gigantic point-of-purchase display for the sale of albums and singles. Elaborate full-color album covers vie for the customer's attention, underscored by any number of hanging or standing mobiles, full-scale cardboard figures, posters, and special display racks, all in color as well. New rafts of these merchandising aids arrive with each month's new releases, so that, ideally, the customer who comes in with a specific record in mind can spot it half the store away, that is, unless his attention is diverted by another cover before he gets to his choice.

The basic technical advance underlying this sea of colors is the steady increase of those record covers with designs printed directly on board, with the board itself run through the sheet-fed printing press. As the demand for more and more full-color covers grew steadily through the forties, fifties, and sixties, technology met the need for machinery that would print more cover sheets and boards more quickly. Printing firms that specialized in record jackets evolved from those which had begun such jobs only as a sideline, and with such specialization came techniques that permitted more than one printing job to be handled on the same sheet run.

Now as many as 20 different covers can be printed at one time, utilizing just four colors to achieve a full rainbow of effects, through printing methods much like those used by magazines to print advertisements and illustrations together. The rapid improvement in photographic techniques and materials has led to similar strides in the quality of the color printing, four color or duotone, that is the basis of album art.

As quickly as the printing of full-color pictures on the inner sleeve became common practice, artists and record companies forced the exploitation of the two extra surfaces for printing lyrics, pictures of artists, and additional artwork. With the time-honored round holes often gone from the sleeve, possibilities expanded even further.

The center label, too, has progressed in recent years. What was once a plain, round black sheet is now frequently a full-color picture, whether tailored to a specific artist's desires or standardized for a giant company. (Warner Brothers' "Beautiful Downtown Burbank" label is a prime example.)

The next step has been the replacement of paper with coated "slick" board for the inner sleeve, a practice now gaining adherents with each passing month. The customer who opens an album at home now often sees an inside package that would put to shame any jacket he could have seen in a record bin a decade ago. Along with one, two, three, or more stereo LPs, his purchase may contain a lyric sheet or libretto, posters on plain or coated paper, a full-color souvenir booklet, glossy photographs of the artist, or, in the case of Stevie Wonder's current best seller, "Songs in the Key of Life," an additional EP (extended play), a 7-inch 33⅓-r/min disc with four additional songs.

Much as a horticulturist develops beautiful if unwieldy strains of flowers, record companies in search of greater sales or placated artists have striven to outdo each other in the creation of elaborate album covers. The enormous sales of many rock releases have made them the most frequent subjects for such experiments, and if one feels such extravaganzas as Santana's multipanel "Lotus" album (never released in this country, reportedly because its package makes it too expensive for its company, Columbia) or the Chicago or Stevie Wonder albums mentioned above mark the crest of the trend, tomorrow's release schedule is likely to prove otherwise.

Of course, albums and singles have not been the only recording configurations available to the consumer. Before the stereo disc was released by Audiofidelity in 1958, stereophonic sound was available only on tape, and the momentum provided by that advantage has kept reel-to-reel, eight-track, and cassette tapes an important growing sales item.

By the time reel-to-reel tapes entered the marketplace, a full-color picture on the 7-inch hinged-cover set up boxes that contained them was easily produced, generally recreating whatever was on the cover of the same recording in its long-playing configuration. Notes and such could be printed on the inside front or back cover of the tape box.

Prerecorded reel-to-reel tapes never achieved the sales blank tapes did though, and it was on eight-tracks and cassettes, with their adaptability to automobile and portable tape players, that manufacturers staked their chances.

The eight-track, pushed initially by RCA, first gained ground in cars and then in the home. As it is currently produced, the eight-track can be packaged in any number of graphic styles, almost all of which involve a label that wraps around the cartridge and is glued in place. These labels, printed in color, normally bear a reduced photo of the record album cover and a list of the titles contained. The cartridges themselves are then boxed in cardboard containers (five different styles are currently in use) with die-cut windows that allow the printed label to show through. Most of these boxes are open at one side, and if laid on edge allow the title on the end of the tape to be read. The boxes are commonly discarded after purchase.

Cassettes, originally a Philips brainchild, are substantially smaller than eight-tracks, and use a more elaborate, expensive form of packaging. The standard container is made of clear plastic through which a color label can be read. Some companies use an opaque box with the label pasted on the outside. RCA has recently started to package its cassettes in printed cardboard boxes. Perhaps because of their more substantial nature, or because of the greater vulnerability of the cassette, these boxes are more often retained along with the tape.

Although they have come to comprise a substantial fraction of total recording sales, tapes have never come close to parity with discs in the competition for the consumer's money. Expensive, complicated equipment and the confusion generated by three warring configurations have had a lot to do with that lag, and the current LP price boost has only recently put album and tape prices into the same category for the first time. But a return to the retail store, the proving ground of graphics and packaging,

tells the full story.

Cartridges, compared to albums, are small in size; by the same yardstick, cassettes are tiny. Housed in glass cabinets or behind counters to prevent what would otherwise be easy pilferage, stacked many units high with only the minute type on one edge visible, these tapes are only slightly more accessible—or "browsable"—than the pigeonholed, kraft paper packaged 78s of the nineteenth century. And with a surface area having only a few square inches available for printing, their graphic possibilities fall somewhere between those of a paperback book and a pack of cigarettes.

If there were no LPs in the store, only the various display materials on hand would promote a given tape. Put another way, the tape cartridge or cassette has been a merchandising hanger-on—it cannot sell itself.

One recent attempt at solving the problem took the form of the "spaghetti box," a long cardboard container which can be displayed on racks—wall-mounted or rotating—either hanging or stacked like paperback books. The weakness of the spaghetti box is that it is a simple matter to break open the package and pocket the tape, and that, far from providing new avenues for design, most of the boxes are standard one- or two-color containers with a window that allows the tape label—still the only artwork on the package—to be seen. These difficulties have kept the spaghetti box out of wide usage.

If the eight-track and cassette are to stand on their own as prerecorded items, then it seems clear from the point of view of a professional in packaging and design that innovations in both these areas will be necessary. The demand for a means of packaging tapes so that they can be displayed out in the open, attract the consumer's eye, and still be difficult to steal, is apparent.

Where the modern record album practically screams off the shelf at the consumer, the tape package barely whispers. The need is for a container—not a spaghetti box or a blister pack—that will provide individual graphics for each artist. This container could be 6 by 6 inches, 7 by 7 inches, or 8 by 8 inches, providing the same point-of-purchase impact that hits the record buyer, and allowing room for all the collateral material that has so far been denied the tape buyer, despite the tape's higher cost. Liner notes, posters, and other artwork are the obvious possibilities. These containers would of course increase the packaging cost to the record company, but with tape-duplicating methods improving, and with the stimulus such packaging might give tape sales, labels would likely adjust their priorities.

In the store such newly packaged tapes could be displayed in newly designed racks, racks that would reach higher than tabletop bins, contain perhaps eight or ten layered pockets, and hold as many units as a standard record rack in a narrower space, possibly making room for an extra aisle in the store. Other display designs are also likely, but without some rethinking of merchandising strategies, tapes will remain the stepchildren of records.

Singles, once the leader in unit sales, have fallen on rather hard times in recent years, and a renovation of that configuration, including a possible change in disc size, the shrinking of the big center hole, and a reduction of speed to 33⅓ r/min may bring about packaging changes. Just within the past year and a half, several labels have begun issuing some singles as "disco discs"—12-inch stereo records, usually at 33⅓ r/min, similar to those given to discotheque disc jockeys as promotional devices—and at least one manufacturer has said that such records *are* the future of the single. Commonly packaged in a board jacket, most of the disco discs list for $2.98, and with the consumer's expectations for sound quality heightened by that price, his interest in more attractive graphics for these records may increase as well. Future disco discs may have designs separate from those of albums with the same material, and may use a lighter board construction.

For the long-playing record, tomorrow's packaging is likely to revolve about printing directly on coated board, for aesthetic as well as practical reasons. New machinery for coating the jackets is rapidly reaching the market, and other more accurate and less labor-intensive equipment is being developed to attempt to hold the line in an inflationary economy, one in which the price of cardboard and other paper products is rising very quickly.

The trend toward inner sleeves made of board rather than paper also stands a good chance of expanding. Where the artist has a strong enough sales history, and where the initial run of the album is large enough—generally over 100 000 units—such printing can now be done without enormous cost. The cardboard sleeve lasts longer than the paper sleeve, and thus better protects the record. Beyond these advantages, the attractive uses to which various record companies and artists have already put the board sleeves have proved to be their strongest selling points, and increasing numbers of performers have demanded such packaging.

While these lighter inner boards may have a bright future, standardization in the thickness of the board is a necessary first step. With record companies demanding various boards for differing sorts of packages, the time needed to order stock is often long, and the relatively low volumes that are usually involved keep costs high.

The distinctions between European and American album packages have been several over the years, and some of those varying styles may merge in the future. European albums have generally been made of a thinner, 14-point board, compared to the 22-point board of American packages. The American package has to be heavier because of the extremely tight high-gloss shrink wrap used on it. This shrink wrap gives the package an attractive sheen and protects it from becoming dog-eared through the often lengthy process of shipping and returns. A lighter board, and the record in it, will warp under such a shrink wrap.

European albums, which have been contained in looser "poly-bags," have made up for the shrink wrap's gloss with acetate-laminated paper covers that have bright sheens themselves. Recent advances in the board-coating process have brought such a gloss within reach of American albums without the high cost of the acetate process, and enable the buyer to keep the cover's shine when he discards the shrink wrap.

This, along with raised lettering, specially textured covers of different board types, and a great variety of novelty covers has made album packages showpieces of graphic art as well as practical, necessary containers for the safe and permanent storage of a delicate product.

Someone said recently that if tape recording had been introduced 100 years ago, and if the phonograph record had come on the market only within the last decade, it would have been hailed as the most remarkable invention of the century, simply because of the ease and flexibility with which it can be used. And if tapes had been around all this time, who can imagine into what forms their packaging might have evolved?

To pose a further question: with how many nongrocery products is it common to keep the container after the item has been opened? Surely there can be little potential for the development of graphics on the carton of a television set, and even book jackets, which after all spawned their own adage and have some care lavished on their design, have relatively short life-spans compared to that of a hard-bound book. Yet how many times have you seen unprotected, black vinyl long-playing records in a friend's home? Of course a phonograph record requires more protection than a television set or a book, but there is still more to the question. There is the pride of ownership that attaches itself, consciously or not, as much to the package as to the recorded product.

By now it must be clear that the past, present, and future of recordings and of the graphic concepts applied to them are inextricably bound one to the other. We cannot assert that without the packaging revolution of the last 35 years there would have been no boom in record sales, but we feel certain that color printing and imaginative packaging concepts have provided a great part of the $2 billion-a-year momentum our industry now enjoys.

The question of whether packaging generated sales or sales fostered more elaborate and expensive design seems to us not so much the choice between the chicken and the egg, but between the egg and the shell. Both spring from the same source—the excitement of recorded sound, an excitement that has changed little from Berliner's discs and Edison's cylinders to "Frampton Comes Alive." If record merchants and manufacturers have been blessed with a remarkable product to sell, they have also sensed the almost limitless potential for extending aural appeal with visual stimulation. For those of us whose work combines graphic art with records and tapes, our art gallery is the retail store, and our patrons express their appreciation for our works, consciously or not, by the millions each year.

The Record Industry in the United States

STEPHEN TRAIMAN

Billboard Magazine, New York, NY

As recorded sound marks its centennial, the music industry looks ahead to continually increasing retail dollar gain and, hopefully, steady unit sale increases as well. Technological advances in recording portend new breakthroughs in both disk and tape, with tomorrow's prerecorded music certain to be far superior in playback quality to anything we know today.

With final industry figures for 1976 tallied, the Recording Industry Association of America (RIAA) estimated sales at about $2.74 billion at retail list price, a 15-percent gain from the prior year. And with some consumer resistance to the recent boost to $7.98 list for premium artist product, a smaller 11-percent gain is forecast for 1977, to about $3.06 billion.

The dollar figures are significant when one considers that the record industry first hit an estimated $100 million at retail back in 1921, the first year individual production—not sales—of records topped 100 million units.

A steady decline from that point to a low sales figure in industry history of $6 million in sales in the midst of the Depression in 1933 followed. It was not until 1945, partly due to the war's end and the availability of petrochemicals, that sales topped $100 million again, estimated at $109 million that year.

While retail dollars are one indication of the industry's growth, with much prerecorded product sold at discount virtually everywhere today, a 60–70-percent ratio gives a much truer picture of the industry's dollar volume. Only in the United States is dollar volume figured on retail list prices, with most other countries around the world using a wholesale price index, or the figure at which records and tapes are sold to distributors and/or retailers.

Regardless of which dollar sales ratio is used, it is unit sales that give the best indication of the industry's present and future growth. And here, in the United States, the brightest picture is painted for tape versus disc, with cassettes in particular showing the biggest unit percentage gains over the last few years and eight-track cartridges continuing their popularity.

Since Philips introduced the first musicassette in 1962, and RCA, Lear Jet, Motorola, and Ford combined to launch the eight-track via car stereo in 1964, the two formats have fast overtaken previously dominant open-reel, which hit a high point in retail sales of $22 million in 1968.

In 1976, while LP album units (multisets count as one unit) were up only 6 percent with an estimated 273 million sold, and singles were up 16 percent to 190 million (after a 20-percent drop in 1975), both cassettes and eight-tracks had solid unit increases to continue their upward growth.

More than 106 million eight-tracks were sold in 1976 at an estimated retail list of $678 million. This was double the number of units sold just five years before, and a 12-percent gain from the prior year.

Cassette unit sales rose even more sharply in 1976, topping 21.8 million at $145.7 million retail list—about 50 percent more than five years ago, and more than a 34-percent unit increase from 1975.

Quad units, both disk and tape, continued to decline in 1976—down 38 percent in list value to $5.1 million and 36 percent in units to 400 000. Reel-to-reel tapes fell to the point where they are no longer counted, from 400 000 at $2 million list value in 1975.

Five years ago prerecorded tape accounted for only 16 percent of total unit sales volume, about 70 million cassettes, eight-tracks, and reels, compared to 350 million albums and singles.

In 1976 nearly 22 percent of unit sales were represented by tape, that is, cassettes, stereo and quadraphonic eight-track cartridges, with more than 128.6 million total.

Ten years ago about $1 of every $10 at retail came from prerecorded tape sales. In 1976 more than $3 of every $10 in music industry retail sales came from cassettes and eight-tracks. Quadraphonic product continued its decline due to the continuing controversy over configuration that virtually killed the market before it had a chance, and

reel-to-reel has dropped below "countable" figures, RIAA says.

Along with changes in popularity of music formats, changes in popularity of types of music, affected by the growing adult music-buying market, are a major force in the industry's future.

An in-depth research study by the National Association of Recording Merchandisers (NARM), comprised of retailers, rack-jobbers, and one-stop distributors responsible for about 85 percent of the sales volume in the industry, points out some significant figures for the future direction of the music business.

After much neglect while it concentrated on the big record-buying age group from 15 to 25, the industry is finally realizing that its expanding market of the future is the rapidly growing 25 to 45 age group.

Through the 1980s this adult market is estimated to expand by 18 million persons or 32 percent, while the youth segment from 15 to 25, now buying the bulk of prerecorded music, declines by 3 million for a 7-percent loss.

The industry must do a far better job to reach this growing segment of the market, which currently buys far less than its population percentage of records and tapes. And certainly the type of music the older buyer prefers is far different than the current sales volume indicates.

A comparison of listening preferences by the 25–45-year-old record and tape buyer and the NARM dollar sales volume in 1975 indicates the key preference differences:

Type of Music	Adult Buyers	NARM Volume
Contemporary (pop, rock, soul)	36.6%	61.4%
Country	22.6%	11.7%
Middle of road (MOR)	16.0%	11.1%
Classical	9.9%	5.4%
Jazz	4.9%	4.6%
Other	9.9%*	5.8%†

* Other adult preferences include gospel, oldies, and folk.
† Other NARM sales include comedy, children's, and ethnic.

The significant product category differences are notably in contemporary, country, MOR, and classical, the four major music areas. Obviously, the music industry is going to have to devote more of its efforts in the direction of adult preferences if it intends to reverse current buying trends.

According to the NARM research study, released at the March 1976 convention of the industry, as the adult nears the 40-age bracket, the buying of LPs drops off more than 50 percent—from 11.9 units yearly from age 25 to 30 to 5.4 units between ages 40 and 45.

Tape buying starts at 4.7 units purchased yearly up to age 29, peaks at 7.2 units between 35 and 39, and drops to the 4.8 unit level between ages 40 and 45.

The average 35–45-year-old buyer, defined by the study as one who has bought a record or tape within the last year, buys 8.7 LPs, 5.7 tapes, and 4.4 singles yearly per respondent. Males purchase 10.7 LPs, 6.5 tapes, and 4.5 singles, while females on the average buy 7.3 LPs, 5.1 tapes, and 4.2 singles annually.

As income rises from under $9000 yearly, buying of prerecorded music also generally increases. When the peak income group is reached, those making $25 000 or more, buying volume drops back to levels about the same or below the lowest income group, those earning under $9000. Thus the industry has to reach those who can afford to buy the most music, but actually are buying the least.

LP sales rise from 5.3 to 11.5 annually as educational levels rise from some high school to those completing college. Tape unit sales are reversed, with 9.6 a year for those with some high school education to 4.7 for college graduates. Single respondents buy 14.2 LPs a year versus only 7.3 for married adults, with tape reversed—3.4 units for singles and 5.8 for married respondents.

Record stores get 32.5 percent of prerecorded music sales from the adult buyer, with 24.7 percent to discount stores, 21.8 percent to department stores, 11.9 percent via mail order, 3.7 percent to variety stores, and 5.4 percent to all other outlets.

The industry has every chance to capitalize on this expanding age group, as it appears optimistic as to the buying future for prerecorded music. Nearly half the respondents to the nationwide survey—48.6 percent—said they buy more product than they did five years ago. Only one in three—33.7 percent—said they are buying less, and about one of every six—17.7 percent—say they buy about the same amount of records and tapes.

U.S. Recording Sales, 1921–1975.[1]

Year	Sales (million $)	Change (%)	Year	Sales (million $)	Change (%)
1921	$106	–%	1949	173	–8.5%
1922	92	–13.2%	1950	189	+9.2%
1923	79	–14.1%	1951	199	+5.3%
1924	68	–13.9%	1952	214	+7.5%
1925	59	–13.2%	1953	219	+2.3%
1926	70	+18.6%	1954	213	–2.7%
1927	70	N.C.	1955	277	+30.0%
1928	73	+4.3%	1956	377	+36.1%
1929	75	+2.7%	1957	460	+22.0%
1930	46	–38.7%	1958	511	+11.1%
1931	18	–60.9%	1959	603	+18.0%
1932	11	–38.9%	1960	600	–0.5%
1933	6	–45.5%	1961	640	+6.7%
1934	7	+16.7%	1962	687	+7.3%
1935	9	+22.2%	1963	698	+1.6%
1936	31	+22.2%	1964	758	+8.6%
1937	13	+18.2%	1965	862	+13.7%
1938	26	+100%	1966	959	+11.3%
1939	44	+69.2%	1967	1051	+9.6%
1940	48	+9.1%	1968	1124	+6.9%
1941	51	+6.3%	1969	1170	+4.1%
1942	55	+7.8%	1970	1182	+1.0%
1943	66	+20%	1971	1251	+5.8%
1944	66	N.C.	1972	1383	+10.6%
1945	109	+65.2%	1973	1436	+4.0%
1946	218	+100%	1974	2200	+9.1%
1947	224	+2.8%	1975	2360	+7.3
1948	189	–15.6%	1976	2740	+15.0%

Source: Recording Industry Association of America.

[1] All tables courtesy *Billboard Buyer's Guide*.

Among the reasons given by those who are buying more, it is significant to note that about 28 percent each said "more interest in music" and "bought new equipment."

Obviously, the new forms of music represented by electronic and digital recording, combined with dramatic new technology breakthroughs such as pulse code modulation and the Elcaset, can only heighten these two prime reasons for future industry gorwth.

The growing market noted over the last few years for "semi-pro" or home recording goes hand in hand with the growth of prerecorded sales as well. For as technology advances in recording and duplication techniques, the better quality of the average record and tape sold should contribute heavily to bigger unit volumes in all categories.

Tomorrow's music industry will reflect the interdependence of the "razors and blades"—the hardware and software—much more than evidenced in today's market. The indications are there for real progress in music recording that will make today's "best" records and tapes far inferior to those expected to be available a few years from now. This includes the viable possibility of a "micro-mini" music cassette with better fidelity than today's premium prerecorded classical products.

U.S. Phonograph Sales

Year	Portable and Table (Includes Compact and Component Systems)		Console		Total	
	Units	Dollars	Units	Dollars	Units	Dollars
1955	2 430		197		2 627	99 000
1956	3 257		531		3 788	140 000
1957	3 402		1 256		4 658	240 000
1958	2 758		1 215		3 973	259 000
1959	2 917		1 387		4 304	339 000
1960	3 075		1 448		4 523	359 000
1961	2 538	109 000	1 451	195 000	3 989	304 000
1962	3 329	137 000	1 625	252 000	4 954	389 000
1963	3 474	143 000	1 668	278 000	5 142	421 000
1964	3 455	146 000	1 704	294 000	5 159	440 000
1965	4 363	175 000	1 767	330 000	6 130	505 000
1966	4 504	181 000	1 799	347 000	6 303	528 000
1967	5 134	173 000	1 492	307 000	6 626	480 000
1968	4 925	184 000	1 570	319 000	6 495	503 000
1969	4 958	200 000	1 362	290 000	6 320	490 000
1970	4 572	160 000	1 048	216 000	5 620	376 000
1971*	4 972	216 000	1 062	209 000	6 034	425 000
1972	6 279	392 000	928	185 000	7 207	577 000
1973	5 234	314 000	901	188 000	6 135	502 000
1974	3 942	212 000	865	186 000	4 807	398 000
1975	2 641	133 000	523	132 000**	3 164	265 000**
1976	3 210	145 000	654	172 000	3 855	317 000

* Prior to 1971, data reflect factory sales by U.S. manufacturers plus those products imported directly by distributors or dealers for resale. 1971 and years following data reflect products produced or purchased by U.S. manufacturers plus those products imported directly by distributors or dealers for resale. **Revised.
Source: EIA.

Blank Tape Software Sales, in Thousands, Share of Market,* and Blank Tape Prices*

	Factory Volume (industry units estimate)			Factory Value (dollars)†		
	1976(Est.)	1975	Change (%)	1976(Est.)	1975	Change (%)
Cassette	186 456	162 156	+15.0%	296 465	251 342	+18.0%
Eight-track	33 810	29 658	+14.0%	70 663	59 316	+19.1%
Open-reel	12 632	12 030	+ 5.0%	41 433	37 894	+ 9.3%
Total	232 898	203 844	+14.3%	408 561	348 552	+17.2%

	Share of Market						Blank Tape Average Retail Price	
	Units			Dollars†				
	1976	1975	Change (%)	1976	1975	Change (%)	1976(Est.)	1975
Cassette	80.1%	79.5%	+0.6%	72.6%	72.1%	+0.5%	$2.37	$2.31
Eight-track	14.5%	14.5%	+/−0.0%	17.3%	17.0%	+0.3%	2.47	2.36
Open-reel	5.4%	5.9%	−0.5%	10.1%	10.9%	−0.8%	5.98	5.75

* Merchandising magazine compilations from manufacturers' estimates.
† Wholesale dollar value from Billboard projections of average wholesale prices.

Playback Units in Use (in millions of units).

End of Year	Auto Radios	Other	Total Radios	TELEVISION Monochrome	TELEVISION Color	Phonographs
1950	18	81	99	10.6		16.8
1951	21	84	105	15.8		18.0
1952	23	87	110	21.1		19.5
1953	25	88	113	27.3		20.8
1954	27	89	116	32.5		22.4
1955	29	91	120	37.6		24.0
1956	32	93	125	42.7	.1	25.6
1957	35	95	130	46.8	.2	27.1
1958	37	97	134	49.7	.3	29.9
1959	39	107	146	52.9	.4	32.0
1960	40	116	156	55.1	.5	34.0
1961	41	127	168	57.5	.7	35.7
1962	43	140	183	60.2	1.0	37.0
1963	45	151	196	62.4	1.7	39.0
1964	47	161	208	64.1	3.1	42.0
1965	55	172	227	64.8	5.8	45.0
1966	64	188	252	64.8	10.0	48.0
1967	73	195	268	63.7	15.3	51.0
1968	74	216	290	62.7	20.9	53.8
1969	80	240	320	61.9	26.4	58.7
1970	85	251	336	61.6	31.6	58.7
1971	92	262	354	62.5	38.2	61.2
1972	93	276	369	64.4	45.4	64.8
1973	94	289	383	64.5	52.6	68.6
1974	100	301	402	64.0	57.0	71.6
1975	101	311	412	66.0	59.3	73.1

Sources: Television Digest Factbook, Radio Advertising Bureau, National Broadcasting Company

Total U.S. Imports of Selected Consumer Electronic Products, 1964-1976, in Thousands

	Automobile Radios		Phonographs		Tape Recorders		Home Tape Players	
Year	Units	Dollars*	Units	Dollars*	Units	Dollars*	Units	Dollars*
1964			135	9 093				
1965			275	11 875				
1966	178	2 564	1 523	25 014				
1967	621	8 584	1 964	33 988				
1968	1 814	29 650	2 129	37 456	4 914	110 262	1 254	26 863
1969	1 791	30 592	2 063	44 400	6 254	142 744	2 505	61 117
1970	2 232	38 535	2 040	52 456	8 076	202 251	3 655	113 213
1971	3 150	51 263	1 926	61 951	8 390	212 920	5 158	145 297
1972	2 924	53 358	2 451	92 997	9 873	266 698	8 263	244 257
1973	4 459	91 271	2 423	95 690	10 470	318 691	7 377	246 963
1974	4 848	110 994	1 934	92 657	9 087	310 653	4 592	137 890
1975	3 996	102 786	1 299	57 780	7 653	272 669	3 222	86 715
1976	5 970	148 643	2 455	103 726	12 664	473 218	4 364	112 875

Source: U.S. Department of Commerce.

* Dollar value is defined generally as the market value in the foreign country (FOB) and excludes U.S. import duties, freight charges from the foreign country to the U.S., and insurance

U.S. Imports of Magnetic Tape Equipment, 1969–1976, in Thousands.

	Tape Recorders/Players						Tape Players Only									
	Audio		Video		Total		Audio		Video		Total		Automotive Tape Players		Total Tape Equipment	
Year	Units	Dollars	Units	Dollars	Units	Dollars	Units	Dollars	Units	Dollars	Units	Dollars	Units	Dollars	Units	Dollars
1969	6 253	142 743	13	5 186	6 266	147 929	2 505	61 117	N/A	N/A	2 505	61 117	2 527	58 090	11 298	267 136
1970	8 078	202 251	24	8 779	8 102	211 030	3 655	113 212	N/A	N/A	3 655	113 212	2 779	60 351	14 536	384 593
1971	8 390	212 920	29	8 138	8 419	221 058	5 158	145 298	N/A	N/A	5 158	145 298	2 739	51 136	16 316	417 492
1972	9 873	266 698	42	16 351	9 915	283 049	8 263	244 257	N/A	N/A	8 263	244 257	3 641	69 615	21 819	596 921
1973	10 470	318 691	76	23 960	10 546	342 651	7 181	235 522	196	11 441	7 377	246 963	4 687	102 327	22 610	691 941
1974	9 087	310 653	34	20 388	9 121	331 041	4 488	133 001	104	4 889	4 592	137 890	4 983	146 655	18 696	615 586
1975	7 653	272 669	40	26 532	7 693	299 201	3 100	78 316	122	8 399	3 222	86 715	4 903	150 468	15 818	536 084
1976	12 664	437 218	70	50 413	12 734	487 631	4 143	98 766	221	14 109	4 364	112 875	9 136	286 472	26 234	886 988

Source: U.S. Department of Commerce

The Record Industry in Europe

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Statistically speaking, the European record business appears to be in a boom situation. While there may be sporadic signs of singles sales dropping off in some areas, this is more than compensated for by a consistent and dramatic upturn in the album trade and in sales of pre-recorded tape—though the 8-track cartridge seems finally doomed to die.

But to quote increased sales figures is one thing. They underline increased demand and stress a basic buoyancy in the record side of the entertainment industry. However, to place reliance on apparently remarkable revenue figures expressed in cash terms as profit is unwise. For virtually every territory has been hit by spiraling inflation which creates increased costs and, in turn, increased prices.

The key European areas are the U.K., Germany, France and Italy, with Scandinavian territories exerting an ever larger influence on the world trade—notably through the outstanding international success of the Swedish group Abba. And there is a great deal of promising activity within the Benelux countries which suggests more commercial success to come.

A look at U.K. production achievements over recent years produces encouraging figures. In 1970, the total number of records pressed was a then-staggering 112.9 million, of which 47 million were singles and 65.9 million albums.

By 1975, the figure had jumped to a total 177.7 million, of which 102 million were albums. Though these figures are for pressings, rather than actual sales, they nevertheless emphasize a tremendous aura of industry growth. But in sales terms, at monetary levels, the increases were further stressed. Though exchange rates have varied considerably over the years, sales income for the U.K. industry in 1970 was $70 million and by 1975 it was up to $215 million, though with surprisingly little increase (roughly $1.5 million) in export figures.

According to the figures, the improvement was predictably carried on into 1976. In a survey of production and sales for 1976, the British Phonographic Industry figures showed that U.K. consumers were spending, in real terms, no more of their disposable income on records and tapes than they did four years earlier. The figures acted as a depressing dampener on the industry in general.

Pre-recorded music accounted for total sales of $292.9 million in 1976, representing 0.34% of consumer disposable income. Though it represented an 8% increase over 1975 figures, it was more than offset by the year's 16.5% inflation as measured by the retail price index.

At the same time, the report was not entirely gloomy. At least deliveries to the trade during the last quarter of 1976 showed a less marked decline than had been noted in the first three-quarters of the year. In fact, singles showed impressive sales strength in the U.K. Against trends in other European areas, the 45 single was the only product which did not decline during the year.

Sales on singles were 56.9 million units, the same as in 1975, and worth $37.1 million at manufacturers' prices. Demand for singles was strong enough to bear price increases roughly equivalent to the retail price index for all items.

Album sales were down by 9% compared with the previous year; cassettes held steady at around 19% of album unit sales; tape cartridges dipped by 38% of the previous twelve months. Average trade price of a single in 1976 went up by 14% and albums by 19%. U.K. album sales were 83.8 million units, compared with the 1975 total of 91.6 million—worth $199.6 million as against $183.4 million.

The U.K. scene then is one of increased sales and increased prices all set in a situation of constantly inflationary trading trends.

Before dealing with the many problems besetting the general European industry, it is worth seeing how the German market is withstanding the various hassles and hang-ups. The West German industry sold records and cassettes valued at $675 million in 1976, showing an

increase of 13% over the previous year. Some 85% of the sales were products of the German industry itself, and the rest were imports or product of television merchandisers such as K-Tel and Arcade.

For Friedrich Wottawa, managing director of EMI-Electrola, the results were satisfactory compared with 1975, but he is convinced that the really spectacular increases in business and turnover are yet to come.

Leaving aside for a moment German views about direct imports, a matter of grave importance to the entire European industry, there is guarded confidence expressed in most other German areas. In 1976, the German industry sold 39.1 million singles. Albums in the low-price category sold 33.1 million; classical albums sold 5.2 million; and pop albums, 27.9 million.

Total sales in the high-price album range were 38.4 million, of which pop accounted for 33.4 million and classical, 5 million. Total album sales, then, were 77.5 million.

German cassette sales increased through the year, with a plus of 84% in the low-price range over 1975. In that low-price area, the proportion of cassette sales to LP sales is roughly 69:31 in favor of cassettes. And in the high-price sector, LPs showed a 7% increase over the previous year, but there is a negative trend generally in German album sales, which is attributable to imports from the U.K. and France, particularly in international repertoire.

German exports of records and cassettes to the rest of the world totalled 30.2 million units in 1976, surprisingly, a shade under the 1975 figures. It is surprising because the basic German view is that the country is well on the way to becoming a major source of international hit material—a view shared by most leaders of German record companies.

The companies are citing a combination of improved production techniques, plus a firmer grasp of the essential criteria which create big-selling records and also sensible working of a deep pool of multinational talent. Ariola managing director Monti Leuftner is convinced the breakthrough into truly international acceptance is on the way. He says firmly:

> "It has taken a long while to find the way, but German productions are increasingly picking up big worldwide sales these days, and it is mainly due to the greater flexibility and artistic versatility of young German producers, arrangers, songwriters and artists. But we certainly have had to work hard at it, for success is very much a matter of studying and learning to meet the accepted high standards of Anglo-American productions as well as create our own ideas in production quality."

At the German level, Silver Convention and Penny McLean (a solo singer from within the trio) have done well for the Jupiter organization and Hansa's Boney M is a group currently figuring in many singles charts with a Jamaican-slanted discotheque sound.

But Leuftner also points to Mireille Mathieu, Michael Holm (specially in South Africa, Scandinavia and France, along with the U.S.) and Udo Juergens as being further examples of how German talent can break out into an international market. Since Germany is in the top five of the main world recording markets (U.S., Japan, U.K., Germany, France), he feels it is about time the German product reached a wider acceptance.

Teldec chief Manfred Peter rattles off names which he feels are fast becoming established outside Germany. He cites Werner Muller, Will Glahe, Klaus Wunderlich, Norman Candler, the Les Humphries Singers, and says there are many more coming through. He stresses two main points: "German productions have been lifted to international standards and the basic sounds of local bands are that much more interesting these days." The Teldec ploy in marketing terms is to have more and more productions specifically made for overseas markets. This has already included the launch of the big German seller Udo Lindenberg in English-language releases.

Yet, the basic inconsistency in the German recording industry these days is such that there was evidence of a slackening in demand in sales figures produced for the first four months or so of 1977. In fact there was a sales upturn of 6% in the first quarter, with sales hitting a 37.1 million mark for records and cassettes.

But there were signs that German productions were doing badly in the German charts. So while the industry was developing plans to get its product accepted at an international level, there were fears about whether its product was losing its grip at the national level. The result was that the industry decided to organize a song contest for Germany's bright young composers and lyricists, and run it in conjunction with coverage and exposure from the Second German TV network.

At any rate the first three months of 1977 showed 10.05 million pop singles sold, and that figure was 3% down in the same period of 1976. Low-price pop albums showed a 13% increase, though, and there was a 16% increase chalked up for full-price pop albums. Both areas of pop cassettes were up: the low-priced by a remarkable 25% over the previous year.

An analysis of German top 20 chart entries for 1976 showed EMI-Electrola on top of the local companies, with 22.44% of all chart records, followed by Ariola (16.37%) and Deutsche Grammophon (11.63%). EMI-Electrola actually produced 64 chart titles and Ariola 62.

A further statistical breakdown of the German singles chart showed that 48.08% of the records listed were international productions and only 21.38% came from national records. And therein lies another cause for concern within the German industry for all its expansion into foreign territories.

The French scene is similarly unpredictable. This is the country where the single has dominated the market for a decade, only to take a dreadful nose dive in the last quarter of 1976—to such an extent that industry pundits are convinced it will never again reach its former glory. Bernard de Bosson, WEA managing director, believes it is all a matter of pricing. The single passed the 10-franc barrier and now often costs the equivalent of about $2.50. In fact, it is possible in France to buy a budget album for not much more than a full-price single.

But France, unlike some other European territories, is hit by a lack of promotional outlet for records. There is a population of 55 million, and only three main radio stations. Michel Bonnet, managing director of Pathe

Marconi, says: "In radio terms, we just seem to be living in the Middle Ages. In Italy now there are around a thousand radio stations operating on a policy of music, and yet we have just three. And only France Inter covers the whole country, and its listening audience is proven to contain the smallest proportion of record buyers."

In general terms, the French industry has expanded at the rate of some 20% annually over the past 4 years. At least 200 companies are involved, though 51% are responsible for 90% of the market. There are around 2000 points of sale and an estimated figure is that some 130 million record units were sold in 1976.

The past history has been most praiseworthy for the French industry. In essence, record companies in France were clever enough not to go for the quick buck. They met inflation and recession with the shrewd move of keeping retail prices below the inflation rate. While inflation averages at least 10% on an annual basis, the record prices increased by only 4%. The result was a success story, except that the government stepped in and slapped a value added tax (VAT) of 33% on records. A much-quoted line in France is that such a tax places Beethoven, the Beatles, Tino Rossi and Charles Aznavour in the same category as hard pornography, for porn movies are taxed at the same VAT rate.

However, there is an optimistic view about eventual French expansion. Jacques Souplet, chief of CBS, accepts the fact that in European terms France lags behind the U.K. and Germany, but he maintains that this merely means France has great elbow room and can only expand.

There is, in truth, a great nationalistic drive to have the French "chanson," a highly emotive kind of pop song, accepted at world level. There are now festivals at which this kind of music is given prominence. Added to that is the view of Louis Hazan, of Phonogram, that in the next 4 years sales of cassettes in France will triple, all to the undoubted advantage of the record business.

Though French sales figures are hard to establish, a basic belief is that in 1976 the industry there sold roughly 130 million records and cassettes against a 1970 figure of around 60 million. Even so, the VAT is regarded as the big crippling blow.

But while the Germans are optimistic about providing an ever larger share of the world market, there is a strong feeling of doubt about the French expanding influence. Though a Charles Aznavour may succeed in the world market, the feeling generally is that French talent gets a poor showing—albeit an understandable one—outside the frontiers of the French language market. There are many local names known to all French citizens but which are totally unknown elsewhere.

Gradually the French lyric is taking on a biting edge, making social and political comment instead of being almost violently romantic, and it is felt this could provide the big breakthrough. But if a French song is recorded in the vernacular, it can hardly expect high sales in countries where French is essentially a school subject and not actually spoken.

Just in passing it should be said that piracy is not as yet as big a problem in France, but growing awareness of home recording is leading to a general industry theory that a tax of 5% should be added to retail prices of blank tapes.

Once into the piracy area, it is worth reproducing the dramatic warning issued in mid-1977 by the International Federation of the Phonographic Industry (IFPI) in London. It was simply that the industry had to stand together as a unified industry to combat disc piracy or the whole industry would perish within 5 years.

At the time of the warning, estimates were that 40% of all discs and cassettes sold in certain continental retail outlets were pirated and the threat was taking on alarming proportions in Germany and Italy.

The IFPI spokesman said:

> "Unless these inroads into our legitimate business are stamped out now by world governments acting through the United Nations, the world record business, never mind just the European area, will cease to be economically viable within a very short time and will be completely dead within five years.
>
> Unity of all branches of the industry, be it hardware production, disc pressing, cassette manufacturing, or wholesale or retail outlets, is the only way to stop the trend.
>
> Last year we achieved a breakthrough in convincing world governments of the status of records as cultural material in the same way as books or films. But the trouble is that government departments, the general public, even the average record company executive, sees our business as a booming one. However the major record companies form small parts of much greater organizations, and if the main boards think their record divisions have become economically unviable, they will axe them.
>
> But the pirates are greedy fly boys who don't give a damn if they kill the goose that lays the golden eggs. They are here today and gone tomorrow, but we in the industry cannot afford to be."

Government action has been taken in Britain about the piracy situation. The Whitford Committee, set up some 4 years ago to examine existing law on copyright came out with a lengthy final report, and it included a call for a levy on home tape recording equipment plus much more severe penalties for music pirates.

In Germany, the Copyright Act of 1965 imposed a levy on a wide range of recording equipment in return for a blanket license to make recordings in single copies for personal use. (An original proposal to impose the surcharge on blank tapes was rejected by the German Parliament.) This system raised 13 million deutsche marks in 1973, which was accumulated by a joint collecting society representing composers, lyricists, performers, record manufacturers and others.

In fact, IFPI has created a fund to reward anyone who can come up with a viable recorded encoding system that can be used in the fight against piracy.

But Germany, where action has at least been taken in regard to a levy on recording equipment, is now in a high pitch of activity to impose a retail levy on blank tape and also place records on an equal tax basis with books. In Germany alone it is estimated that home duplication costs the industry at least $7 million a year. One demand is for $1.20 to be levied on each tape, splitting the money between performers, composers and record companies.

The problem has been that the tax on recorders has not brought in enough money to satisfy industry groups. In 1965 the hardware tax amounted to approximately $6.25

on each piece sold and now it is more like $1 on each unit sold. The fight in this area goes on.

Elsewhere on the European scene, Sweden is providing an interesting case history. Although this is the country with the highest per capita expenditure on records, it now finds itself struggling with a predicted 5% or 6% increase in sales over 1976. It was felt earlier in 1977 that had it not been for a sudden and dramatic upsurge in cassette sales, there could be a substantial downturn in sales overall. Yet this is a country which has in previous years produced a 20%–30% annual increase.

The industry in Sweden generally believes that things are going to be much tougher from now on—despite the international success of Abba. In straight figures, Bo Byllenpalm, head of Phonogram Sweden, says:

> "Labor problems will be created by the fact that Sweden now has a Conservative government for the first time in 40 years and the government is supporting the Employers' Federation on wage restraint. We cannot go on increasing salaries by 10% to 15% a year because we are losing our competitiveness in the export market and this creates a big import problem. Last year inflation ran at 8%. This year it is between 10% and 12%, and salary increases of only 2% to 3% are being discussed. Prices go up by say 6%.
>
> You can say we're shaken by developments and that a continuing decline in purchasing power could have serious repercussions on the record industry."

A general Swedish belief is that the country has one of the most sophisticated markets in the world, going for the "quality" performer, but rejecting the pure teeny-bop acts.

Stig Anderson, the man behind the phenomenal success of Abba, believes Swedish chances of international acceptance depend on "having our eyes and ears open and listening more carefully, because the next worldwide hit or act could so easily come from Yugoslavia. Abba has changed the thinking in the international record industry."

Throughout the Scandinavian area, as in most other European territories, the problem of direct imports is ever present. In Finland, last of the four Scandinavian countries to be seriously hit by the problem, there were some $6.4 million worth of imported tapes and discs in 1976, roughly the same as in 1975. But over a 5-year period (1971-76) the total value has risen by 125%. The main source, with $2.1 million of business, is the U.K. In Finland, the amount of direct imports would have been bigger without some state-created laws passed to help the country's balance of payment situation. All goods have to be prepaid before they are released by Customs, and for 2 years there was a special import deposit law.

But there are similar problems in Sweden (worst hit by direct imports) and in Denmark and Norway. Actual sales figures from these countries take a long time to filter through, but a 10% growth rate is a reasonable average. The 1975 figures on manufactured record levels for Denmark were: 3.30 million (albums) and 1.24 million (EPs and singles); for Finland: 1.93 million (albums) and 461 000 (singles), and it is believed that cassettes will outsell discs in Finland in 1978; for Sweden: 14.9 million (albums, on domestic sales figures) and 1.4 million (singles, also on internal sales figures); and for Norway: 2.77 million albums and 507 513 singles (also on domestic sales returns).

In Austria, the 1976 figures showed increased sales all around. But while total sales of cassettes rose from 1 710 185 units in 1975 to 1 979 460 units in 1976, representing a monetary increase from $8.23 million to $9.33 million, the relative situation over discs was not so good.

Sales of 6 138 536 million in 1975 went up by only some half-million units, with a monetary increase of $19.8 to $20.5 million. So, at least for that year, figures did not reach what was regarded as a norm of 10%. However, part of the K-Tel sales in Austria were not included because of contractual and distribution problems. However, Austria showed an improvement in singles from 31.7% to 37.8%. The market trend in Austria remains towards high-priced albums and cassettes,with a drop in mid-price product, and 8-track cartridges selling so little that they are now regarded as of virtually no importance in the marketplace.

In production terms, the Austrian cassette situation has shown remarkable growth. In 1976, the figure was up to 1 876 475 from just 1 001 082 in 1975, beating even the 50% growth rate of the previous year. Production for foreign countries was 500 000 albums and 200 000 cassettes on a direct basis, and the remainder was exported by Austrian record companies mainly to Belgium, France, the U.K., Scandinavia, Switzerland and West Germany.

In the Benelux areas, Belgium (with a population of around 10 million) presented 1976 figures in the region of 7.15 million album units and 10.5 million singles, with a total retail sale value of some $62 million. And the Netherlands (population of 14 million) was finally expected to show internal sales figures of around 23 million albums and 8 million singles, with a sales figure in terms of approximately $100 million.

Figures for 1976 in Italy are approximately 15 million albums and 23 million singles, in a country of 56 million people. But Italy is currently producing a remarkable situation because of its radio coverage and exposure. While RAI-TV and Radio remains the official state-controlled network, there has been a positive mushrooming of local radio stations—some unlicensed, and others unapproved. It has been estimated that there are around a thousand stations and most depend on musical content to survive. The result is a great new promotional medium which in turn stimulates the Italian industry and boosts record sales. For the Italian industry, these commercial radio stations represent a whole new ballgame in terms of gaining air space for new record product.

Spain is another area where precise figures are hard to come by; but an estimate of sales for this land of 36 million people would be a 1976 total of 6.4 million album units and 16 million singles.

Piracy is rife in Greece, where it is estimated that up to 60% of tapes and cassettes on sale are illegal. But with a population of 9 million, there would still be a balance of more music exported than imported—and there is a definite trend toward Greek music being more widely accepted overseas.

In Western Europe piracy and direct imports are ever-present threats to the well-being of the industry. But now

there is the threat of counterfeit records and tapes to add to the headaches caused by the pirates and bootleggers. The situation has become so threatening that there is a growing conviction that there has to be urgent action on a fully international basis.

According to Geoffrey Bridge, director-general of the British Phonographic Industry:

> "This new enemy is much more difficult to trace than pirate product, its predecessor, for counterfeit product is usually identical in every way to the legitimate originals, even down to sleeve cover and design. One of the major sources is the U.S. But now Europe is having more than its fair share of counterfeiting."

As yet there is no evidence, Bridge says, of printing and pressing counterfeit records and tapes in Britain, but he knows much comes in from continental Europe. The investment required to set up counterfeit production facilities is greater than for pirate or bootleg material, with the need to forge existing sleeve artwork; but the outlets for sale are much the same, including market stalls and retailers, along with direct mail.

Target of the counterfeiters is generally mainstream pop product, and compilations of the television-backed material have also come in for close attention. The BPI, watchdog of the British record companies, is raising $150 000 from Phonographic Performance Ltd. over the next 2 years to fight the various kinds of pirate operators.

During 1976, a total of 92 cases (80 in 1975) were reported to the BPI lawyers, 34 involving piracy (46 in 1975) and 58 on bootlegging (34 in 1975). But Bridge is confident enough to say: "We consider that piracy and bootlegging are still under control in Britain and that not more than 5% of the U.K. tape market and 1% of the disk area is involved." But the fight against counterfeiting remains in its infancy.

The general European record industry is not only capable of handling fast-rising problems but also of coping with unusual surprises. For example, in early 1977 there was a remarkable growth in the demand for singles in the U.K.—a move which flew in the face of anticipated trends. In order to cope with this demand, custom-pressed British singles were coming in from the U.S. and from Europe generally in hundreds of thousands as Britain tried to meet this extraordinarily high demand.

For several months it seemed that everyone was buying singles, though it was noticed that album and cassette sales did not suffer at the expense of the whim. One single, Showaddywaddy's "Under The Moon Of Love" could not make the million mark in sales terms for weeks, just because there were no copies left in the shops. In the end, the single was pressed in Paris, while new product from Gary Glitter and the Drifters had to be pressed in New York.

Though singles sales continued an upsurge right into 1977, the "panic-station" weeks in the post-Christmas sales rush were not repeated.

Also in Britain, the amount of money expended on television merchandising reached a near-frenzied rate in 1977, though again the rush calmed down when it was realized that there were so many records being offered that the effectiveness of the campaigns was being drastically cut down. In 1976, though, K-Tel spent $3.06 million on TV advertising, which was more than any other record company, whether merchandiser or mainstream. The 1975 figure for K-Tel, easily the leader in the TV-merchandising field, was $2.38 million. Key competitors are Multiple Sound Distributors and Ronco, and television advertising has restored many old names, notably Bert Weedon and the Shadows, to the best sellers.

Generally speaking the 1977 picture was of "writing on the wall" for most European territories. It was accepted that some companies would ride high on a financial success wave, but mainly at the expense of others who had gone cold, rather than through grabbing a healthy slice of an expanding market. It was realized that the record industry would not necessarily, as believed historically, benefit in times of economic recession. That might have been true in days gone by, but now the recession was fired by rampant inflation.

The theory now is that 1978 will prove the salvation, certainly in the later months of the year. In Britain, there remains a feeling of concern over the obvious influences at sales level of European artists like the Swedish Abba, the Greek Demis Roussos and various others like Boney M and Silver Convention. At full European level there is a deep feeling that the market to conquer is the American market. "Get a hit in the U.S.," the saying goes, "and all the local European problems will disappear."

One important move in the U.K. has come from publishers who are stepping up pressure on British Customs and Excise authorities in an all-out effort to stem what is described as "a colossal flow" of imported records which slip through the royalty collection net. Most, it is said, come from the U.S.

Griff Rigby, investigator for the Mechanical Copyright Protection Society (MCPS) says that if the Customs would cooperate with the society by identifying the importers, the problem would be virtually solved in a day. But the Customs people say they cannot cooperate because of a section of the Official Secrets Act. The main hope is that the law will be changed or even dropped at government level. The MCPS is fighting its case on the fact that it is currently a one-sided arrangement. Customs personnel get the names of importers who pay a royalty to the society, but illegal importers known to Customs remain unnamed. Certainly in 1977 the MCPS investigator unearthed one consignment of 400 000 albums, held in a bonded warehouse for movement to Holland. In that case, the MCPS was able to advise its Dutch counterpart so that the full duty could be charged.

Today the royalty collected is a percentage of the selling price: 8% for imports as against 6.25% of retail price for records made in the U.K. But a change in law is needed before the MCPS can make further progress.

Meanwhile the U.K. mechanical rate remains at 6.25% despite lengthy debates before a three-man Copyright Royalty Tribunal. The rate, set up in 1928 and described by writers as "derisory," was suggested to be increased to 8%, in line with many other countries. Again, inflation was named when the tribunal said: "Partly by reason of

the increase in record prices and the enormous increase in the volume of record sales, the value of the total mechanical royalties paid to composers has greatly increased.'' But whether the value of the money matches that of 1928 payments is arguable.

Any European investigation has to include the volatile market in Italy. The biggest problem there is piracy, followed by internal wranglings which make it hard to find full efficiency. But Italian product is coming through strongly at world level and once the economic problems are ironed out, the outlook could be good.

But piracy remains the one big problem. The growth of small radio stations has helped by providing promotional outlets for new product which would not be involved in the lifestyle of the pirates.

As for the European Iron Curtain countries, there is a stimulating enthusiasm for pop at all levels and music generally at most levels. In Hungary, certainly, there are no basic restrictions, contrary to general belief. At the start of the so-called rock revolution there was a tendency to prohibit certain aspects of the music, but that turned to active encouragement and now various Hungarian groups are flourishing. Fonograf, Omega Red Star and Locomotiv GT are among the most important. Hungarian radio in turn produces many pop and rock programs. Discotheques grow in popularity.

But in Hungary, as in other countries such as Poland, Russia and Czechoslovakia there is a reluctance to talk in monetary terms. Poland, in fact, was the first Socialist country in which rock was played, and now hard rock or ballad styles are most popular. Artists like Mud, Procol Harum, Rory Gallagher and Alvin Stardust from the U.K. are welcome visitors, but Joan Baez' appearance at a Sopot festival passed virtually unnoticed.

The Russian situation particularly is growing fast; artists of the caliber of Cliff Richard and James Last appear there with great success. The state record company is Melodiya and it is engaging in various deals with Western countries, but sales and financial information are not released outside.

The European recording industry, at all levels, is showing commendable growth but the ever-present problem of inflation cuts into profit margins. The problems of piracy, bootlegging, direct imports and now counterfeiting are being fought strongly in some territories and less effectively in others.

But overall the accent is on development, on putting its own house in order—and a determination from the so-called lesser markets, such as Sweden, Spain and Italy, to break into the full international big-sales circuit.

The Record Industry in Latin America

GEORGE TAVARES

CBS Records International, New York, NY

Music has always been known as the common language, penetrating with impunity any geographical boundaries. From the record industry's earliest times, classical music has been international—virtually a global "lingua franca." Popular music, at the beginning, was rooted in the country of its origin, often derived from folkloric groupings within the population. Now pop music has far surpassed classical music in its permeation of international markets.

Artists like Neil Diamond, whose international sales now almost equal his domestic sales, have come to realize the importance of international success. Chicago's number one best seller in Brazil, "If You Leave Me Now"; Albert Hammond's hits in Spain and Latin America; Gigliola Cinquetti's hits in Italy, Brazil and Argentina; Vicente Fernandez's hits in Mexico, Latin America and the United States; Roberto Carlo's hits in Brazil, other Latin American countries and Europe as well as Julio Iglesias's hits in Latin America, Europe, Canada and the United States, to mention just a few, all demonstrate and corroborate the universal appeal of music.

While it is true that music of all kinds has a universal appeal, the differences, sometimes subtle, between countries can be radical in terms of audience acceptance. It is these very subtleties that contribute to the complexities of the international music business and make it the ever-changing and dynamic field that it is.

World market oriented record companies, principally CBS and RCA of the United States and EMI of England, have recognized these complexities in the Latin American record industry and have for varying periods of time operated special divisions devoted to meaningfully servicing this area. Goddard Lieberson, past president of CBS Records, stated this policy well when its Latin American division was formed ". . . to contribute significantly to the music culture of each country by recording native artists and furthering the international recognition of each nation's creative talent, and to increase worldwide distribution of repertoire produced by American artists . . . ."

The record industry in Latin America is no less complex in serving such an area of cultural affinity with over 300 000 000 inhabitants. There is a clear-cut way-of-life philosophy that is continually applied by these world-oriented record companies—that is, not to infringe upon the right of individual companies in each country to operate their own business in an atmosphere of freedom. This philosophy is an implied corollary to Mr. Goddard's statement of policy.

Individual tastes and national tastes differ from market to market. Therefore, though policy is made remotely at international headquarters and overall management and commercial direction is given by divisional offices, local market executives are the best qualified to understand the subtle differences in country-to-country tastes. Since national tastes vary drastically in each country, so also do distribution patterns. Heavy reliance is made on local management, most familiar with the culture, heritage and musical preferences, to guide the methods of operations. Politics play a vital part in the economic well-being of each country and mineral wealth, frequently unexploited, abounds. It is a land of tremendous promise and potential, but here, as perhaps nowhere else in the world, an intimate knowledge of the local situation in each area is essential in maintaining a business relationship. Currency inflation continues to be a major difficulty which, coupled with restrictions on the withdrawal of profits or capital in some areas, can make conditions somewhat untenable. Latin America remains a region of sharply defined contrasts.

Annual per capita incomes range from $332.00 in Honduras to $1291.00 in Venezuela. Yet with the stark realities of the very wealthy and the poor of the "favelas" there is an expanding middle class providing an excellent market for records. Some $400 million dollars was spent last year for recorded music in Latin America and there are now over 30 000 000 record players in use not to mention the ever-growing number of low-cost cassette players.

While devoted to their own music and exciting rhythms, record buyers welcome foreign artists, especially when the record is in the idiom of the country. In response to this new appreciation, more and more stars are recording a song in several different languages to assure local acceptance abroad. So the interchange continues—communication of ideas, of artistic endeavor and successes. The guidelines remain fluid to adjust to the lowering of barriers and to the heightening of interests in the vast potentials of the record market. The world grows larger as people reach out for new entertainments, for new values. The world grows smaller as people relate to other tastes and greater understanding. New countries open up to trade. Established areas flourish with the infusion of technique and expertise. From day to day, from country to country, the patterns of growth spread irresistably.

But it took a while for all of this to come about. Actually, it happened before the concept of the multinational corporation, with its world-oriented marketing plans, which developed in the 1940s. Before then, the export business and the then-foreign subsidiaries claimed the attention of United States record companies even in the very beginning. Edison had an English affiliate dating from 1878, and Berliner dispatched William Barry Owen to England in 1898 to establish the English Gramophone Company in the record business there. The Victor Company was founded in 1902 and began exporting in 1903. This activity was extended to all of Europe, including Russia, by all of the United States companies. The real and compelling reason for this was the great demand for records which had to be met by domestic production to satisfy the local tastes and to simplify distribution. Quick establishment of production and marketing facilities was the only way that participation in these lucrative foreign markets could be accomplished.

The situation was different for Latin America. First of all, the market was not as large as the European one. It could be satisfied largely by special agents traveling selected territories and selling machines and record sets chosen on the basis of their universal appeal. Another handicap was that patent and trademark protection was not as full in Latin America as it was in Europe.

These and others were only temporary deterrents for probably the world's most progressive record company of the period—the Victor Company. By 1920, an export department had been established and was an efficient, effective, and aggressive organization. Special records were pressed for the different export areas and instruments were especially protectively treated to withstand tropical conditions. The home office was outfitted with a corps of translators. A staff of highly skilled salesmen were trained for the various territories. This effort almost immediately resulted in the setting up of foreign subsidiaries in Latin America and other countries. The first was the Pan American Recording Company in Argentina in 1921. Other subsidiaries were set up from year to year in Latin America and throughout the world, including Mexico and, in 1928, in Brazil and Chile.

The objective of this effort, which was not limited to Victor, was to establish local record companies to serve the territories and not primarily as an outlet for the product of the mother company; although such recordings were made available as demand dictated, either as imported manufactured records or as metal parts (matrices) from which the records were manufactured locally. Many of these companies which started as subsidiaries are, today, principal record manufacturers. A large portion of them have become independent. And, almost invariably, totally local record companies sprung up, often bettering the success of the foreign subsidiaries.

Though the recording industry started in Latin America in 1915, in Argentina, and in the early 20s in Brazil, Chile, and Mexico, some record organizations are just beginning to extend their overseas businesses beyond that of licensing arrangements. However, CBS placed its bid for the Latin American international record market as early as 1946 in Mexico; in the 50s for Argentina and Brazil; in the 60s for Colombia and Central America; and in 1970 for Venezuela. As an example of the success that world-oriented record companies have attained, CBS Records International now produces and sells one out of every three LPs sold in Latin America. As the market has expanded, and the number of record companies has continued to increase, the tendency persists for many of the newer or smaller independent companies to concentrate on building up artists and repertoire, using the major record companies to manufacture and distribute on a licensing basis. Many of the newcomers serve specific sections of the pop market which, while remaining international, has become more stratified with the development of individual tastes in, for example, folklorico, jazz, soul, and ranchera. In Latin America there are more than 90 record companies with a substantial share of the market. Nearly 200 additional record companies are gainfully established on the periphery of the business.

The sharp increase in cost of the oil-based raw materials (notably polyvinyl chloride) essential to record manufacture caused a corresponding rise in selling prices which initially disturbed the progressive expansion of the market. Many manufacturers responded by concentrating on new techniques for making more efficient use of materials and achieved significant success. This and the continuing quest for further technological innovation is likely to offer far-reaching benefits in terms of advancing literacy levels and educational attitudes for Latin America. With these advances and the realization that records continue to be a relatively inexpensive form of home entertainment, world record markets have remained generally buoyant.

Before reviewing each country with its own rhythms and market idiosyncrasies, it is necessary to realize that the greatest problem concerning the sources for Latin America is the lack of information and even contradiction. It is also necessary to realize that there are in reality no specific Latin American rhythms, just a total synthesis of Pan American cultures and musical expressions.

ARGENTINA

Argentina is a prime example of the Pan Americanism of music with its annual sales of recorded music of over 70 million dollars and its diverse rhythms of tropical as

represented by Cuarteto Imperial and Cuarteto Leo; Henry Nelson and Los Prados singing balada; folklorico as demonstrated by Jorge Cafrune; folklorico romantico by El Chango Nieto and the tango immortalized by Julio Sousa. The tango best manifests the blending of the international, common language of music. Though the tango is most revered as an inherent rhythm of Argentina, musicologists trace its roots to the fandango of the Africans, the habanera of Cuba, the candombe of Buenos Aires and refined in the courts of Madrid (which were scandalized by the frenzy of the fandango) as well as in France under the care of Carlos Gardel.

Next to the United States, Argentina has the largest population of European descent in the Western Hemisphere, approximately 97% of its 25 million population being mostly Spanish, Italian and German. It probably has the most highly developed economy on the South American continent, and is a leading record producing country. In 1975, 12.8 million LPs and 14.5 million singles were sold to the 25 million population. Proportionately to population, this is less than one-half the sales in the United States. There are the three world-oriented record companies doing business there: CBS, EMI, and RCA. In addition, there are thirteen principal Argentine companies in the market.

High tariff walls protect the domestic economy. The importation of records, like that of other consumer goods, is relatively small; however, domestic record and record player production is strong and cassettes and tape cartridges are flourishing. The government's new liberalized posture with respect to investment laws and repatriation of dividends reinforces the attractiveness of Argentina's strong position in the record marketplace.

Carlos Gardel, who was born in France, sang the first lyrical composition of the tango, "Mi Noche Triste" in 1917 from the tango melody "Lita" composed by Samuel Castriota. Gardel known as "El Morocho" was the popular singer in the early 1900s who accented the coming of the tango.

About this time records as a product began to take hold over the original music cylinders, and Max Glucksmann from the Lepage House of Records and Cylinders in Paris founded "Los Discos Nacional" of Argentina in 1915. Los Discos Nacional recorded Ricardo Firpo's famous conjunto tangos in an attic over El Gran Splendid movie theater in Buenos Aires. Under exclusive contract to Max Glucksmann, Firpo's instrumental tangos, "De pura Cepa," "Sentimiento criollo," and "Indiecita y De Madrugada" became part of Argentina's national heritage. Glucksmann then signed on Gardel and his singing partner Rozzano under a similar exclusive contract. They not only brought words to the tangos but success to Discos Nacional.

BRAZIL

Brazil is a melting pot of cultures, languages and people. This can be seen in the rhythms of the carinbo as sung by Messias Holanda; the samba by Pedro Jorge, Groupo Candombe and Baianunfo; the bassa nova, a mutant form of the samba and jazz; and the balada romantica sung by the Brazilian idol Roberto Carlos and the new star, Claudia Telles. The samba with its roots in African tribal dances, influenced by the Portuguese and Spanish, is the base for much of the Latin-rhythmed music so popular now in Europe.

Probably because of its unique Portuguese heritage, Brazil has demonstrated its leadership role in creative music by its national performers, and through a special pride of the communities which is responsible for developing local talent to its full potential. Roberta Carlos is such an artist—without a doubt the largest selling artist in Brazil.

Brazil is not only the largest country in South America in area, but it is potentially one of the richest in the world. Covering nearly half of South America, supporting almost half the continent's population, Brazil is rich enough in minerals, timber and water power to support a fully industrialized society. Its vast area and variety of soils and climate lends itself to almost any kind of agriculture. Slightly over 4% of its land is now under permanent cultivation, yet it already supplies nearly 40% of the world's coffee, over half of South America's bananas, and huge crops of sugar cane, cotton, grains, rice and oranges.

In 1975, the 107 661 000 population spent $140 000 000 or $1.30 per capita for records and tapes. This is about one-tenth of that spent per capita in the United States. However, when one realizes that this expenditure exists in the context of a yearly per capita income of $513, one sees the importance of the record industry to the cultural life of the country. Rio de Janeiro and Sao Paulo are the two important record centers. There are four world-oriented record companies doing business in Brazil: CBS, EMI, Polygram, and RCA, along with fourteen Brazilian majors.

COLOMBIA

Still the third largest country in area in South America, Colombia originally included all of what is now the Republics of Panama, Venezuela and Ecuador. It has 900 miles of coastline on the Pacific and almost 1100 miles on the Caribbean. It is unusual that Colombia's three largest cities are inland: Bogotá, the capital; Cali, the coffee and mining center and Medellin, the industrial center. Barranquilla, the major seaport, is on the Caribbean.

With a population close to 25 million, Colombia accounted for over 15 million unit sales of recorded music, embodying the major rhythms of the cumbia, as played by the Banda de Nueva Esperanza and La Protesta de Colombia; balada sung by Claudia of Colombia and Gretta; and the vallenato presented by Hermanos Zuleta and Jose Linares.

There are 16 record companies in Colombia. CBS and Philips are the two major outside companies in the Colombian marketplace. Even though outside repertoire is featured by these companies, about one-half of their business is with Colombian musical product. This is true even in the case of CBS which represents the catalogs of EMI, Disneyland, Vista, and Capitol. That these catalogs get good representation is attested to by the fact that EMI's award for "The Best International Licensee" went to CBS Colombia.

CENTRAL AMERICA

South of Mexico, between the Pacific Ocean and the Caribbean, are the seven countries of Central America, six of them independent Latin-American republics and the seventh the small, self-governing colony within the Commonwealth of Belize.

Air routes and the new Pan-American highway have helped to increase trade with Mexico, the United States and neighboring South America and Caribbean countries. The Central American Common Market, to which all but Panama belong, is potentially a source of economic strength.

Several modern record manufacturing plants, like CBS Indica in San Jose, Costa Rica, have been established in recent years to augment the import of records from Britain, the United States, Mexico and South America, and to make possible greater promotion of local artists as well as better distribution for imported products.

In 1976 the 18 million inhabitants accounted for sales of over 4 million record units. Dicesa (Discos CentroAmericanos, SA) and Industria De Discos CentroAmericana S.A. (CBS Indica), operate generally in British Honduras, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. Among the top sellers for Indica are artists such as Claudia de Colombia and Hermanos Lopes; while international best sellers include names like Roberto Carlos, Leo Dan, Javier Solis and Gigliola Cinquetti.

MEXICO

Mexico, the third largest country in Latin America, (after Brazil and Argentina) has one of the highest rates of population growth in the world. It offers a large middle class market, with growing per capita wealth. Its several large cities offer large market centers; Mexico City, for example, and its environs contain 25% of the population and a substantially large share of per capita wealth. This cosmopolitan city reflects many cultures, especially French and Spanish. Guadalajara is the second largest city and is growing rapidly.

As the world was coming out of the post-World War I era, Mexico was entering a peaceful post-1912 revolutionary period. It had an abundance of music, but no actual recording of their home-grown works. Finally, along came a man, Eduardo C. Baptista Covarrubias, who was to point it in a new direction.

Actually, the first imported equipment and product from the United States and Europe was imported by Baptista Covarrubias in 1921 via a company called Fonografica Victoria. It was small, at first, but it served as the introduction for two new labels at the time: Okeh (from the United States) and Odeon (from Argentina). Covarrubias decided it was time to organize the first record manufacturing company in the country. Thus, in a crude and homemade studio, which included cardboard loudspeakers and other unsophisticated equipment for 78 r/min, he started his task. It was almost like being in an igloo, only five meters in diameter for 11 musicians and their instruments.

Two of the top singers at the time—Alfonso Ortiz Tirado and the internationally famous Tito Guizar—became the guinea pigs in the launching of the country's recording industry. It was done in secret. However the entire nation was to hail the efforts after the product was released under the Fabrica Nacional De Discos label.

In order to stimulate the sales, Baptista Covarrubias applied a gimmick of giving gold change for silver upon each sale. The promotion worked—two pesos for the disks, 20 pesos for manual equipment, and 30 pesos for automatics. Originally, there were some conflicting attitudes with radio, however, that later diminished and a joint effort resulted in order to ensure the industry's success.

Don Eduardo's success steered him into establishing another new label, Peerless, which would later become one of the most long-standing companies in Mexico. Most likely, Don Eduardo never imagined that over 50 million LPs would be purchased annually by approximately 70 million people, 2 850 000 of whom have record players and who, on the average, buy 25 records each annually, of which 60% are stereo. About one-half of the record business is centered around Mexico City but the Guadalajara and Monterrey areas are also important. The total Mexican record market is intensively serviced by 37 record companies. From the outside, there is CBS, EMI, Polydor, and RCA. Gamma and Peerless are stalwarts doing business at home.

Similar to the market in the United States, radio promotion plays an important role in Mexico. There are 750 radio stations in the republic: 643 are AM and 107 are FM. They are serviced by all of the major record companies of Mexico, either directly or by mail.

The importance of the Mexican market to the world-oriented record companies is indicated by the fact that CBS Mexico has one of the most extensive artist rosters in CBS Records International. The key to this success has been the development and the promotion of innumerable acts, all representative of the various rhythms and blends of music typical of Mexico with artists reflecting every nuance of the national musical heritage: Vicente Fernandez, named 1977 folklore singer by the Concerts Reporters' Association; "Balada Ranchera" sung by Leon Don; "Sonora Satanera" with tropical; marimba by Marimba Chiapas; Los Alegre De Teran sing the northern strain of the nortena; La Banda with "La Banda de Mazatlan;" Gualberto Castro and Manoella Torres, both balada singers; and Los Panchos with the bolero are but a few.

VENEZUELA

Venezuela is unique among South American countries in several ways. A third larger than Texas, and half again as large as France, the country is rich in natural resources. Its Orinoco wilderness may some day provide wealth to rival Venezuela's coast where the Lake Maracaibo oilfield has made the country one of the largest producers of oil in the world, and which has brought in tremendous amounts of foreign capital to finance extensive economic development. With 1750 miles of coastline on the southern boundary of the Caribbean Sea, Venezuela is closely

related both geographically and economically to its North American neighbors.

A fast developing country, with a population of nearly 13 million, Venezuela has been under stable political government for more than seventeen years. Iron ore mining, the steel industry, leather and textile exports together with a rapid growth of a stable middle class, and booming medium and small industries aided by the government make Venezuela the leader in the Latin American economy.

It is estimated that 500 000 families own a record player, some 40 000 jukeboxes, 127 radio stations and four television channels provide continuous exposure for popular music. Clubs and night life in the coastal metropolitan areas add a cosmopolitan flavor to the musical life of the country.

To protect the domestic record industry, the importation of pop records is prohibited. There are 18 record companies, eight pressing plants and six recording studios. Classical records are imported and this category can sometimes be widened to include jazz and folk music. (BASF, CBS, and Polydor are active outsiders.) The 13 million Venezuelans purchase over 4 million LPs a year with Venezuelan rhythms comprising over 45% of the sales. These rhythms include the joropo, which is characterized by the national anthem, as well as sung by Los Cunāos; merimgue criollo with Becuadros; and waltz criollo and seis por derecho, both presented by Los Cunāos, one of the most popular Venezuelan groups.

The outside companies stress the development of their artist rosters to become competitive in the Venezuelan market as well as to be contributors of source material for the international domain. As it is with all other areas in the world of music, the cross-fertilization of creativity and talent is strong in Venezuela. Vying for national as well as world honors are Grupo Guaco, Los Vecinos de La Cuadra, Roberto Carlos, Claudia de Colombia, Leo Dan, Las Jilguerillas, Edgar Winter, Vikki Carr, Luis Aguile, and others.

The record business in the other Latin American countries not specifically mentioned follow much the same pattern as those discussed. For instance, in Chile with its population of more than 10 million, EMI and Philips along with six Chilean companies are engaged in an industry centered in Santiago. The physical shape of the country, both horizontally and vertically adds a special problem to distribution.

The record industry is committed to total service for Latin America. Replete with its Pan American rhythms and musically conscious populace, Latin America not only enjoys its own musical heritage but the musical repertoire of the world as well. The international record companies have committed themselves to developing and preserving this Latin American musical heritage by investing in the economies of the Latin American countries in the form of new record and tape manufacturing facilities, technical and repertoire personnel and even retail stores. It is only with the support and perseverance of these companies, that the art and poetry of the musical genius of Latin America will prevail for posterity's sake.

ACKNOWLEDGMENT

The author wishes to give a special acknowledgment and thanks to Sr. Alberto Alonzo, Sr. Rinel Sousa, and Sr. Rene Lopez for their guidance and consultation.

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Far East—Problems and Growth Potential

TOKUGEN YAMAMOTO

RCA Records

The Far Eastern countries, except Japan, can still be considered developing countries as far as their record industry is concerned. However, the record industry has been firmly established in each country, regardless of the problems and struggles common to the record industries in the developing countries of the western world.

All Far Eastern countries, again with the exception of Japan, have one major problem in common which is hampering the healthy growth of the record industry in each country. That problem is the so-called "piracy," which simply means copying and selling copyrighted records and tapes without paying any royalties. For the past two decades this has been the major concern and therefore a painful battle for the owners of master records in the western world.

EMI, Polydor, and Phonogram through their own operations in the region and the other record companies through their licensing arrangements have tried to cope with this situation. The solution being worked out is twofold. Naturally one aspect is the legal steps being taken by each company or through the International Federation of Producers of Phonograms and Videograms (IFPI). IFPI has done an excellent job in Hong Kong, Singapore, and the Philippines and is now working actively in Korea and Taiwan. These legal steps take time as governmental and, in some cases, court actions are involved. The other is the bold actions taken by each record company individually, that is, different companies have made it possible to have legitimate records and tapes available in the piracy stricken countries. Such actions have been pioneered by RCA, EMI, Polydor, and Phonogram. Among others, these legitimate products compete successfully with pirate records, and have been gaining ground over pirate records.

However, of late the battle against piracy has become an even more difficult problem with the advent of cassette recorders and playback equipment. The phonograph record piracy is being brought under control, but the cassette piracy is a serious problem in all countries. This is a new problem that needs to be resolved in order to protect the basic rights of the artists and record companies. In Indonesia alone, every month more than one million copies of cassette tapes containing copyrighted materials from the western world are being manufactured and sold, and yet no copyright fees are paid to the original owners of such recorded materials. Such copying activities are also prevailing in Malaysia, Singapore, Thailand, the Philippines, Hong Kong, Taiwan, and Korea.

This is almost cynical when one knows that while the modern technical development is just marvelous with the invention of the easy to record and playback cassette equipment with which one could also easily record off the air or from tapes or phonograph records, the improvement in the legal protection has been at a snail's pace. Most Far Eastern countries do have some kind of legal protection for copyrights, but it is so antiquated that it does not cover the most up-to-date situation of piracy.

In spite of all these problems, record companies like RCA, EMI, Polydor, Phonogram, and CBS have taken steps and have entrusted their materials to their licensees in these countries. However, each has helped in developing indigenous local product sung in native languages.

While the movies of the western world have been seen by millions of people in the Far East, the music of the western world has also found its way into the Far East, through either legitimate or pirated records or tapes. Thus John Denver, Carpenters, Elvis Presley, Paul Anka, Neil Sedaka, Andy Williams, and Perry Como have crept into the lives of the teen-age groups. An American hit is likely

to be a hit in the Far East within the following 6 months.

It is, therefore, a fact that the pop music of the western world has firmly established its foothold in the Far East, but on the other hand the local language record business has also grown enormously.

In Korea, Korean pop song records sell far more than English song records; in the Philippines, Takalog version records are gaining their momentum; in Indonesia, the native Indonesian songs are gaining their firm position over the pirated foreign cassette tapes, and in Hong Kong, Taiwan, Singapore, Malaysia, Indonesia, and Thailand, the Chinese language records and tapes are either predominant or making more impact on the people's daily lives than the western music.

As has happened in Japan, the cross pollination between East and West is bound to happen even in the record industry. Even in these mystic oriental countries where the traditional music sounds weird and, therefore, unfamiliar to the westerners' ears, the modern sounds they are creating are similar to the "pop music," if not already hard rock music, of the West. It is conceivable that songs in Korean, Japanese, Chinese, Indonesian, Malaysian, or Thai could be predominant over western music.

On the other hand, the English language records produced in Japan, the Philippines, or Korea might find their way into the markets of the western world, as has already happened with some talented pianists, violinists, and conductors from Japan, Korea, and Taiwan.

It is especially gratifying to note a news report in the March 27, 1977, issue of an eastern paper that the official radio of the Peoples' Republic of China in Peking has broadcast the entire score of Beethoven's Fifth Symphony. Thus that vast country with its eight hundred million people who have just recently been told that Beethoven is an enemy of the people is also entering into one world of music which we are part of.

It is perfectly conceivable that once the great music of the West is properly introduced to China with governmental approval, whether it be classical or pop music, suddenly there would be a thirst and the desire to quench that thirst for the music of the West. When this happens, China would be pressing millions of copies of Beethoven's Fifth Symphony, The Sound of Music, or John Denver if not the Beatles or Elvis Presley, and artists from the West would be visiting China on extended concert tours as each year more than 1000 foreign artists are visiting Japan and some of the Far Eastern countries.

To make all of this happen to the music business in the Far East, will take bold and farsighted people with patience, vision, and determination.

The Recording Industry in Japan

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This paper provides a brief outline of the history of the recording industry in Japan, with particular emphasis on the technical aspects. Information previously presented concerning this subject is limited, and we therefore made an attempt at reporting the history as faithfully as possible, documenting it with pictures and other data where available.

INTRODUCTION: The annual record production in Japan during 1976 reached 200 million units, while music tape production exceeded the 30 million mark. The corresponding sales volume was $690 million, and related audio product sales grew to $1841 million during 1976. The Japanese recording industry is now the second largest in the world, following the United States.

THE BEGINNING OF RECORDING AND PLAYBACK IN JAPAN

The history of the recording industry in Japan began with the introduction of an Edinburgh-made tinfoil phonograph in 1878. At that time, James Alfred Ewing, then 23 years of age was invited to come to Japan from England to accept the position of professor on the Faculty of Art at the University of Tokyo. He brought the tinfoil phonograph with him and, on November 16, 1878, tested recording and playback with the machine at the university laboratory. This was the first recording test in Japan, and it followed by only one year the first conception of a phonograph by Charles Cros of France and the successful, first public presentation of the testing of a tinfoil phonograph by Thomas Alva Edison of the United States.

Professor Ewing, following his successful laboratory test, gave a public demonstration at Tsukiji in Tokyo on March 28 the following year, 1879. According to a newspaper article published at the time, the surprised and loud voice of a journalist attending the demonstration proclaimed, "Journalists will fall into much trouble if such a machine is produced!" and this was captured and played back on Ewing's machine. This journalist's comment seems to us to have represented the feeling, at that time, of concern about the new product's relationship to the newspaper industry.

Afterwards, Ewing's phonograph was lost, to be found again 80 years later by Kei Ikeda, then Governor of the Japan Audio Society (JAS), and others. They reconstructed it and restored it to its original condition for display in the National Science Museum in Tokyo. The unit shows itself to be of British origin by the imprinted lettering, "J. Milne & Son Makers, Edinb." It has a flywheel with a handle and a simple combination of needle and diaphram used for both recording and playback. It is very similar to the model demonstrated by W. H. Preece of England (Fig. 1).

It is quite amazing that the tinfoil phonograph was introduced into Japan, a far-away country in Asia, at almost the same time as it was introduced in the United States and in England.

In 1890 Edison's improved model phonograph, class M, using a wax cylinder, was presented to our Emperor by the American Ambassador to Japan. This unit (Fig. 2) has been well preserved and is kept at the National Science Museum.

In those days, wax cylinder phonographs and wax cylinders were already being commercially sold on the U.S. market. In Japan the Horne Company, managed by F. W. Horne of the United States, and Araki Shokai, a trading company, started to import the phonographs for domestic distribution in 1896. At the same time, Sanko-do and other companies were established to record Japanese classical music, etc., on the wax cylinders and attracted much public attention.

THE ADVENT OF THE DISC ERA

Emile Berliner invented the phonograph utilizing a disc record in 1887, and shortly thereafter, disc records and phonographs began to gain popularity. Fred W. Gaisberg, an engineer of The Gramophone Company of England, came to Japan in early 1903 to record Japanese music, having just completed the first recording of an Enrico Caruso in Italy the year before. In Japan Mr. Gaisberg recorded 110 10-inch discs and 166 7-inch discs which were used in Hanover, Germany, to press records of Japanese music for sale with the Angel label on the Japanese market (Fig. 3).

Following Mr. Gaisberg's example, many engineers came to Japan from both Europe and the United States, and recordings were frequently taken in Japan. The American Columbia Record Company visited Japan to record 900 discs in 1903 (Fig. 4), the German Beka Company came and made 130 disc recordings in 1906 (Fig. 5), and this was followed by 892 disc recordings taken by the Victor Talking Machine Company of the United States in 1907 (Fig. 6). All those recordings were sent back to the respective countries for the records to be pressed and the finished products were exported to Japan.

The phonographs and records of that period were appreciated by only a limited number of music lovers in Japan, as both the machines and the discs were imported and sold at high prices. The general public, nevertheless, apparently appreciated the phonographs and records as is evident from the new word that originated during this period, "hayari-uta" or "popular song." Incidentally, those old records are now regarded as extremely precious items among Japanese record collectors.

At last, in 1907 the first record manufacturing company was established in Japan. This was Nihon Chikuonki Shokai Kabushiki Kaisha (Japan Gramophone Trading Company) using the label of "Nipponophone." This company later developed into the present Nippon Colum-

Fig. 1. Kei Ikeda experimenting with Ewing's tinfoil cylinder phonograph in 1958.

Fig. 2. Edison's wax cylinder phonograph, class M, presented to the Emperor in 1890.

Fig. 3. 7- and 10-inch discs with the Angel label imported from the Gramophone Company.

Fig. 4. Columbia (U.S.) record marketed in Japan.

Fig. 5. Beka-Grand (Germany) record marketed in Japan.

bia Company, Limited. Nihon Chikuonki marketed the first Japan-made phonographs and records, marking the very first step of the Japanese recording industry (Figs. 7–10).

Electrical recording began in 1925, marking a new era and the formation of many new record companies, one after another, in Japan. Japan Polydor was established in May of 1927, Victor Company of Japan in September of 1927, Teichiku Records in February of 1934, and King Record in March of 1936. With the development of these Japanese record companies, domestic production of both phonographs and records skyrocketed as the completely Japan-made products became popular. Satoru Ibaragi was the first to develop and manufacture audio components, such as transformers, phonograph pick ups, and loudspeakers, in Japan. His work extended to designing and building high-quality radio-phonograph consoles. One of his designs, an "all-wave" electric phonograph called the Delica (Fig. 11) was awarded a gold medal at the Exposition of Paris held in 1937 as a result of its highly regarded technology. Mr. Ibaragi is probably the only living Japanese inventor and developer who actually visited and met Thomas Edison at his laboratory.

Fig. 6. Victrola (U.S.) record marketed in Japan.

Fig. 7. Nipponophone produced by Nihon Chikuonki Shokai, the first Japanese record and phonograph manufacturer, established in 1907.

Fig. 8. Nipponophone no. 35 Japan-made phonograph.

Fig. 9. Nihon Chikuonki Shokai's advertisement.

Fig. 10. Home entertainment by phonograph in 1910, painted by Tsuruzo Ishii.

Fig. 11. The Japan-made Delica phonograph was awarded a gold medal at the Exposition of Paris in 1937.

THE INTRODUCTION OF LONG-PLAYING RECORDS IN JAPAN

The public's desire for long-playing time existed from the early days of the industry. World Records of England marketed records providing from 10 to 100 minutes of playing time, and these were designed to be played back at a constant linear tracking speed. The World Records' LPs were first marketed in 1921, followed by Nitto Records' LPs, using the same principle, in 1925 (Fig. 12). These records provided 15 minutes of recording and playback on each side, and 18 different records were sold under the Tsubame (Swallow) label (Fig. 13). Also, Edison experimented with the microgroove record, utilizing the hill and dale recording method, in 1927. This record provided 40 minutes of recording and playback time using both sides.

In 1934 an LP recording and playback system, called Filmon, was invented by Shozo Konishi, and was developed into a practical model through the efforts of Koichi Tsubota and Ginjiro Sato. An endless acetate film, 35 mm wide by 0.23 mm thick by 13.1 m long, is used in this device with the needle running along a groove at a constant linear speed of 610 mm/s. One hundred grooves are cut into the endless belt, and this provides 36 minutes of continuous recording and playback time (Fig. 14).

The Filmon machine gained a high reputation throughout Japan in those days, and the voice of Prime Minister Hiranuma of that time was said to be recorded using this machine. The Filmon recording belt production was difficult and required much labor. The process involved wrapping eight wax belts around a 4.18-m diameter vertical drum, finishing the wax surface, then laterally cutting the surface of the drum with a slowly traversing magnetic cutter head while rotating the drum at a speed of one turn in 21 seconds, corresponding to a circumferential speed of 610 mm/s. After cutting of the wax master was completed, graphite was applied followed by copper plating. This belt-making procedure is similar to disc record production, but great pains and much effort were needed due to the extremely large size of the belts (Fig. 15).

Those early trials and efforts simply could not lead to the remarkable success that the LP record industry has achieved today. The failure is readily attributable to the high noise levels and the limited dynamic range as a result of the poor-quality plating and raw material of those days

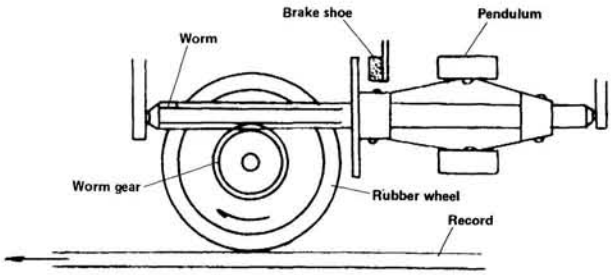
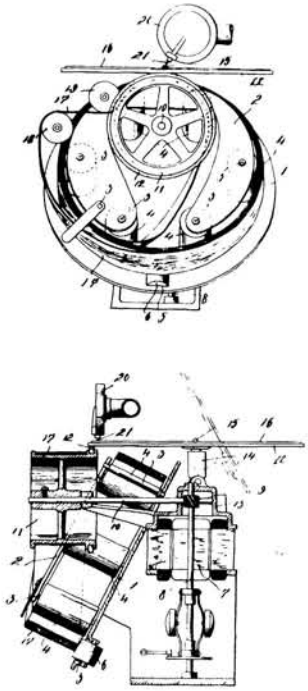


Fig. 12. Constant linear tracking speed mechanism.

Fig. 13. Nitto Records' LP with Tsubame (Swallow) label in 1925.

a



b

Fig. 14. **a**. Filmon's 1934 machine. **b**. Details of recording and playback system by S. Konishi.

used for record production. Long-playing time was the only merit of the machines and processes of that era.

The Japanese recording industry, which had been severely damaged during World War II, was tremendously inspired by the LP record development by Columbia and the 7-inch, 45 r/min disc release by RCA, both of the United States. The first marketing of LP records in Japan was initiated by Nippon Columbia in 1951 which imported disc masters to press LP records in Japan for domestic distribution. Later, in 1953, Denon went ahead with the manufacture of a large-size cutting lathe for 33⅓-r/min records which represented a first in the history of records in Japan (Fig. 16).

The Victor Company of Japan, Limited, made its first LP record by cutting with the above-mentioned lathe and marketed the records in the same year, 1953. Then in 1954, Japan-made EP (extended play) records started to sell, and the traditional 78-r/min records were gradually replaced by the LP and EP records. This new period was called the "hi-fi" age during which new and different audio techniques were developed in rapid succession, one after the other, and in this way the record industry grew remarkably with the support of music lovers.

THE AGE OF STEREO RECORDS

In 1958 the Victor Company of Japan began to market the 45/45 stereo records, being the first in Japan to follow the established trend in the United States. Other Japanese record companies also soon entered the stereo record market to generate, along with the Victor Company of Japan, a so-called stereo record boom. The new word "stereo boom" was popularized due to the explosive stereo record sales increases every year at that time in Japan. In order to improve the sound quality of stereo records, new cutting and plating techniques were developed along with vast improvements in pressing machines and in the chemical compounds used for the raw material of the disc itself.

The first Japanese industrial standard (JIS) for stereo records was issued in 1967, with the agreement of the Japan Phonograph Record Association, to clarify and to provide minimum standards for stereo record quality and characteristics. However, there was severe competition among the various companies to provide better quality recording. In 1963 the Victor Company of Japan adopted RCA's Dynagroove technology in order to reduce tracking distortion. Toshiba-EMI Ltd. developed and employed the pinchless tracking simulator (PTS) system in 1968, and Nippon Columbia Company, Ltd., adopted a nondistortion cutting system designed by D. Cooper in 1970 to improve sound quality.

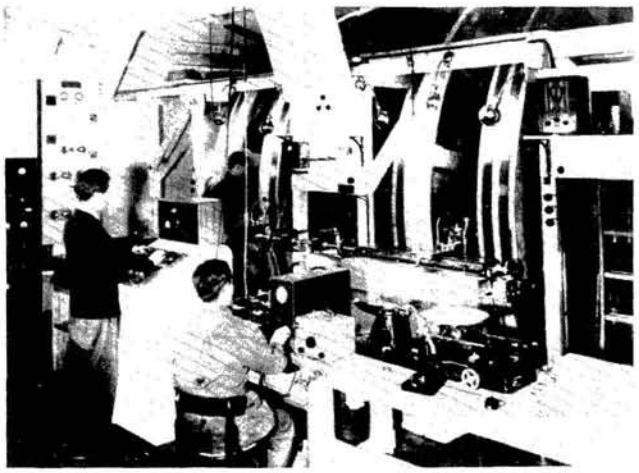


Fig. 15. Filmon wax belt cutting room.

THE LATEST RECORDING TECHNOLOGY IN JAPAN

With prevailing multitrack tape recorders, multichannel recording technology advanced greatly in the 1960s, and, as a result of the trend, audio engineers began to develop an interest in increasing the number of recording channels of records.

The Victor Company of Japan developed a three-channel record using a frequency multiplexing system between 1961 and 1965 (Fig. 17). The third channel was recorded and played back with a carrier of 24 kHz (18 kHz in the beginning) having a frequency deviation of ±4 kHz and yielding a signal having a bandwidth of 50–5000 Hz with a signal-to-noise ratio of 47 dB. At that time there were only a few pickup cartridges that enabled tracking of the three-channel records, and, consequently, this record system was not further developed to the level of practical use. However, this system contributed to the later development of the four-channel record and its practical utilization thereafter.

Since 1969, development and merchandising of quad-

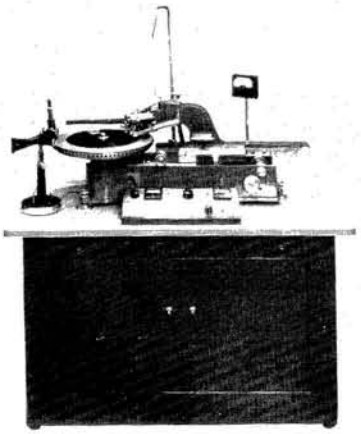


Fig. 16. Japan's first cutting lathe for LP records manufactured by Denon in 1953.

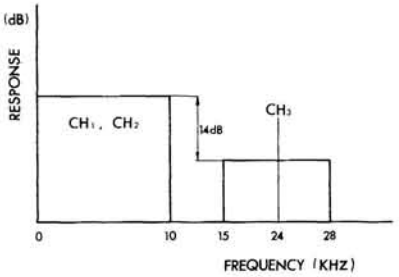


Fig. 17. Three-channel disc record developed in 1961 by the Victor Company of Japan.

raphonic recording were undertaken in both the United States and Japan, while the three-channel record was further developed into the CD-4 record system which is in practical use today.

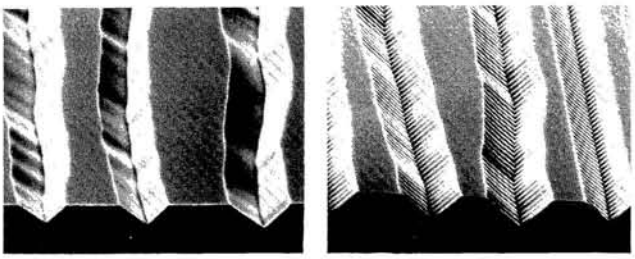
The CD-4 record was announced by the Victor Company of Japan on September 2, 1970. Its name derives from the words compatible, discrete, and four-channel. In October 1970, the CD-4 record system was demonstrated at the 39th Convention of the Audio Engineering Society, held in the United States [1]–[3].

The CD-4 is a disc into which a subcarrier signal is multiplexed during recording in the range of 20 to 45 kHz using a 30-kHz carrier (Figs. 18–20). Later, CD-4 records were adopted and improved by RCA and other companies in addition to the Victor Company of Japan. Those CD-4 technological developments contributed not only to the improvement of recorded sound but also to the overall audio technological level, including pickup cartridge characteristics [4].

The Japan Phonograph Record Association settled on a standard for CD-4 records in 1971, followed by the regular matrix and SQ matrix record standardizations made in 1972. Recently in 1976, the UD-4 record was standardized. In this way, the Association helped in promoting the quadraphonic disc record development.

With the advent of quadraphonic technology developments, high-fidelity sound field generation techniques began to be further considered in more detail, and the binaural system with ambience suddenly attracted keen interest from audio engineers.

In 1975 Matsushita Electric Industrial Company, Ltd. announced an ambience control system based on the binaural technique [5]. The Victor Company of Japan introduced a new biphonic technology which enabled generation of a sound field with ambience by reproducing the binaural signals through the loudspeakers.



a **b**

Fig. 18. Record grooves by S. E. M. **a.** stereo. **b.** CD-4 (x130).

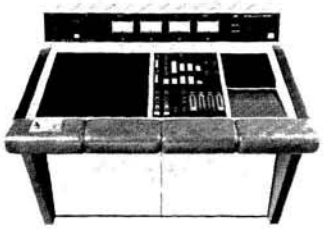


Fig. 19. New CD-4 modulation system.

The company also introduced the Quad-Biphonic system which was a combination of the binaural and quadraphonic technologies to assure stable, 360° localization and depth feeling of the sound image using the CD-4 record as a medium. A further development of the Quad-Biphonic system is expected by both engineers and music lovers.

In the latter half of the 1960s noise reduction systems were more widely used, and dynamic range extension techniques began to attract the interest of engineers. In 1972 Nippon Columbia Company, Ltd. developed a master tape recorder utilizing a pulse code modulation (PCM) technique, and the records transferred from masters using this system were marketed (Fig. 21).

In the PCM master tape recorder the audio signal is converted into pulse coding for recording by a video tape recorder, and then the recording is decoded into the original audio signal in playback. Using this new master recorder, characteristics have been greatly improved as compared with those obtained using conventional tape recorders, such as dynamic range of 87 dB, frequency response of direct current to 20 kHz $^{+0.2}_{-1.0}$ dB, and total harmonic distortion of 0.1% or less.

In the future digital technologies will also be applied to disc recording. Video disc technologies are now being developed by many organizations throughout the world. These will combine to realize a revolutionary disc

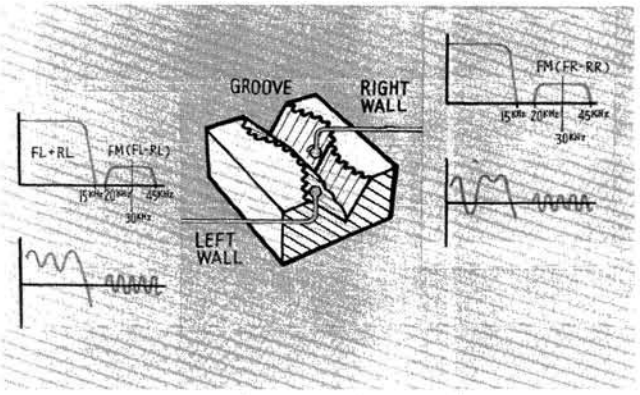


Fig. 20. CD-4 four-channel discrete disc system.

Fig. 21. Nippon Columbia's portable PCM recorder model DN-034R.

that can accommodate not only video signals but also audio signals. The dream of the ultrahigh-fidelity or ultralong-playing-time audio disc will come true, making an epoch in the recording industry.

THE PRESENT STATE OF THE JAPANESE RECORDING INDUSTRY

As indicated in the Introduction, the record and music tape production figures are showing yearly increases of from 10 to 20% in Japan. As seen in Fig. 22, 12-inch (30-cm) record production increased sharply to become comparable to the production of 7-inch records in units. Fig. 23 shows that cassette type music tapes have far outpaced cartridge types in terms of production.

The high annual sales growth of audio products is clear from Fig. 24, and the household audio product diffusion rate is now approaching the 60% level.

At present, sixteen record companies and three music tape specialist companies are the members of the Japan Phonograph Record Association. The association provides

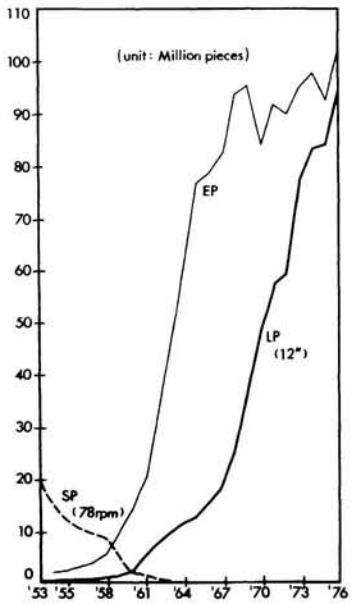


Fig. 22. Japan's disc record production.

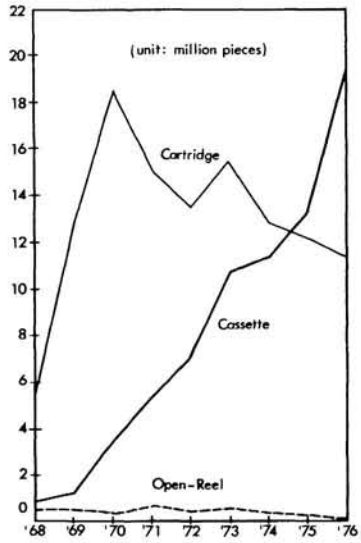


Fig. 23. Japan's music tape production.

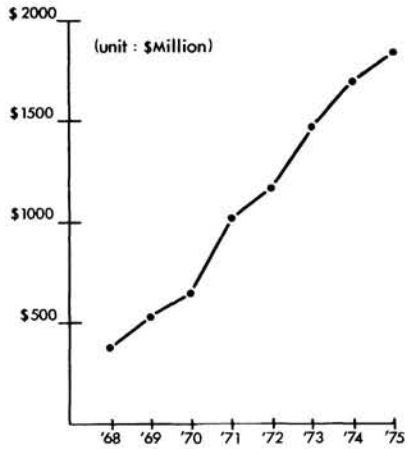


Fig. 24. Japan's stereo equipment sales.

for an engineering committee to review common technical problems among the members. Record, studio, recording, and other subcommittees are also provided for. New technology introduction, problems requiring discussion and adjustment among the members, and standardization matters are discussed in this committee. The committees are organized by engineers from the member companies of the Japan Phonograph Record Association, and they continuously work closely with and cooperate with the EIAJ, RIAA, RIEE, and IEC. The Record Association's aim is to further contribute to technology exchanges and international standardizations between the various industries and between the various nations as well.

ACKNOWLEDGMENT

The author would like to express his deep gratitude to the Japan Phonograph Record Association's bureau staff and to the AES Japan Section executives and Mr. Kei Ikeda, Japan Audio Society, for their valuable contributions to the preparation of this paper.

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Mechanical Sound Recording in Czechoslovakia

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In the past years the *Journal of the Audio Engineering Society* always gave enough room to monographic papers concerned with scientific and technical aspects of the mechanical sound recording. The present panoramic centennial issue is an opportunity for us to contemplate upon the role which sound recording played and still is playing in our rather small nation in the middle of Europe in Czechoslovakia. Although in this connection some technicalities cannot be avoided, we want to draw attention primarily to those untechnical aspects which the public is almost unaware of, but which we think are by no means less important.

The very beginnings of the mechanically generated sound have with most nations a slight flavor of technical legends. They mostly are quite charming but certainly cannot be only laughed at, as they express the primeval desire of mankind to possess means for repeated listening to sound, a possibility that has always been connected with automatons.

Turning our attention back to Czechoslovakia, it seems likely that in the 12th century the news of sound automatons existing somewhere was conveyed to the local ancient aristocracy by wandering minnesingers welcomed in their castles. The minnesingers, on their pilgrimage throughout Europe, came to learn the novelties and sang about them in their poems, mentioning, surprisingly often, kinds of simple sound machines (usually it had been artificial birds singing on artificial trees or the like). We may presume that even the king's messengers traveling at that time as far as the world of Islam could have seen the automatons with their own eyes. It is regrettable that none of these wonder machines celebrated in songs were preserved till our time.

We cannot exclude the possibility that something could have existed in quite an elementary form in the Rudolphian period of Renaissance at least (at the end of the 16th and the beginning of the 17th centuries). At that time the rather eccentric interests of the Emperor Rudolph II had opened doors to many scientists (Tycho de Brahe) as well as charlatans, to artists but also to swindlers. Some of the ancient legends of Prague, the most famous of which is about the giant robot Golem and rabbi Löw, seem to support it. Though in this respect we have to put up with mere hypothesis, it cannot pass unnoticed that already in the very beginning of the second millenium, undisputable proofs of knowledge of acoustics were found in the territory of Czechoslovakia. For example, in the 10th century monastery complex of Davle we can wonder at resonators built in the walls, and in the castle of Humprecht we find ourselves in rooms of unusual shapes, provided with unmistakable centers of sound concentration.

The first historical name that could appear in connection with mechanical sound is that of Wolfgang Kempelen who was born in the year of 1734 in a town which is now the capital of Slovakia. His talking machine (Fig. 1) is described in detail and documented by drawings in his well-known book "Mechanismus der menschlichen Sprache nebst der Beschreibung der sprechenden Maschine" (Mechanism of Human Speech with a Description of the Talking Machine), published in 1791. Unfortunately the machine, despite its fame, was not preserved. The once awakened interest in similar apparatus—speech synthesizers in fact—has found many followers in Bohemia. There is evidence that the first performance, after its presentation in Vienna, of the Euphonia talking machine by Faber took place in Prague in July 1842. According to the documentation of that time, the machine had not even failed when "saying" the famous Czech linguistic rarity "strč prst skrz krk," which consists only of consonants. Six years later, in the spring of 1848, sound automatons of the Frenchman Droz were demon-

strated in Prague. Yet it is known that already the 18th century was noted for a growing production of various automatic playing machines in a broad variety of types, from quite small ones up to big orchestrions which in the 19th century reached their golden age and high quality, especially in Prague. Nevertheless, the inhabitants of Czechoslovakia, which at that time belonged to the Austrian monarchy, had not experienced a really recorded sound that is more than its mere synthesis until after the invention of the phonograph. The various tinfoil phonographs at the National Technical Museum in Prague document that soon after the news of this invention, it underwent several stages of practical verification in our country, at least in scientific circles. Later, when the wax cylinders became known, mainly commercial traveling agents acquainted people with the new machines by demonstrating them in various towns.

The phonograph reached the widest public recognition at the occasion of the Jubilee Industrial Exhibition in Prague in 1891. This exhibition was aimed to show the growing economic potential of the Czech industry and served especially for the display of products of pure Czech origin. There were only three exceptions to this principle: Van Houten's cacao, flight with chained and unfastened balloons, and Edison's phonograph. The Edison Company had brought to Prague recordings from its branch office in Berlin, but immediately sensed the national emancipated character of the exhibition and right on the spot started to record Czech actors, comics, and singers (Fig. 2). This instantly caught the attention of visitors, and these recordings became popular all over the exhibition, especially when the future national anthem "Kde domov můj" (Where Is My Home) was recorded. Regarding the fact that the exhibition had nearly 2 500 000 visitors—what amounted to about half the inhabitants of Czech territories—the sound recording soon enjoyed great popularity all over the country. Imported cylinders and phonographs could soon be seen in various shops of optics and mechanics. These very often started their own simple production of wax cylinders. Foreign producers, especially Edison and Columbia, soon discovered that their best chance lay in recording Czech repertoire. Still well preserved from these days of rapid development are samples of the first stages of mechanical recordings, such as those of Czech singers (O. Mařák) and composers (B. Smetana), which nowadays have a great value. In them the dreams came true which many of our elder publicists, such as the poet Vítězslav Hálek or later the theater critic Jaroslav Vodák, had cherished long before, and which were the expression of their longing to preserve the voices of our outstanding actors and singers for future generations.

Furthermore we did not have to wait long for films revived by the sound of the phonograph, which was realized in Bratislava already at the end of the 19th century.

With the new century came a swift rise in production of programs recorded for cylinders or phonographs. The records Pathé, with a vertical cut, presented light music as well as the 8th Slavonic Dance by A. Dvořák; on still one-sided records Columbia offered parts of the Smetana operas. One of the first opera stars to be heard on records was our world-renown singer Ema Destinová. Simultaneously the producers of cylinders and records flooded the market with universal, anonymous world repertoires which have a certain value only as far as they express the atmosphere of that period.

Some producers in Prague offered cylinders with virtuoso whistlers which, besides other things, reveals the influence that technique has over the artistic sphere. These recordings of whistlers, whose tones are known to be sinusoidal and therefore within the limits of the frequency range attainable at that time, created the illusion of perfectness as the recording was without distortion, and hence showed the cylinder to be of remarkably high quality.

In the first decade the Czech production of cylinders was represented by Čechie, which is interesting for its attempt to build up—despite the limited means of its

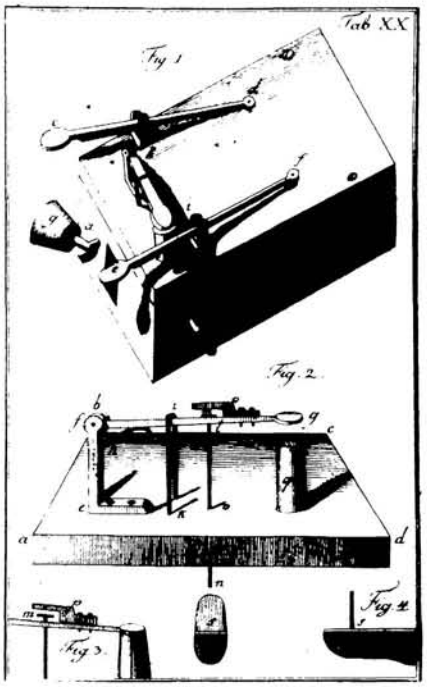

Fig. 1. Main part of the Kempelen talking machine.

Fig. 2. Recording studio in the pavilion of the phonograph at the Jubilee Exhibition in Prague in 1891.

proprietor—a genuine Czech repertoire of good quality. In their catalog appeared light entertainment programs as well as titles of recorded well-known opera singers of the National Theater which always has been a symbol of our national theater culture, chamber orchestras, etc. The second society in Prague, Electra, was a branch office of a German firm, and its dependence for repertoire on its mother firm was obvious.

Within a very short time the first factory of phonograph records was founded in the North of Bohemia, in Ústí nad Labem. The products were known as Zonophone records. It might be of interest that the brother of Emil Berliner, Josef Berliner, took part in founding the factory. This firm also favored Czech repertoire, though not always of the best quality. However, with the beginning of World War I all these enterprises had ceased to exist.

The cultural function of mechanical recording simultaneously found its utilization in another field—it helped the development of professional studies. It is known, for instance, that the Hungarian composer Béla Bartók used phonograph cylinders for recordings of Slovak national songs. His collection of more than 800 folklore recordings survived. A few years later, the famous Moravian composer Leoš Janáček used the phonograph for his studies of the intonation of colloquial talk, which greatly influenced his operas.

Soon after the declaration of the Czechoslovak Republic in 1918, foreign fims became interested in participating in our production. The Zenophone company was taken over by His Master's Voice. The new epoch gave rise to many smaller enterprises and record firms, but they mostly were influenced from abroad. By the fall of 1920, two Czech societies were established—Ultraphon and Esta—and they started to compile a new program catalog.

In this period a unique action was undertaken by the Czech Academy of Sciences and Arts. In collaboration with the French firm Pathé they organized a wide recording program aimed at establishing special archives of recordings. Several hundreds of records were made with recordings of different dialects existing in Bohemia and Slovakia, of national music and songs, of exceptional interpretations of music and poetry, and of declamations of contemporary poets and artists. The uncommercial character of the entire work was quite extraordinary though later some of the records were sold. Today this complex represents a collection of unique sound material of great value for linguistic studies. In the collection the poem of the Czech poet Jiří Karásek ze Lvovic, glorifying the phonograph and entitled "Greetings to Infinity," is also included.

The development of Czechoslovakia's own progressive repertoire that characterized the years around 1930 and the efforts of Ultraphone and Esta came to an abrupt end with the German occupation of our country and soon afterwards with World War II. Despite the difficult conditions, some editions saw light even in that time, among them the "Czech theater" and recordings of outstanding musicians of this time, such as the conductor Václav Talich.

During the war the phonograph record was given a new special function. Especially for the younger generation, which was standing all of a sudden in isolation from the outer world, it became a means of keeping up the continuity and it was a great support in maintaining the national existence. Besides the official editions, many recordings appeared unofficially, namely, those of modern music. Due to a shortness of professional recording material, the recordings were made, for example, on Roentgen films and with surprisingly good results.

The liberation of Czechoslovakia at the end of World War II gave ground for a change in the structure of the Czech economy. Individual small firms were united under Ultraphone to form one central national organization named Supraphon, which soon became the most important center of culture for the restored society. It gave this big organization the possibility to expand the cultural program of utilization of records and to realize the concept formed already during the war. The phonograph record ceased to be regarded merely as a subject of business and became a cultural property. In its repertoire it aimed at offering the best quality of national as well as international music. Extreme care was devoted to the choice of both composers and interpreters. The existing catalog of records comprises all the titles and editions of the past 30 years, and many prominent names and musical bodies appear on its pages. Through Supraphon such personages as David Oistrach or Svjatoslav Richter went to meet the audience of the world scenes. This new national enterprise had the power to build up a chain of hundreds of shops specializing in the sale of records and to have its own technical research. One of the sophisticated enterprises of Supraphon was the opening of so-called music theaters, which were centrally governed from Prague (Fig. 3). They might be described as theater halls combining live performance with music reproduction; they are comfortably furnished in the style of a club, and some varieties have adjacent rooms for exhibitions. The program is a combination of a phonograph record reproduction with a ballet on the stage, or with recitals of poetry, sometimes with projection of slides or films. It might also be a dramatic scene or any other form that would illustrate the reproduced music accordingly. In these music theaters the phonograph record

Fig. 3. The first theater of music in Prague.

reaches its highest impact in becoming the integral part of a synthetic artistic expression. These theaters enjoy immense popularity because they also introduce records of other origins and acquaint the audience with international phonograph productions. Above all, their programs are favored for their diverse attractions including music as well as the spoken word (which in general has an important share in the Czechoslovak production) and aesthetics of movement. No less significant is the role of the Gramophone Club. Its 150 000 members from the entire republic may choose each year from nearly one hundred special titles. The G-Club distributes its journals *The Young World* and *Hifi Fans*. Its *Revue G* has a good professional standard. In recent times another society was founded which belongs to the union of composers and concert artists, bearing the name of Panton. Consequently, their repertoire cannot hide the signs of this influence. The editions include young performers, authors, and artists, and some special recordings. Since the federalization of our country in 1968, the Slovak firm Opus began to show a growing activity and improved its program.

As can be seen, the phonograph record has always played the role of a significant cultural factor in Czechoslovakia. The reason might be connected with the fact that the phonograph industry is within the sphere of the ministry of culture and not that of industry.

The activity of the record industry is not only directed toward production, but it has for instance a special central service from which smaller towns or villages may borrow assorted programs of records of a certain type. It supports a small dramatic group called Lyra Pragensis, which organizes live programs of poetry and provides subscriptions of creative arts (especially graphic and plastic). Furthermore, phonograph records are very inexpensive in Czechoslovakia.

All these activities initiated by the phonograph record organizations favorably influence the cultural life in our republic and guarantee that good music can be heard literally all over the country. The democratizing function of sound recording, which gives people feelings of joy, quiet meditation, and outright pleasure, thus found its fulfillment. And this certainly is the most valuable achievement in the year of the 100th anniversary of the moment when man listened in mute admiration to the miracle of his own voice from a machine made with his own hands.

Corroboree and Other Music

RAY DARNELL

RCA Ltd., N.S.W. 2113, Australia

In the land of the kookaburra, bandicoot, wombat, and koala bear the record industry can be expected to be something special. The most surprising thing about it is that the per capita expenditure for records in Australia is greater than that in the United States and second only to that in Sweden. The figures are $10.97 in the United States, $11.15 in Australia, and $15.45 in Sweden. Since there are 13.6 million Australians, that multiplies out to a $151 640 000 annual industry.

Maybe a part of this success is due to the use of radio, the jukebox and the television to promote records, much the way they are used in the United States. There are 118 commercial and 93 government radio stations in Australia. Some of them are the "middle of the road" (MOR) variety, playing music to live by. There are a good number of stations which play rock music and at least an equal number featuring country music.

There are 4000 jukeboxes in the business, which is effective show-and-tell advertising for records, plus wide coverage by television stations of the concentrated population in the coastal regions.

The life style of Australians is more similar to that of Americans than to any other people, which is one reason why its record business is so much like that of the United States. The majority of sales is in popular music, including contemporary. Country and western music sales are stronger than in the United States. Classical sales account for little more than 5%.

This likeness to the American market shows up again when the source of the repertoire is examined. Of course, this is dynamic and is apt to change even drastically in the face of strong popularity of new artists or groups. Nevertheless, over the last several years about 45% of the repertoire has come from the United States, 30% from the United Kingdom, 12% from Australia, and 13% from the rest of the world. The 12% figure from Australia derives partly from the regulation that radio stations must use 20% of their air time for playing the works of Australian artists.

The recordings of new artists and groups from other countries achieve popularity in Australia almost simultaneously with their release in their homeland. There have been countless examples of this in the last several years, foremost among them were the Beatles in the early 1960s. It happened again in 1975 when the Abba group from Sweden became the number one sales item. In 1976, this group's recordings accounted for 8% of all record and tape sales in Australia. All of the established artists and groups from overseas have large followings in Australia. There would be little difference in the listing of the top 50 on the charts in the United States from the top 50 listing in Australia.

For the Australian artist, it is not a reciprocal arrangement. Even those who are definitely world renown have seldom succeeded in gaining the recognition they deserve without traveling overseas. However, there is an impressive list of more than 20 who have done just that: Marjorie Lawrence, Joan Sutherland, Olivia Newton-John, Helen Reddy, and Marcia Hines have all made the grade. Peter Dawson, Rolf Harris, Leonard Teale, Gary Shearston, Brian Cadd, Daddy Cool, Reg Lindsay, and Slim Dusty are known internationally. For the groups that have emerged on the international scene, the list is The Seekers, The Bee Gees, The Little River Band, Air Supply, The Dragon, Ariel, Rabbit, Atlantics, and Sherbert. According to the population of Australia, this is a fantastic accomplishment. The United States has more than twenty times the population of Australia. It would indeed be difficult to come up with nearly 500 American artists and groups that have equal recognition.

One might wonder why it is so important to Australia to have local recording artists since its life style is so similar to that of the United States. One might think that the American artists could supply that need. One must understand, however, that music is both passive and active: or,

in other words, listening is only one-half of the enjoyment. Giving expression to the particular situation confronting an individual, group, community, or country is the other half, at least in the context of this approach. Sometimes this expression is so vivid that the unique situation is pictorialized throughout much of the world. Such was the case when A. B. (Bango) Paterson wrote "Waltzing Matilda":

> Once a jolly swagman camped by a billabong
> Under the shade of a coolibah tree,
> And he sang as he watched and waited till his billy boiled,
> 'You'll come awaltzing, Matilda, with me.'

The Australian recording industry began as a viable commercial operation in October 1926 when Columbia established its recording studio at Homebush, a suburb of Sydney in New South Wales. The industry employs approximately 3000 people today. This is only one-tenth of one percent (0.001 or one-thousandth) of the Australian workforce. There are 38 000 000 record units sold annually, which is 10 for every Australian household. There are 6.5 million 7-inch singles, 22 million LPs, 9 million cassettes, and 0.5 million cartridge tapes sold annually.

There are eight principal recording studios, headed by the Australian Record Company, Ltd. and EMI (Australia). Five others are in Sydney: A.T.A. Pty., Ltd; Copperfield Sound Productions; Festival Records Pty., Ltd.; J. Albert & Son; and Trafalgar Recording Studio. Armstrong Studios is located in Melbourne. Records are manufactured by six, five in Sydney (Australian Record Company, Ltd.; EMI Ltd.; Festival; M7 Records; and RCA Ltd.) and one in Melbourne (Astor Records Pty. Ltd.). K.G.C. Magnetic Tape Pty. Ltd. and Klarion Enterprises Pty. Ltd. (at Sydney and at Melbourne) are custom tape manufacturers.

There are nine record and tape distributors. The Australian Record Company distributes CBS, Epic, Portrait, Harmony, Odyssey, Philadelphia, International, Caribou, Bethlehem and TSOP labels. Astor has their own label, MCA, Pye (UK), Cream, Casablanca, Vanguard, Janus (GRT), Chelsea, Playboy, and Alshire. Besides their own, EMI handles Capitol, Rocket, Columbia, Parlophone, Motown, Arista, Decca, Albert Productions, and His Master's Voice.

Festival has added United Artists, Mushroom, and Interfusion to their list. M7 Records has extended their distribution to include Youngblood, Pennyfarthing, Electric, Eureka, Hammard, Cherry Pie, and Trans-Atlantic. Phonogram Pty. Ltd. takes care of Fontana, DG, MGM, Mercury, Philips, and Polydor. RCA, Ltd. distributes RCA, ABC, Wizard, Anchor, Ariola, Grunt, Erato, and Camden. Reader's Digest handles their own record distribution. W and G Distributing Co. Pty. Ltd. are in business with their own label and Country Gold. WEA Records Pty. Ltd. list Asylum, Atlantic, Big Tree, Black Lion, Bronze, Elektra, Nonesuch, Reprise, Swan Song, and Warner Brothers.

The vinyl resins for record compounds are imported from the United States and from Europe. However, 90% of the compound used is manufactured in Australia. An Australian manufacturer supplies about 35% of the cassette tape used and another furnishes some 60% of the C-O cassettes. All record and tape labels, jackets, slip cases, album covers, inserts, and packaging materials are manufactured in Australia.

Until about 1970 most of the home instrument variety of playback equipment for records and tapes was manufactured in Australia. However, at about that time there was a great interest in recorded sound, and the demand for consumer playback equipment also increased. The trend was and still is toward modular units and away from the console-type or "stereogram" units as they are called in Australia. The Australian hardware manufacturer has not been able to compete with those who supply the world market with this equipment.

In general, the Australian record business is, indeed, very robust. It looks as if it will remain one of the most active centers of interest in recorded music.

A footnote on the industry in New Zealand reveals that in this country with one-fourth the population, record and tape sales are proportionately about 70% of that in Australia: 1 million singles, 4.4 million LPs, and 1.1 million cassettes add to a total of 6.5 million units. Importation of all recorded product is prohibited. Six companies distribute records and tapes (EMI, Festival, Music World, Phonogram, RCA, and WEA), but only EMI and Phonogram have pressing plants and they are used by all the others. There are four recording studios, one is in Wellington, two in Auckland, and one in Christchurch, which handles most of the work. All in all, the industry in New Zealand is a neat business serving a population of 3.1 million.

Before the Fine Groove and Stereo Record and Other Innovations.....

by WARREN REX ISOM

It has been repeatedly stated that record buyers are a timid lot when it comes to accepting innovations in records and equipment. As an example, it is cited that on November 26, 1925, Victor introduced two new products: the Orthophonic Victrola and the Electrola. That year 42 446 Orthophonic Victrolas were sold, but only 9 Electrolas. It is claimed that these sales numbers indicate reluctance on the part of the record-buying public to accept change. But there are other facts. The Orthophonic Victrola produced the best sound yet heard; the Electrola was certainly no better. The price tags for comparable models were: Orthophonic Victrola, $300.; Electrola, $650. The difference in number of sales reflected the good judgment of the buyer, not reluctance to accept innovation.

One of the most important innovations in the record industry was the change of record speeds, in spite of the fact that generally speaking it matters little what the speed is; it is only important that it be the same and constant.

Back in the handcranked phonograph days when the same instrument was used for both recording and reproduction, what was recorded had to be reproduced at close to the same speed, otherwise, the difference between recorded and reproduced material would have been too great. However, within broad limits, the exact speed was unimportant. Several factors determined what the broad limits were. For better quality, the crank was turned at a comfortable speed, otherwise jerky motion resulted. This comfortable speed was found to be about heart-beat rate—between 60 and 90 per minute. It is interesting to note that armies and bands march at this cadence, and speeds in this range are specified for handcranked farm equipment.

Those who used handcranked phonographs soon learned that if they turned at a lower speed more time could be recorded on the record, but lower speeds gave bad sound. At higher speeds, the sound was better but the recording shorter. They also knew that larger records played longer than smaller records. The original cylinder records were large in diameter and almost impractical in size. Spring-wound motors were necessary before the cylinders could be reduced in size and operated at speeds first of 120 r/min and, later, at 160 r/min for good sound. These speeds were beyond the comfortable range for manual operation. It was soon found that speed is one of the variables of a record system specification. The other variables are the quality objectives, the quality of the recording materials, the size of the record, the length of play and the factor of cost or economics. Change one and all the others are affected.

With the wind-up phonographs that were used for reproduction only, it was desirable that the speed be about the same for all records, but it was not really important since the speed of the player was adjustable. The same situation existed with the first motor driven units—the speed was manually adjusted until the sound was right for the listener.

In 1925, when electrical recording came into existence, a decision had to be made as to what speed would be used for recording. At that time, Victor was operating at 78 r/min, Edison was using 80 r/min for his disc, while some others were using 82. If Maxfield and Harrison wanted their system adopted by Victor, then 78 r/min was the speed to use. An honest and compelling reason was that Victor's 78 r/min was the predominant speed and it was selected for maximum compatibility between the old and the new. In fact, 78 r/min was selected, but it turned out to be 78.2608 r/min because it was necessary to synchronize the recording turntable to the 60-hertz line and 78.2608 r/min was the only speed at which it could be done practically with a simple worm-gear drive. This, however, is not true for spur gears.

The 78.26086957. . . speed is obtained with a gear ratio of 46 to 1 between the synchronous motor and the recording turntable. This can be achieved with a one-tooth worm gear mating with a 46-tooth driven gear. This is the most direct and simple system preferred for precision work. This speed can also be obtained by a spur-gear train of two 12-tooth pinions, one intermediate 46-tooth gear and 144-tooth turntable drive gear. For 78 r/min exactly, the gears are 13-tooth pinions, 39-tooth intermediate, and a 200-tooth final turntable drive gear. There is not a practical simple worm gear drive to obtain 78 r/min exactly from a 60-hertz synchronous motor.

The 33⅓-r/min speed came about when Western Electric synchronized motion pictures with records shortly after the introduction of electric recording in 1925. A reel of 35-mm motion picture film runs for 11 minutes. A record was needed to play the same length of time, which was 3.66 times longer than the 3-minute 10-inch 78-r/min record. It was also necessary that the sound be equal to that of the best records. The minimum needle-in-the-groove velocity was 16.33 in/s. To obtain the minimum groove velocity would require, at the end of play of the

record under design, a minimum music groove diameter approximately twice that of the 78-r/min record if its speed was to be approximately one-half of 78 r/min. If the speed was to be a little less than one-half, the minimum diameter would have to be larger. Ten inches would seem to have been indicated since the 78 minimum music groove diameter was more than 4 inches. With this determination made, the speed of the record was next in order. Since some difficulty was previously experienced in locking 78 r/min to the line, the motion picture projector people were consulted. What would be a convenient speed approximately one-half of 78 that could be easily locked to the 60-hertz line? The answer was 33⅓. A simple worm drive with a one-tooth worm and a 54-tooth driven gear or a spur-gear train with 18-tooth pinions, a 108-tooth intermediate, and a 162-tooth final turntable drive gear did the job perfectly.

With this information in hand, it was determined that 11 minutes of playing time would require 33⅓ grooves for each minute or 366.6 grooves. At 75 grooves per inch, a music groove band or area on the record of 4.884 inches wide was required, or an increase of 9.77 inches in diameter over the minimum music groove diameter, for a total diameter of 19.77 inches. This meant that a 20-inch diameter record was required.

Increasing the groove pitch over the very conservative figure of 75 per inch used in the trial calculation gave the additional record area needed for limiting the maximum music groove diameter of 19½ inches on the 20-inch record to provide a guard band at the circumference. This, in essence, is the story of the origin of the 33⅓ r/min record speed.

For the 33⅓ 12-inch LP, only the arithmetic is different. For a 23-minute record, 766 grooves are needed. At a pitch of 300 per inch, this is a music groove band of 2.553 inches wide for the maximum music groove diameter of 11½ inches on a 12-inch record with a ¼-inch guard band. This leaves a minimum music groove diameter of 6.394 inches; more than needed but found useful for progress. On the basis of such a calculation, the decision was to stay with the 33⅓-r/min speed. The average wavelength for the top frequency reproduced was 0.0055 inches for the 78 r/min compared to 0.0012 for the 33⅓. The improvement in compound had more than offset this difference.

The story of the 45-r/min single can be told more briefly. The commercial policy decision was to have a 7-inch high quality fine groove 5½-minute single record plus other features not relevant here. In this instance, all of the design variables except the speed had been established. The arithmetic said 45 r/min. No other figure would fit. The selection of this speed was a well-considered determination in every instance and not the product of caprice. However, there is another—shorter—version of how it was chosen: 78 minus 33 equals 45.

Did the war of the speeds cause record sales to dive from 1948 to 1950? It is true that during 1948 and 1949 and for a while thereafter, when Columbia and RCA introduced fine groove records, sales in the United States did turn downward from a continuous upward curve. Then, when RCA in 1950 began releasing records on both speeds, and when Columbia did the same in 1951, record sales soared again. The other and more important half of the story is that during the introduction of the new speeds, the U.S. was experiencing a post-World War II depression with increasing unemployment, frequent layoffs, federal government expenditures reduced by 60%, and per capita income decreased by 7%. The downward turn of record sales coincided with these conditions. In 1950 almost simultaneously with both companies releasing records on both speeds, a conflict started in Korea. Expendable income became more plentiful and record sales responded accordingly. After factoring out the effect of the national economy, the battle of the speeds could not have been heard even around the block. For better or worse, the record industry is not a world unto itself.

Prior progress had set the stage for fine groove record developments that came in the late 40s. No one thing can be named as the most important prerequisite for a fine groove record. A lot of conditions had to be met before it could happen. As important as any other was a record material equal in quality to the demands of the new record. Comparative dimensional figures indicate the severity of the demands. A wavelength of 0.0012 inches at an average speed of 12.4 inches per second for a 10-kHz response is required for the fine groove record, whereas a 0.0055-inch wavelength had been sufficient for the 5 kHz top frequency of the 78-r/min record. If the signal-to-noise performance is expected to be the same at these frequencies, the fine groove record demands six times more information per square inch of record music groove surface than does the 78-r/min disc. In other words, compared to the 78-r/min record, the fine groove record has a music surface utilization factor of 6. Vinyl compound supplied this demand with ease. For the 30 dB better signal-to-noise figure that was sought, orders of magnitude of improvements in final record performance were indicated.

A lot of decibels had to be found. Fortunately, there were many places where they could be found. In the late 30s work on a nitro cellulose material for original recordings began to produce promises of excellence that blossomed into spectacular improvements by the middle of the 40s. This was a major contributor of these needed decibels. No better basic material has been found to date, some 30 years later.

The coming of electrical recording in 1925 was as important as the new materials. In its evaluations since, the elegance of the engineering by Henry C. Harrison and Joseph P. Maxfield has not been overly emphasized. The practical effect of this was to relieve the record of the necessity of bearing the brunt of the work associated with the reproduction of the recording. The meaning of this is best seen by comparing the stylus force used before and after electrical recording. For acoustic reproduction, a stylus force of 9 ounces was used by the Edison Diamond Disc phonograph. The stylus force of a current fine groove record playback cartridge is 0.75 grams. Very roughly, 9 ounces is 300 grams. The force ratio between 300 and

0.75 gram is 400 to 1. The meaningful ratio between the stylus pressure in the two instances can be approximated by factoring the force ratio of 400 with the music surface utilization factor of 6. The figure of merit for the improvement is 66. In practical terms, it was found that the abrasion between the record groove and the stylus has been reduced 1000-fold from the worst to the best, and surface noise reduced proportionately. Record life accordingly has benefitted immensely and the overall record quality and performance has been improved by a large order of magnitude. It has taken the one-half century since 1925 to realize all of this.

The bulk of the improvements that made the fine groove record possible were contained in these three developments: the vinyl compound for records; the nitro cellulose for lacquers; and electrical recording. Beyond these were other important and necessary developments. The fine groove record depends upon a precisely shaped jewelled recording stylus. Edison had been aware of this need before 1890 when he began to use wax as a recording material. The first use of an electrically-heated cutting stylus was in 1892 by W. Bruening. The importance of burnishing facets was known in the period also, but the perfection of this art was left for the fine technique of Isabel Capps to experimentally develop cutting styli shapes to remove the thread of material from the groove with the minimum of distortion of the lacquer surface. Her refinement of this art to a science has reduced the noise on the master disc to a level at which it is no longer of major concern.

Playback styli of a constant shape and permanent character was high on the list of priorities for Edison. His use of wax for cylinders could tolerate no damage for a stylus with an ever-changing profile. He used a diamond stylus on his Diamond Disc phonograph. The importance of the stylus to the quality of playback was generally ignored almost until the advent of the fine groove record. These are some of the developments that heralded the coming of a new day for the recording of sound on discs.

In all the areas of the record industry, there has been a succession of leaders who have nurtured these developments. Sometimes a leader in one area can visualize the overall needs of the industry. One such man was Louis Sterling whose ultimate contribution was that of managing and directing the EMI organization to become in time the largest record company in the world. He had an uncanny sense of the need for electrical recording, supported it in his own laboratories before the work of Maxfield and Harrison was known, and when it was known, reacted quickly and positively to gain the right for his company to use the technique. During the course of these events, he directed Isaac Shoenberg of his research department to develop a system of electrical recording which would avoid the Western Electric patents. Shoenberg set a remarkable young engineer to work on this project. The young man was Alan Dower Blumlein, who in a career of 20 years cut short by a wartime accident in 1946, established himself without peer in the field of recording techniques. Within 5 years he had developed an electrical recording system using a moving coil microphone and the Western Electric equipment was shipped back to America. He and his group also designed a portable version of the system. Both recording systems served EMI for a score of years. The BBC also made use of them.

A. D. Blumlein had the technical initiative characteristic of the genius. Accounting for the difference in situation, time, and place, he could be favorably compared to Edison. The most alike of their many similar characteristics was their attention to details. Edison's British Patent 1644 for "Improvements in Means for Recording Sounds, and in Reproducing such Sounds from such Record" (April 24, 1878) had its 20 claims supported with a provisional specification backed by 67 sketches. Mr. Blumlein's patent issued in 1931 as number 394,325 by British Patent Office had 70 claims.

It was not only the details of this patent but particularly its substance that marked his greatness early in his career. He had completed the development of the vertical-lateral (VL) stereophonic recorded sound system as well as a 45-45 system for records, in spite of the limitations of the compound and all of the other inadequacies of records of that day. Not only did he complete the developments but his evaluation of the two systems anticipated the decision of the record industry by some 25 years. No wonder the British record industry engineers accepted the decision of the engineering committee of the Recording Industry Association of America with patriotic dignity when it declared in favor of the 45-45 system. Alan Dower Blumlein is a legendary engineer of the record industry of the world.

Even before—certainly after—stereo, and particularly from the beginning of recorded sound, the quest for the ultimate in sound has been a relentless inspiration for all those who believe that technical progress is forever possible. And in addition, there were and are many others who strive within their limits of knowledge, skill, and commitments to make "systems" sound better. Often times, it has been this second group that has pointed the way for the innovations by recognizing improvement, by resisting retrogressive change, and by improvising on their own. Although it is impossible to give clear-cut examples of this, there are several instances in which this group action has been an important factor. One was the surprising public acceptance of recorded sound indicated by the early success of the jukebox and by its seemingly eternal life. Another was the tenacious clinging to the cylinder record with its inconvenience of handling and storage, and with its dull lackluster repertoire for more than a decade after the Edison Diamond Disc phonograph was introduced in 1913. The third instance is the countless things that phonograph owners still do to identify themselves with the effort to have improved sound.

The inadequacies of the first record players were legion but none were as obvious as the single piece funnel-like elongated cones that were used for directing the reproduced sound from the machine to the listener. These "horns" were not so inadequate for an audience of one standing over the machine but for a larger audience seated in front, the horns, aimed at the ceilings, completely missed their mark. The first "add on" or accessory business was born to correct this deficiency. No sooner had

the delivery of the phonograph been made before the horn man came to demonstrate in the home of the new owners the vast improvement that the separately-purchased morning glory horn would make in reproduced sound. Invariably, it was purchased. It was not long until the popularity of these add-on horns convinced the manufacturer that they were needed as part of the original equipment.

In most of the parlors of this early period, the phonograph was placed on a stand-table that sooner or later, because of acoustics, aesthetics, or domestic tranquility, ended up in a corner of the room with the horn (loudspeaker) pointed diagonally. That was fine for adults, but for a child four or five years old, it was impossible. Children always requested that the player be put on the floor and, at grandfather's house, the request was always granted. There the child stood in front of the machine with his head literally stuck in the horn. He listened to his favorites again and again: "The Preacher and the Bear"; "Casey Jones"; and "Uncle Josh." He memorized these by an osmosis-like process due to repeated exposure. Ever after, until early adulthood, he was called upon at family affairs to give recitations more often than the phonograph was played. He was always ready to go without windup; the only difficulty was shutting him off.

What he was doing at his grandfather's was hearing everything that came from the cylinder by putting himself in an acoustical envelope filled with the reproduced sound which completely absorbed his audio consciousness. What Edison was doing at his recording studio was attempting to register on the cylinder everything that came from the performers. Edison went about this at one time exactly as the boy did. He built a brass recording horn 200 feet long in which he placed the recording artists. The boy had more success in his listening than Edison did in his recording. Edison gave up on this technique for recording.

Edison's objective was to bring the artist into the listening area—the living room or parlor. To do this, he worked hard to record the direct sound only, not the reverberation or house-effect of the studio. He technically accomplished his goal: he was able to record orchestras with as many as 35 instruments all of which could be heard on playback. If the instrument could not be recorded, he barred it from the recording. The widespread demonstrations of his unbelievable tone tests gave a measure of his technical success in meeting his acoustical objective. These tone tests were instituted with the introduction of the Diamond Disc phonograph. In a concert hall filled with invited guests from the press, industry, government officials, and distinguished citizens, an artist appeared on the stage with a Diamond Disc phonograph. His live performance was alternated with the playing of the record. The audience was asked to indicate when the record was being played, and it always left the demonstration convinced that the reproduction was indistinguishable from the real performance. Walter Welch, the author of the first article in this issue, conducted many of these tests.

Even amid advertisements crying trickery, lawsuits charging infringement, and lack of top recording stars, Edison started a stampede among independent record manufacturers to the hill-and-dale disc. Then, at the most critical time for following through on his technical success, he was asked to take charge of the antisubmarine warfare developments at the United States Naval Department during World War I.

There was no trickery in these tone tests. Edison had succeeded in bringing the artist into the listening area unencumbered by the acoustics of the recording area. Therefore, it is not surprising that from the stage of a concert hall, there would be little to distinguish the recording from the actual performance. There were no telltale superimposed acoustics.

The other recording companies, especially Victor, were doing exactly the opposite. Their objective was to take the listener to the recording studio or concert hall. Edison's great success did not necessarily mean that he had the right approach for ultimate commercial success. It is almost certain that he did not. His approach was proper for him as a home body and a loner who never longed, as is said in the vernacular, to go out and get with it. The current success of the recording industry is based on the other concept: recorded music takes the listener away from it all; it transports him away from his station in life to a land of make-believe. There may be a few but unknown surviving record companies that use the Edison approach.

The validity of the "head-in-the-speaker" (acoustical envelope) approach to critical or enjoyable listening has been supported by the sequence of developments several times during the past. One was that during the beginning of the electrical recording era, phonographic loudspeakers were often placed at ankle height and almost always hidden behind a grille or enclosure. Thus, largely nullifying any sense of presence. At the same time, radio was putting the "head in the speaker" by use of earphones, headsets, and table models. The listening room acoustics were effectively sealed off from the listener. This plus the knowledge of the place of broadcast supported the illusion of presence at the performance and added the thrill of "being right there."

Many of those who have grown up at the same time as the record industry have frequently tried to bring the ultimate in recorded sound into their own home. Some of these experiments were naive, others more sophisticated, and some of them were even meaningful. The permanent magnet loudspeaker gave a new freedom to these do-it-yourself audio projects. In mono days, a permanent-magnetic 10-inch loudspeaker was put in the cold air return duct of the hot-air furnace. This distributed a delayed, principally low-frequency audio signal throughout the house which enhanced the presence of the sound from both the radio and the phonograph by enlarging the acoustical envelope. Another audio activist rebuilt one end of his living room as the mouth of a gigantic horn reaching back 50 feet or more into his yard. Those that heard it claimed the same sensation of presence that the child enjoyed with his head in the morning glory horn of the Edison cylinder machine. Stereo sound gave new opportunities for experimentation in the home. One of the most successful was for those who had a dining room at one end of the living room which was as long as the dining room was wide and with an opening between the two. Stereo

loudspeakers were installed in the wall on each side of the opening, one set facing the living room back-to-back with a set facing the dining room. This loudspeaker arrangement enhanced the presence of stereo by twofold. Another house might not permit this arrangement, but it was found that four-loudspeaker stereo recovered much of the enhancement.

But this was 1966 and four-loudspeaker stereo had already become a commercial reality with the introduction of the eight-track stereo cartridge a year or so before. Consciously or otherwise, four-loudspeaker stereo put a lot of inventive minds in gear. Some thought was given and action taken to enhance the sound of this arrangement by introducing fixed time delays in the signal going to the rear loudspeakers. Other processes went further by using networks to sort out the salient features of the stereo signal and to direct their playback with regard to loudspeaker placement. Generally, in-phase signals were regarded as direct sound and sent to the front loudspeakers while the out-of-phase signal was considered ambiance and went to the rear. The first QS equipment used this approach, as did Dynaco. E. Roerbaek Madsen in the May, 1970 issue of the *Journal* reviews "The Extraction of Ambiance Information from Ordinary Recordings." The object of these betterment systems reported so far, both do-it-yourself and those commercially available, was to better hear the recorded sound.

The next phase started with the consideration of adding more information to the record. Stereo sound was not making full use of the recording capacity of the record groove; the idea was that the unused capacity could be utilized to record more spatial information directly. This reasoning was based upon the knowledge of information theory but prompted by the desire "to recreate acoustical events as accurately as possible." These thoughts may have been in the mind of Peter Scheiber of Bloomington, Indiana when he translated ideas into equipment in 1967. The spatial information was encoded with the stereo signal and decoded on playback. He worked on the "bugs" and the perfection of the system for a couple of years and then gave a climactic demonstration to an overflowing AES section meeting in the RCA studios in New York in 1969. This meeting indelibly marked the great and excited interest in achieving a new dimension for reproduced sound. After that, it was only a short time before the announcements were made. R. Itoh of Sansui had invented the QS matrix in 1969. CBS Records demonstrated its stereo/quadraphonic matrix-with-logic system before the Recording Industry Association of America Engineering Committee in August 1970 and announced the SQ system publicly in June of 1971, with Sony its equipment-supplying partner. In addition, Electro-Voice was active in developing chip components to ease the incorporation of matrix playback in standard record player designs.

In the meantime, however, other things were happening: at the 25th Anniversary of the David Sarnoff Research Center at Princeton, New Jersey in September 1967, RCA had publicly demonstrated four-channel sound from tapes; in August 1970, RCA introduced four-channel sound on eight-track tape cartridges; in October 1970, the Victor Company of Japan (JVC) introduced discrete four-channel sound from records at the 39th Convention of the AES. These events served notice that the continuing progress in electronics supported an approach that was deemed to be impossible only a few short years before.

These developments which have brought about all types of four-channel systems open wider the opportunities for achieving the ultimate in sound reproduction.

The most recent supreme effort on the part of the recording industry for the betterment of reproduced sound has produced four leaders just as the early evolution of the phonograph produced its four; namely, Leon Scott, Thomas A. Edison, Emile Berliner, and Eldridge Johnson. Using the technique of competitive sports, they can be matched-up, one-on-one for Peter Scheiber, Takahashi Inoue of four-channel discrete sound, Benjamin Bauer of the SQ system, and Howard Durbin who did so much at Electro-Voice to promote the incorporation of circuitry in players to accommodate the new recording techniques.

Ideas must be backed up with hardware before the innovation can be of any significance to the industry. This has been especially true for four-channel sound. Not only were demands of the new systems met by turntable, electronics, and loudspeaker developments, the suppliers of playback cartridges extended themselves in behalf of the innovation and again proved their place to be among the most important in the industry.

The introduction of the Dolby noise reduction system in 1966 immediately set the stage for further progress in recording and record manufacturing, which materialized almost immediately. To date, as is generally known, noise reduction systems, including the later dbx system, have up-graded the performance of the popular cassette tape system. What may not be so well known is that discrete four-channel recording is virtually dependent upon noise reduction.

The quest for the ultimate in recorded sound for audio engineers is much like the pursuit of general welfare for social scientists. There is complete agreement with the general objective. The difficulty is that in both areas the crucial words of the statement of the objective prove to be a weasel phrase capable of so many meanings that in any specific use they are meaningless. Every social scientist has his own definition of "welfare," which he will defend with the full force of his professional reputation. Likewise, each audio engineer has his own notion of "the ultimate in recorded sound" and too many of them give too high a priority to its defense. This happens most obviously when the objective can only be defined in terms of an engineering judgment, compromising the practical with the theoretical. In these instances, there is a strong tendency on the part of too many to dissipate their energies in establishing a medieval scholasticism seeming to make permanent that which can be made obsolete by continued technical progress. There is no better example of this sort of thing than in the literature of four-channel recording. There has been so much emphasis on the technology and the details of its development and metered performance in

terms of dBs versus coefficients that one wonders if the objective of better s-o-u-n-d input for the human ear has been forgotten.

After all, the basic objective of four-channel sound is to more effectively transport the audio consciousness of the listener back to the acoustical environment in which the original performance took place. One way to do this is to establish a controllable acoustical envelope in the listening area that can duplicate in miniature and to scale the acoustical envelope in which the recording was made. To date, four-channel recordings have done this most successfully, essentially by using four loudspeakers with enough power to establish a recognizable acoustical envelope independent of the playback environment. After all, is not this bringing the concert hall to the listening room? Maybe so, to an unimaginative person, but it may be better described as transporting the audio consciousness of the listener to the locale of the audio event. This is for reasons of dimensions, semantics, psychology, technology, and emphasis. Most studios or concert halls would never fit in a living room, "audio consciousness" is much more easily transported imaginatively than are concert halls, it takes the listener "away from it all," loudspeakers are available that can control a miniature and scaled acoustical envelope in a moderate-size listening area, and it places the emphasis on the recording, not on the development of an imposed playback art form. The growth of technology insures that the ultimate in reproduced sound will be achieved progressively, for technical progress is forever possible.

The description of the boy with his head in a horn started this discussion of the acoustical envelope but as Edward McIntyre of *The New York Times* has said, "The importance of the acoustical envelope has been known since the ancient Greeks built their amphitheaters on the Athenian hillsides." However, this concept of transporting the "audio consciousness" of the listener via the acoustical envelope is known as the Georgian effect, for Georgia was, in fact, the name of the plantation of that boy's grandfather.

The LP and the Single

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The work of Maxfield and Harrison in the 1920s and that of Hunt and Pierce in 1938 laid the foundation for fine-groove and long-playing records. Low mechanical impedance pickups, inspired by Hunt and Pierce, made possible the commercial realization of fine-groove recording. This is manifest in the 33⅓-r/min long-playing record and in the miniaturization of the 78-r/min single by the 7-inch (17mm) 45-r/min record.

For nearly 50 years following Edison's demonstration of his phonograph, a continuous effort was made to refine it. This work was almost all empirical and the results had to be judged subjectively. There was much room for improvement.

In the early 1920s scientists and engineers at the Western Electric Company undertook a theoretical analysis of the phonograph, and the results of their work had a tremendous impact upon the industry. This work is described in Maxfield and Harrison [1], presented to the AIEE in February, 1926. It is interesting that this effort was made outside of the record and phonograph industry. Demonstrations and offers of licenses had been made to Victor and Columbia two years earlier.

In their analysis use was made of electromechanical analogies. Mechanical systems were converted to their equivalent electrical circuits. The results of circuit analysis were then transferred to mechanical form, thereby establishing the design parameters for the system. This technique was applied to the design of an electrically driven disc record cutter and an acoustical phonograph.

The cutter was an electromagnetic one having a balanced moving iron armature and a rubber line mechanical resistance damper. It had an enormous effect on the cutting of master records. It not only relieved the limitations of the recording studio imposed by the horn mouths, which were replaced by microphones, but additionally it made possible a far superior frequency response and recording level. Vacuum tube amplifiers were used to raise the microphone output level and to drive the cutter armature.

The recording characteristic was basically constant velocity with a crossover to constant amplitude below 200 Hertz. Constant velocity is consistent with acoustic reproduction. The compromise below 200 Hertz was thought necessary to avoid excessive amplitudes. It was prophetically observed that if electrical reproduction were used, it would be possible to compensate for modification of the recording characteristic.

Probably because vacuum tube amplifiers were expensive and required batteries, their phonograph was an acoustic one. It was manufactured by Victor and was called the Orthophonic. Its performance was vastly superior to any previous phonograph. However, its commercial life was limited because shortly after its introduction radio–phonograph combinations began to appear. Radio was a dirty word at Victor in those days.

There was an enormous population of acoustic phonographs in use at the time on which the electrical recordings gave quite acceptable results. All the sound energy emanating from the horn was derived from the work done by the record in vibrating the needle. As a consequence, bearing forces of several ounces upon the record were required to keep the needle from jumping out of the

groove under its work load. To bear the huge resulting pressure it was common practice to include abrasive material in the record compound to grind the needle to fit the groove, and thus to distribute the force over a larger area. This required frequent needle changes because the elongation of the facets ground thereon would interfere with the high-frequency components of the recorded wave, giving rise to distortion. Even when electrical pickups appeared, they were fitted with needle chucks and still required needle forces of an ounce or more.

The first talking pictures to be commercialized successfully used disc records as the sound source. It was a development of Western Electric, called the Vitaphone. This required a record having a playing time equal to the running time of a standard reel of moving picture film, about 11½ minutes.

Maxfield has shown (U. S. Patent 1637082) that the size and rotational speed of a disc record are dependent variables. The independent parameters are the permissible minimum groove velocity, the groove pitch, and the playing time. Using the then current 78-r/min parameters, the optimum record required a 16-inch (401-mm) diameter and a speed of 33⅓ r/min. While sound on film soon replaced disc for talking pictures, the 16-inch (401-mm) 33⅓-r/min record became a useful standard for radio broadcast transcriptions. By reducing the stylus diameter and increasing the number of lines per inch, the playing time of 15 minutes was easily accommodated.

Later, in designing the LP record the optimum speed was found to be so close to 33⅓ r/min that there was no reason to choose another.

Unquestionably, the most significant development subsequent to the Maxfield–Harrison work was that of Pierce and Hunt. Their paper [2] marked the break point between the heavy replaceable needle designs and the lightweight jeweled stylus types of today. Their pickup bore on the record with a force of 5 grams and had a jeweled stylus accurately ground to engage the side walls of the groove. This low force suggested the possibility of a smaller tip radius, a smaller groove, and a greater playing time. This was anticipated in their paper [3] in which a 12-inch (305-mm) 33⅓ r/min record having a 19.2-minute playing time was proposed. The present-day LP record differs from this only in that the maximum displacement is one half that assumed in the paper, effected by placing the low-frequency crossover at 500 Hertz instead of 250 Hertz. The reduced displacement permits 275 lines per inch as compared to the 175 lines suggested in the paper.

Attempts at longer playing records previously had been made, the most notable of which was the effort by RCA in 1931. They were 12-inch (305-mm) 33⅓-r/min records with somewhat smaller grooves than 78s. The heavy reproducers quickly degraded the smaller groove, and the speed stability was unsatisfactory. The center-driven turntable was subject to flutter and wow.

Two developments set the stage for successful implementation of fine-groove and lower speed records. First were the lightweight pickups, inspired by the Hunt and Pierce pioneering work, which appeared commercially after World War II. Second was the rim-driven turntable. The latter came into common use in player attachments for 78 records. Most radio sets had a phonograph receptacle into which these attachments could be jacked. They were much less expensive than the center spindle drives and offered a distinct advantage in performance. Because of the tight coupling of the motor rotor to the turntable rim, the considerable flywheel effect of the rotor is imparted to the turntable. The kinetic energy is proportional to the square of the speed.

After CBS purchased Columbia Records in 1938, a policy was established that all recording would take place at both 78 and 33⅓ r/min. The 78-r/min masters were processed and the 33⅓-r/min safeties were kept in file with a view to future use. Remakes of 78s damaged in processing could easily be rerecorded from them. These safeties were invaluable when the commitment to long-playing records was made. They were, of course, segments of about 4 minutes, as required for 78s.

A team was organized to "splice" these safeties to complete movements. A point in the musical score near the end of a side was chosen, and the number of revolutions to the end of music was counted. From a precise starting point on the succeeding segment the turns were counted to the start of music. From the cue point in the score the difference would be counted out to establish the release of the succeeding disc which was held slipping on its turntable until the count was completed. A cross fade was executed at the musical splice point. This transfer was so smooth that it won the approval of the most exacting conductors and artists.

These 33⅓-r/min spliced safeties were then used to cut the processing masters for LP records. Thus a disc-to-disc-to-disc transfer had to be made for all the pretape LPs. This required precise control of the recording and reproducing frequency characteristics to avoid quality degredation. By 1950 tape equipment of adequate quality was available to eliminate the disc spliced safety.

A very severe and perplexing problem in cutting the LP master was that of noise which increased as the diameter of the groove decreased. This could be reduced by using a cutting stylus with a greater degree of "dubbing," but this would cause loss of high-frequency response. "Dubbing" is the application of reverse facets on the leading edge of the cutting stylus, reducing the noise but effecting self-erase of the shortest waves. This problem plagued every master attempted, since it had to be a compromise between loss of highs and background noise.

A massive campaign was mounted to attack this problem which included variations in the formulation of the lacquer master discs, heating the discs, cooling them, and consideration of cutting at higher speed, although the response limitations of the cutters would be a sacrifice.

It was eventually postulated that the function of the "dubbing" facets was to generate heat to flow the lacquer to a smooth surface. This was supported by the fact that friction heat so generated at the inside was only one fourth that at the outside, the groove velocity bearing a 1:2 ratio.

The problem was solved by winding a fine wire around the stylus near the tip and heating it with a direct current to equalize this differential. A patent was never applied for

on this invention because of timidity or lack of zeal on the part of the attorneys. Columbia enjoyed its use as a trade secret for about a year. It inevitably leaked and was therefore made the subject of a paper to establish Columbia as its originator.

Columbia's commitment to introduce the LP was evidently a well kept commercial secret. An agreement was made with Philco to manufacture and market a player attachment, both to be announced in June of 1948. In April of that year CBS invited RCA to a demonstration of the LP in the hope that they would join in the manufacture of LPs. It was felt at Columbia that eventual success of the LP would require that the repertoires of all companies be available to the public.

RCA chose not to join, but it has been reported that assurance was given that if RCA should in the future release a long-playing record, it would follow the Columbia standards.

At this time RCA had a fine-groove record of its own and a record changer for it all designed and ready "on the shelf." The development of this record and changer was described by Carson, Burt, and Reiskind in June 1949 [4].

It is interesting that the reproducing stylus diameter and groove pitch for this 45-r/min record are the same as for the LP. There is evidence that CBS was not unaware of the fine-groove recording work proceeding at RCA. In any event it is of interest to compare the commercial philosophy leading to the contrasting developments.

An analysis of that portion of the Victor catalog known as "The Music America Loves Best" showed that 80 percent of all selections and 70 percent of the "Red Seal" selections were less than 5 minutes long. Taking all Victor records weighted for sales volume, 96 percent were under 5-minute duration. Thus the choice of 5⅓ minutes was made for the new record. RCA introduced the 45-r/min record and changer in early 1949, thereby initiating the "battle of the speeds."

The Columbia approach was weighted overwhelmingly to classical music, even to the point of neglecting the popular single. An attempt to counter the 45-r/min with a 7-inch (178-mm) 33⅓-r/min record was made, but it never won real acceptance. In 1950 RCA capitulated to the LP. In 1951 Columbia gave in to the 45. So the heralded battle of the speeds resulted not in victory for either approach, but in establishing the need for both a single and a long-playing record.

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The Coming of Stereo

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FOREWORD: The author, as Manager of Engineering RCA Victor Records, later as Chief Engineer, as a member of the Engineering Committee of the Record Industry Association (RIAA), and as Chairman of the Electronic Industries Association (EIA) Committee R 7 Phonograph Combinations, was heavily involved in the standardization of the stereophonic record. This is the story of his personal involvement.

INTRODUCTION—It Was Cold: It was cold as Roy McClay[1] and I stood with overcoats and hats on, with our backs to a small gas heater in Sugden's Laboratory listening to his version of a stereophonic disc recording. It was also our Thanksgiving Day, but my wife would have dinner by herself at the hotel in London, for we would not be back until late. I had joined the RCA Record Division in July 1956, and in November Roy took us for a visit of record plants in Europe. One of our first stops was to hear Sugden's stereophonic record demonstration. The verdict—not outstanding, but promising.

Weeks later, in Zurich, still cold and paying for heat at the hotel but not getting much, we met Arthur Haddy, Chief Engineer of the Decca Record Company of London. Arthur quite frankly told us that they had been working on a stereo record system for some years. He was now finalizing on a system that was good. Next year, 1957, he would be ready to demonstrate and tell us all about it, but not before then.

At last we were back home and warming up again. Out in Hollywood Dr. John G. Frayne's telephone at Westrex was ringing. Another call from another RCA man and another plea for a stereo disc recording head. Later John stated, confidentially, that the pressure, or annoyance, was so great that he started Davis on the development of a stereo recorder before he received approval from the upstairs office.

[1] General Plant Manager, RCA Records.

DEMONSTRATIONS

Westrex 45-45

In September, 1957, Westrex began private demonstrations of their 45-45 stereophonic disc recording system, two channels of information being recorded in a single groove. Each driving coil of the recorder operated at an angle of 45 degrees with respect to the surface of the record and 90 degrees with respect to the other coil. Thus each groove sidewall was modulated independently with information from one of the two channels [1]. (See Figs. 1 and 2.)

RCA members heard the demonstration September 5. The results were good and McClay immediately ordered a recorder, delivery as soon as possible. The following week a demonstration was given to other RCA Record Division officials.

Westrex and Decca

Shortly after the September 5 demonstration, Roys received a telephone call from Haddy. Could he please arrange a demonstration of the Westrex system for Arthur? Arrangements were made for a demonstration on September 25, and Roys would meet Haddy in Hollywood that morning. At breakfast Arthur insisted on arranging for the cab. While on the way he explained why. The trunk was filled with his equipment, pickups, turntable, records, and amplifiers. A complete setup except for the loudspeakers. He was hoping for an A-B test. It was somewhat embarrassing to inform Dr. Frayne about this, but Westrex generously agreed to have Haddy's system set up using their loudspeakers.

The recorder used by Decca was similar in design to that of Westrex. The two driving coils operated at a 45-degree angle with respect to the record surface. However, the two channels of information were not applied

directly, but through a matrix network, so that a laterally modulated groove resulted for one channel and a vertically modulated groove for the other channel, hence a V-L system.

In retrospect Haddy deserves a medal, for his bold action resulted in a condition ideal for evaluation, an opportunity to hear both systems in the same acoustical environment. The low surface noise and brilliant high frequency response of the Decca records was impressive—an indication of experience in recording and processing stereo records.

Two other members of the RIAA Engineering Committee were present, J. W. Bayless of Capitol and C. Lauda, Jr., of Decca (American, not affiliated with Decca of London). Bayless herded us into a corner, and we quickly agreed that time was needed to carefully evaluate both systems before standardization.

After a night flight to New York, the Decca V-L system was demonstrated to others from the RCA Record and Home Instrument Divisions. Following there was the usual pressure interrogation—which system and how soon. A decision, by the end of the year, was accepted. Later, the services of M. S. Corrington were requested to study the tracing distortion of the two systems.

Westrex—AES Convention

On October 11, at the Annual Convention of the Audio Engineering Society in New York, Dr. Frayne demonstrated the Westrex system. The demonstration was well received; some 500 persons were estimated to be present.

STANDARDS MEETINGS

EIA R 7 was designated as the Committee on Phonograph Combinations and Home Recordings, H. E. Roys, Chairman. Three of the subcommittees were very much concerned with stereophonic records: R 7.1 Records, W. S. Bachman, Chairman; R 7.3 Record Changers, W. Faulkner, Chairman, and R 7.5 Pickups and Needles, C. F. Jensen, Chairman.

November 7, 1957—EIA R 7, 7.1, 7.3, and 7.5

A meeting of these committees was held at IRE headquarters in New York on the above date. Some 37 persons were present representing some 26 different companies. The meeting was planned to be an informative one to discuss the two stereophonic disc systems, V-L and 45-45. Dr. Frayne presented information on the Westrex 45-45 system. Mr. Toller-Bond, representing London Decca, presented information on the V-L system. Members of the RIAA Engineering Committee expressed a need for time in order to evaluate the two systems. The pickup people expressed a need for test records. R. C. Moyer announced that as a temporary measure, not having a stereo recorder, he had borrowed a vertical recorder and had cut a vertical frequency record. Pressings would be distributed at the close of the meeting.

Surprisingly, two standard proposals were made for the 45-45 system at this first meeting. B. B. Bauer proposed that the outer groove wall be associated with the right-hand channel and thus activate the speaker on the right, as seen by the listener. He also proposed that "in-phase" modulation be that which would result in a lateral groove. Both proposals were voted upon and accepted.

The meeting was adjourned at about 12:30 P.M. That afternoon subcommittees R 7.3 and 7.5 held a meeting with Mr. Jensen serving as chairman. Problems created by the stereo disc were discussed and a program outlined for a following meeting to be held in Chicago, January 7, 1958.

December 17, 18, 1957—RIAA

RCA played host for the meetings held in Indianapolis on the above dates. This was a memorable meeting for many because of the difficulty encountered when leaving due to a severe snow storm in that area—two hours over Midway airport before landing. Committee members present were Bachman of Columbia, Doherty of MGM, Lauda of Decca (American), Savory of Angel, Uecke of

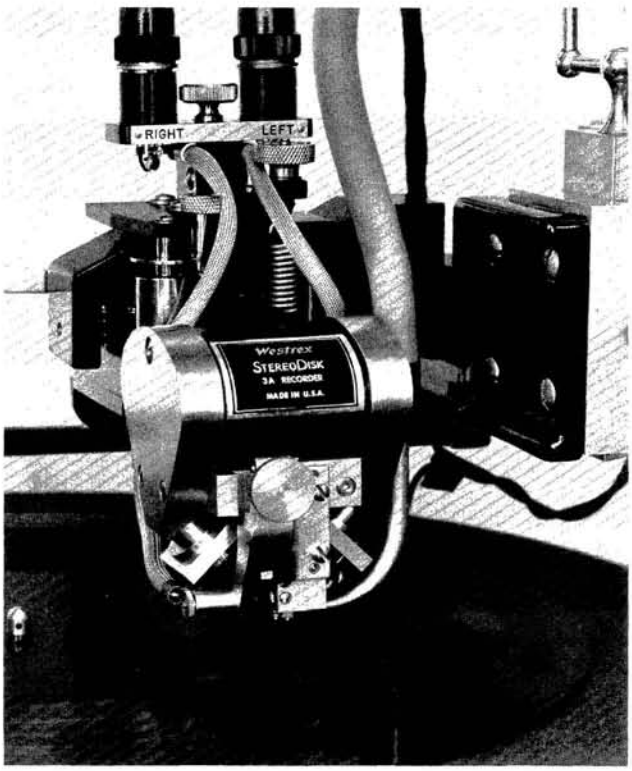

Fig. 1. The Westrex record.

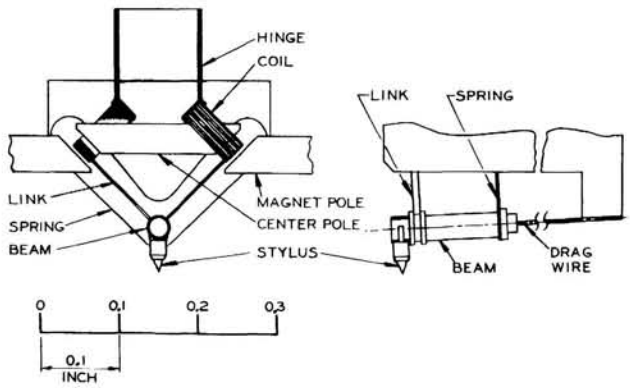

Fig. 2. The Westrex pickup.

Capitol, and Roys and Moyer of RCA. Noted guests were Dr. G. F. Dutton of EMI, England, and Dr. Frayne of Westrex.

Problems were presented and discussed. Corrington gave a thorough report on his tracing distortion study, pointing out the need for a smaller stylus tip for playback. The final consensus of opinion was that the 45-45 system offered sufficient advantages so that it should be designated as the standard. It was further recommended that the reproducer tip radius should be 0.5 to 0.75 mil and that the bottom radius of the groove should remain at 0.2 mil.

Dr. Dutton reported on a meeting held in Zurich, November 28, 1957, where representatives from London Decca, DDG, Electrola, EMI, Philips, Teldec, and Telefunken were present. The group decided that the 45-45 system was more acceptable as a standard. They recommended a reproducer tip radius of 0.5 to 0.6 mil, a bottom groove radius of 0.2 mil, and that other dimensional standards of the fine-groove records be maintained.

Thus at the Indianapolis meeting an international decision was reached. The 45-45 system should become the standard.

January 7, 1958—EIA R 7.3 and 7.5

The meeting of the subcommittees on Record Changers and Pickups and Needles was held in Chicago at the Conrad Hilton Hotel. Some 43 persons were present representing some 25 companies. The Chairman informed the groups of the outcome of the December RIAA Meeting in Indianapolis. The 45-45 was the selected system.

Based upon a survey of changer manufacturers, a stylus tip radius of 0.8 ± 0.1 mil and a vertical force of 6 to 8 grams were recommended. The need for cartridge terminal and dimensional standards was recognized and proposals were made and accepted.

With respect to equipment availability, the committee felt that if the record industry provides adequate test records by the end of January 1958, then third-quarter 1958 production of equipment appears feasible.

January 21, 1958—EIA R 7, 7.1, 7.3, and 7.5

The EIA meeting of the above committees was held at IRE headquarters in New York. Some 60 persons were present representing some 44 different companies. This was stated to be the largest attendance of any engineering committee meeting held at IRE.

M. S. Corrington gave a detailed report on his study of tracing distortion of the two systems [2] which was based upon the earlier work of Pierce and Hunt [3]. For the 45-45 system both channels are recorded vertically, and both even- and odd-harmonic terms would be present. There would be a strong second harmonic. For laterally recorded records, LPs, the even-order terms are canceled out. Therefore, if the quality of reproduction of stereo records is to equal that of LPs reproduced on existing equipment, then a smaller reproducer tip must be used for stereophonic reproduction.

W. S. Bachman reported on the results of the RIAA meeting in Indianapolis. The 45-45 system was selected to become the standard. Arthur B. Haddy reported on the outcome of the meeting in Zurich where European engineers decided in favor of the 45-45 system. Other distinguished guests H. Redlich of Teldec and Drs. Herrman and Schlesswig of Telefunken were introduced. Both Haddy and Schlesswig recommended a smaller tip size for reproduction. A. D. Burt, RCA, described some pickup work they had been doing. Distortion encountered with a 1.0-mil tip was objectionable, whereas the results with a 0.5-mil tip were good.

C. F. Jensen reported on the meeting held in Chicago. Their recommendation of the larger tip size was then questioned in view of Corrington's report and other reports just presented. This was information not available at the Chicago meeting, so the subcommittees agreed upon another meeting after lunch to reconsider the tip size and vertical force recommendations. The groups also stressed the need for test records. Chairman Roys reported that RCA had some uncalibrated 45-45 frequency records that would be distributed at the close of the meeting.[2]

The question of reproducing stereo records on existing equipment created much discussion. EIA reported receiving many inquiries about this. B. B. Bauer was approached and agreed to serve as Chairman of an ad hoc committee to prepare a suitable statement on the subject matter for EIA.

W. S. Bachman called for a vote of approval for the recommendations made by the RIAA Committee, namely, that the 45-45 system be approved as the standard system. Approval was expressed. He then called for approval of the RIAA dimensional recommendations except for the stylus tip radius. Approval was also expressed.

In the afternoon the EIA groups R 7.3 and 7.5 convened. Appreciating the information presented at the morning meeting the members, in the interest of providing good stereo reproduction, agreed upon a reproducer tip size of 0.7 ± 0.1 mil and a vertical stylus force of 6 ± 1 grams.

Following the above meeting, the ad hoc committee under the direction of B. B. Bauer held its meeting. Among the volunteers were Messrs. Benjamin, Faulkner, Machin, Moyer, Person, and Tatter. The essence of their statement was that a good percentage of existing instruments would not play stereo records without some damage to the records.

INTERLUDE

The RIAA Board of Directors met February 7, 1958, and although they did not object to the 45-45 standard proposal, neither did they approve it.

On March 17, 1958, Columbia Records demonstrated to RCA their system of achieving a compatible stereophonic record—one that could be reproduced on existing monophonic instruments without damage. The low-frequency components of the signals being recorded were controlled dynamically to limit the vertical amplitude, and at the same time increase the low-frequency lateral amplitude so as to overcome any appar-

[2] This proved somewhat embarrassing later, when it was learned that Westrex had brought calibrated frequency records for sale, but did not say so after RCA's giveaway announcement.

ent acoustic loss of low frequency response. This was the result of some three years of development work.

RCA made many tests in which the same effect was achieved in a simplified manner. Tests were also made with Columbia recordings made from RCA tapes. Final listening tests were made with persons present from home instruments and the laboratories in addition to those from the Record Division. The conclusions reached were that the quality of the compatible record suffered in comparison with the LP and the full stereo record. The Record Division decided to go full stereo and produce the LPs as they had been recorded in the past.

On March 25 the RIAA Board of Directors decided in favor of the full stereo record and the 45-45 system was approved as an industry standard.

FINALE

March 27, 1958—EIA R 7, 7.1, 7.3, and 7.5

This EIA meeting was held in New York at IRE headquarters on the above date. Some 53 persons representing some 37 companies were present.

Dr. P. C. Goldmark described the system developed by Columbia for producing compatible stereophonic discs and demonstrated some recordings.

W. S. Bachman reported that the standards and recommendations prepared by the RIAA Engineering Committee concerning the stereo disc had been approved by the RIAA Board of Directors. These standards, having been approved by these EIA Committees on January 21, would now be submitted to EIA for their approval.

C. F. Jensen reported on the outcome of their meeting held the afternoon of January 21. They recommended a stylus tip radius of 0.7 ± 0.1 mil and a vertical force of 6 ± 1 grams. The Committee members felt it was desirable to know more about record wear before accepting the proposal.

Prints prepared by Lee Gunter proposing appropriate dimensions for pickups were distributed. Some additional dimensions were felt desirable before surveying the industry.

A need for definitions of new terms involved in stereophonic reproduction was stressed.

H. E. Roys reported that RCA was planning to produce "full" stereo records and continue to produce LPs as they had in the past.

Dr. Goldmark was given a vote of thanks for his presentation.

SUMMARY

Both systems of recording stereophonic records, V-L and 45-45, had been demonstrated by the end of September 1957. Record engineers here and in Europe decided in favor of the 45-45 system by the end of December. The record industry, after considering means of producing a compatible record, decided by the end of March 1958 in favor of "full" stereo and the 45-45 system. Thus some six months after the introduction of the two systems an international standard was agreed upon. The agreement was reached before major manufacturers not already involved could get into production.

In achieving this, three major EIA meetings were held, in addition to those held by record engineers both here and abroad. The attendance at the EIA mettings was outstanding. The cooperation of all involved was remarkable. One may pause to consider why. Except for a few, all were in the same boat, lacking knowledge and experience in the stereo disc field. New pickups had to be designed. Record changers required some revision. Record production entailed refined procedures. The lack of stereo recorders and test and music records imposed severe handicaps. All-out cooperation was essential.

The services of the standardization organizations EIA and RIAA must be acknowledged, for without their status and services it may well have been impossible to bring together the many recognized authorities needed to make the decisions.

The attitude of the Decca Record Company of London should be truely appreciated, for they could have introduced the stereophonic record on their own, using either the V-L or the 45-45 system. Yet they preferred to wait and encourage a common agreement. Haddy said many times, "Roys, it does not matter which system we choose, we must have one and only one system."

Jim Bayless expressed it aptly during a visit with Capitol after production was in full swing and the stereo records were being well accepted: "We did a great job."

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Magnetic Tape Recording Reels, Cassettes, or Cartridges?

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First published information on the feasibility of magnetic recording appeared in 1888. The history is reviewed in brief. An attempt is made to portray and review the sporadic nature and rate of technical development, including major factors responsible.

A short summary is given of building an industry within an industry: the background of stereo-8 tape and its impact on tape technology, FM broadcasting, the music industry, and the economic life it created for the electronic sound product market and the companies associated with it. The Unisette and Elcaset tape systems' possible market impact is mentioned. Finally, the author's firm position on the future of discrete quad is outlined.

THE BEGINNING

It all began in 1888, when Oberlin Smith was overlooked when he proposed magnetizing a wire to record sound. The article appeared in *The Electrical World* on September 8, 1888 and was entitled, "Some Possible Forms of Phonograph."

The Oberlin Smith article describes the fundamentals of what ultimately evolved to what we term magnetic recording. In a humorous sidelight of this classic article, the author suggested some possible applications of magnetic recording, for example,

> "In Fig. 6 the arrangement is precisely the same as in Fig. 4 except that the circuit is made through the telegraph wire W—and the receiving telephone H in Boston or some other distant place. Of course the record might be made at the receiving end instead of the transmitting end of the line, and thus our hypothetical young lady might, while listening to the impassioned pleadings of her chosen young man, be preparing evidence for a future breach of promise suit."

These are shades of today's telephone "bugging," and this was suggested by Smith in 1888, 89 years ago.

For the next half century magnetic recording was almost ignored. A number of patents were issued, summarized in an article by Carmen F. Williams,[1] published in *IRE Transactions on Audio,* and dated March 12, 1956, covering magnetic recording for the period of 1888 to 1952.

In the early days a great deal of development work was tied in with the emerging talking-motion-picture film industry. As a result of matching the speed of the tape to the early film speed, we now have "standard" tape speeds of 15 inches per second, 7½ inches per second, 3¾ inches per second, and 1⅞ inches per second.

Steady progress was made in developing the technology from 1900 to the present. However, commercial progress was not as smooth. It was not until we began to emerge from the depression that commercial interest began to develop. Because of problems with magnetic materials, steel wire began to emerge as a recording medium in the late 1930s, and after World War II it formed the basis of the first consumer application of magnetic recording.

After the conclusion of World War II it was discovered that Germany had developed a "Magnetophon." This machine used magnetic material bonded to a plastic tape to record and reproduce sound. The equipment was manufactured by Allgemeine Elektrizitäts gesellschaft (A.E.G.). A.E.G. and I.G. Farben cooperated in developing the tape which was produced at I.G. Farben in Ludwigshafen and sold by Magnetophon, Inc., Berlin. This technology, in combination with the developing technology in the United States, formed the basis of an information explosion that occurred from 1944 onward.

MAGNETIC TRANSITION TO TAPE

On December 31, 1946, Marvin Camras[2] filed a patent application for a binaural magnetic recorder and a significant seed for a billion-dollar industry.

During the late 1940s the consumer market was domi-

[1] Staff member, John Crerar Science Library, Chicago.

[2] Staff scientist, Illinois Institute of Technology Research

nated by reel-to-reel wire recorders. In the meantime research was moving forward to provide magnetic sound on motion-picture film (8 mm, 16 mm, and 35 mm). Similarly, the broadcasting industry was buying early adaptations of the Magnetophon from such companies as Brush and Magnacord. Because of their low cost, coated paper based tapes were soon introduced. By 1948 it was clear that wire recording would be supplanted by magnetic tapes. There were two fundamental reasons, better fidelity and the ability to edit. Consumer products were introduced and the reel-to-reel industry was born using ¼-inch wide tapes with 7-inch and 15-inch diameter reels. (Later smaller diameter reels were introduced.)

In the late 1940s and early 1950s the first consumer tape players were produced. Brush was one of the first catering to the consumer market. The industry was a monophonic industry populated by broadcasters at one end of the spectrum and hobbyists at the other. Because the "consumer" market was limited to hobbyists, its growth was slow. The availability of high-quality FM music broadcasts opened the market to audiophiles in the 1950s. Although they had been recording music directly from records, the advent of FM increased the practicality of their hobby.

The first consumer reel-to-reel stereo tape recorders appeared on the market in the 1950s. This allowed recording of the stereo records that were first introduced during this period.

INTRODUCTION OF CONTINUOUS-LOOP TAPE SYSTEMS

In the meantime the broadcasting industry developed a more convenient form of tape storage. In 1957 the endless-loop cartridge evolved as a by-product of the Cousino cartridge.

The initial design of the cartridge consisted of a continuous loop in which the inside strand of the endless loop is pulled from the center and returned to the outside circumference of the tape mass. The resulting sliding action between each adjacent tape strand required special tape-locating devices and lubrication to overcome malfunction and/or complete binding.

The initial cartridge designs utilized a pinch roller mechanism that was integral with the tape deck. The cartridge would be inserted, then the pinch roller would swing up inside the cartridge and trap the tape between itself and the capstan. Thus was born what would ultimately become the automatic radio station.

In 1956 Motorola introduced one of the first two-track continuous-loop cartridge systems to the Ford Motor Company. This was shortly after Chrysler found that the disc playback system was not commercially practical. At the time we submitted our cartridge player to Ford, the product apparently was ahead of the market and there was interest generated, but because of the great economic risk, neither Ford nor the software people would consider supporting the program. Therefore they concluded that the market simply was not ready for a cartridge-type automotive player at that time. In retrospect, we must say that they were absolutely correct.

We, as others, continued to follow the progress of magnetic recording, waiting for the optimum time to make a serious entry into the market. In the early 1960s the four-track continuous-loop cartridge system was developed. The four-track system had been, for all practical purposes, launched by Earl Muntz for dealer installation, and it did enjoy limited success within a limited market, but it proved that an automotive market did indeed exist.

By way of establishing background, there were other significant parallel developments. In the late 1950s Rex Isom and Virgil Graham, RCA Record Division, came up with the idea of encasing reel-to-reel tape in a cartridge to simplify handling. It was about the size of a paperback book (thin) with a ¼-inch tape and a speed of 3¾ inches per second. For a multiplicity of reasons it was not a commercial success. This development, however, marks a significant milestone in the cartridge history. The concept reappeared some years later as a transformed device, called cassette.

CASSETTE

This concept was the product of a joint effort by Philips of Holland and Theo Staar[3] of Belgium. The evolutionary technological chain reaction will be continued later in this text; it spawned from the original RCA planar cartridge and subsequent technical developments. In the meantime, cassettes became well entrenched in the mono voice recorder market and a smashing success. The cassette dominated the world mono portable voice recorder market practically from its very start. Advancing technology provided a revolutionary transition through stereo designs which led to music application. Later sophisticated improvements were achieved in tape materials, oxides, magnetic heads, speed (wow and flutter) control, with innovative, more reliable electromechanical designs, including automatic reverse and more simplified operation.

The cassette today enjoys the largest unit volume and is one of the most commonly used magnetic tape products. Application ranges from simple mono-record playback units to commercial application, such as dictating equipment, telephone answering apparatus, audio training tool, plus computer ancillary application. In addition it has penetrated the high-end music record–playback market with noise reduction circuits such as the Dolby and others. Interestingly the performance improvements satisfied all but the most discriminating audiophiles. Within the recent past, improved automotive units have been introduced to the market, reflecting the years of technological advancement. Current product representations reflect a more optimistic automotive market opportunity. The author extends plaudits to all segments of the industry involved for achieving what appeared to be unachievable twelve years ago.

Technical progress, certainly in the dynamic sectors of science, are nonlinear in growth. Cassette technological improvement has to represent one of the near ultimate in logarithmic rate growth, particularly in the high-end con-

[3] Theo Staar—Staar Brothers Engineering Firm, Brussels, Belgium.

sumer audio product tape application. The foregoing statement considers the major fundamental problems directly associated with the low tape speed of 1⅞ inches per second and the great technical progress made over these past ten years.

STEREO-8 SYSTEM

The tape programs at Ford Motor Company were virtually dormant until 1964 when Bill Lear, of Lear Jet fame, contacted Harry Tucker, an engineer in Ford's advanced concepts area who was a personal friend of Dr. Don Frey,[4] then General Manager of the Ford division. Bill had developed a cartridge that was essentially the same as the continuous-loop cartridge, except that the pinch roller was integral to it. RCA proposed the possibility of eight tracks on ¼-inch tape. This was also suggested as feasible by Armour Research of IIT, Chicago. It simplified the tape-deck mechanism. Lear proposed to manufacture the tape deck as well as the cartridge, using a synchronous-motor drive in which the capstan was the motor shaft.

Ford Motor Company had evaluated disc player systems such as Chrysler had, and the four-channel cartridge system which Muntz was producing. They also reviewed cassettes and felt that the complexity of the tape systems was such that, with the pressures for safety, they could not be considered. Product-design marketing guidelines were another important factor. Dr. Frey, Division Manager of the Ford Motor Company, reached the conclusion that eight-track would best fill all the marketing and safety requirements. Their retained outside engineering counsel, however, advised that it was impossible to produce, within the time frame they were considering, eight-track cartridges of recordings, maintain the fidelity and accuracy of head placement, and, of course, have the system live through the rugged environment of automotive application at a price that the consumer would be willing to pay.

Three other companies and Motorola were each asked to present their proposals on tape systems to Ford, which could include an integrated radio unit. We proposed a compatible four-track, eight-track unit which could sense either cartridge and would accommodate either configuration. We thought that this would provide a safety factor to ease the engineering pressures that Ford management encountered. We also had excellent background experience with Ford Motor Company. Historically a product was developed over the usual time cycle of 2½ years. However, we were looking at a completely new product concept where the management's desire was to launch it and be first on the market, giving the selected supplier only nine months to complete and finalize the design, tool, and produce. We shared Ford's concern that using the drive motor shaft as a capstan was likely to create serious field problems. History has proven this to be a correct assumption. Needless to say, we proposed a belt drive.

With our long experience with Ford and having survived a number of crash programs in which we met our commitment dates, they reached the conclusion that the risk with us would be less. Conversely, Motorola's upper management was in disagreement as to whether stereo-8 was a practical product for the market, particularly inasmuch as it was a totally new configuration. This was a very logical concern. Nonetheless, we were awarded the project and proceeded with the design of a compatible four-track, eight-track system.

To illustrate the kinds of risks assumed by the companies, one only needs to realize that Motorola was scheduled to lose its long-standing major radio production contract with Ford Motor Company due to Philco acquisition. We then directed our resources to sterco-8 (Automotive Division). Furthermore, most of the engineering was done without a purchase order. This author had Don Frey's approval, and it was all that Elmer Wavering, General Manager of the Automotive Products Divison (later to become Vice Chairman of Motorola), required. When the purchase orders were assigned, the contract was agreed to without any finalized price of the tape–radio combination unit. Ford and Motorola had built enough trust in one another's integrity that that detail was unnecessary. It may sound unbelievable in this day and age that business was conducted that way, but this is a true story.

Early designs (Fig. 1) show that the cartridge slot was above the dial scale rather than below, as it is currently in most concepts. This was to provide and accommodate the space for the pivot and positioning of the pinch roller for the four-track cartridge. We actually completed the total design and tooled the whole unit for dual compatibility. However, when about 75% of the time had elapsed, we reviewed with Ford management the fact that we were running a tight deadline and that if we removed the engineers' insurance of four-track compatibility, we could

Fig. 1. Stereo-8 team. Left to right background: Floyd Fibranz, project engineer; Al Dusey, chief radio engineer; Charles Lyon, chief tuner engineer; Al Huber, mechanical engineer; and Bob Wolf, chief mechanical engineer. (Not in photograph, Fred P. Hill, director entertainment products, the author's strong supporter in the tape program from the mid-50s.) The author in foreground holding first tooled stereo-8 unit for Ford Motor Company. *Courtesy Motorola.*

[4] Dr. Don Frey, currently Chairman of the Board of Bell & Howell.

then be assured of having eight-track on stream through full and total commitment. After some days of deliberation, they came back and advised us to concentrate on eight-track only.

During this short period we had the problem of developing and accommodating rigid automotive standards within the rugged mobile environment (Figs. 2 and 3). Speed variation and motor reliability were our first major concerns. We decided to use a transistor speed regulator for better performance. Locating and training a good drive motor supplier was another problem. We sent a team to Japan and assisted the supplier and subsuppliers to produce an end quality motor. Capstan shaft and magnetic heads also took much of our attention and effort. Dropout and amplitude variation posed problems, motor load another, as well as single-pack versus twin-pack tape within temperature ranges of −20°F to +140°F. Wow and flutter plus tape protection, head positioning, and control, vibration, and voltage variations were additional acute problems. Each of these design areas posed major problems which called for maximum effort for resolution within the time frame.

One of the significant problem areas was the eight-track cartridge itself and the interface with hardware plus the determination of proper standards to be sure that we could live within the framework of a practical, value-engineered commercial product. As a result, there were rather unique weekly meetings of engineering personnel: RCA, Ford, Motorola, and Lear Jet. From these meetings everyone pooled their ideas, disregarding respective patent positions relative to the cartridge in order to establish good commercial standards expediently. It was unique to say the least.

The RCA Record Division agreed to take the risk of providing software for an untested unknown market. Spearheading and quarterbacking the RCA team was Irwin Tarr,[5] then Record Division Vice President for Planning. RCA backed the program with full commitment. During this intervening period, the author became Vice President–General Manager of Motorola's Automotive Division.

This author was asked to comment on how one creates an industry within an industry. Stereo-8 as a new concept with reel-to-reel, four-track, and cassettes all preestablished in the tape market did quite logically create competitive reaction and general industry consternation. We can provide only a simplified summary within the pages allotted. It would be impossible to relate the human resource pressure problems, the engineering budget expansion, the total dedication to achieve the objective: acceptance of stereo-8 as a new tape concept system and a major force in the market.

Dr. Don Frey, then Ford Division Manager, has to be considered the catalyst. He committed the Ford Motor Company as the hardware customer to a new tape system concept to be produced within a short time frame (nine months versus 2½ years). This pioneering risk was taken by one who has an outstanding technical background. There was full cooperation: Ford, RCA, Motorola on hardware, and RCA and Lear on the cartridge.

While the Motorola Automotive Division was taking major risks on stereo-8, our Consumer Products Division (Quasar) did not think stereo-8 could succeed. They had the company franchise for Motorola-branded auto sound products and home audio equipment and components. The Automative Division had private label, primarily for the automotive industry. We were, however, by far the largest volume producer of car radios.

To attempt to put the bits of our strategic game plan together, a short review supporting the initial appraisal of the stereo-8 concept is in order. The majority of our business is with automotive manufacturers as a contractual supplier, so we obviously would be tuned to their interests. Not until the eight-track concept had been proposed was there any excitement in cartridge tape players generated by the automotive industry. To understand why this occurred, one must understand the basic problem of the automotive manufacturer in tailoring the design of his product to satisfy a wide range of customer interests. They

SPECIFICATIONS

SPEC	Room Temp (72° F) Typical	At 0° F
Freq Response	50 − 10,000 Hz	50 − 10,000 Hz
Signal to Noise Ratio	-50 db weighted	-50 db weighted
Crosstalk	100 Hz, -40 db 1000 Hz, -50 db 8000 Hz, -50 db	100 Hz, -40 db 1000 Hz, -50 db 8000 Hz, -50 db
Separation	100 Hz, -30 db 1000 Hz, -35 db 8000 Hz, -40 db	100 Hz, -30 db 1000 Hz, -35 db 8000 Hz, -40 db
Tape Speed	3.75 ips ± 3%	3.75 ips ± 4%
Drop Out	.5 db to 3 db	.5 db to 3 db
Wow & Flutter	.16% to .24%	.26% to .3%
Input Voltage	11 VDC to 16 VDC	11 VDC to 16 VDC
Max Undistorted Power Output In Each Channel (Watts)	100 Hz, 3.5 400 Hz, 4.0 1000 Hz, 4.0	100 Hz, 3.5 400 Hz, 4.0 1000 Hz, 4.0

Temperature Range: -20°F to 145° F

Fig. 2. Initial stereo-8 specifications for first units delivered by Motorola to Ford Motor Company for their 1966 model cars. Obviously many refinements and modifications occurred since that time.

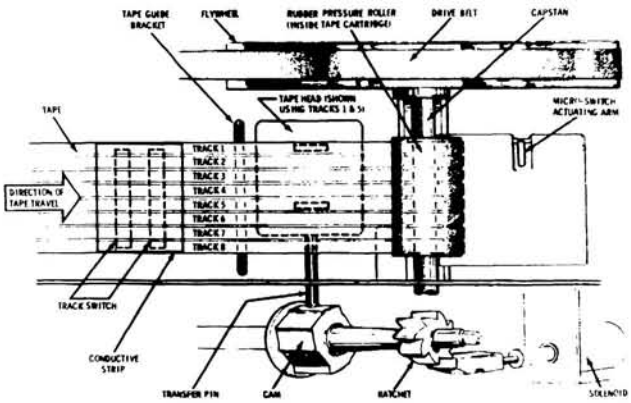

Fig. 3. Head positioning and channel switching detail.

[5] Irwin Tarr, now Director Video Systems for Panasonic. (Recipient "Billboard" Trendsetter award jointly with author for introduction of Quad-8.)

have to develop the happy compromise for comfortable accommodations suited to the short statured individual or one who is very tall, a styling variety that will satisfy the young adult market or the very sedate and conservative. The power train must provide the best compromise between good performance and economy, now complicated by pollution control. This is the fundamental philosophy followed by the automotive industry when evaluating their basic product or an accessory option. This design philosophy prevented consideration of early cartridge tape systems until a more favorable compromise was developed to satisfy the wide range of market requirements. The system had to accommodate pop tunes, the full music of a broadway show, or an opera, with a minimum of discontinuity in the program material. Because of the pressures for safety, the system had to be simple to operate, with a minimum of manual control and distraction to the driver. The tape speed had to be such that it could provide the high-frequency response required for the presence and lifelike characteristics which are a basic requirement for a good stereo effect. In addition, for a new product of this type to be ultimately successful, there had to be compatibility between automotive and eventual home type units. The customer could then justify the sizable investment in his tape cartridge library.

This, in essence, is the rationale that supported the decision to move into the eight-track direction, after all tape systems had been evaluated completely. There was no emotion in the decision, it was a very objective evaluation to establish what was considered to be the most practical compromise to satisfy the broadest market base.

The eight-track system was designed to meet the rugged environment of automotive application, with simple operation and a tone quality to satisfy the discerning home listener. The system possesses features that appeal to the broad market—simple operation, compact size, long playing time, a degree of selectivity, good sound quality, reliability, and, most importantly, auto and home compatibility.

The eight-track system has features which are not found in conventional record changers. It will automatically repeat itself after the four stereo programs have been played, thus providing continuous music for up to 80 minutes between selection repetition. This is ideal for background music applications in the home, professional offices, etc. The system is essentially foolproof. Even a three-year old child can operate it without damaging the unit.

We took a major risk and, in fact, the author took a great risk in his personal career with an overcommitment in engineering budgets to meet the timetable. For example, we had a three-phase engineering program going, 1) the tooling and launching of the product, 2) covering the anticipated areas of possible weakness, and 3) a program to cover the following year's models in which we dropped the four-track requirement entirely and placed the cartridge slot below the dial scale.

RCA certainly has to be given great credit for proposing eight tracks on a strip of tape. Lear came up with the cartridge design and generated initial interest.

We marshaled all the key personnel, both mechanical engineering and electrical engineering, in order to meet what appeared to be an almost impossible objective. We did meet the date, but not without problems. However, we got full cooperation from Ford and from RCA in order to successfully launch this new system concept.

In the meantime the author met with all the principals of General Motors who were interested but decided that, if the system was appropriate, they would build their own. We, on the other hand, offered free counsel and our experience gratis if they thought the system had merit. Their response was affirmative, so they decided to proceed. It was most important using the domino theory to obtain major commitment to this new tape concept by the largest potential supporters. In the meantime we took the following actions: we sold Borg Warner on marketing their private brand tape player for dealer (aftermarket) installation. They established their own national distribution. It was becoming apparent to the author that we had a "winner." Still, our consumer group (Quasar) would not support us in the home market. We met jointly with RCA principals to review the home product. To save planning and development time, the author proposed that we, the Auto Division, manufacture the first home units for RCA. Our proposal was accepted with some trepidation. We delivered the product to RCA; we now had a nucleus base to cover original equipment, aftermarket (dealer), and the home market. During this same period we had a team covering Japan and Europe, evaluating best component sources. At the same time we developed a synchronous motor for the home tape deck.

Coupled with these actions, we made proposals to Chrysler, AMC, and VW, using the domino leverage, namely, Ford, GM, etc.; the rest is history.

We then launched an eight-track joint venture in Japan over ten years ago in anticipation, under the Kennedy Round of reducing tariffs, that much of the tape product would be imported from Japan, and we felt that we should have at least half the action. Therefore, we formed a partnership with Alps Electric Company[6] after having screened many companies. They have now become one of the world's biggest producers of private label decks, plus complete audio tape products to the largest Japanese and American electronic companies in the following concepts: stereo-8, quad-8, and cassettes.

During the intervening period we had to make many personal missions to the heads of CBS, Capitol Records, etc., to try to broaden the available stereo-8 library and to broaden the total commitment. It was an evangelistic mission which took no end of effort. However, it was a total commitment, with the risk of the author's personal career. But we were sure in the Automotive Division that we would succeed because the concept appeared to be so logical.

Now in recent months we read of critics, in particular one in the United Kingdom, in which it was suggested that stereo-8 was one of the greatest mistakes made in the tape

[6] Alps Electric Co., large respected supplier of electronic components to the world market.

industry. This is a surprising remark when one considers what stereo-8 did for the rest of the tape, radio broadcast, and music industries. First of all, the cassette was initially intended for voice alone. Now, without the pressures of the success of stereo-8, one must ask the question of how rapid would have been the progress of audio cassette technology in the areas of tape, tape quality, oxides, tape heads, mechanical speed controls, electronic speed controls, and noise reduction circuits such as Dolby, if it had not been for the competitive influences. We are sure that these programs would have been delayed very substantially. The stereo-8 boom provided massive economic stimulus and support for a broad range of related supporting companies. It expanded public awareness and acceptance of tape systems as a music storage and playback medium.

Another interesting point is that stereo-8 put a lot of pressure on the record industry and forced improvements in the general quality of the disc. Ultimately we had standard discs produced by the major companies with fidelity and signal-to-noise performance that exceeded performance of the stereo-8.

Most importantly, stereo-8 opened a new untapped mobile market to the music industry which could not be served by the disc. It helped and, in fact, brought solvency to some financially troubled music companies.

One other important point is that we were producing FM stereo receivers and were concerned about the fact that the FM broadcasters were aiming for programming directed principally toward the home market. In fact, they tended to neglect a very large mobile market. The same might be said for the music industry in terms of the value it gained by being able to broaden its total base by serving the home disc player market and a mobile automotive market. With compatibility for home and car, you can well imagine the stimulus that it gave to the entire prerecorded music industry.

We were very unsuccessful prior to the introduction of stereo-8 in getting the FM broadcasting stations to move to higher power, to circular polarization antennas, or, in effect, to improve the total ERP to provide better FM stereo automotive reception. They ultimately announced very major promotion and performance improvement programs within their association, aimed directly at the competition that was posed by tape. The result is that across the country we now have for the most part a vastly improved FM broadcast system, not only due to stereo-8 pressure, but precipitated very early in the game by its competition.

QUAD SYSTEMS

Now we might touch upon the updated generation of stereo-8 or quad-8 (Fig. 4). From the earliest days of sound recording and reproduction, the industry strived to achieve the ultimate in user impact or, in effect, to provide the listener with the live experience. Music is an emotional experience. It can create moods and feelings. It does influence one to recall memories by listening to music which one has long remembered and associated with some experience. Over the years we have evolved from monaural records to stereo records to stereo tape. You will remember that years ago it was great to have a mono hi-fi. Almost everyone seemed to be pleased with it. Stereo, of course, added another new dimension in sound. Although very few mention the fact, we want to predict here that discrete quad will be a full-blown highly accepted entertainment system ultimately. You cannot stop progress. Four-channel discrete sound will provide a more nearly total full-life presence, with full ambience impossible to be achieved any other way.

In April 1970, during the International Music Industry Conference in Spain, Motorola and RCA jointly announced plans to introduce four-channel sound tape systems. In that meeting we had some of the world's best known producers of music. We had two vehicles equipped with prototype quad designs. The excitement that was generated was so high that we had absolutely no doubt whatsoever that this indeed was a new medium that would be embraced by the music industry and would be ultimately successful. Initial commercial product introductions were a sad economic experience, maybe because the automotive quad units were pitched toward a youth-oriented market, and software supplied was the least perishable variety which did not coincide with the desires of that market. This is a very understandable situation. It is somewhat analagous to the problems when we first broadcast color TV and advertisers refused to pay the premium for color when there were so few color sets, while people, conversely, did not want to pay the high prices for color receivers with such limited color programming. We were faced with a somewhat similar situation in this instance, but the delay in the full acceptance of quad was created by a multiplicity of factors. The initial strategy was, of course, the introduction of quad-8 which we hoped would also stimulate four-channel reel-to-reel. The CD-4 disc was coming along under development, and we assumed we could reach a timetable somewhere in 1974–1975.

Coincident with the CD-4 development, FM discrete quad FM broadcast systems had been developed by Dorren, RCA, GE, Zenith, and others, including Motorola. However, we were confronted with the petroleum crisis which had a multiple effect, aggravating and deepening the recession, and in addition, forcing the new speed limits to 55 miles per hour. During the recession the youth-oriented market suffered most in the layoff programs; therefore the quad market suffered accordingly. When speeds were reduced, the truckers discovered that CB radio was a wonderful device to make it possible to exceed the speed limits by communicating with each other relative to the location of police vehicles. This started the

Fig. 4. Typical stereo-8 quad player.

CB radio explosion, which in turn generated many other complications. It created an awareness of CB communication by owners of motor vehicles and home owners. The FCC was flooded with mountains of complaints, including abusive use of the new "adult toy," and TV interference. Some were operating with illegal power. A follow-on was the demand for more channels, the demands for class E band, all of which applied tremendous political pressure on the FCC. This logically slowed down the EIA effort to get a quad discrete FM broadcast system approved.

Coupled with this were the multiple-matrix systems which had been introduced and in fact tended to confuse the market. The author will be the first to say that the matrix quads indeed do enhance the sound of stereo, but they do not provide the impact that an artist and good producer mixer is able to accomplish with discrete quad. There is absolutely no doubt that discrete quad is going to be the sound system of the future. One will never stop technical progress, and this indeed is progress. It will provide the producer of music with the ability to give complete mobility to sound, coupled with ambience which you cannot achieve equally well with any matrix concept. We have stood hard and fast in this position, and we want to take this opportunity to say without qualification that we will have an FM discrete quad broadcast standard approval ultimately. A discrete quad FM broadcast standard approval by the FCC will be the key to initiating the real beginning of a healthy quad market, home and mobile.

When we initially launched quad-8, we oversimplified the problems associated with that launching. One is the education required by many of the artists on the merits of the concept and techniques that are possible. It also forces the one mixing to be a virtual artist himself to provide a good quad recording. The dealer in turn has to properly demonstrate quad with the right software in order to create the proper consumer impression. So here we are requiring an educational program with some music producers, some artists, and certainly the dealers and the lay public.

NEW TAPE SYSTEMS

With cassette technology pushed near the point of economic diminishing returns it just had to happen. There are other spinoffs of the original coplanar cartridge: the Unisette by BASF of Germany and the Elcaset from a Japanese consortium (Fig. 5 and 6). Unfortunately we do not have details on the Unisette except that in its flat-area size it is somewhat similar to the RCA original and the Elcaset. However, it is not interchangeable with the Elcaset.

The ultimate success of the Unisette or Elcaset systems may be hard to judge, but most certainly they will have an impact on the high-end cassette home units and part of the open-reel markets. The Elcaset system has the support of a number of the most formidable and respected Japanese

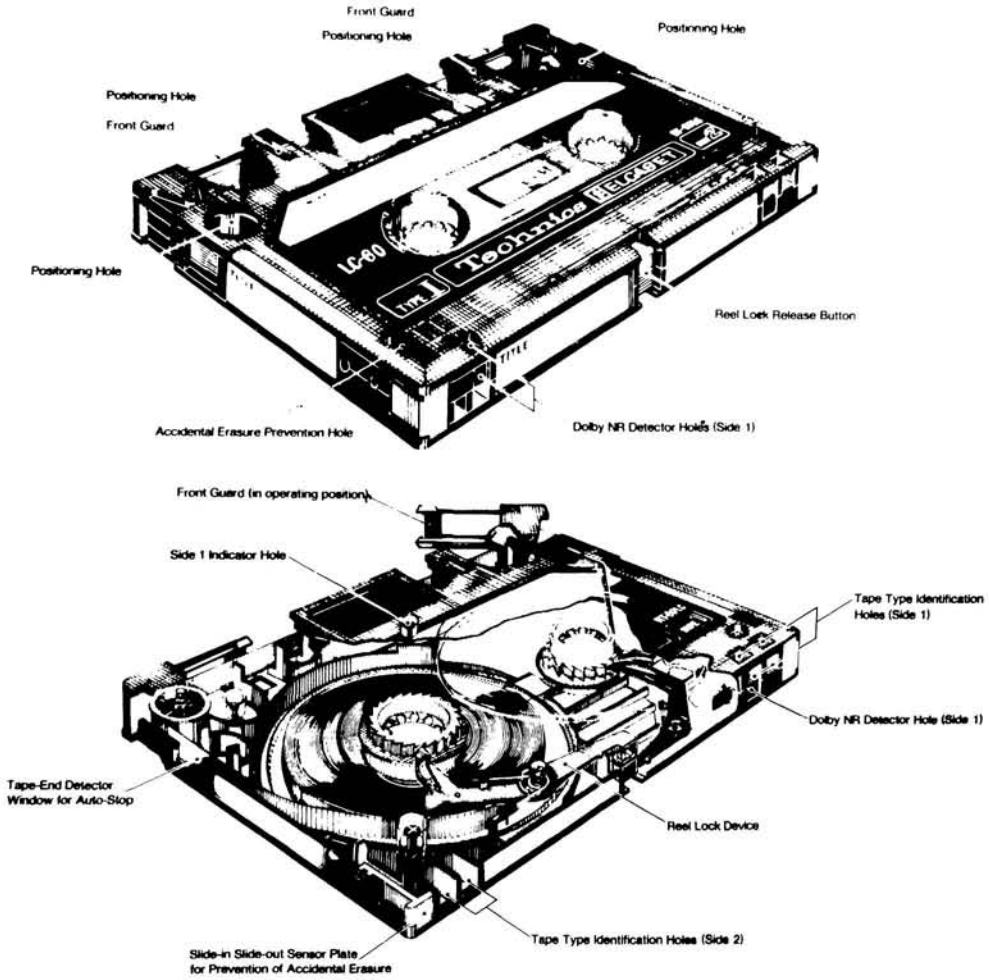

Fig. 5. Elcaset, plays and records like open reel, but handles like cassette. *Courtesy Panasonic.*

Fig. 6. Compact cassette/Elcaset/open-reel tape comparison.

	Compact Cassette	Elcaset	Open-Reel
Size	approx. 4 × 2½ × ½ inches (102 × 64 × 12 mm)	approx. 6 × 4⅛ × ¾ inches (152 × 106 × 18 mm)	7-, 5-, or 10-inch diameter
Tape speed	1⅞ in/s (4.8 cm/s)	3¾ in/s (9.5 cm/s)	3¾, 7½, or 15 in/s (9.5, 19 or 38 cm/s)
Tape width	5/32 inch (3.81 mm)	¼ inch (6.3 mm)	¼ inch (6.3 mm)
Tape Thickness	0.5 mil (0.012 mm) with C-90 tape	0.5 mil (0.013 mm) with LC-90 tape	1.5 mil (0.038 mm) with long-playing tape
Accidential erasure prevention	Yes (permanent)	Yes (defeatable)	None
Automatic detection	CrO_2 tape only	3 types of tape + Dolby NR	None
Automatic program selection	Starting point only	Any particular program	Starting point only (some decks)
Mono/stereo compatibility	Yes	Yes	No
Adaptability to multihead configuration	Possible	Easily possible	Easily possible
Tape threading	Unnecessary	Unnecessary	Neccesary

RS-7500US Technical Specifications (Tentative)

System	3-head 4-track 2-channel Elcaset system
Tape speed	7½ in/s (9.5 cm/s)
Wow and flutter	0.06% Wrms
Frequency response	25–18 000 Hz ± 3 dB (tape type I) 25–20 000 Hz ± 3 dB (tape types II, III)
Signal-to-noise ratio	60 dB (tape type I, 315-Hz peak level) 63 dB (tape types II, III, 315-Hz peak level)
Distortion	0.8% (tape type III)
Inputs	Microphone: sensitivity 0.25 mV/applicable; impedance 400 Ω–20 kΩ Line: sensitivity 60 mV/input; impedance 100 kΩ
Outputs	Line: output level 580 mV/load, impedance over 22 kΩ Headphone: output level 60 mV/load, impedance 8Ω
Motor	1 frequency generator servo-controlled dc motor Recording: 1 super permalloy head
Heads	Playback: 1 Super permalloy head Erasure: 1 double-gap ferrite head
Power requirements	AC: 120 V (U.S.), 110/125/220/240 V, 50/60 Hz (not necessary for conversion)
Power consumption	30 Watts
Dimensions (W × H × D)	17¾ × 10 × 13¾ inches (45.0 × 25.3 × 35.0 cm)
Weight	30⅛ lb (13.7 kg)

companies. Nonetheless, the audio tape market will expand with each system sharing the market based on the respective values as viewed (or heard) by the end user.

In review, we have a multiplicity of systems. Much can be said for each. We will be the first to say that looking ahead 20 years, there has to be some question as to which of the existing systems will still be with us.

However, as long as we are using a magnetic storage medium, the information is readily transferable by recording in whatever the new concept. Invariably the customer has a library investment which far exceeds his hardware investment, so what he will probably do ultimately will be to select and edit the material that he desires from each of his tape cartridges, reels, etc., to the new format, whatever it may be.

Dr. Thomas G. Stockham will review "Records of the Future" as part of this special issue. Therefore we will refrain from making any prognostications except to say that there are, and will be, many ways to store and play back audio material. Technical progress will continue.

ACKNOWLEDGMENT

The author wishes to acknowledge the great assistance from Dr. J. Schultz, Director, IIT Research, in making available bibliographies on magnetic recording history, and from Marvin Camras of Dr. Schultz's staff, IIT Research, and his associates. He also wishes to thank Charles Mathey of Motorola for assisting in the research of early history, as well as Bob Wolf and Tony Raef of Motorola; and Panasonic for the Elcaset literature.

The Jukebox, the Radio and the Record

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Research of historical information shows a close association between the record and coin-operated machines, which began with Edison's early commercial efforts and continues to the present. The evolution of the record served as a catalyst to the development of radio and the jukebox with mutual benefits resulting. It is shown that, at times, conflicting interests stimulated technical progress.

Edison is credited with the invention of recorded sound, but he was adamant in his belief that its primary function was to serve as a dictating machine. He believed that this great invention was above services as an entertainment medium. It was only through the efforts of his franchised distributors to stave off bankruptcy that they turned, in desperation, to the entertainment field, with coin-in-the-slot one cylinder machines.

Gelatt quotes Edison's business philosophy as of January 1891 as follows:

> "Those companies who fail to take advantage of every opportunity of pushing the legitimate side of their business, relying only on the profits derived from the "coin-in-the-slot," will find too late that they have made a fatal mistake. The "coin-in-the-slot" device is calculated to injure the phonograph in the opinion of those seeing it only in that form, as it has the appearance of being nothing more than a mere toy, and no one would comprehend its value or appreciate its utility as an aid to businessmen and others for dictation purposes when seeing it only in that form."[1]

It is interesting to note that remnants of Edison's philosophy remain to this day.

Home use of this early phonograph equipment was extremely limited by cost. An economic fact of life which Edison did not comprehend is that, of all potential customers, operators of coin-in-the-slot equipment could afford the high price of his machines because of the income derived through their operation. It is still the basic economic principle of the jukebox industry that the income from the machine must in a few years recover the original investment plus a profit.

In the early years, coin operation was so important to the infant record industry that in 1891, 16 of the 19 holders of franchises with North American Phonograph Co. were in the jukebox market with 1249 units in the field [2].

The record predated the jukebox as we know it today and, of course, predated practical radio as well. Nonetheless, coin-in-the-slot entertainment was known before the advent of the record. This took the form of coin-operated mechanical devices which were essentially music boxes.

The earliest coin-in-the-slot record playing machines played a single cylinder upon the deposit of a coin and were operated by the public through curiosity rather than in appreciation of musical performance or fidelity. The first such instruments were acoustically operated for both recording and playback with ear tubes (not a very sanitary procedure by today's standards).

In Gelatt's very interesting historical documentation of the industry, it is amusing to read of the circus-like demonstrations that were made with the early cylinder machines of various sound effects, reproduced poorly, but nonetheless touted as being a true reproduction of the

original sound. This has a strangely familiar ring, reminiscent of similar demonstrations during the first and second cycles of "high fidelity" followed by stereo and more recently by four-channel sound.

The invention of the disc phonograph record by Emile Berliner in 1888 was an event of great importance to the industry although many years were to pass before it would replace the cylinder through sheer functional superiority.

In 1896 the Multiplex Phonograph Co. of New York marketed a five-cylinder coin-operated machine which played the five cylinders in rotation [2]. The first known disc-playing jukebox was manufactured by Universal Talking Machine Manufacturing Co. of New York but was marketed in Berlin, Germany. The year 1905 saw the first domestic disc-playing phonograph built by Julius Wilner of Philadelphia which played twelve 10-inch records in rotation upon the deposit of a nickel. This mechanism used a new needle for each play. A more successful machine was introduced the same year by John Gable which *selectively* played 12 records. This was a basic development to the eventual success of the jukebox industry. Another equally important Gable innovation was the use of a magnetic slug detector to thwart the efforts of that early day's delinquents. About 1906 the horn replaced the ear tubes so that groups of people could simultaneously enjoy the music.

Paralleling the coin phonograph development in the early 1900s was another infant industry engaged in the manufacture of automated music boxes. In 1902 Justus P. Seeburg, the founder of the J. P. Seeburg Co., developed such a machine which was pneumatically operated deriving its power from electric motor driven bellows [3]. The 1910 Seeburg Model Orchestrion utilized piano roll type programming for mechanically playing piano, violins, mandolin, flute, snare drum, cymbal, triangle, and other percussive effects. By the early 1920s this business developed into self-contained organs and organ and trap drum combinations featured in large movie theaters of the era. By 1928 this company had phased out of the piano/organ business and produced its first nonselective, eight-record phonograph.

During the lean first years of the great depression, all industry, including the jukebox industry, went into semi-hibernation but by the mid 30s AMI, Rudolph Wurlitzer Co., J. P. Seeburg Co. and Rockola Manufacturing Co. were building selective jukeboxes with electronic amplification [2].

By 1939, 225 000 jukeboxes were in operation throughout the United States and required 13 000 000 10-inch discs each year to maintain current programming [1]. This was a steady dependable record market with a stabilizing influence on the record industry.

During World War II the industry converted to the manufacture of military supplies ranging from weapons to complex electronic gear. This experience established a base for more sophisticated technology within the industry for the postwar years. The early postwar years tested the production capability of all manufacturers, as jukeboxes were turned out in record quantities to meet the pent-up demand. These consisted of 20-, 24- and 40-selection models incorporating mechanisms of better design and performance than their prewar predecessors. The 40-selection model was produced by AMI. During that period of time (and since) customers in taverns and saloons were more inclined to roughhouse tactics than to the tender treatment of sophisticated equipment. The magnet pickups used in those days carried 3 to 8 *ounces* of stylus force on a 3-mil stylus.

By late 1947 inventories began piling up in all manufacturers warehouses and the market glut dropped jukebox sales to near-zero level. Factory shut downs were mandated by economic pressures during this difficult time.

With production virtually at a standstill, the engineering department of the J. P. Seeburg Co. worked diligently to perfect a new mechanism which had been under wraps since prewar days. This mechanism was introduced in a new phonograph, Model M100A, in December of 1948 and relit the fires of the industry [4]. This revolutionary bombshell was a 100-selection mechanism which played 10-inch, 78-r/min records vertically with a double-side pickup operating with 1 ounce of stylus force. This mechanism which selectively played both sides of 50 records, at last provided a showcase for new records on their way to popularity in addition to the top 10 or top 20 which previously enjoyed the full spectrum of the limited programming available for the 20- to 40-selection machines.

While the jukebox industry was suffering upheavals from a severe recession and the development of revolutionary new equipment, the long-playing record was under development at Columbia and the 45-r/min record by RCA. The LP was introduced by Columbia in June 1948. These developments made it obvious to all persons in the industry that the 78-r/min record was dead and that a vinyl microgroove replacement of vastly superior performance was at hand.

THE SINGLES MARKET

The introduction of the LP seemed to leave little doubt that it was the best medium for classical music because of its long playing time. This was not the obvious choice for popular music for which the 7-inch 45-r/min record or the 7-inch 33⅓ disc introduced by Columbia were perfectly adequate in terms of playing time for singles. A period of indecision occurred during which time the jukebox industry was not certain as to which fork in the road to take. Extensive investigation at Seeburg of both the 7-inch 33⅓- and 45-r/min records left little doubt that the 45-r/min disc supplied all the playing time necessary for singles but with better fidelity because of the higher speed. The die was cast to proceed along the 45 r/min route. A new mechanism was developed and tooled to play this disc with a new, custom magnetic pickup supplied by Pickering & Co. and operated with a stylus force of 7 grams. This mechanism played 50 records both sides for 100 selections with the turntable rotating in opposite directions for opposite sides of the record. The pickup arm utilized viscous damping to stabilize the vertical pickup arm on the extremely flexible 45-r/min disc. This mechanism was introduced in a new jukebox, Model M100B and was in

production in October 1950 [5].

The introduction of the 100 selection 45-r/min caught the record industry with an inadequate supply of 45-r/min discs but proved to be a shot-in-the-arm for this speed for popular music. Promotional efforts by Seeburg directed toward independent record manufacturers helped convince them to produce the 45-r/min record. The establishment of an expanding market for their product in the home was being cultivated by RCA and others. In less than one year a sufficient variety of music by many artists became available.

In August of 1955 Seeburg introduced a 200-selection 45-r/min jukebox incorporating a "tormat"[R] ferrite-core matrix to register and store selections. At the same time, the industry went to a dual price concept to be able to play EP records for 15 cents; singles for 10 cents. The dual price approach was essential to extend the base for programming.

In September 1958 stereo became the vehicle for jukebox music although at that time the availability of stereo material on 45-r/min singles was extremely limited. Machine manufacturers found it necessary to underwrite stereo records to assure adequate supplies for the operators.

Stereo presented problems in public places far different from the two-loudspeaker configuration of a home living room. Considerable experimental work with various geometrical arrangements was necessary to establish multiple loudspeaker presentation of stereo in relatively large rooms. A line of loudspeakers of suitable quality was required, arranged to provide a semblance of two-channel reproduction to all areas of location. It was usually not possible to provide the stereo spread attainable from two properly placed loudspeakers. Typical locations utilized stereo to provide uniquely different reverberant sound with directional characteristics that were unusual.

Subsequent improvements in the stereo systems included new magnetic pickups operated at 2 grams stylus force and better solid state amplifiers. Two-way loudspeaker systems with LC crossover networks and engineered acoustical enclosures greatly improved total performance.

In 1969 custom digital LSI microelectronic systems were introduced by Seeburg for coin and credit function and for a unique selecting system for the console phonograph selector and remote consolette units [6]. The credit system was programmable by plug-in printed circuit boards to handle coinage variations for all combinations used in the United States and most foreign countries. The selecting system allowed highspeed selecting from many remote points with greater accuracy and reliability.

SELECTIVITY

"The music you want when you want it." This expression has been used many times to describe the unique attribute of jukeboxes. Over the years many nonselective coin-operated systems have been devised and marketed but none have survived. People just will not spend money to hear someone else's preprogrammed music. They tolerate but do not buy background music. This explains why the single record is essential to this market. When people gather in public places it is a transient phenomena; young people, ever active, want their music in small packages. This is why the LP record has never been used in this market. Manufacturers, notably Seeburg, have long had in production highly reliable LP record changers with 50 records (100 sides) developed for the home market but not used in commercial coin-operated phonographs. The ability to select a single or a group of singles, each of his own choosing, is the preferred format for virtually all players of jukeboxes. Patrons apparently enjoy "shopping" the many titles displayed on modern multiselection jukeboxes to find the musical selection to suit circumstances and mood.

The need for selectively has also discouraged the use of magnetic tape in this industry. This medium has been explored and evaluated by virtually all manufacturers who have concluded that the singles disc is still the best medium. Unfortunately, tape is not economical for singles. Tape cartridge pioneers, such as Bernie Cousino, were able to develop small cassette formats technically suitable for jukebox use. Unfortunately, such formats did not come into popular usage.

DISTRIBUTION

Singles records are distributed worldwide to virtually every hamlet. This presents another essential ingredient to the jukebox industry; a medium as volatile as popular music must be quickly available virtually simultaneously in all parts of the country to satisfy the jukebox demand because hit singles sometimes skyrocket to popularity very quickly and typically last a couple of weeks and drop out of circulation. That short cycle requires fast distribution to exploit the market. No other medium has to date been capable of meeting this requirement for instant distribution.

MUSIC QUALITY

Before the smoke cleared away from around the battle of the speeds, the consensus was formed that serious music belongs on LP records and kid stuff on 45-r/min records. In the early 50s after the initial effort by RCA to present serious music on 45-r/min records was abandoned, the 45-r/min became a medium suitable for jukeboxes in schools or other juvenile hangouts. The kind of music preferred by mature adults became rather scarce.

In the early 60s J. Cameron Gordon, an innovative executive, in evaluating the dearth of "adult music," equated the need for adult music with the fact that most jukeboxes are placed in saloons and restaurants frequented mostly by adults who did not especially appreciate the music then available on 45-r/min discs. It was recognized that the available music was quite acceptable in teenage hangouts and off-campus school coke-and-hamburger counters but something more sophisticated was needed. This need was filled by a program sponsored by the machine manufacturers to underwrite 33⅓-r/min, 7-inch "little" LPs in order that a broader spectrum of music variety would be available. By this time two-speed machines were developed, the first appearing in 1963

capable of relating speed to center-hole diameter. The little LP record was cut at a finer pitch than conventional 45 or typical popular LPs and at a level approximately 2 dB lower than reference level to avoid overcutting. This permitted 9 minutes total playing time per side but usually playing time was only 6 or 7 minutes. The initial concept priced both sides of a little LP at 50 cents. This was later, by popular choice, dropped to 25 cents per side. The move to pricing each side separately and permitting the selection of each side of the little LP independently again relates to the preference for selectivity and for the selected musical unit to be of less total time. This permitted the patron to select singles of his choice at 10 cents each, 3 for 25 cents or a little LP side for 25 cents.

The musical content of the little LPs was selected by reviewing new, popular LPs and from such albums, selecting a total of six tunes suitable for jukebox play.. The little LP plus innovative industrial design provided the necessary stimulus to get the industry rolling again.

The automatic speed changing required for the two-speed equipment was achieved by the use of belts, pucks, or an electronic motor power source at 44.4 Hz for 33⅓ and 60 Hz for 45-r/min.

THE RECORD SHOWCASE

Considering the requirements over the years for single records, EPs and little LPs to satisfy the appetite of 600 000 jukeboxes presents a substantial dependable market for virtually all record companies. The showcase provided for new records by the jukebox means a great deal more to the record industry than merely the sale of the required records to fill the jukebox need (approximately 60 000 000 per year). The jukebox has always provided a market test for new releases. This became a sales tool which was readily understood by all elements of the record business. As a result, performers as well as artists and repertoire people and record company executives appreciated the value of the jukebox showcase in stimulating record sales. The importance of the jukebox as a showcase led to technical problems which will be described later.

The American Society of Composers, Authors and Publishers (ASCAP) through the years tried unsuccessfully (until recently) to have congress pass legislation enabling them to receive a share of jukebox income through various formulas proposed from time to time. Although the sale of a record to a jukebox operator provided the usual ASCAP performance stipend, ASCAP argued that the music was performed repeatedly on jukeboxes and that they were entitled to income for each play. They were not sympathetic to the phenomena of the showcase the jukebox provided as a means of substantially increasing gross sales.

LEVEL

The jukebox is required to play at any volume including maximum mechanical volume control setting, with reasonable limits of distortion. As we all know, in noisy locations the volume control is frequently set at maximum representing rms power ranging to 100 watts per channel. This requirement places some burden on the gain tolerances of amplifiers and pickups as well as power handling capability of loudspeakers. A typical location requires a rather modest acoustical level when few patrons are present because noise levels are low but as the evening wears on and boisterous crowds gather the volume control inevitably inches upward with the jukebox competing for attention with the noise of the crowd. The volume control is typically close to the hand of the proprietor or an employee to facilitate adjustment level as required. This is a rather sensitive point because in a room full of people some will desire a low level while others will demand to hear the music for which they have just supplied some coins. This requires no small degree of diplomacy and considerable jockeying of the volume control. It is easy to understand that because records are not all recorded at the same level further complications are added to the above situation. This condition is further burdened by the desire for performers whether they be vocal groups, solo instrumentalists, or any of the assorted combos to have their records sound loud on the jukebox so that they will be heard.

It is fortunate that the length of jukebox singles is only 2 to 3 minutes so that the recording engineer has plenty of space to spread out the recording. Even with this advantage, the demands for level have been known to out-strip the capability of the cutting stylus which, of course, leaves the playback stylus, with its spherical geometric limitations, in an impossible situation. The author has microscopically examined some of the worst examples of overcutting created by the demand for level. Some of these examples were diagnosed as groove-wall gouging by the heel or trailing edge of the cutting stylus. Many articles have been written about the limitations of a spherical stylus in tracing a modulated groove. It is well known that a level is reached at which the playback stylus motion will trace an approximate sawtooth path while playing a sinewave. This occurs when the ratio of amplitude to wavelength reaches a critical value at which the stylus radius fits the curvature of the groove at peak amplitude. With such levels distortion from the playback system reaches intolerable levels regardless of the quality of the pickup and playback system.

It is easy to imagine that these overcut records had no resemblance whatsoever to the original performance. It is my belief that a whole generation of Americans grew up believing that the raucous results of overcutting was the way music was supposed to sound; this undoubtedly led to some of the musical styles which sounded live, like the overcut records.

Let us pity rather than blame the recording engineer usually performing his duties for a large record manufacturer through the instrument of custom recording for an independent record company. His task was to satisfy the customer and to cut the record the way the customer wanted it cut. His technical arguments about level and quality usually fell on deaf ears. And imagine, if you will, the plight of a bartender trying to pacify a crowd of customers intermixing old favorite selections at civilized levels with some of the loud recordings generously intermixed. This situation stimulated the jukebox manufactur-

ers to develop an automatic volume control (AVC) first used in the industry in 1953. When playing a record, this electronic circuit started the amplifier volume at low level at the beginning of a record and gradually faded in the first few musical passages, all the while sampling the program material for level and adjusting the level accordingly. This circuit typically had a time constant in excess of 10 seconds so that the level was maintained fairly constant from record to record but allowed for virtually full dynamic range on a short-time basis. This system worked extremely well. It was capable of actually compressing the level of super loud records to less than normal level if so desired and raising the level of low-level records. A level reduction of 10 to 15 dB on a loud record was not uncommon. This system was effective in discouraging the battle for level but it took some time before those responsible for high level became aware of the new development. When they did discover the AVC's presence, countermeasures were attempted but generally had little effect on the results. There were outstanding exceptions, however, where an extremely long and deliberate pause in the music allowed the level of the amplifier to build with ear shattering results on the next loud passage. Fortunately, such records were uncommon and never attained great popularity.

QUALITY OF REPRODUCTION: (EQUIPMENT PERFORMANCE)

We all have heard modern jukeboxes which sounded terrible for reasons other than excessive level. It is regrettable that some operators of jukeboxes supply equipment maintenance on a demand basis only. This individual will not replace a pickup stylus until someone hangs an "out of order" sign on the machine. When he finally replaces the styli, does this restore the quality of reproduction? By this time the records have been destroyed, but they will not be replaced until obsolete.

Quality of reproduction obtainable from jukeboxes has always been on a par with better quality home instruments of the component class. This statement should be qualified to include proper maintenance of stylus and records as well as proper adjustment of bass and treble control settings. In the early 50s amplifiers of 25 watts rms continuous power rating were available with 12 to 15 dB of inverse feedback. At that time the audio industry typically utilized not more than 6 dB of feedback in home reproducing and public address systems. Frequency response of such amplifiers was basically 20 Hz to 20 kHz but with the response characteristics deliberately shaped to complement the characteristics of the output transducer system.

The phonograph industry's first attempts at high fidelity produced equipment with an anemic low end and rather accentuated top end. Years before this the jukebox designers understood the public's need for adequate bass and provided up to 20 dB of electrical boost. It is true that the early bass boost circuits were extremely sharp incorporating tuned iron core circuits to provide what became known as "jukebox bass." However, by 1950 this had significantly changed to bass boost circuits which raised the entire low-end response in the way generally recognized as optimum for the next 20 years in the audio industry. Another feature of the early coin-operated phonograph audio system was the use of heavy duty efficient woofers consisting of a single heavy duty 15-inch woofer or two or more heavy-duty 12-inch loudspeakers. After experience in hundreds of thousands of commercial establishments, the thesis developed that when people gather in public places they do so on a social basis with conversation as the primary element of conviviality. Under these typical circumstances, jukebox music is designed for the atmosphere of excitement it engenders, but it must not interefere with the intelligibility of speech. This requirement naturally leads to the reduction in treble response by turning down the treble control, allowing midrange and bass to provide the level needed but with attenuated high frequencies. It may be concluded that in public places people need jukebox music at a reasonable level and as free from distortion as possible but missing significant parts of the frequencies above 3000 Hz. It is recognized that this conclusion is contrary to the concept of "balance" needed for appreciation of music. The only plausible explanation for this contradiction seems to lie in the fact that jukebox patrons are primarily concerned with other pursuits of the moment, and music appreciation is not one of them.

COOPERATION IS THE KEY

It has been shown that the jukebox has been a useful instrument for the sale of records. The record industry has returned the favor by making technical information available through the Recording Industry Association of America (RIAA) and the engineering departmens of individual record companies. The big three, RCA, Columbia and Capitol have the know-how and incentives to push the state of the art with a steady stream of improvements, and they have given much of their time to share this knowledge and solve problems. This is a healthy environment for the continued growth of the entire audio business.

AUDIO VISUAL

Many people have wondered why the medium of audio-visual entertainment has never become a factor in public places. Scopitone in France has produced color film in the 16-mm format of superb quality, and the subject matter was certainly compatible with the entertainment sought my night-time fun seekers. The author believes that the failure of the audio-visual medium to attain success as an entertainment medium in public places is explained in the preceding section of this paper. Patrons generally do not want to be distracted from their primary activities. Visual entertainment simply cannot compete with the visual attraction of a pretty, live woman.

RADIO

This medium has enjoyed a dual life: The first phase might be called BTV (before television). Its characteristics changed completely with the introduction of television as each medium exploited its strongest qualities.

In the days before TV, radio diversified its activities to

bring into the home virtually every form of audio signal that could be utilized to entertain and inform the American people. During that period of time its attention to reproduction of music was further divided by a significant predominance of live broadcasting. That era was outstanding for its live broadcasts of virtually every class of music in existence. The format tended to plug the artist but not specific records. During this era the great bands developed and renewed interest in serious music was cultivated. A very beneficial side effect of this phenomena as it pertains to the record industry is that as a band or orchestra became nationally known, its records began selling widely so that this showcase of radio was in effect a two-step process of first selling the artist and, from this popularity, selling his or her records.

With the advent TV a large percentage of radio programming was taken over by the superior communication gained by the addition of the visual picture. This had the effect of concentrating programming of radio time on the reproduction of music with news as a companion feature, thus providing continuous exposure of records and tapes. This pie was neatly divided in the early days: FM represented the classical and other serious music, and AM concentrated almost entirely on popular music. In recent years this mix has changed but the popular music concentration proved of such value to the record industry that it spawned a new phenomena called payola.

Payola was proof positive that the airing of a tune opened the doors to instant success if the music had any merit of its own. For those too young to remember, a brief accounting of this phenomena is in order. In 1960 a subcommittee of the House of Representatives held hearings which disclosed that dozens of record companies were paying disc jockeys to plug their records. As a result the house passed an amendment to the Federal Communications Act making participation in the payola scheme punishable by a $10 000 fine, a year in jail or both [7]. It developed in these hearings that payoffs were carried in the books as promotional expenses. There can be no argument with that statement. By 1966, in a new investigation it became apparent that payola, although illegal, was not dead, but it had gone underground. This required payment in forms other than cash and not directly related to the services performed.

It is a powerful fact of business life that a record played by some idolized disc jockey the night before causes a fantastic spurt in sales the following day. Cause and effect are quickly related and the value of services performed understandably appreciated. It is consequently difficult for promoters of records to ignore the "free" advertising opportunity presented by the radio disc jockey. The investigations of 1966 proved that it is difficult to get the necessary evidence for conviction and, therefore, the 1960 legislation was largely unenforced [8]. This form of "advertising" has attained a stature to command attention of persons other than disc jockeys [9]. As recently as March 1977 the FCC began an investigation of new and complicated forms of payola in the popular music industry.

Regardless of one's reaction to the subject of payola, one must acknowledge that it is difficult for a record company to describe the merits of a new release using mere words in other forms of advertising. After all, the playing of a record is necessary for a subjective decision to buy. The playing of a record is a more direct form of communicative advertising than driving a car is for a person considering its purchase. The demonstration value of a jukebox performance or a single play by a radio station are highly valuable and valued sales incentives.

LISTS

Various published lists of "Top 10, Top 50 and Top 100," are the results of jukebox popularity and radio exposure as well as current sales. Such lists are utilized in local markets by local radio stations and nationally by the trade press. *Billboard* and *Cash Box* lists of the 1950s and 1960s were largely influenced by jukebox play, but in recent years, more comprehensive means of judging total popularity have been developed by these and other publications.

MOBILE ENTERTAINMENT

One market remains in which radio still dominates all others; the huge segment of the population at any given moment traveling in automobiles. Although tape cartridges and cassette players have entered this market, the percentage of the listening audience utilizing tape playback does not pose a threat to the dominance of radio. It is the author's opinion that stereo FM is a highly enjoyable form of mobile entertainment and will continue to prosper with improvements in both disc and tape.

Although it appears on the surface that radio does not have the selectivity which has been found so essential to the jukebox industry, it does in fact have a selectivity of its own through the selection by the listener of stations broadcasting the type of program to his or her liking. This is rather formidable selectivity when one considers the wide choice of stations in the AM and FM bands in major metropolitan areas.

WHERE DOES THE FUTURE LEAD?

We are aware of the shortcomings of present recording and playback systems: distortion caused by nonlinear elements, tracing distortion because of differences in the recording and playback mechanisms, and noise from many sources. It is amazing that, with all the deficiencies, our present highly-sophisticated systems are capable of such astonishingly realistic duplication of the original performance. It is only when the listening environment approaches the ideal that the deficiencies of our equipment begin to show.

By combining new technology and starting with a clean sheet of paper, it is conceivable that music now on an LP record could be easily packed into a disc two inches in diameter, and use only one side. Considering the state of the art in digital techniques, lasers, multiplexing and microelectronics, we should have as many channels as desired and the record should never wear out. Could such systems more closely approach perfection and economically feasible? Only time will tell.

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Quadraphony—A Review

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INTRODUCTION: Following several years of use and proposals of a number of alternative terms, "quadraphony" seems to have gained general acceptance for defining the reproduction of sound by a rectangular array of four loudspeakers in a horizontal plane, with the system having the capability of simultaneously feeding the loudspeakers four recognizably different signals.

REALISM—AN UNENDING PURSUIT

Quadraphony is but the latest advance in a long series of developments in sound recording and reproduction, with each generation of audio engineers making their contribution. Since Edison, one hundred years ago, first demonstrated a way to record the sound of the human voice and to reproduce it recognizably, the drive for progress has been unremittingly in the direction of increased "realism," that is, the ability to convey to a listener in his own home the impression of participating in a live performance. Other papers in this issue of the *Journal* detail the various mechanical, acoustical, and electrical innovations made in the pursuit of realism in sound reproduction. Seventy-five years elapsed following Edison's invention before recording technology reached a level that permitted serious consideration of the inclusion of spatial effects in sound reproduction in the home. Then, in the late 1950s, two-channel stereophonic systems based on magnetic tape and disc recordings found quick acceptance. Despite exaggerated advertising claims of "concert-hall realism," it was clear that, given the acoustics of the domestic listening room, two-channel sound reproduction was fundamentally incapable of simulating the ambience of the majority of live-performance environments where the auditor is immersed in a sound field resulting from direct and reflected waves arriving from all directions. Consequently, as soon as the initial excitement of stereo had passed, the search was resumed for the "true realism" that would accurately recreate an original sound field in all its dimensions.

Some of the possibilities of surround-sound reproduction had already been learned from experience with the multichannel systems used in special motion-picture theater showings of Walt Disney's reknowned "Fantasia" and the Cinerama productions, as well as several other experimental efforts. But these all were based on the optical or magnetic recording tracks in complex professional equipment quite unsuited for the mass consumer market. Glimmerings of feasibility for multichannel consumer systems began to appear in the early and mid 1960s with the development of four-track magnetic recorders using 1/4-inch-wide tape. It was then that a number of experimenters, including this writer, set up quadraphonic systems consisting largely of laboratory-built apparatus and began to hear and to demonstrate to limited audiences the variety of effects achievable with surround sound in listening rooms comparable to those in homes. Little, if any, documentation of these early tests is found in the technical literature. This absence is due partly to the fact that the tests were a few years premature relative to commercial development of system components, partly because the laboratory apparatus required only straightforward (but not trivial) extensions of existing recorder technology, and partly because there was very

little reliable and relevant psychoacoustic knowledge available at that time to serve as a basis for analysis of the observed effects.

QUAD GOES COMMERCIAL

By 1968/1969 the picture had changed. Modestly priced four-track tape recorders and players had been developed. Small high-quality loudspeakers and solid-state amplifiers were available. Moreover, for some years studios had been making multitrack master recordings that could now be remixed to provide a library in the quad format. This combination of circumstances persuaded several companies, notably Acoustic Research, Inc., and Vanguard Records, to market quadraphonic systems based on four-track reel-to-reel tapes [1]–[3]. Shortly thereafter RCA entered the market using its Quad-8 cartridge format with 4-track players [4]. With the availability of quadraphonic programs on tape, several FM radio stations in Boston, New York, and San Francisco arranged for experimental broadcasts in the quad mode [5]. In each city, two FM stations broadcast stereo simultaneously from the same four-channel tape source, with each station carrying two of the four channels. Listeners were required to set up two complete stereo receiving systems in the listening room to reproduce the total quadraphonic program. While this awkward arrangement was tolerable for a few experimental broadcasts, it obviously was unacceptable as a continuing system, and the conventional FM stereo broadcasts, along with the conventional stereodisc phonograph records, which provided music for the majority of consumers were unsuited as commercial quadraphonic media. Thus, while the quadraphonic tape systems served to generate initial interest, the commercial growth potential of quadraphony was restricted by the two-channel limitation of the two principal media.

ENTER MATRIXING

Near the end of 1969 the vista for commercial quadraphony suddenly expanded with Peter Scheiber's demonstrations of four-channel sound reproduction via a two-channel stereo transmission medium [6]–[8]. During the first months of Scheiber's demonstrations the constraints of licensing negotiations and patent applications prevented him from describing his technique to the public, and the demonstrations were mystifying to listeners, although they generally acknowledged the existence of recognizable quadraphonic effects. It gradually became clear that Scheiber was using a form of what is now called 4–2–4[1] matrixing with separation enhancement, concerning which more will be said in later sections of this review. The matrixing concept had a tremendous impact on the exploitation of quadraphony, for now conventional phonograph records and FM broadcasts, as well as stereo tapes, could carry four-channel programs, albeit with a predictable loss of source localization in reproduction relative to the original discrete signals. Numerous variations in the matrixing coefficients and in enhancement schemes were quickly put forward, with the proponent of each pointing out its superior features. It was in 1970 that early commercial versions of the CBS SQ® and Sansui QS® systems, as well as an Electro-Voice system, were demonstrated and described. A considerable library of 4–2–4 matrixed phonograph records has been issued, encoders are in use in many FM radio stations, and consumer equipment incorporating appropriate decoders is widely available.

THE FOUR-CHANNEL DISC

From time to time over the years researchers in various laboratories had experimented with ways of increasing the information that could be recorded in a phonograph-record groove [8], [9]. The most promising technique involved the use of a modulated carrier at a superaudible frequency recorded simultaneously with, and superimposed on, the conventional baseband audio. In principle, this capability should permit the recording and reproduction of four discrete audio channels on an otherwise conventional record. Pickups capable of reproducing the high-frequency carrier as well as the baseband audio are required in playback. It was the Victor Company of Japan (JVC) that first succeeded in developing such a system to the point of commercial introduction [10]. The JVC four-channel carrier disc system was announced in 1970, only a year after the first matrixing demonstrations. Several American recording companies soon adopted the JVC system and issued records in this format. The following several years saw a succession of improvements in disc cutters, mastering techniques, circuits, record compound, and pickups, all aimed at increasing the signal-to-noise ratio and reducing carrier-dropout effects sometimes experienced in the case of the earliest carrier records and players. Thus at the present time we have four-channel tapes, a discrete four-channel phonograph record, and several 4–2–4 disc systems, all co-existing in the market place.

BROADCASTING

As was suggested earlier, a number of FM broadcasters were quick to show interest in four-channel programming, but the simultaneous transmissions by paired stations was not an acceptable mode. By 1970 several systems had been proposed for carrying four discrete program channels within the allowed bandwidth of an FM transmitter and for receivers capable of handling these broadcast signals and providing the four discrete audio output signals [11]–[14]. All the proposals for discrete channels involved multiplexing by means of subcarriers within the FM baseband spectrum. Some of these proposed systems were used in experimental broadcasts, and the Federal Communications Commission (FCC) in the United States was petitioned by system proponents to institute rule-making proceedings to permit continuing FM four-channel broadcasting. In an effort to expedite the proceedings, and with encourage-

[1] The numerical notation 4–2–4 or more generally, m–t–n, denotes the number of channels at various points in the overall system; m is the number of original channels, t, the number of transmission channels after matrixing, and n, the number of presentation channels after dematrixing.

ment from the FCC, the Electronic Industries Association established the National Quadraphonics Radio Committee (NQRC) in 1972. The committee membership was composed of the several system proponents as well as many other interested parties. During the next three years the NQRC carried out extensive analytical studies, listening tests involving large numbers of auditors under controlled test conditions, laboratory tests of transmitters and receivers, and a series of experimental broadcasts using carefully selected test signals as well as musical-program material. The results of these studies were presented in a report to the FCC late in 1975, together with a request to initiate rule-making proceedings [15]. However, as of this writing no such action has been taken by the FCC.

Meanwhile, FM quadraphonic broadcasts via 4–2–4 matrixing systems had become commonplace after being initiated as soon as 4–2–4 encoders became available [16]. These broadcasts were permitted by the FCC since only the two conventional stereo channels were needed.

We shall now endeavor to fill in this sketchy history of quadraphony with some of the technical details, although the technical discussions must be compressed and oversimplified because of *Journal* space limitations. References to other publications will direct the interested reader to more complete presentations.

ALLOCATING THE SIGNALS

Discussions of quadraphony are commonly based on the idealized square array of four loudspeakers depicted in Fig. 1. The auditor is assumed to be situated at the center of the square facing the front side of the array. Although this symmetrical arrangement will seldom be feasible in listening rooms in homes, it is a useful convention for analytical studies. The cardinal directions are center front (C_F), left front (L_F), center left (L_C), left back (L_B), center back (C_B), right back (R_B), center right (R_C), and right front (R_F). In the interest of economy of notation we will use the symbols L_F, L_B, R_B, and R_F to denote also the electrical signals in the four quadraphonic channels appropriate to the square array. Electrical signals representing sound sources must be allocated among the four quadraphonic channels in such a way that an auditor will perceive the locations and relative intensities of the reproduced sources in the way intended by the producer responsible for the sound pickup or recording.

A common method of allocation, or mix-down, particularly in America, is the one termed "pairwise panning." In pairwise panning, which is an obvious extension of the two-channel stereo technique, each pair of adjacent quadraphonic loudspeakers is regarded as a stereo pair. A phantom source may be located at any point between the pair simply by dividing the electrical signal for that source between the two channels in the correct ratio. Thus an equal division of the signal between two channels should place the phantom source midway between the two loudspeakers. For other ratios the phantom source will move closer to the loudspeaker producing the stronger signal and, in the limit, one loudspeaker becomes a discrete, real source when the signal is fed to only that loudspeaker[2]. Source localization by means of pairwise panning works well for the pair of loudspeakers in front of a centrally situated auditor. As in stereo, localization effects deteriorate progressively as the auditor moves laterally from the central location. Moreover, psychoacoustic tests show that localization perceptions are less acute where the loudspeaker pairs are to the sides or rear of the auditor [17]–[19].

Other methods of signal allocation utilize diagonal channels and even all four channels in semirandom fashion as in the common case of front-stage sounds with concert-hall reverberation surrounding the listener.

Analytical studies made following the advent of quadraphony have shown that pairwise panning involves some redundancy in localization information and is not the optimum form of signal allocation. Several workers have suggested more effective methods of allocating the signals [20]–[22]. Discussion of this matter is facilitated by reference to Fig. 2 where the loudspeaker array, with its center at 0, is sketched in. The allocation problem consists of providing signals in the four channels L_F, L_B, R_B, and R_F, such that during quadraphonic reproduction an auditor at the center will judge the sound produced originally by a source S to come from an intended direction ϕ with an intended intensity relative to any other sources that may be present.

We note in passing that if the length of the vector 0S is made proportional to the sound pressure in a wave front approaching at azimuth ϕ, this vector will have components $x = S \sin \phi$, $y = S \cos \phi$. These two components together with the magnitude S are sufficient to specify the direction and magnitude of the source, showing that three signal channels are a minimum number required for transmitting quadraphonic information. However, more than three loudspeakers would have to be fed from these three channels in order to provide a satisfying distribution of reproduced sound in a listening room. If the three signals defined above are allocated to four channels for distribution to four loudspeakers, the expected quadraphonic sound field is produced. However, the four

[2] The implementation of pairwise panning in the studio is commonly a sin-cos panpot [98] having a joy-stick control knob. This permits not only the panning described above, but also the further addition of any desired amount of signal to all four channels simultaneously as a monophonic component in the program.

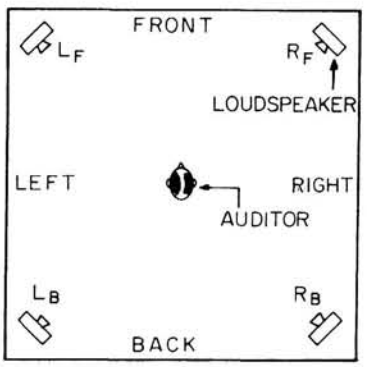

Fig. 1. Square array of loudspeakers commonly used in analyses of quadraphonic reproduction.

channels are underutilized since they are carrying no more than three channels' worth of information. The three-channel system provides a uniform scanning resolution around the 360° horizon, but does not permit discrete sources in reproduction in the form of excitation of a single loudspeaker without crosstalk in adjacent loudspeakers.

An optimal four-channel system will use its full information-carrying capacity while maintaining a constant sound power for every value of source azimuth. Cooper and Shiga [21] set forth some criteria for optimization and derived an optimal channel-allocation weighting function expressible as

$$M = \exp\left(j\,\frac{\psi}{2}\right)\left[\cos\frac{\psi}{2} + \cos\frac{3\psi}{2}\right]. \qquad (1)$$

After some trigonometric conversions, the magnitude of this function becomes

$$|M| = 2\cos\psi\cos\frac{\psi}{2} \qquad (2)$$

where ψ is the azimuth angle between an intended source direction and the channel, or loudspeaker, direction. A polar plot of this function applied to the R_F direction is shown in Fig. 3. Identically shaped functions aimed at the other three corners will provide the optimal encoding in their respective channels. The plot has been normalized to unity maximum output. The relative phase of signal allocations for various source azimuths is indicated by + and − signs in the plot. We see that if an intended source azimuth coincides with the R_F direction, all of the signal will go to the R_F loudspeaker, with zero signal to the other three loudspeakers because of nulls in the polar plot.

When the intended source direction is C_F, the L_F and R_F channels each will receive a signal whose relative magnitude is 0.653 (−3.7 dB), while each of the rear channels will carry out-of-phase signals of relative magnitude 0.327 (−9.7 dB). Through the use of nonunity coefficients for the bracketed terms in Eq. (1), the rear lobes in the allocation function may be reduced and even eliminated, but at the expense of broadening the front lobe, and vice versa. The resulting functions are suboptimal as judged by the Cooper–Shiga criteria. The out-of-phase signals in the rear loudspeakers for frontally situated sources contribute to acoustic particle velocity in the proper sense at the center of the array, and auditors have demonstrated better localization scores with the optimal function than with pairwise mixing for which the rear loudspeakers are silent [18].

The three-channel allocation function noted above in passing can be synthesized by linearly combining an omnidirectional polar pattern with two bidirectional (figure-eight) patterns at right angles to each other. Hence this form of allocation can be achieved by picking up the original sound field by three coincident microphones having these directional characteristics. Electrical synthesis of the three-channel allocation function can be accomplished by means of sin–cos potentiometers.

Synthesis of the optimal four-channel function by means of microphones appears not to be practical since this requires the addition of a four-leaved-rose directional characteristic associated with a sin 2ψ polar pattern. Microphones having this polar response are not available. The optimal four-channel synthesis can be accomplished electrically, however. J. J. Gibson[3] has devised a panning unit for this purpose and has implemented it in a three-channel version. Addition of another sin–cos pan pot is needed to convert the three-channel system to the optimal four-channel version. Since the relatively-complex optimal four-channel panpot devices are not generally available, studio engineers must continue to use the pairwise-panning technique, even though it has been demonstrated to be less effective than the optimal approach. The optimal

[3] J. J. Gibson, private communication. The three-channel optimal synthesizer was demonstrated in tests at the FCC Laboratories, Laurel, MD, in 1976.

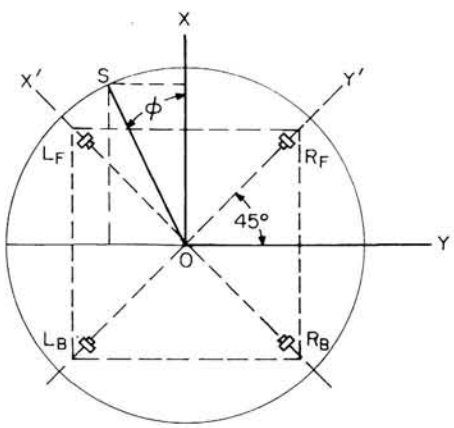

Fig. 2. Coordinate axes and azimuthal angle of sound source direction for allocation of signal in four channels.

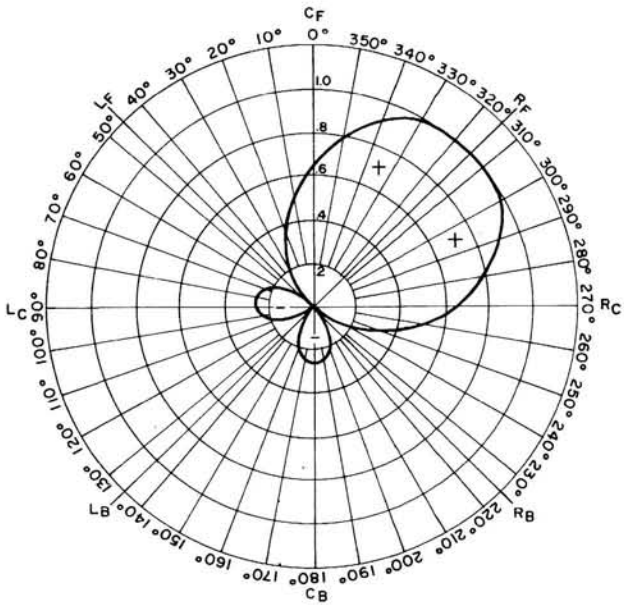

Fig. 3. Polar plot of optimal function $|M| = 2\cos\psi\cos\psi/2$ for allocating a sound source in four channels. Plus and minus signs indicate phase-reversal regions.

allocation according to the Cooper-Shiga criteria, as considered here, is applicable to a 4–4–4 system. In the case of systems employing certain forms of matrixing additional criteria may have to be taken into account, making the optimization procedure less clear-cut. This will be touched on in the following section.

MATRIXING

The preceding section considered the problem of encoding an acoustical sound field in terms of electrical signals in four separate channels that ultimately will feed four (or more) loudspeakers. However, in nearly all quadraphony applications (the major exception being four-track tape recordings) the actual transmission or recording of the four channels is accomplished through the use of linear combinations of the four signals. The process of creating these linear combinations using electrical and/or electronic components and circuits is termed "matrixing." The term and the technique were first used in quadraphony during the early development of the 4–2–4 systems, at which time "matrix" and "discrete" differentiated between 4–2–4 and 4–4–4 systems when the only implementation of the latter was four-track tape. This use of "matrix" and "discrete" quickly became so common that it is not likely to be discontinued, even though such usage is inappropriate and ambiguous in light of more recent developments.

An example of simple matrix encoding in a 4–4–4 system is the following, where each term represents the magnitude of the signal in the corresponding channel:

$$\begin{aligned} M &= L_F + L_B + R_B + R_F && \text{monophonic} \\ Y &= (L_F + L_B) - (R_B + R_F) && \text{left–right} \\ X &= (L_F + R_F) - (L_B + R_B) && \text{front–back} \\ U &= (L_F + R_B) - (L_B + R_F) && \text{diagonal.} \end{aligned} \tag{3}$$

M, Y, X, and U are the signals that might be carried in the audio transmission channels of FM broadcasting. This particular linear combination is advantageous in providing immediate compatibility for reproduction through monophonic or stereophonic systems. For mono, only the M channel is used. For stereo only M and Y are used. If M, Y, and X are used, we can derive a 4–3–4 system capable of quite acceptable quadraphonic performance since, as noted previously, three channels are sufficient for establishing the azimuth and relative magnitude of a sound source in a horizontal plane. When all four transmission channels are used, we again obtain the ability to energize any one of the four loudspeakers as a discrete source in reproduction through use of the following decoding equations:

$$\begin{aligned} L_F' &= M + X + Y + U \\ L_B' &= M - X + Y - U \\ R_B' &= M - X - Y + U \\ R_F' &= M + X - Y - U \end{aligned} \tag{4}$$

where the primed terms represent the signals in the four quadraphonic channels after dematrixing. The four original signals are thus recovered in a 4–4–4 system.

In a 4–3–4 system the U channel would not be transmitted. Inserting Eqs. (3) in (4) and setting $U=0$, yields

$$L_F' = 3L_F - L_B - R_B + R_F \tag{5}$$

with corresponding equations for the other three channels. Thus if the original signal were in only the R_F channel, in reproduction the L_F channel would carry R_F crosstalk at a level of about −9.5 dB.

If Eqs. (3) and (4) were used as a 4–2–4 system by using, for example, only the M and Y channels, complete left–right isolation would be obtained, demonstrating stereo compatibility, but there would be no front–back separation, making this form of matrixing quite unsuited for 4–2–4 use. Any other pair of Eqs. (3) are similarly unsuited for a 4–2–4 system. Clearly, more information is required in the matrixing equations if any semblance of four-channel reproduction is to be achieved by a 4–2–4 system. This additional information can be inserted as a combination of phase shifts and channel weighting coefficients. Analysis shows that a total of 180° of relative phase shift must be distributed between the L_F, L_B, R_B, and R_F terms in the matrixing equations, and complementary distributions must be included in the dematrixing equations. By juggling the phase and amplitude distributions in the 4–2–4 encoding–decoding equations, one can obtain modest simultaneous left–right and front–back channel separations in reproduction. Or one can emphasize the left–right separation at the expense of front–back, and vice versa. One example of encoding equations including weighting coefficients and phase shift is the following:

$$\begin{aligned} L_T &= 0.92L_F + 0.38R_F + j(0.92L_B + 0.38R_B) \\ R_T &= 0.38L_F + 0.92R_F - j(0.38L_B + 0.92R_B) \end{aligned} \tag{6}$$

where +j signifies a 90° phase advance and −j a 90° phase delay. L_T and R_T are the two transmission-channel signals.

The corresponding decoding equations and the resultant four-channel outputs are

$$\begin{aligned} L_F' &= 0.92L_T + 0.38R_T \\ &= L_F + 0.71R_F + 0.71jL_B \\ R_F' &= 0.38L_T + 0.92R_T \\ &= 0.71L_F + R_F - 0.71jR_B \\ L_B' &= -0.92jL_T + 0.38jR_T \\ &= 0.71jL_F + L_B + 0.71R_B \\ R_B' &= -0.38jL_T + 0.92jR_T \\ &= 0.71jR_F + 0.71L_B + R_B. \end{aligned} \tag{7}$$

This is an example of a "symmetrical" matrix. We see that if L_F' is the intended presentation channel, the signals in the two flanking channels are down in level by only 3 dB, with the L_B' signal being 90° advanced, while the diagonally opposite R_B' is silent. An exactly similar result occurs at each of the other three corners. Any symmetrical matrix can be transformed into any other by simple circuits. Any symmetrical 4–2–4 matrix is a member of a hierarchy of 4–4–4, 4–3–4, and 4–2–4 encoding systems, each derivable from the others by adding or subtracting transmission channels.

"Nonsymmetrical" matrices may be obtained by using other values of coefficients and phase angles in Eqs. (6) and (7), and there are an infinite number of combinations to choose from. One effect of, and one reason for, using a nonsymmetrical matrix is to increase the separation in one direction, e.g. left-right, but at the expense of separation in some other direction. An example of encoding by a nonsymnmetrical matrix is given in Eqs. 8:

$$\begin{aligned} L_T &= L_F - 0.71jL_B + 0.71R_B \\ R_T &= R_F - 0.71L_B + 0.71jR_B. \end{aligned} \tag{8}$$

One of the possible decoding matrices is represented by Eqs. 9:

$$\begin{aligned} L_F' &= L_T = L_F - 0.71jL_B + 0.71R_B \\ R_F' &= R_T = R_F - 0.71L_B + 0.71jR_B \\ L_B' &= 0.71jL_T - 0.71R_T \\ &= 0.71jL_F + L_B - 0.71R_B \\ R_B' &= 0.71L_T - 0.71jR_T \\ &= 0.71L_F - 0.71R_F + R_B. \end{aligned} \tag{9}$$

We see that in this nonsymmetrical example, infinite left-right separation is achieved, but diagonal crosstalk is present.

A very important consideration in arriving at a matrix design is quad–stereo–mono compatibility. It is advantageous for a record company to issue recordings that can be reproduced without serious degradation in all three modes from the same disc. Similary, quadraphonic FM broadcasts must be acceptable when picked up by stereo and mono receivers. This compatibility constraint requires a certain amount of compromising of the reproduction in one mode to improve the reproduction in another. Since there is no mathematical basis for optimizing this compromise, the judgment as to the best trade-off can vary from individual to individual and from company to company. However, once the basic policy decision has been made regarding the nature of the trade-off to be used, mathematical relationships can be written to formalize the decision and to lead to a matrix design. Frequently, the trade-offs made for compatibility reasons will lead back to a 4–4–4 signal allocation different from the optimal allocation discussed earlier. Space does not permit a discussion of the variety of trade-off judgments that have been made and of the matrices based on them. The interested reader is invited to study the copious literature describing various 4–2–4 matrices and the rationale behind their designs.

Among the systems currently of interest, nonsymmetrical matrices are used in the CBS-SQ® system, the British Broadcasting Corporation (BBC) matrix H system and the United Kingdom National Research and Development Corporation (NDRC) 45J system, while the Sansui QS® system and the Cooper-Shiga BMX system employ symmetrical matrices.

SEPARATION ENHANCEMENT

While 4–2–4 systems offer pleasing quadraphonic effects and surround sound, both analysis and listening tests demonstrate that the basic system cannot duplicate the localization precision and sharpness of acoustic images produced by 4–4–4 systems. Consequently, most of 4–2–4 systems employ circuitry in addition to the matrices to enhance the localization capability of the system. An early form of enhancement consists of automatic gain riding in the four reproduction channels. The program voltages are monitored electronically to determine which channel carries the strongest signal at each instant. The gain of that channel is increased and the other channel gains are decreased while maintaining a constant total power, thus emphasizing the corner location of the predominant sound. However, this simplistic approach has been abandoned in favor of more complex techniques [23]–[28]. One technique employs a combination of gain-riding and cancellation of crosstalk by blending signals between channels, all controlled by electronic monitoring of the reproduced program voltages. Another of the newer techniques continuously varies the coefficients of the decoding matrix, again in response to signals generated by program sensors. The coefficients are varied in such a way as to reduce crosstalk of a predominant source with a concomitant increase in crosstalk of any weaker sources that are present in other channels. This sharpens the localization of the predominant source, while spreading out a weaker source. It has been suggested, on the basis of psychoacoustic tests, that an auditor is unaware of a modest amount of weak-sound spreading since it is obscured by "directional masking." Still another enhancement system was demonstrated recently in which the control time constants as well as the matrix coefficients are varied in accordance with reproduced program characteristics [29]–[30]. Details of this system have not been disclosed. These advanced enhancement systems require a large number of solid-state devices capable of performing many different functions. It is the development of integrated circuits [28], [31] specifically for this application that makes these enhancement systems feasible for the consumer market.

DISC RECORDING

Conventional two-channel stereophonic disc records can carry quadraphonic signals that have been encoded from four into two channels by any of the 4–2 matrices, and a sizable library of recorded selections have been released in this format. The 4–2 encoder is used in the mixdown prior to cutting the disc master. In playback the 2–4 decoder is needed to complete the 4–2–4 record–reproduce system for quadraphonic listening.

Two 4–4–4 disc systems have been introduced commercially as of this writing, one being the CD-4 system of the Victor Company of Japan [10], referred to earlier, and the other being a QMX system developed by the Nippon Columbia Company [32]. Both systems employ frequency-modulated (or phase-modulated) carriers in the vicinity of 30 kHz to carry two signal channels in addition to the two conventional baseband channels in a stereo record groove. By way of example, the frequency-band assignments for the CD-4 system are shown in Fig. 4. The left-hand groove wall carries the L_F+L_B signal as baseband modulation, while the L_F-L_B signal in the form

of modulation of a 30-kHz carrier is superimposed on the audio frequencies in the baseband. The modulation index and frequency deviation of the carrier modulation are controlled so all significant modulation sidebands fall within the 20–45-kHz band. The right-hand channels are handled similarly on the right-hand groove wall. A number of important advances in technology were required to permit acceptable performance with the carrier discs. Pickups having smooth response to at least 45 kHz were developed [33]–[34]. This high-frequency response requirement as well as record-wear problems called for an improved pickup stylus in a high-compliance stylus arm [35]–[36]. To achieve a reasonable life of the high-frequency modulation in the groove, a new record compound was formulated [37]. Nonlinearity due to tracing distortion and groove-wall deformation in playback can cause serious intermodulation of the carrier signals by the baseband signals. It was necessary to develop circuitry for use during recording to cancel this distortion very precisely in playback [35], [38], [39]. This "up-talk" intermodulation is dependent also on the relative recorded levels of baseband and carrier signals. Circuits for controlling the carrier level in a programmed manner were provided [10]. Crosstalk between carriers on opposite walls of the groove leads to another form of distortion, which is compensated for by still other circuits [35], [38]. In order to record the very short, high-curvature carrier wavelengths on the master lacquer it was necessary to redesign the geometry of the tip of the cutting stylus [40]. Because of bandwidth limitations of existing disc-mastering cutters, the mastering is done at one half the normal playback record-rotation speed [41]. Several of the complex modulation, demodulation, control, and noise-reduction functions [42]–[44] are performed by integrated-circuit packages. Carrier-disc systems have been adopted by a number of record companies that have released a substantial number of recordings in this format.

Playback of such a recording through a suitable demodulator yields four output signals, namely, L_F+L_B, L_F-L_B, R_F+R_B, and R_F-R_B. Combining these sum and difference signals in a simple matrix gives the four original quadraphonic signals.

FM BROADCASTING

As in the case of disc recording, the 4–2–4 quadraphonic systems can use standard stereophonic FM transmission technology and equipment. For 4–2–4 quadraphonic reception the receiver must be equipped with a suitable decoder with the four conventional quad outputs.

FM transmission for a 4–4–4 system is, of course, more complex and will require changes in FCC rules. Nearly all the proposed systems [11]–[14], [45]–[57] for 4–4–4 transmission follow the general principle indicated in Fig. 5. The audio transmission signals are described by Eqs. (3), with each of the four signals being assigned to a portion of the 95-kHz-wide frequency space allotted to an FM broadcast station. The M, or monophonic, signal goes to the baseband audio channel. The Y, or $L-R$, signal modulates a 38-kHz subcarrier. So far we have nothing more than the standard stereo broadcast arrangement. The X, or $L+R$, signal also modulates a 38-kHz carrier, but 90° out of phase with the Y modulation. A synchronous detector in the receiver can separate the X and Y signals. The fourth signal, U, modulates another subcarrier at 76 kHz. A pilot tone at 19 kHz is used to synchronize the subcarrier detectors in the receiver. The baseband, the three modulated subcarriers, and the pilot tone are combined to modulate the RF carrier of the FM station. Detection in the receiver yields the four audio transmission signals M, Y, X, and U, which may then be dematrixed to give the original L_F, L_B, R_B, and R_F quadraphonic signals.

The presence of a subcarrier centered at 76 kHz precludes use of the Subsidiary Communications Authorization (SCA) transmission band now authorized by the FCC. Alternative SCA subcarrier frequencies are proposed in order to retain this service during quadraphonic broadcasts. However, if the U channel is not transmitted, the present SCA service will not be affected. Nevertheless, rule changes are required to accommodate the additional 38-kHz subcarrier. Elimination of the U channel results in a 4–3–4 system, as discussed earlier. Some system proponents include this as an option. Transmission of all four signals reduces the quadraphonic signal-to-noise ratio in audio reproduction by 9.4 dB relative to conventional stereo reproduction. The corresponding degradation for the 4–3–4 option is 2.9 dB. As a basis for comparison, the signal-to-noise ratio for standard stereo reproduction is −26.2 dB relative to mono reproduction.

THE SOUND AND THE JURY

After concluding this sketchy review of the technical aspects of quadraphony, it is appropriate to ask, "How does it sound?" This question is asked repeatedly by

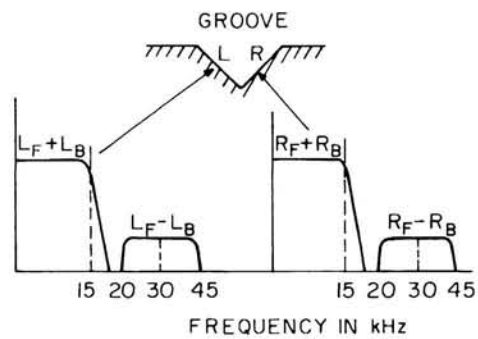

Fig. 4. Channel assignments in CD-4 disc-recording system.

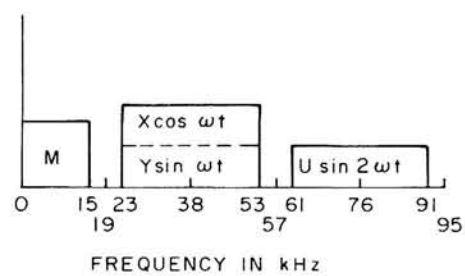

Fig. 5. Disposition of audio baseband and subcarrier signals in a proposed four-channel FM broadcast system.

everyone working on systems and components for four-channel audio, and every company so involved routinely conducts listening tests to evaluate developments. Selection of juries and judges for these tests starts with the individual engineers intimately involved in the work and spreads out to include colleagues, managers, corporate officers, and recording producers and musicians. In some cases panels of trained and experienced auditors are recruited and kept on call. While such listening tests are an indispensable part of any quadraphonic development program, giving valuable direction to the effort, they sometimes fail to measure up to accepted standards for scientific validity. In any case, the findings of such in-house tests are seldom documented in the technical literature for scrutiny by and benefit to the engineering community. The BBC, with its published reports, is a notable exception in this regard.

Persons who are frequent participants in listening tests can become highly skilled at detecting subtle changes in the sound field that result from changes in the signal processing system. However, even when gross changes are observed, any consensus value judgment as to whether or not a change represents an "improvement" often is elusive, and different individuals hearing the identical effects will render different judgments. This is inevitable because the small, finite number of four channels forces any quadraphonic system to be a set of compromises and tradeoffs, with an observer's judgment depending on the weight he attaches to the various tradeoffs—such as left–right versus front–back separation, quad performance versus stereo and mono compatibility, and, of course, the big one: complexity (= cost) versus performance. Add to all this the constraints of patents and licensing arrangements, and it is small wonder that consensus is hard to find.

In spite of the foregoing problems, a significant amount of new knowledge has come out of quadraphonic listening tests in the last few years. For example, the investigation by Nakayama *et al.* [58] showed how auditors' preference increased with increasing the number of transmission and reproduction channels from one through eight. Preferences for various loudspeaker arrangements in the listening area were shown also. Kohosaka *et al.* [18] conducted localization tests using the hierarchy of UMX matrices and found that the rate of improvement in localization diminishes beyond the 4–3–4 level of complexity. Nakabayashi [59] studied the effects of channel amplitudes and phase shifts on the localization and naturalness of sound images. Cabot *et al.* [60] provided additional data regarding image localization to the side and rear of the auditor. Matsudaira and Fukami [61] and Bower [62], [63] also measured localization and image sharpness as a function of channel phase differences, but in a two-channel arrangement. Ratliff [19], with a more elaborate setup of multiple and moveable loudspeakers, provided additional data on the dependence of localization and image spread on phase shifts and interchannel levels, while Crompton [64] conducted extensive comparisons of a number of 4–2–4 matrices, with and without separation enhancement. The last three investigators are members of the BBC team currently working on quadraphony.

The most extensive single program of listening tests to date was carried out by the National Quadraphonic Radio Committee (NQRC) [65]. Two hundred auditors in two cities participated in comparing the relative performance of 4–4–4, 4–3–4, and 4–2–4 systems. The program, which included both localization tests using carefully chosen signals and preference tests using musical material, was designed statistically to give a rank ordering of the three systems as well as to give an indication of the magnitudes of the perceived differences between systems. The localization tests and preference tests yielded results that correlated well with each other in ranking the 4–4–4 system highest with the 4–3–4 system a very close second. A 4–2–4 system without separation enhancement was ranked considerably lower. This 4–2–4 system was tested since an enhancement system was not available to the NQRC. This leaves open the question of the effectiveness of various enhancement systems in bringing the 4–2–4 performance closer to that of a 4–4–4 system. Very recently another series of tests were instituted at the FCC laboratories. The FCC tests were to include enhancement. As of this writing the outcome of these tests is not known [4].

There have been several efforts [27], [66]–[69] in recent years to provide theoretical bases for quadraphonic localization in terms of physical parameters such as acoustical wavefronts from several sources, acoustical energy considerations, and wave diffraction around the auditor's head. While these analyses provide insights into some of the mechanisms, and while there is considerable agreement between theoretical predictions and observed effects, none of the analyses presently is comprehensive enough to encompass all the psychoacoustic phenomena experienced in quadraphonic sound reproduction.

REALISM—THE UNENDING PURSUIT

Whether, in the present context, one regards "realism" as purely the re-creation of concert-hall acoustics in one's living room, or as bringing the musicians into intimate ensemble with the listener, or as a new, creative sonic event born in the imagination of an artist, quadraphony provides a more flexible and versatile medium for attaining one's goals than any that was previously available. Nevertheless, both technically and artistically quadraphony is only a new, though more efficacious, compromise between what is desired and what is feasible. We will not attempt, in these pages, to conjecture as to what still more advanced sound reproduction system will be developed by the next generation of audio engineers. There are indications that, with four channels, we have reached the point of greatly diminishing return if we think of further improvement simply in terms of adding more channels. We should hope, rather, for some new concept

[4] The results of the FCC tests have been made available as we go to press, issued by the Federal Communications Office of Chief Engineer, Laboratory Division, entitled, "A Subjective Evaluation of FM Quadraphonic Reproduction Systems—Listening Tests," Project No. 2710-1, August 1977.

in sound pickup and distribution, including the transducers at both ends of the circuit. With appropriate new transducers, the use of a large number of channels, actually or in effect, may appear more reasonable. Meanwhile our pursuit of auditory realism on a more modest scale must be directed to getting the most from our exisitng four-channel systems, as through optimal encoding procedures and by exploring and exploiting the capability of four channels to convey auditory elevation as well as azimuthal information [20], [70].

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Electronic Music

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INTRODUCTION: What is electronic music? Is it a brand new kind of music, or is it rooted firmly in our musical traditions? Must it use only sounds that are electronically generated, or are electronically processed "natural" sounds also permissable? Must electronic music be consigned to tape's magnetic domains, or may the performer be allowed to play directly to an audience? And how about the sounds themselves? May traditional timbres be simulated? Must electronic music sound "electronic"?

The above questions are sufficient to convulse the argumentative among us into paroxysms of noisy, futile debate. Electronic music has existed as a potential artistic resource for a century, as a subject of widespread experimentation since the end of the World War II, and as a major factor in the music business for the past decade. Throughout the development of electronic music, there have been uncountable attempts to categorize and restrict its musical domain, yet today it is nigh impossible to identify an area of music that has not been enriched through the use of electronics. Synthesizer recordings have shed new, clarifying light on the substance of traditional music, while opening our ears to new timbres and textures. The vast expanse between pure sound effects and pure music has been explored with electronic instruments in opera, film, TV, and records. Students from kindergarten through graduate school are gaining new insight into the acoustical and physiological aspects of music as well as the aesthetic aspects. And, of course, composers and performers are producing music that would be impossible with only traditional acoustic instruments. In fact, with each succeeding year, it becomes more and more difficult to objectively consider electronic music as a distinct, bounded entity.

My own definition of electronic music is therefore very broad: Electronic Music is music which is made with electronic equipment. This particular definition simply serves to point out that electronic music is a medium of musical expression which, as it happens, is miscible in any proportion with the traditional pallette of acoustic musical instruments. Although it has spawned an awareness of tone color as a compositional element, the electronic music medium has been employed to interpret the song and dance of vernacular music and the tonal counterpoint of baroque as successfully as it has been used to develop and realize the most aggressively avant garde composition.

In focussing on the musical resources rather than the technological features of the electronic music medium, we identify four distinct areas:

1) Electronic circuits vibrate (produce audio signals) in ways that are fundamentally different from those of acoustic instrument components. This is because electronic circuits are almost always discrete systems that are described by ordinary differential equations, whereas acoustic components are distributed systems, and are therefore described by partial differential equations.

2) It is often useful to separate the sections of an electronic audio signal producing system so as to allow the musician to assemble his own combination of elements, and to adjust each element according to his particular needs. In other words, with electronics it is practical to supply a musician with a "kit of parts" out of which he assembles his own "instrument." This capability does not exist with acoustic instruments.

3) The means for electronically generating and modifying audio material may be kept separate and independent from the control interfaces which the musician "plays,"

or through which he otherwise issues commands, in order to produce the audio signal changes that constitute music. This affords musical instrument designers the freedom to optimize some portions of an instrument system for best audio signal production, while optimizing other portions for the most efficient communication of the musician's commands. Except for very few cases such as the pipe organ, acoustic musical instruments have vibrating elements which also serve as control elements. An example is the violin string which vibrates while the musician's finger is actually on it.

4) Electronic technology includes the capability of storing sequences of sound events and, more recently, the capability of storing sequences of command (control) signals that define sound changes. This single capability is perhaps the most profound contribution that technology has ever made to music. Not only has it freed the musician from the necessity of making his music in real time (live), but it has enabled him to physically manipulate and arrange sounds by handling a recording medium such as magnetic tape.

In examining specific uses of the electronic music medium, the most interesting question to ask is: "To what extent are those features of the medium that differentiate it from acoustic music being utilized? It is simply not necessary or desirable to argue the purist's position that only certain types of music are "right" for realization through electronic music, that there are fundamental musical limitations to the medium, that live music is better than recorded music, or that the musician does not have the right to "cherry pick" as he strolls through the orchards of technology in search of musical resources. Neither is it worthwhile to even consider the question, "Is electronic music less natural than music played on acoustic instruments?" No music is natural! Music is produced only after people invest strenuous and extended effort to gain intimate control over vibrating systems such as vocal cords, a violin, or a synthesizer. Furthermore, all musical instruments, except for the human voice, are highly contrived technological artifices. They are differentiated not by their degree of "naturalness," but by the technological periods in which they were developed. The string instruments were perfected when woodworking was a flowering technology. Piano designers utilized the processes of a fully industrialized society. And the electronic music medium is being developed now, a time when electronic technology is dominant and the golden age of manufacturing appears to be yielding to what people are calling "the postindustrial era." What people really mean when they accuse electronic music of sounding unnatural, mechanical, or, worst of all, inhuman, is that it sounds just plain different from what they are used to, or that the musician, in exploring the new medium, has not yet succeeded in gaining the control necessary to properly realize his music.

This discussion of electronic music deals primarily with the relationships between the functions of electronics devices, and the types of resources that musicians have found useful. It will steer clear of making subjective evaluations or discussing aesthetic aspects of specific pieces of music. First, however, it will sketch a brief history of electronic musical instruments to illustrate that precious little is new under the sun.

ELECTRONIC MUSICAL INSTRUMENTS PRIOR TO 1945

Much of the information in this section is taken from Dr. Thomas L. Rhea's Ph.D. thesis [1]. Through the years, the technologists of the electronic music medium have tended to be frustrated musicians and chronic putterers. Thaddeus Cahill, developer of the Telharmonium, was also endowed with the ability to think big. Although not strictly electronic (it predated the invention of the vacuum tube by about a decade), the Telharmonium embodied many basic principles that have been used in the electronic music medium: the generation of pitched tones from alternating electricity, the addition of harmonics to determine tone color (additive synthesis), and a touch sensitive keyboard to shape the sounds and control their strengths. Cahill generated his signals with a bank of over a hundred alternators, each capable of producing as much as 15 killowatts of power. The tones were combined in giant mixing transformers, and then sent out over leased telephone lines to subscribers who heard the music on telephone receivers fitted with horns. The musicians performed at the touch-sensitive keyboard console, while listening to their playing over "monitor speakers" of the same type that subscribers had. Cahill's Telharmonium was built in Holyoke, Massachusetts, and shipped to New York in 1906 in some thirty railroad box cars. This first polyphonic, touch sensitive music synthesizer remained in service in New York for only a few years, until the forces of electronic technology (the invention of radio) and crass economics conspired to end telharmonic music as a viable commercial venture. The basic idea was resurrected again in the 1930s in an instrument that was somewhat more of a commercial success: the Hammond Organ. Instead of monstrous generators, the Hammond Organ used tiny tone wheels to generate individual pitches, and employed electronic amplification to boost the tone wheel signals to drive loudspeaker. Designed and tooled by a group of master machinists (Hammond manufactured electric clocks before it got into the music business), the Hammond organ offered musicians a few potent musical resources plus that rarest attribute of all: reliability. Hammond remained the largest manufacturer of electronic organs for decades, a tribute to the enduring value of a well designed musical resource.

The Theremin was one of the very first wholly electronic musical instruments. Developed during the 1920s by a Russian physicist and amateur musician, Lev Sergeivitch Terman, the Theremin is played without being touched. The performer moves his hands in the space surrounding the instrument to vary pitch and loudness of the tone. Terman licensed RCA to make and sell his instruments in the United States. RCA built Theremins on the same production line as their first superhet receivers, and attempted to sell them through the same dealer network of radio stores. From this venture, RCA learned that introducing a new musical instrument into the con-

sumer marketplace requires a combination of delicacy and tenacity. A merchandising approach involving classical promotion and distribution is sure death. This lesson is being relearned even today by musical instrument manufacturers large and small. After a brief time in the musical instrument marketplace during which only a few hundred Theremins were sold, RCA discontinued production and sold the rights back to Terman, who continued developing the instrument as an experimental venture.

In Europe, the same pattern emerged with different instruments and inventors. Friedrich Trautwein developed the Trautonium, an electronic musical instrument controlled by a fingerboard-like rheostat. The rights were sold to none other than Telefunken, which, it is reported, made a grand total of fifty instruments before bowing out. Maurice Martenot, a French instrument designer, developed the Ondes Martenot, a monophonic (single tone) electronic musical instrument whose control means included a six-octave keyboard, continuously variable pitch band, and touch sensitive articulator bar. Unlike Terman or Trautwein, Martenot not only kept production of his instrument under his own control, but he also established a school for developing and teaching performance techniques. Original compositions for Martenot are routinely performed in Europe, even today.

All of these instruments, Theremin, Trautonium, and Martenot, pointed the way to experimentation with new control devices for electronic musical instruments. The Solovox, and similar instruments that were less successfully marketed, were some direct precursors of the whole class of instruments called synthesizers. The Solovox contained a single tone generator and a variety of waveshaping, frequency dividing, filtering, and envelope shaping circuits. Each circuit could be switched in by the musician. In other words, the musician *synthesized,* or assembled out of aural components, the sound quality he desired. Manufactured by Hammond, the Solovox was designed to be mounted on a piano right in front of the keyboard. By depressing a specified combination of switches, the player could set up an orchestral-like timbre, which he could then play monophonically with one hand while he played the piano with the other.

The use of electronic technology to assemble, store, and manipulate sound sequences may be traced back to the Coupleaux-Givelet Synthesizer, which was introduced in 1929 at the Paris Exhibition. The Coupleaux-Givelet system used punched paper tape to pneumatically activate controls that determined the parameters of four independent voices. Programmed mixing and level control was accomplished by varying the coupling between two coils, by moving one of them with a bellows. The Hanert Electrical Orchestra, developed by John Hanert around 1945, enabled the musician to draw a "score" (program) for a piece of electronic music on a continuous roll of paper. A carriage containing an elaborate photocell array travelled down the paper, "reading" the score and "conducting" the ensemble of sound producing circuitry. After World War II, the RCA Electronic Sound Synthesizer was developed under the direction of Dr. Harry F. Olson. Programmed by a paper roll punched with a set of binary codes, the RCA Synthesizer produced four independent lines of sound (Fig. 1). Each line was programmed with a degree of detail that allowed the sound parameters to be redefined as often as thirty times a second.

ENTER THE TAPE RECORDER

The development of the Theremin, Trautonium, and the many other performance instruments early in the electronic music medium followed in the tradition of acoustic musical instruments. Musicians mastered these instruments simply by developing suitable manual dexterity, and applied these skills to real-time performances of a limited (or even unique) set of tone colors and response modes. The instruments of Coupleaux-Givelet, Hanert, and RCA, on the other hand, sought to bypass the performing musician by going directly from composer's score to finished music. The availability of the tape recorder immediately after World War II added a new dimension to electronic music. With tape recording, any sounds, electronic or acoustic, brief or extended, ordinary noises or pure pitches, could be manipulated, assembled, fragmented, combined and stored. The work of experimental musicians in Cologne, Paris, and New York focussed on developing technical procedures and aesthetic rules for tape composition. Music using electronically generated sounds came to be known as just plain "electronic music," music using recorded "natural" sounds came to be known as "musique concrete," and the facilities that were established to support tape composition came to be called "classical studios."

A typical classical studio consists of three main sections: sound generating and modifying, mixing and patching, and recording. A basic feature of the classical studio that differentiates it from both the early electronic performance instruments and the early programmed synthesizers is the separation of the studio components from one another. In a classical studio, all signal paths are established with patch cords. The musician organizes his studio to provide the desired function or operation. Tape composers working in classical studios soon learned that there is a conceptual continuity between physically organizing sounds on tape on the one hand, and assembling a network of electronic components to produce or modify

Fig. 1. The RCA electronic sound synthesizer.

sounds, on the other hand. It became possible to regard the medium itself, as well as the pallette of sounds of which it is capable, as a carrier of musical content. Music need not be defined only by fixed patterns that imply underlying harmonic structures. With patch cords and enough things to patch together, music can also imply elegantly-proportioned networks of signal flow. Thus, in addition to greatly increasing timbral resources available to musicians, the classical studios added a whole new dimension to musical communication.

THE VOLTAGE CONTROLLED SYNTHESIZER

As first conceived, the voltage-controlled synthesizer is not a uniquely defined piece of equipment, but rather an approach to systems design in which a) each system component performs a single signal generating, modifying, or control function, b) a large number of signal path networks is possible, and c) the principle of voltage control is utilized to expand the means of sound control. The combination of these properties results in an open-ended, generalized musical instrument system that can easily be used (and indeed has been used) to produce virtually any type of music. Each of these features will now be described in detail, and their musical value will be discussed.

As in the classical studio, the signal generating, modifying, and controlling of a voltage-controlled synthesizer are performed by single function components which are connected into a network by the musician. Audio signals originate in oscillators that generate regularly repeating waveforms, in noise sources that produce random waveforms, or in devices external to the synthesizer. Regularly repeating waveforms give rise to pitched tones. The shape of the wave itself determines its harmonic content and therefore its beginning tone color. The repetition rate of the waveform determines the perceived pitch of the resultant tone. Random waveforms give rise to pitchless, hissing-type sounds.

Audio signal modifier components consist of three main groups: filters, amplifiers, and mixers. Filters attenuate some portions of the signal's spectrum (set of frequencies) while allowing other portions to pass. Amplifiers (or attenuators), merely change the amplitude of the signal, while mixers combine signals in a predetermined proportion.

These are the basic audio signal generating and modifying processes of electronic music. In a classical studio, these processes are static or quasi-static. That is, the functional components are set up to produce a sound or group of sounds. During the actual production of the audio signals, the operating parameters of the components remain constant, or at most are slowly varied by manual control. In a voltage-controlled synthesizer, the main operating parameters of the modules (functional components) may also be vaired by applying control signals. These control signals are entirely separate from the audio signal path. They do not correspond directly to sound vibrations, but to changes in the properties of the produced sound. As an example, consider a voltage- controlled oscillator, the output of which is an audio pitched tone. Now, a second oscillator is brought into the picture. Assume the second oscillator produces a 5 Hz sine wave. If the second oscillator signal were mixed with the output of the first, no sound change would be heard. If, on the other hand, the second oscillator signal were fed to the frequency control input of the first oscillator, then the frequency of the first oscillator would rise and fall with each cycle of the second oscillator's output. The first oscillator's tone would have a periodic pitch variation, or vibrato. Using synthesizer terminology, we would call the first oscillator the tone or audio oscillator, and the second oscillator, the control or modulating oscillator. It is important to note that these two oscillators are not distinguished because they have different capabilities, but because they are being used in fundamentally different ways. A wide range voltage controlled oscillator may be used for either audio or control signal generation. Furthermore, a control oscillator can itself be the receptor of a second control signal. A hierarchy of control signals thus enables extremely complex sound textures to be generated by a single audio source.

QUANTITATIVE ASPECTS OF VOLTAGE CONTROL

Acoustic parameters are generally proportional to the exponentials of musical (subjective) values. In particular, musical pitch intervals are frequency ratios. Stated another way, frequency is exponentially related to pitch. Likewise, audio signal amplitude is exponentially related to subjective loudness.

Voltage-controlled oscillators (VCOs) whose frequencies are exponentially related to the magnitudes of their applied control voltages are ideal for electronic music applications. Since the introduction of the early voltage-controlled synthesizers of Buchla and Moog in 1964, this type of oscillator has become a standard of the electronic music medium. The usual control voltage input/frequency output relationship is: a control signal increase of one volt doubles the frequency, or raises the pitch by one octave. The equally tempered chromatic scale is generated simply by increasing the frequency control voltage in 1/12 volt steps; pitch transposition is accomplished by adding multiples of 1/12 volt to the control signal that produces the pitch pattern. Furthermore, timing relationships are just as simply manipulated when the voltage controlled oscillator is operated in the subsonic region. If an oscillator is programmed to produce a control signal sequence for a rhythmic pattern, a one volt increase in the control signal applied to it will double the speed of the pattern, a 7/12 volt increase will give very close to a 3:2 speed increase, and a 5/12 volt increase will produce a nearly 4:3 speed increase.

It is desirable to design voltage-controlled filters (VCFs) so that the relationship between the filters' characteristic frequencies and the voltages applied to their control inputs are the same as the exponential oscillator frequency output/control voltage input relationships described above. If, for example, the center frequency of a voltage-controlled bandpass filter increases one octave for each one-volt increase in control input, then that filter will

impart the same pitch patterns to "noisy" (randomly pitched) audio material as an oscillator would produce when controlled by a given control signal sequence. When voltage controlled oscillator and voltage-controlled filter are driven by the same control sequence, then the filter tracks the oscillator, thus establishing a harmonic structure that is independent of pitch.

Voltage-controlled amplifiers with exponential gain/control voltage input relationships are also useful for music production. In a typical VCA, a one-volt increase in control signal input quadruples the amplifier's gain, or increases it by 12 dB. A negative-going control voltage ramp causes the amplifier's gain to decay exponentially, thus imparting a percussive amplitude envelope to a constant-amplitude audio signal being fed through the VCA. A positive-going control ramp results in an exponential increase in gain. Adding a fixed voltage to a given VCA control signal pattern shifts the loudness level without affecting the shape of the amplitude/time contour; a negative-going ramp to which one volt has been added imparts a percussion envelope to an audio tone that is simply 12 dB louder than that imparted by the ramp itself.

Accurate, wide range voltage control was first made practical by the availability of silicon diodes and transistors. In fact, the volt-ampere characteristic of a typical forward-biased silicon junction is accurately exponential over five decades of current. The first exponentially voltage-controlled synthesizer circuits, developed in 1964, used conventional silicon transistors and diodes to compute the exponential control characteristic. Those early VCOs were typically accurate to 1% over a 10:1 frequency range, and the exponential scale factor was proportional to the absolute temperature of the circuit components. The most accurate currently-available VCOs use temperature-regulated silicon junctions and precision integrated circuits to achieve an accuracy of 1% over a 1000:1 frequency range, with a scale factor that is independent of normal variations in ambient temperature. For a musician, this improvement is of crucial importance. Tuning for tonal music was always difficult with the early VCOs, while the newest circuitry is suitable for microtonal as well as diatonic music.

THE SYNTHESIZER SYSTEM

Most present-day voltage controlled modular synthesizers incorporate the same basic components: wide-range multiwaveform VCOs for audio pitch and periodic control signal generation, wide range VCAs for imparting amplitude/time contours to audio as well as control signals, and one or more types of VCFs for imparting dynamic spectrum variations to audio material. The most popular type of VCF is the 24 dB/octave lowpass/resonant filter; the sound variations it produces have become identified with "pop" electronic music more than any other single device. Other audio signal generating and modifying modules include fixed frequency filter arrays, reverb units, mixers, and noise generators. Control signal generators include envelope (transient) generators, audio signal envelope extractors, and sequential pattern generators. Manual controllers (performer interfaces) include keyboards, touch sensitive plates, fingerboard-like ribbon controllers, and pitch-to-voltage converters. Most modular systems utilize conventional patch cords to establish signal paths; other systems use pin or switch matrices. In all cases, the synthesizer system is completely general. Any logical interconnection network (as well as a large collection of illogical but interesting patches) contains the potential for making music. The musician is free to think of music making either as the construction of a process, or as the production of a series of well-defined sounds. Fig. 2 shows a modular system designed primarily for process construction. A bank of sequential controllers, each capable of triggering off others, provides the means for generating elaborate hierarchies of control patterns, which are then used to produce continuous successions of sound movements.

THE COMMERCIAL ASPECT OF ELECTRONIC MUSIC

The listening public first became aware of the elctronic music medium subliminally, through radio and TV commercials. Eric Siday, Raymond Scott, and other pioneers of the sound logo, explored electronic sounds in widely-heard commercials during the 1950s and 1960s, well before electronics infiltrated pop music through the rock and roll idiom. The early commercial musicians were generally aware of the activity in tape composition. They were the first to use modular synthesizers for commercial music. One of these musicians, Walter Carlos, studied at the Columbia-Princeton Electronic Music Center before setting up his own multitrack tape studio in a corner of his living room (Fig. 3). Working part time in his studio over the 2-year period from 1966 to 1968, Carlos developed his technique and, in collaboration with Benjamin Folkman, produced the music for *Switched-on Bach,* the largest selling classical LP album of all time.

The success of *Switched-on Bach* and the trend toward heavy use of electronics in pop music spurred a furious activity in electronic music record production during the late 1960s. A few of these were successful. In response to requests by musicians for small synthesizers for live performance, several manufacturers introduced relatively

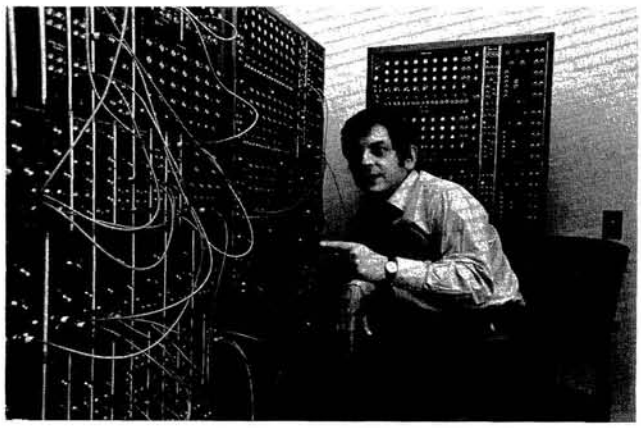

Fig. 2. Joel Chadale explains the synthesizer system at the Electronic Music Studio of the State University of New York at Albany.

small-scale prepatched instruments during the early 1970s. English keyboardist Keith Emerson pioneered the use of synthesizers in rock music by including a programmed modular synthesizer in his act. At the present time, music production techniques that are tracable to the classical electronic music studio are routinely employed by musicians in studios and on stage. Several successful performance groups play on nothing but synthesizers and related electronic hardware. Musical experiments of the 50s and 60s are now earning points toward cliché status. And synthesizers are the fastest-growing segment of the musical instrument industry.

THE DIGITAL COMPUTER

The use of large digital computers to synthesize audio signals predates the introduction of the voltage-controlled synthesizer by nearly a decade. In terms of hardware operation, digital computers make audio signals in entirely different ways than analog synthesizers. Waveforms are computed one point at a time. Each point is a high accuracy number that specifies the magnitude of a narrow time slice of the desired waveform. The numbers are fed in sequence to a digital-to-analog converter that constructs the continuous audio waveform. Instructions from the musician are fed to the computer through punched cards or other conventional data entry means. The computer generally takes longer than the actual duration of the sounds to compute all of the waveforms.

In terms of software, however, sound synthesis programs such as Music IV and Music V are closely related to the operation of a voltage-controlled synthesizer. These programs present the musician with a collection of functional elements that correspond closely to synthesizer modules. The musician assembles the elements into "instruments," and the instruments into an "orchestra," by conventional computer programming rather than by patching and knob-turning. In effect, the digital computer models an analog synthesizer, which in turn models a simple vibrating system.

Direct digital synthesis provides an extremely powerful experimental resource. However, the operation is noninteractive. In practice, a musician spends several hours to program a short segment of music, then waits several hours or days more until the computation and conversion are complete.

In order to have a real time interactive audio signal generating system with the advantages of digital data processing, Max Mathews and his colleagues at Bell Labs designed and built the GROOVE system (Fig. 4). This system uses voltage-controlled analog modules for the audio signal chains, and a small digital computer to generate and process the slow moving control and timing signals in real time. The musician has a variety of control interfaces at his disposal: keyboards, joysticks, rotary knobs, and a CRT readout that graphically displays as many as fourteen control signal contours. A disc file stores the programs for complete pieces of music. A system of this type goes far beyond the composing and editing capabilities of conventional voltage-controlled synthesizers. It even has the potential for bypassing the multitrack recorder in the composition process.

THE STATE OF THE SYNTHESIZER ART

The digital synthesizer recently designed and constructed by Hal Alles of Bell Labs is representative of the current state of the art in electronic music hardware. Alles' instrument includes a) a digital audio signal synthezier, b) a variety of manual controllers, c) a small controlling computer, d) a data entry terminal, and e) two floppy disc drives for data storage. The digital audio synthesizer in effect contains 64 high accuracy oscillators, 32 filters, 32 amplifiers, 256 envelope generators, and similar numbers of supporting functions. The manual controllers include two five-octave touch sensitive keyboards, 72 slide levers, and four 3-axis joysticks. The data entry terminal contains a full alphanumeric keyboard and a CRT display. And the on-board computer is capable of coordinating the control of the entire instrument in real time. The instrument is self-contained (except for power source) and occupies some 12 cubic feet of space. It is capable of producing and

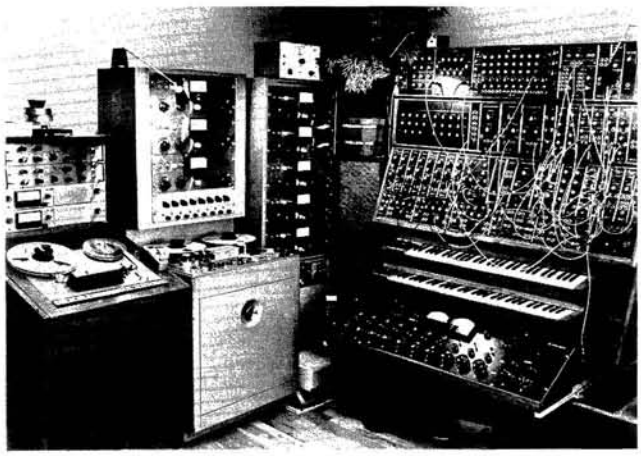

Fig. 3. Walter Carlos' studio, where *Switched-On Bach* was made. Carlos built the 8-track recorder out of surplus Ampex parts, and designed and built his own mixing board.

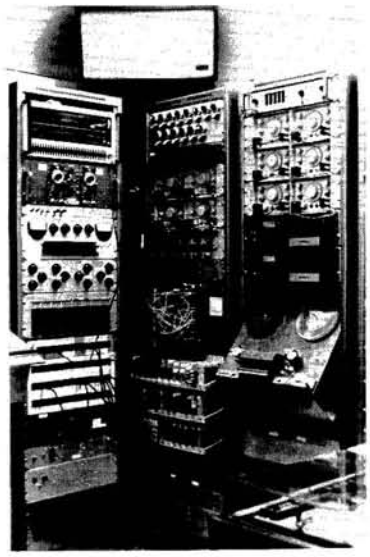

Fig. 4. The GROOVE system at Bell Labs.

storing music of a level of complexity approaching that of a small orchestra.

WHAT ABOUT THE FUTURE?

Developments in the electronic music medium come about when musical needs and emerging technology are combined with a touch of imagination and foresight. Imagination often involves the utilization of ideas that were previously discarded. In future decades, the influence of personal computing will be the major technical force shaping electronic music. Already digitally-programmable synthesizer components are being sold to computer hobbyists. Focus will shift from sound production to sound control. Even in present day commercial synthesizers, the audio circuitry is eclipsed in size and complexity by the control circuitry. As the complexity of control means increases even further, the information content of the sounds themselves, as well as the music into which they are assembled, will also increase.

I do not believe that brain wave control will become a significant factor in electronic music in the next decade or two, despite the appeal that the idea has for many musicians. Human hands happen to be extremely efficient manipulators. A virtuoso pianist transmits as much as several hundred bits per second of a pitch, timing, and dynamics information to his instrument. Electronic instrument control interfaces designed to fully exploit the capabilities of a musican's hands will undoubtedly supplant the simple keyboards and controls of today's synthesizers. An example is an experimental touch-sensitive keyboard currently being developed at the Indiana University School of Music. Each key on this keyboard is touch-sensitive in three dimensions. Accusations that the requirement of lengthy practice on such a keyboard enslaves the musician are countered by assertions that musical content increases in proportion to the amount of control that a musician exercises.

Finally, the exotic, technological mystique surrounding the electronic music medium will wither away as the whole electronic involvement continues to infiltrate our daily lives. As more and more musicians explore electronic music with open minds and ears, our preoccupation with the electronic music medium itself will give way to an increased awareness of the musicians and their music.

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The Art of Becoming a Creative Member of the Record Industry has Become a Science..... by WARREN REX ISOM

Undoubtedly, for a nontechnical person the world's best description of a highly complex electronic component is the term "black box." Generally speaking, before a year ago, the recording industry had been described to the public and particularly to those students who might want to appraise for themselves the career opportunities it affords in the same noninformative way. In the last year, the Audio Engineering Society has sought to relieve this void of information by the publication of "*A Guide to Careers in Audio Engineering*" and by including in this Centennial Issue the composite portrait of "The Audio Engineer" by Dewitt Morris. The purpose of this introduction is to give some information—perhaps not readily available—specifically related to becoming a member of the recording industry in a creative position.

In fully developed countries of the world today approximately one one-thousandth of the work force is engaged in the record industry. This includes all classes of employees and associates from the lowest paid laborers to artists and technical people as well as top management. In the simplest terms, of those who work for a living, one out of one thousand work in the recording industry. Applying to this number the well-known rule of thumb that some 2 percent are in creative positions, means that if there were one thousand in a particular company, 20 of them would have creative careers. This fact is not, in itself frightening, but it becomes meaningful when it is applied to a given situation. It takes an area with a total work force of one million to provide a statistical base for a record company with 1000 employees. Thus, to seek a creative position in the record industry is to narrow one's objective to 20 in a million.

This is a formidable objective, with sufficient challenge to tax the dedication necessary to achieve it. But, there is a "scientific" method that can be used to reach the target. In the language of the space age, it involves the continuous midcourse correction of the flight plan. In simplest terms, it translates into an admonition to always know where you are going. In practice or in application, it means that one compares the similar opportunities that exist in all of the peripheral and service industries with those in the record industry. This widens the base tremendously and without compromising the ultimate objective, for the first prerequisite for navigating, after setting the course, is to get off the ground. After all, the technology of the record industry in all of its forms is not exclusively applied to that industry. Even important parts of the technology may be more central and critical to another larger industry.

An illustration may enhance appreciation of this fact. One technical university graduate, employing the above career-launching methodology, accepted a position in a local sound products retail store as a loudspeaker expert. He immediately was responsible for outfitting several new churches-in-the-round with loudspeaker systems. He solved the problem beautifully and creatively by suspending a cluster in an octagonal enclosure over the pulpit. The installations were so good that the system became known among his colleagues as the "Voice of God." His success unequivocally qualified him for a position as loudspeaker designer in a record company at a time when renewed emphasis was being given to the improvement of the weakest link in the chain for the reproduction of recorded sound. Few people, however, can expect to achieve full course correction after the first fix or reference point.

The creative positions in the record industry can be listed for reference. First and foremost are the artists. No one knows how to become an artist. However, though very few of them start at the top, it has been done. Some of the most successful can not read music but those who can have never found it to be a handicap.

The producers are equally important as creative men. It is their contribution to present the artist at his greatest advantage. Sometimes this entails almost full direction of the artist. Most often, the artist and the producers are not members of the staff of the record company. They are independent but often work under contract with one record company.

Every record company has an artist and repertoire staff composed of people who manage the relationship between the artist and producer with the company. These people must know the needs of the company in terms of the repertoire of the artist and the acceptance of the market.

The recording engineer is an artist, as Peter Burkowitz points out. Mr. Morris spells out the other positions on the list. There are some other functions usually not mentioned but nevertheless important and creative. They are editorial positions on publications and public relations personnel in information services. Of all of these 20 or more position titles, not more than three are exclusive to the recording industry.

This peripheral approach to career launching widens the opportunities by a factor of nearly 10. This is also true for many of the other professions.

Even so, this is only a partial answer to the question that a person long established as a record engineer is asked repeatedly; that is, "How does one become a recording engineer?" Recently I sent the following reply to an inquiring youngster: "There is no precise answer that can be typed out on a card and given to all who ask. In mathematical terms, the answer is to be found in the solution of an equation with a multitude of unknowns—one for each unique situation. Since, in your case, there are many unique situations (for instance, you are one; your prospective employer is another; etc.), there will be many equations, all to be solved simultaneously. If you have more unique situations (unknowns) than you have equations, the solution will be even more complex.

"The above is neither nonsense nor an evasion of the question. It is true and is written to condition you to the complexity of finding a particular job for which there are more qualifications than any one person can fulfill.

"A bit about schooling in the context of your interest. Schooling, training, education, or whatever it might be called, has the objective of readying a person for learning, skills, knowledge, and wisdom. Every man must strive to have his full share of each. Life for you is to be a continuous process of learning. You are going to learn on the job, in training for your job, in formal advanced courses, and from your colleagues and associates. You will receive more learning from your associates than any other source. This is natural for they will have a keen interest in you and your welfare and you will spend more time with them than you will in educational pursuits.

"But you must be equipped to learn from them. To do this, you must take advantage of the best educational opportunities available to you. You must learn the fundamentals of your profession before you can benefit from your association with them. The more you can contribute, the more you can learn.

"The basic fundamentals of the audio engineering profession are physics, acoustics, electronics, any and all forms of music, the art and science of human relations, and, to a varying degree, all the branches of learning centering on the communicative arts and sciences. The longer your period of learning continues and the more knowledgeable you become, the richer and fuller your life will be.

"Above all, hope to be smart, try to be informed, and court lady luck. If you are smart, you can become informed; and, if you are informed, you are ready for lady luck to smile upon you. With these things going for you, you can be confident of the future ..."

The time card of Thomas A. Edison for the week of August 27, 1912, reports a total of 95 hours and 49 minutes worked. The photograph of this card is displayed in the Charles A. Edison Fund collection under the caption asking "What is invention?" and giving the answer "1% inspiration, 99% perspiration." This is a good quote but poor reporting on Edison's part. He knew well that any amount of inspiration coupled with a great deal of perspiration would never, or hardly ever, result in invention. He knew his pattern of successful invention, for he repeated it 1097 times (more often than any other). It was analyzing the problem, finding the form that the solution must have to be most useful, being determined to achieve, having confidence in his abilities, and a willingness to work until achievement was obtained or failure was complete. There may be today those who are not willing to pay the price that Edison paid for success. Perhaps they do not demand so much from life. After all, success can be determined to a very large degree by how high the goals are set. In any event, we in the profession are grateful to Edison for all his accomplishments—poor reporting notwithstanding—for we know that his equals will be few and far between.

The Audio Engineer—Circa 1977 What Does He (or She) Do?

DEWITT F. MORRIS

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INTRODUCTION

"In the beginning, God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep . . ."

Genesis, 1C, 1.2v

Silence was also "upon the face of the deep," for there were no auditory organs—no transducers to convert the cataclysmic vibrations of the new earth's atmosphere into organic sensory perceptions.

The first "audio engineer," therefore, was the Divine Creator, who, through His miracle of evolution, designed and perfected the remarkably complicated and efficient auditory systems of the earth's animal world, including homo sapiens.

Human endeavor in audio engineering can never approach the perfection of nature's gift of hearing, although the wonders of present-day electronic technology appear to be more the handiwork of the Father of the Universe than of human hands and minds.

Modern audio technology began with the invention of the telephone in 1876 and the phonograph in 1877. It has since progressed at a dizzying pace through the vacuum-tube era, the electrical transcription, sound-on-film, solid-state electronics, integrated circuits, and is now embracing space-age digital techniques.

The audio engineer, regardless of his specialized field of endeavor, performs one or more of a variety of functions:

Operations
Maintenance, service
Research and development
Product and systems design
Manufacturing
Consulting
Teaching
Merchandising.

Audio engineers of 1977 perform these functions in a wide range of industries, environments, and cultures.

ENTERTAINMENT

Recorded Music

The phonograph record industry is in several ways the premier audio industry. In size (sales above $2 billion a year) it is next to the telephone industry, which is the largest. Within this industry, audio professionals work in every level of management, research, and operations.

The recording itself (if at top professional levels) takes a battalion of skilled audio engineers.

Experts in Acoustics and Studio Design

These experts plan the physical facilities and supervise all phases of their construction. During construction and after its completion, they employ highly sophisticated sound measurement instruments to verify design criteria for sound transmission loss (isolation) between studios and control rooms and to/from their exterior boundaries. Other sophisticated measurement instruments are employed to verify the acoustical parameters of each studio and control room: reverberation time and diffusion at various audio frequencies, absence of induced vibrations, adequacy of noise threshold.

Design Engineers

Engineers, both in-house and those employed by equipment manufacturers, design the recording equipment and supervise its installation and testing. Today these functions demand knowledge of and experience with both analog and digital circuitry and techniques, as recording systems embrace automation and computer technologies.

Recording Director of "Tonmeister"

The recording director supervises the actual musical and audio performance, from the studio setup to the final end product—the record, tape, cartridge, or cassette. His work is a demanding blend of art and science, requiring knowledge of and a sensitivity for music and musical expression, as well as a thorough mastery of the recording

process and the operation of its component equipment, from microphones through finished tapes and disc mastering. His task commences long before the recording session begins, usually in conferences with the artists, musical director, and/or the "A & R" (artist and repertoire) executive of the group or record company sponsoring the session. Through these conferences, he develops a rapport with the artists and their concepts, and determines the methods and techniques that will be utilized to achieve the desired end result: for example, whether the musical work will be performed in its entirety in real time, or whether various musical elements will be successively recorded and then combined during rerecording (mixdown). He will determine how the studio will be set up and microphones placed, and he will make a detailed chart for the setup crew to follow. He will determine the need or possible need of special signal processing equipment, and whether the original recording will be done on 1, 2, 4, 8, 16, 24, 32, or more magnetic tracks. If he will not actually operate the recording console, he will brief the operator (mixer) on the nature of the session.

During the recording session, the recording director (tonmeister) may actually perform as the "mixer," operating the recording console, or he may supervise that activity. He will also be responsible for track assignments (in multitrack recording), for recording levels, tonal balance, and general supervision to assure that good engineering practices as well as good musical performances are achieved in keeping with desired artistic goals.

Console Operator (mixer)

When the first acoustical phonograph records were made in the late 1800s, and until the advent of electrical recording in the early 1920s, a "mixer" was unheard of. Musicians and vocalists were arranged before the opening of a large horn whose throat contained a diaphragm attached to a mechanical transducer which converted sound energy directly to recording stylus movement. The only adjustments for tonal balance were (1) relative placements of the artists, (2) megaphones and acoustic reflectors to amplify weak sound, and (3) linkages in the mechanical transducer which could adjust the overall "gain" of the system depending upon the maximum sound level at the horn.

With the advent of electrical recording in the 1920s, the horn was replaced by a single microphone, and single-microphone recording continued for many years. Multiple microphone techniques, requiring that a "balance" be achieved by adjusting the relative outputs from the several microphones, developed in the mid-thirties, and the "mixer" became an important member of the recording crew.

Since that time, mixing consoles have evolved from the simple microphone mixer/switching panels developed for early radio broadcasting, to the highly complicated, extremely versatile, very costly (up to $200,000) consoles of 1977—and the evolution continues at an accelerated pace.

Today's console operator has at his fingertips a (to the uninitiated) bewildering array of knobs, buttons, flashing lights, digital readouts, and meters. Behind this imposing panel sophisticated circuitry permits him to control the signals from as many as 40 (or more) microphones or other sources, and ultimately to deliver these signals in a desired combination to as many as 32 (or more) individual console outputs and one to four monitor loudspeakers.

Each input signal is amplified and modified by various signal processing devices on its tortuous path through the console system. The "mixer" may employ filters, equalizers, compressors, limiters, phasers, flangers, delay lines, reverberation, noise reduction, and other special signal processors to achieve desired effects. He is also able to process the signals differently for the control room monitors than for the actual recording. When "laying down tracks," for example (successively recording separate instruments, vocal or orchestra sections on individual magnetic tracks), the actual recording may be relatively unprocessed, except for noise reduction compression. A separate "mix" may be employed for the monitor speakers, however, simulating the full range of signal processing and approximate balances that will be used in the final product. This mix, or even different ones, may be simultaneously fed to the performers' earphones as they contribute their part.

Complicated multitrack original recording may span many days, weeks, and continents. Rhythm tracks and a lead vocal may be "laid down" on a 16- or 24-track two-inch magnetic tape in Hollywood, perhaps over a span of several days. A month later, strings may be added in Vienna or London. A week later, additional instrument tracks or vocal accompaniment may be tracked in New York or Nashville. If the original master tape will not provide enough tracks for all the required (or alternate choice) elements of the performance, a second 16- or 24-track tape may be employed by using one track of each tape for digital "time coding." This permits precise synchronization of two or more tape machines during recording and subsequent playbacks. In this manner, up to 30 individual music tracks are available with two 16-track tapes, or up to 46 with two 24-track tapes. A few 32-track tape machines are now in service.

Not all music recordings are this complicated. Many are still made in real time, with all parts recorded simultaneously, though most of these employ multitrack techniques to permit adjustments in balance and signal processing of individual tracks during subsequent rerecording (mixdown).

The 1977 console operator performs highly demanding work. He must keep abreast of new technologies as they are introduced; he must have an appreciation for and a sensitivity to many kinds of music, although he may be a specialist in one. He must have a good rapport with both the musician and the engineer, and be able to communicate on equal terms with both. His is the glamor job in the recording studio—the envy of the music-loving audiophile. It is also a physically and mentally demanding one, and a pressure cooker of responsibility. For, while a mistake in a live performance or the mixing thereof will pass and soon be forgotten, the recording mixer's inadvertent error, if not caught and corrected, could destroy the finished product or mar it forever.

Tape Recordist

This member of the recording studio control room team is responsible for the recording machines themselves and their operations. When the first magnetic recorders were introduced in 1947, monaural recording was relatively simple. In most studios the mixer handled both his console and the tape recorder. Progressing through stereo, 3 tracks, 4 tracks, 8 tracks, 16 tracks, and now 24 and more tracks, music recording became more and more complicated, requiring increased specialization.

Today's studio tape recordist performs duties far more demanding than the "button pushing" of the late 1940s and early 1950s. For a typical multitrack session in 1977, his routine might go something like this.

1) Set up and check out two 16- or 24-track recorders. De-gauss. Clean. Verify that all channels are working and levels are correct. Patch inputs and outputs per mixer's chart. Set levels and verify operation of noise-reduction systems.

2) Load tape and record level and azimuth tones at head of reel. Fill out headings of legend forms for each roll.

3) Set up additional machines for tape delay, etc., as required.

4) During recording, make sure various console outputs are assigned according to plan to proper tracks, and that other tracks are protected from inadvertent recording. Make sure various tape outputs are assigned according to plan to proper console inputs for monitor and performer headphone feeds.

5) After "takes," rewind as directed for playbacks or tracking.

6) Keep meticulous log of all takes and their locations on the tapes by time code. Note which takes are accepted in whole or part. Note which tracks contain what instruments, vocals, effects, or are still blank.

7) Monitor recording levels and all parameters of tape machine operation.

8) Supervise operation of accessory tape machines being used for delay, etc. (Make sure tape won't run out before the end of a take.)

9) Worry a lot that you might accidentally erase or record over a good take, or a good track on a take. 'Fess up quickly if it should happen, so it can be corrected before the musicians leave and someone gets stuck for the price of another session.

10) After the session, tidy up the legends and tape reels, make sure the right legend is in the right box. Deliver the tapes to their proper custodian.

11) Break down the tape machine patching, noise-reduction systems, etc., to normal standby status. Make out a discrepancy report to Maintenance for any malfunctions or improper performance of the tape machines which may have occurred.

While the tonmeister or console operator bears ultimate responsibility for proper engineering of a recording session, the tape recordist's job is demanding and his responsibility equally great. During multitrack recording, some tracks are being "played back" while others are being recorded. A track may be "punched in," or purposely erased and rerecorded from a certain point in the take to replace a poor performance or musical mistake. The possibility of human error is multiplied as the number of tracks increases. The tape recordist must be a true professional, with the discipline and attention to detail of an airline pilot.

This is the usual apprenticeship for a promotion to console operator or "mixer," and while his own duties are demanding, the tape recordist is always absorbing techniques and methods of the various mixers with whom he works.

Mixdown Mixer

Following completion of all the original multitrack recording of a record album (or single record), the mixdown mixer performs the task of creating final stereo and, possibly, monaural and/or quadraphonic tapes. These tapes will then be used for record mastering, cassette, and cartridge duplicating masters.

The mixdown mixer may, or may not, be the same individual who operated the console for the original recording. He or she will again work closely with the recording director, A & R representative, and the artists in this important phase of multitrack recording.

The mixdown mixer's console and ancillary equipment are essentially similar to those used for the live recording, and the studio console may indeed be used. The outputs from the multitrack tape machines become the console inputs, in place of the microphones. The mixer's function now parallels that of a live performance mixer—that of combining all the various tracks in real time to a 2-track, 4-track, or monaural tape. He works with the same wide range of signal processing equipment: filters, equalizers, phasers, flangers, compressors, limiters, delay lines, and noise-reduction devices to achieve the desired artistic results.

It has been speculated that the ideal mixdown mixer would have four ears, four eyes, and eight arms, a degree in music and another in electronics. The various magnetic tracks of the original multitrack tape were each recorded at normal full level to maximize the signal-to-noise ratio. Now the signal from each must be separately processed, varied in level, sometimes switched off or on, moved or "panned" from one aural position to another—all during the brief span of a few minutes. Difficult sections of a musical selection may be "mixed down" separately and combined in the final master tape by splicing.

Some mixdown mixers of 1977 are aided by automation, which is now finding its way into many studio consoles. Console automation employs one or more control tracks on the multitrack tape to record and playback digital data to/from a computer/processor. These data are derived from the positioning or movement of various console controls, and simulate the results of those positionings in subsequent playback without operator action. In this manner, multiple adjustments may be sequentially made, and the processor's memory updated during successive remix passes. Once a desired tonal balance, combination of track elements, and correct levels have been achieved, the automated console will repeat the entire

performance precisely on any subsequent playback.

Automation helps perfect the mixdown mixer's final result by allowing him to concentrate on difficult sections of the musical selection, one at a time, until each is reproduced precisely as desired. While automation does permit the mixdown mixer to be more creative, it multiplies his technical chores by requiring him to learn and become proficient at new techniques.

Disc Recordist

1977 recording engineers specializing in disc recording do not have to manually crank up heavy weights to provide the motive force which turned governor-controlled recording turntables in the late 1800s and early 1900s. Nor do they have to shave the heavy wax platters from which early phonograph records were produced. The disc recordist of today works with highly complex mastering equipment, including a control console, signal processing equipment, and automatic lathes which cut stereo or quadraphonic grooves with fantastic precision into the lacquer coating of aluminum record blanks.

His recording lathe is fully automated, requiring only the push of a button to lower the cutting stylus, execute a lead-in spiral, begin the normal groove pitch at precisely the correct diameter, start the tape playback machine, and switch on the audio channels. During the recording, the lathe system will automatically make spirals between musical selections. At the conclusion of the last album selection, it will switch off the audio, spiral in, make a concentric lockoff groove at exactly the correct diamter, lift the stylus, and stop the tape machine. Even more remarkable, during the stereo recording special electronics and electromechanical devices preview the audio channels and provide automatic changes in groove pitch and depth to accommodate level changes and varying frequency spectra of the audio program, to prevent overcutting in both the vertical and lateral planes of the groove, while maximizing playing time of the record.

Despite the advanced state of lathe automation, 1977's disc mastering engineer has plenty to do and much to learn. Though the recording director, console operator, tape recordist, and mixdown mixer may have performed their tasks well and professionally, the disc recordist is often faced with many alternatives and problems if he is to achieve an optimum end product. He employs sophisticated signal processing equipment, including high-frequency limiters and predistorters, to allow for record processing and playback limitations. He may make numerous tests "cuts" of difficult musical passages, examine them carefully under his microscope, and play them back before he ever cuts the first master. On new releases he will make a complete lacquer "dub" for approval by the recording director, A & R representative, and talent before mastering begins. He will make a careful written log of the exact setup used for each record side, including settings of all controls and variations from band to band throughout the side.

If he is recording quad matrix discs, he must utilize the correct matrix encoder in the audio channels, and playback test cuts in the correct quad format to verify channel "separation" and aural placement of sounds. If he is recording in a CD-4 or other "discrete" quadraphonic mode, recording may be done at half-speed or some other rotational speed slower than the standard, to assure proper accommodation of supersonic carrier frequencies. Disc mastering is a combination of art, science, and apparent witchcraft. Recording "heads" or transducers are *cooled* by a flow of helium to prevent overheating. The recording stylus is *heated* by electrical current through a few turns of resistance wire to improve burnishing of the groove sidewalls. All these elements require a jeweler's precision and conscientious care by the recordist to ensure a good product and prevent damage to very costly equipment.

Maintenance Engineer

Phonograph recording in 1977 is a highly capital-intensive venture. A modern studio complex may have an investment of a million dollars or more in consoles, tape machines, disc recorders, microphones, loudspeakers, amplifiers, signal processing equipment, electronic music equipment, etc. The maintenance engineer and his technical staff work around the clock to keep it in working order, modify it for special applications, and install new equipment as technology advances. Just when he becomes comfortable with a console or recorder, it becomes obsolete and in comes a new one. He spends much of his time, on and off the job, studying new technologies and keeping abreast of new equipment, and, equally importantly, of what the competition is doing. He works with both digital and analog circuitry, magnetic and disc equipment, and sometimes optical and video projection equipment as well, if his studio is involved with music scoring for films or television.

Tape, Cartridge, and Cassette Duplication

In 1977 the phonograph record is still the most popular end product of the recorded music industry. However, 8-track cartridges and cassettes have gained a sizeable share of the market through the popularity of personal, automobile, and recreational vehicle stereo.

Audio engineers work in tape duplication design and maintain the highly specialized equipment for mass-producing reel-to-reel, cartridge, and cassette tapes from the recording studio's master tapes. Special engineering problems are faced and solved by the duplicating engineer. While the master tape and end product are "audio," the high-speed duplication process multiplies their audio frequencies four or more times. Bias frequencies are in megahertz. Yet the equipment must be engineered to be operated by relatively unskilled production workers, and to perform within close specification tolerances with minimum down time for maintenance.

Radio and Television Broadcasting

Radio broadcasting today (AM and FM) is technically 90% audio. From the microphone, tape or cartridge player, or turntable through the transmitter modulator it is an audio operation. In recent years the drive for high audio

quality in broadcast stations has gained intensity as the growth of "fidelity consciousness" among the listening public makes it more and more necessary and advantageous for a station to have clean, attractive sound—the very commercial life of a station may depend on it. The audio professional with skill in producing and maintaining high audio quality is usually a consultant in smaller, independent stations, and a valuable member of the management team in large stations and station groups. He works with consoles and amplifiers, equalizers and filters, limiters and compressors, and specialized signal processing devices to maximize transmitter modulation and minimize audible distortions.

The automated broadcast station presents the audio engineer with additional challenges: he must become an expert in control logic and logging systems, automatic multicartridge and reel-to-reel playback machines, production recording, computer technology, and programming.

Stereo and quadraphonic FM broadcasting further complicate the work of the audio engineer. Channel phasing and separation require careful designing and constant attention through the entire program chain, from microphone or turntable to and including the antenna system and the on-air monitors.

Audio in television broadcasting, from the beginning of regular programming in the late 1940s, was a "poor relative" of its more glamorous new companion, video. "A picture is worth a thousand words" seemed to be the industry attitude, and for many years television audio received scant attention and performed its necessary but second-fiddle chores with equipment and techniques cast off from its radio and motion picture cousins. This is rapidly changing as television matures technologically.

The audio engineer working in television in 1977 has higher equipment budgets and, in most stations, a mandate from management to achieve the highest audio fidelity possible within the limitations of the transmission system. Equipment manufacturers have responded to this demand, and a steady stream of new items, specifically tailored to the requirements of television, have been, and continue to be, introduced.

The audio engineer in television now has reliable wireless microphones in highly miniaturized form to provide good-quality sound pickup in scenes where boom microphones are impractical and fixed microphones cannot be used; he has sophisticated signal processing devices to eliminate or reduce to an acceptable level background noises, hum, etc., which previously would have seriously marred a program or rendered the sound unusable. He has state-of-the-art control consoles, interlocked with video controls so that sound sources and picture sources are simultaneously switched. He has highly portable sound recording equipment, interlocked by time coding with video or film recorders for electronic news gathering and special remote events.

The television audio engineer works closely with his video counterpart, their roles sometimes overlapping or merging, requiring him to keep abreast of technologies and techniques in both audio and video, live and recorded.

Motion Picture Sound

Television has had a profound effect on the theatrical motion picture industry. A high percentage of films produced today are for television release, rather than for the screens of movie houses. Engineering techniques and the equipment designed and used by audio engineers in this field are dramatically different in 1977 than they were even a few years ago: the huge trailer loads of equipment required as late as 1960 for location sound recording have given way to small, portable tape recorders which can be slung from a soundman's shoulder. Magnetic tape and magnetic film have replaced optical sound tracks in all but the final release prints, and many of these use magnetic tracks or separate multichannel sprocketed tapes.

Original Film Sound

Movie dialogue is now recorded almost exclusively on sprocketless magnetic tape. Music scoring is done primarily to multitrack tape, the final takes then being transferred to magnetic film for editing and remixing (dubbing). When projection is required for synchronization during scoring, TV screens or video monitors frequently replace the screen, and the work print is projected via closed-circuit television. Electronic metronomes supply precise tempos, replacing the film loop "click tracks" formerly required.

Dialogue and Effects Replacement

"Looping" a motion picture to replace unacceptable dialogue or to replace one language with another for foreign release was once a very costly and time-consuming process. Newly engineered equipment and techniques in use today greatly simplify the procedure. Modern magnetic recording machines are electronically programmed to permit a small section of a scene to be recorded over and over again, until the voices are in perfect "sync" with the projected action, without affecting the recording prior to and following the section. Rewinding is at high speed, with the tape and film stopping precisely at a preprogrammed cue point each time. The finished result is an entire dialogue scene, in perfect sync, on one piece of tape—requiring no internal editing. Sound effects incidental to the replaced dialogue are recreated in a similar fashion. Sound effect experts create live footsteps, paper rustles, door opens and closes, etc., while watching the scene on a screen or monitor.

Rerecording or "Dubbing" Mixer

All the elements that go together to make the final sound track for a motion picture are brought together finally on the "dubbing stage." The dubbing mixer's task closely parallels that of his music recording counterpart, except that he receives visual cues from the screen or TV monitor, actually watching the movie while he combines the various sound elements to achieve an artistic and technically appropriate product. His console is expansive and contains much of the same modern signal processing

equipment as does a music recording console. It may have operating positions for three or more "mixers." One may mix only the various music tracks, bringing them in or out on cue, cross-fading from one to another. Another may similarly handle effects. A third may concentrate on dialogue, changing equalization to improve a difficult original pickup or effect a better match between spoken lines or scenes. Automation "memory" systems may be employed to assist in these tasks. The head mixer, under the supervision of the director, concentrates on correct balance among dialogue, music, and effects, matching audio perspectives to the visual perspectives of the scenes. The mixer(s) may be handling from just a few to several dozen separate sound sources, each on a separate roll of magnetically coated film, synchronized to the projector or TV monitor. As in dialogue replacement, high-speed rewinding of all the separate tracks in synchronism, and electronic programming to stop rewind precisely on cue saves hours of nonproductive time during rehearsals, and between "takes" of a mix. Simultaneous "mixes" may be recorded separately of the music and sound effects only, minus dialogue and/or narration. This "mix" will then be used for foreign releases by adding the replacement dialogue and ambient sound effects in later dubbings.

If the product is for theatrical release, the "dubbing stage" will be in the form of a small theater, with acoustics and sound reproduction closely matched to an "academy standard." This is a reproduction curve prescribed by the Academy of Motion Picture Arts and Sciences to assure uniformity in theater sound reproduction. If it is to be a television release, some modification may be made to the reproduction characteristics, or different monitors may be used to achieve a balance and equalization curve more suitable for home TV.

Optical Film Recordist

The sound engineer responsible for optical film transfers performs the final audio step of a film sound track before it is combined with picture in release prints. He works with both magnetic and optical equipment, rerecording from the finished, edited magnetic track to an optical negative film. The sound track may be variable density, variable area in one of several different configurations, or the new "variable hue" color soundtrack, which produces multichannel audio from a single track. His work requires special knowledge of photographic emulsions and their properties, in addition to basic audio recording practices. He must make test soundtrack samples at various exposure settings on each new batch of raw film, have it developed normally, and a family of prints made at different exposures. These test films contain cross-modulation or intermodulation signals. Playing the prints back on a standard optical "dummy" projector, he picks the combination of negative and print exposures which reproduce with minimum distortion. He then specifies these exposures for all subsequent optical tracks on that negative film and print stock. He employs limiting and/or compression to reduce the dynamic range of the recording to prevent overmodulation and maximize the signal-to-noise ratio. He may also employ noise reduction encoders for releases to be shown in theaters equipped with reciprocal decoders. He may be using a digital, all-pass (passive), or acoustical delay line in the program feed to the optical galvanometer or light valve, to permit anticipatory control of the noise-reduction shutters in the optical recorder, which make the soundtrack opaque in the absence of signal. These techniques, and many more unique to the industry, are constantly being improved and perfected, requiring the sound engineer specializing in optical recording to continually upgrade his knowledge and skills.

Theater Sound Engineer

Many theatrical films produced today require special sound reproduction systems (as well as projection systems) in theaters where they are shown. Audio engineers design, install, and maintain multitrack magnetic reproducers, special projector sound heads, unique loudspeakers, and special effects systems to produce dramatic realism or entertaining auditory illusions. Specialists in theater acoustics work with architects on specifications for new theaters, or modifications of existing structures to accommodate the special requirements of these innovations.

High Fidelity

Audio engineers of 1977 who design and customize consumer sound systems work in a highly competitive, innovative industry which has progressed through startling evolutionary stages since the invention of the phonograph in 1877.

Design Engineer

His modern electronic products employ printed circuits, large-scale integration of components into minute chips, digital readouts, and other technological fallouts from space-age scientific research. The line of demarcation between products designed for professional use and for consumer use has become more and more indistinct. Consumer reel-to-reel tape recorders, cartridge and cassette units, AM/FM tuners, turntables and record changers, and loudspeaker systems are designed to remarkable standards of quality and carefully value-engineered for mass production. Product designs are short-lived, requiring constant redesign or replacement with new models as technology and consumer sophistication expands. Audio engineers working in this field must constantly update their knowledge, not only in the state-of-the-art, but in the trends of the music industry and consumer tastes, to avoid being leap-frogged by their competitors.

Custom Designer

Many audio engineers in 1977 engage in custom building sound systems for serious audiophiles, musicians, and others who desire and can afford them. They use commercial consumer and professional audio components selected to please the tastes and budgets of their clients on an individual basis, and customize the installations to har-

monize with their surroundings. Acoustical measurement instruments are employed, along with corrective equalization, to carefully "tune" the total system, including its acoustical environment, for uniform response and pleasing performance.

Music Synthesis

By 1977 electronic synthesis of musical sounds has become an important and growing field for audio engineers. In no other segment of the audio profession are technical and artistic innovation so intimately intertwined. The audio engineer specializing in this fascinating field must master music theory and electronic theory, and have equal facility in both. Synthesized or "electronic" music is a large, growing element of broadcast programming and advertising, in the pop-rock music industry, and among composers of serious music.

The audio engineer working in electronic music makes use of computers, spectrum analyzers, and other sophisticated measurement instruments to examine and define all the audio components of each complex musical note of a given musical instrument. He will then develop electronic circuitry which will produce each of these components and combine them in precise relationships, so that when the result is amplified and converted to sound by a loudspeaker, the musical note is closely approximated.

The engineer works with piezoelectric, electromagnetic, and electronic signal generators, ring modulators, filters, equalizers, and both digital and analog circuitry to achieve his results. He works in the realm of the tempered musical scale with as much facility as he does with logarithms and algebraic equations. In many instances he was first a musician, and electronics became his second discipline. Through electronics he has learned not only to synthesize familiar musical sounds, but to create new music which had never before been heard, and which enriches the culture of our era.

Concert Hall and Theater Sound Reinforcement

Here again, the audio professional with strong bonds to music performs a combination of technical and artistic functions. The technology of concert hall reinforcement has advanced substantially by 1977. Once rejected by music professionals because of high distortion and unnatural sound quality, reinforcement systems of good design, properly operated, are not only welcomed but demanded today by these same professionals because of the improvement that can be obtained in orchestra and vocal balances and listener enjoyment. A skilled and competent designer of concert hall systems works toward anonymity—not notoriety. His systems are most successful when the audience is unaware that they exist. His tools are acoustical measurement instruments, microphones, amplifiers, delay lines, equalizers, limiters and compressors, and loudspeakers. After acoustical conditions have been met to his satisfaction, and the installation carefully designed and completed with components suitable for the environment and its intended use, final adjustments and "tuning" are performed. This "tuning," or equalizing of the system shapes the frequency response of the entire system, including the hall itself, so a desired "house curve" results. If his work is performed professionally, the resulting system provides ample reinforcement of the live performance while preserving the illusion that only the "live" sound is being heard.

Theater reinforcement for drama aims for intelligibility, rather than the full musical quality of the sound, and thus has somewhat different characteristics. But here, too, a successful system requires high skill on the part of the designer. The tools and equipment are similar to those used by the concert-hall system designer. Frequency response tailoring will be different, especially at the low audio frequencies, which will be attenuated. Because of movement of the actors, close miking is often impossible. Microphones may be concealed in the footlight wells; sometimes wireless microphones are used. The system is designed and "tuned" for maximum gain before "ringing" or "howlback," to ensure adequate reinforcement without danger of oscillation. Delay is introduced into loudspeaker systems more than a few feet closer to the audience than the actors' positions. Thus the Haas effect aids in preserving the illusion that only the "live" sound is being heard, rather than the reverse condition and a disturbing "echo."

COMMUNICATIONS AND EDUCATION

Public Address

The universality of amplified sound, of announce systems in public places, has created interesting and rewarding careers for audio professionals. From churches and airports to auction rooms and hospital corridors, from corporate board rooms to mammoth sports arenas, the varying requirements of sound system design call out the full skills of the 1977 audio designer.

The "P.A. man" of the early 1930s worked with crude, inadequate equipment and a meager fund of knowledge. Though he employed the best available skills, results were all too frequently unpleasant, distracting, and only marginally effective, so that speakers refused to allow amplification or shied away from the microphones, further compounding the poor P.A. man's problems.

Today's sound system designer has much more going for him: acoustical considerations have higher priority in architecture; there is a broad spectrum of professional audio equipment, allowing systems to be custom-designed with readily available components to achieve excellent results in almost any environment; and, of equal importance, today's successful sound system designer has been well schooled in the accumulated knowledge and experience of past generations of audio and acoustical experts. His design approach is highly scientific, as well as aesthetic.

He uses electronic calculators, computer programs, and complex mathematical formulas to evaluate the acoustical properties of a proposed structure, and to predict all performance parameters of his proposed system. He uses reverberation measurement equipment and techniques to verify his calculations after construction (or in existing structures). He then completes his installation of equip-

ment. This may be as simple as a single microphone, single amplifier, and single loudspeaker. Or it may include multiple microphones and other sound sources, mixer, switching circuits, compressors or limiters, equalizers, filters, delay lines, multiple loudspeaker clusters, and/or dispersed loudspeakers to obtain uniform coverage.

Except in simple systems with few acoustical problems, he will then proceed to refine and balance the system to obtain the design objective of coverage without "hot spots" or cancellations, which may involve moving loudspeakers slightly or replacing certain loudspeakers with other types, carefully checking phase relationships and adjusting relative loudspeaker levels. Now the system will be "tuned," using real-time analysis or pulse analysis test equipment and filters (usually in third-octave or narrower increments) to adjust the frequency response of the system, including the sound reflected back to the microphones, to a smooth "house curve" appropriate to the system's intended use. Then, with microphones open and the system in normal use mode, this "tuning" will be refined at successively higher system gains until adequate reserve of sound pressure level is obtained before "ringing" or regenerative feedback will occur. This process may be repeated for all possible combinations of open microphones and microphone positions, and the results averaged. Narrow band-reject filters may be installed to inhibit regeneration at troublesome discrete frequencies. The result of such a well-conceived and executed installation is a stable, reliable, highly intelligible sound system.

Sound system specialists also design and install background music and paging systems, semiautomated announce systems for transit terminals, and noise masking systems for conversation privacy in large office areas.

Telephony

The oldest electrical audio technology of all is moving toward radically new techniques. Advances in electronics, combined with a new climate of competition in telephony, are opening the telephone industry to new ways of doing old things and new things altogether. Both within the giant public utility systems and state owned or controlled telephone companies throughout the world, and in the proliferating private "interconnect" companies, audio engineers are working hand in hand with technical experts in allied technologies to keep telephony ever in the forefront of scientific communications progress.

Much of the new technology is concerned with signals at radio and light frequencies: communications by signals beamed up to and down from satellites, or sent along fiber optic "cable" in the form of light. But a telephone link must be an audio operation at each end, and the telephone industry in 1977 continues to be the largest single user of audio technology.

Audio engineers in this industry work in various areas of research and product design: transducers, amplifiers, limiters, noise reduction, switching, equalizers, filters, hybrids, two-way repeaters, and transmission.

Voice communications still are the primary business of the telephone industry. However, its wires, coaxial cables, satellite links, microwave relays, and fiber optic bundles also carry computer data, facsimile, teleprinter, and more importantly to the audio engineer, radio and television programming. These services require wideband, superior transmission paths and relay equipment throughout the worldwide telephony network.

Dictation

The first practical use Edison envisioned for his new invention, the phonograph, was as a dictation machine to replace the stenographer. In 1977 audio engineers are continuing to develop new and improved technology and machines to improve office efficiency. "Word processing centers" now employ centralized dictation equipment, with inputs throughout the office complex.

Underwater Sound

Audio engineers and acoustic physicists working in this specialized field in 1977 are involved with many fascinating endeavors, ranging from classified military projects to research in the vocal sounds of porpoises and whales.

They design systems for receiving underwater signals and recording the data. Components may include hydrophones, interconnecting arrays, and both analog and digital recording. Their design work is highly specialized, partly because of the special packaging requirements for an unfriendly sea environment. A representative development is the sonobuoy for picking up underwater sounds and relaying them via radio to a remote receiver. Their work includes all types of measurements on acoustic signals and noise: spectrum analysis, time analysis, peak level measurements, cross and autocorrelation measurements on electroacoustic transducers, and acoustical materials and environments.

Audio-Visual Devices

Education at all levels, including business and industrial training, makes heavy use of audio-visual devices: slide and film projectors or video tape units, coupled with special audio systems. Many audio engineers are employed today in designing, manufacturing, and installing these specialized products and systems.

Language Laboratories

In many colleges and universities today the teaching of languages is accelerated and perfected through the use of "interactive audio" systems, installed in many duplicate positions. The student listens to a recorded lesson, records his response, listens to his response, records a second try, etc. Audio engineers are employed in the design, installation, and servicing of these specialized recording systems.

Speech Synthesis

Many research engineers specializing in the audio field are involved in a fascinating new field, unexplored until very recently. Speech synthesis is the process of creating intelligible speech from information of a nonspeech character. Examples are a "memory," holding telephone numbers in digital form, which can respond in synthetic speech to an inquiry; the automatic translation of computer

digital data to synthetic speech. What is in a sense the reverse process, called "speech recognition," is also being actively developed. This includes such systems as the voice-operated typewriter, and computer data entry and retrieval via voice. These systems may also require automatic "recognition" of certain voices to secure privileged information.

Control of the Environment

In 1977 society is increasingly concerned with the pollution of our environment, including noise pollution. Audio engineers devoting their efforts to this field are central figures in the enterprise. They make essential surveys and measurements, and along with acousticians develop strategies for effective isolation, reduction or elimination of potentially harmful and disturbing noises. They are called as experts to help develop legislation regulating noise pollution. They devise systems for monitoring noise, to allow enforcement of regulations. They act as consultants to individual business and governmental organizations on control of noise in particular locations.

AUDIO IN SCIENCE AND MEDICINE

Hearing Aids

Early man soon discovered that he could augment the outer ear's capability by cupping his hand as an extension thereof to better discern faint sounds. This led to the ear trumpet, long used by the hard-of-hearing. The birth of the electronic era brought significant improvement with the development of the hearing aid.

Audio engineers working in 1977 in the field of hearing-aid research and development are continuing to advance this science, which has matured dramatically since the advent of solid-state electronics. New designs are remarkably compact, almost invisible, and increasingly more comfortable and efficient for the wearer.

In at least two major universities, in 1977, audio engineers are working with medical researchers toward the perfection of a promising new method of restoring hearing in certain cases of total deafness. Called "cochlear implant," the technique involves surgically implanting a subminiature transducer in the cochlea of the inner ear which provides an electrical stimulus directly to the auditory nerve, in response to sounds received by an external electronic hearing aid. At this writing, experiments have been successful to the extent that sound can thus be clearly perceived where there had previously been complete deafness due to incurable incontinuity in the inner ear. Although the character of the sound is not yet sufficiently defined for speech communication, there is high hope that continued development will refine the technique to at least this extent.

Aids to the Blind

Other audio engineers today are engaged in research and development of remarkable auditory aids for blind persons. These include small hand-held sonar devices, with which a sightless individual can learn to detect obstacles in his path and orient himself to his physical environment. Talking books utilize the products of audio engineering, including automatic speech time compression, which puts lengthy spoken material into shorter space and time without altering pitch or intelligibility.

Psychoacoustics

This has been one of the most fascinating fields for scientific investigators since electronics brought greatly improved sensitivity and accuracy to measurement about 50 years ago. From early experiments on the human ability to detect pitch changes, to the latest studies of how we localize sound sources in multichannel stereo, the often surprising intricacies of the human ear–brain system have kept a corps of talented investigators busy. Audio specialists in 1977 are continuing this work on dozens of open topics, investigating such fundamental questions, for example, as the relation of loudness to stimulus, or the detailed requirements for intelligibility in sound projection.

Audio in Medicine

Audio engineers working in the field of medicine in 1977 are aiding in the attack on human disease and suffering. Audio techniques have become the means of diagnosis of a number of conditions that are difficult or impossible to detect by other methods. In addition, audio is basic in the monitoring systems that have made dramatic improvement in the control of heart disease and other afflictions. Improvements and extensions of these techniques are under development by audio specialists in the laboratories of hospitals, medical schools, government agencies, and electronic equipment manufacturers.

SUMMARY

As audio technology has expanded and matured, the roles of scientists, engineers, technicians, and artists have become progressively more interrelated—the bounds of their disciplines less defined, particularly in the fields of entertainment. Evolution of new equipment and techniques is a process of contiguous circles. A new need spawns a concept, which, when implemented through engineering, results in a product or technique; operators find ingenious new ways to use the product, and develop new needs. Their feedback to the designers spawns a new concept, and the next circle is started.

Audio professionals of 1977 are in the classroom and laboratory, the studio and concert hall, the factory and hospital, in the skies and under the seas, working to augment, extend, and preserve the remarkable capability of—and to please—the human ear.

ACKNOWLEDGMENTS

The format for this article, and many direct quotations, are from "A Guide to Careers in Audio Engineering," by Emil Torick and Robin Lanier, published in 1976 by the Audio Engineering Society, Inc. Material for underwater sound was furnished by Robert S. Gales, Department of the Navy, Naval Undersea Center, San Diego, California.

Recording, Art of the Century?

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INTRODUCTION: In 1929 *The Phonograph Monthly Review*, in commenting on the reasons for the famed inventor's retreat from the phonograph business, stated that "Mr. Edison himself regarded the phonograph as merely a machine. He has never had any understanding of music: how could he hope to succeed in a musical venture?"

This argument sounds familiar to all who have experienced the long way that the art of recording took from the first mechanical approach to today's highly sophisticated enterprise.

Those who only participated in the very beginning might not have had any doubts that Edison was right, because, initially, the idea was to capture "sound," in the broadest sense of the word, and proportionally, music is only a small faction of all sounds, Music only came into the picture subsequently when a subconscious feeling must have told Edison that chirping birds and chatting relatives were probably not the most fruitful attractions for his new invention.

Present insiders, however, will have no doubt that the medium was music geared from its very inception. Probably they are no longer aware of how discouraging in terms of music was the first cry from this new baby.

If we reflect on a centennial of recording techniques, and also try to extrapolate into the future, we must realize that from 1877 through the late 1940s every step that the medium took toward evolution was done by engineers who added piece after piece to the perfection of the instrumental scenery. Artistic achievements then occurred sometimes as a result of what had been made technically possible. The most recent and most spectacular "proof of the pudding" is quadraphony where, a long time ago, the chaste experiment of one well-known capacity has pulled a whole industry into the development of a technical novelty of which the artists still must contribute the stuffing.

So one does not wonder why generations have considered the process and profession of "recording" as part of the engineering procedures that were engaged in the development of the medium. Moreover, these engineering procedures have during the times been lifted to the most demanding heights, so that the solid comprehension of 4 and more years of full-time specialized study is required to understand the secrets of signal behavior and the terms in which it is delineated.

In reality, recording is not an engineering discipline. It rather is an art that makes, or should make, strong and systematic use of engineering tools and methods. Basically this was true with the first real musical recording, made in 1888 by the young pianist Josef Hofmann in Edison's laboratory.

It is an art because recording is not only a means to engrave the musical signal into a groove, or to magnetize it on a tape coating. It rather means to "anticipate" the most subtle phrases from the singer's throat, the brass' mouthpieces, the violinists' bows, and the double bass pizzicati, to name a few, and to relate these to the total, in just the right proportion and according to the intentions of the artists. It means to follow and guide, with your hands at the controls and your ears at the monitors, the flow from whisper through outburst, and to bring it in good shape to the average home. It means splicing together hundreds of takes which perhaps represent in fragments the climax the performer was capable of reaching that day. It also means playing the keys of creative distorters and whatever enhancers, while the gang in the studio delivers their raw material. Moreover, it means to search, detect, and process for reanimation with the listener all illusions and emotions which the performer expressed or tried to express, and it also means to help those artists who may not have been born as a Callas or a Beatle to express themselves. To this extent the recording man is also a kind of an accoucheur

and psychiatrist, regardless of whether he is called producer, or balance engineer, or tonmeister, or what have you.

It is only relatively recently that this main aspect of the soundman's business is really recognized and appreciated, though awareness of it is still somewhat exclusive. It began with the advent of the "do-it-yourself" performers in the 1950s, highly forced by the pop groups. And in the classical field, this awareness was the father of the "tonmeister" concept which has since yielded spectacular results.

Today we know that the two components of the recording art, creative electroacoustical interpretation and engineering, are indispensable ingredients of one and the same discipline. During sessions the ingredients can appear in one man or be split into two or more. However they are divided or organized, it will only work if the sum of the two is complete and not compromised.

The actual recording business around the world no longer worries about basic technical imperfections. After 100 years we find almost everywhere a technical outfit that has at least come of age in terms of frequency response, wow, and flutter, and noise. Speaking about distortions, we would like to include this in the basic achievements as well, since it should be possible to eliminate it everywhere and under all circumstances. Alas, distortion does not blow the channel as overpressure does a hose. So we will have to live with it for another while until (hopefully) somebody develops the "audio hose."

THE TECHNIQUES

The Beginning

When Edison shouted into his first horn "Mary had a little lamb," he had no studio, no control room, no mixing desk, and there was no producer who could have told him that he did not properly pronounce "little" and that he might have gained by putting more excitement into his phrasing.

This was the situation for some time to come. The first approach toward artistic "directives" was the supervisor who pushed the performer toward the recording horn on soft phrases and pulled him back on loud shouts. Some artists soon learned to move on their own. Except for the horn, or later the number of horns, which protruded from the holy secret, and the provisionally damped room in which the entire arrangement was located, nothing was needed. The physical data of the procedures were unknown and the practical measures purely empirical.

An early note says that evaluating the frequency response was accomplished by playing tuned pipes or the like, whereby the amplitude was almost random. Refinements through the years mainly involved the size and material of the horns, their matching to the rubber tubes, size and composition of these tubes, and the cutting device itself. The diaphragms in the cutter head and the conduction of their vibrations via the lever or shank into the cutting stylus, as well as the stylus itself, were painstakingly guarded secrets of the company, if not of the man who operated the machine, The engineer's main activity outside the session hours was to test and try new diaphragm materials, new vibration conductor configurations, and new stylus shapes and materials. The target was a wider dynamic and frequency range not so far away from what their modern colleagues aim at. And the ads proved them right. At any time it was the just released "brand new" cut which not only out performed anything existing, but which was the absolute climax of all the arts to come.

During the cylinder age every single piece was an individual performance, played or sung by artists who had the exhausting job of repeating the tune as many times as needed. Physical strength was thus the most favored of all talents.

The first thorough change came about when 10 years later, in 1887, Berliner introduced the replicable flat disc. Then only one original was needed for a number of copies. With this improvement, recording could concentrate on its roots: true artistic moods and emotions, and the subtleties of phrasing and expression; once a performance had all of this, it could be duplicated without the fear of losing it on a subsequent version.

The records of recording history show remarkable achievements during the acoustical era when, for example, Arthur Nikisch recorded the first complete Beethoven's 5th on five sides in 1913.

The cylinder companies followed suit hesitatingly. Understandably, it took them quite some time and effort to develop a matrixing process, which finally came into being years after the flat disc had made the game because it could be duplicated

Electrical Recording

The real revolution, however, came along with electrical recording in the early 20s. Suddenly the main attributes that made a performer or a piece of music suitable for public performance were not only brought down to size, but they could be disregarded or even detrimental to recording. The great era of whispering and screaming, of semivoiced crooning and magnified hoarseness, of sexy pianissimi and sublime exclusiveness had its advent. Mere power and a rigid body were no longer prime attributes.

To the recording man, the first carbon microphone, psychologically, was replacement of the horn. He thought in one-microphone terms (today a "progressive" idea again) before the first mixing box was realized. This also applied to the acoustic environment which, for many years to come, was kept very much to the dead side.

After that huge step, advances in recording techniques slowly but continuously developed an understanding of the various electroacoustical parameters. During the very early days with microphones, the most essential parameter was the direct current flowing through the carbon cell. However, it was soon realized that the microphones had a frequency response, and acoustical pattern, and noise, and the first battles over who had the better noise began between the man with the microphone and the man who operated the cutting with the newly introduced electromagnetic cutterhead and the huge tube power amplifier.

A setup with three or four carbon microphones, a mixing box with the adequate number of power-line-type lever

controls, the subsequent cutting machinery, and the heavy stock of storage batteries plus large ampere- and voltmeters and charge rheostats was quite a luxurious enterprise. How far the voices and instruments were put in front of the microphones depended on guesswork and experience. The results must have been exciting as well as frustrating, because we find remarks in old books and periodicals where record lovers bitterly complain about the disillusioning harshness and the direct attack of sound that came with the new approach. Those who remember that, when overloaded, a carbon microphone could easily act like an expander may imagine what sort of "attack" the connoisseurs meant.

Overload and noise problems were soon smoothed when the dynamic microphone appeared. It was a considerable step forward in stabilizing working conditions, frequency, and dynamic range. Mixing several such microphones was first done on the low-level side before the main "station" amplifier. But it was soon realized that the much lower level of dynamic microphones brought about new problems of line interferences, such as switching klicks and hum (some ac power lines were already in operation at that time).

With the introduction of microphone channel amplifiers and dynamic microphones the scope of action was considerably widened. Throughout the past, strongly damped studio rooms and close-up miking were regular practice.

No acoustic ingredients of any substantial kind are detectable in the piles of recordings made prior to around 1925. This practice continued for some years even with the better dynamic microphones, until gradually, encouraged by experiments in real concert halls, an appreciation of the beauty of the acoustic environment developed and was, occasionally, given a faint chance to participate. One of the first historical recordings we remember that displays audible "hall" reverberation is Beethoven's first with Klemperer and the Berlin State Opera (1927). Interestingly, this is acoustically recorded, while the other side is electrical (Egmont, Leonore III, Coriolan Overtures).

With the advent of the condenser microphone in 1928 a further audible improvement was achieved. The "big bottles" with the tiltable condenser capsules on top became a familiar sight in most of the more frequented recording locations, at least in Europe. One of the most remarkable relics from that time is the recording of "Salome" under Klemperer with the Berlin State Opera. Contemporary experts would easily rank it among other good tapings from the 50s. Still, most sessions went along with one or two microphones. Three or even four were considered an "affair." Technically it would have been possible to combine a batch of those mighty 200- or 600-ohms T or L controls, but there was no real eagerness to do so for pure music purposes. Those who turned the knobs were brave engineers who did not imagine that it could have been the technical task of the engineer to compensate for each partially lacking balance. Probably the first who ran into these banks of round knobs were the motion picture people who indeed had a very difficult task to compose in real time whatever complex action came in from the numerous sources.

One of the earliest partners to the recording man who ran along with the sessions and took hold of the artistic side in a spectacular manner was Fred Gaisberg. He really started what today encompasses the work of the "producer." With his activity the artist's performance stopped being random and was put under guidance and control. This assisted the knowing and capable among the actors, as it brought some less knowing and less capable to unexpected highs and development of self-consciousness. He was the first who did not simply "buy" and artist and sell his voice or instrument like chewing gum, but rather invaded his soul and beliefs and made him feel that his producer stood for the entire listening public. His unparalleled success and rapport with artists cannot merely be explained with the exceptional knowledge of plain business plus music. This combination of capacities has been in great demand since.

The teamwork with a producer of that caliber may be regarded as the root of the later standard model: producer plus balance engineer. However, how it works depends strongly on the engineer as well. In the old days, where not too much was obtainable, since adding another dozen microphones or a batch of flangers was not possible, the engineer was well equipped if he had some basic feeling for sound and a good knowledge of solid tools, volts, and amperes. Later, when equipment gradually became more sophisticated, the interaction between the controllable and the achieved created an increasing demand for artistic awareness on the part of the engineer as well. One can say that the development of recording devices, particularly the means of control, has gradually confronted the engineer with artistic requirements. This is particularly true if one knows, and has experienced, how helpless a producer will be if the phrasing that is about to come in a performance does not trigger any impulse from the ears of the engineer down into his fingertips. Lengthy talks of what to do and scientific introductions into the meaning of notations is not the most rewarding business alongside the console and among team members in action. It must click without words. Therefore, today the engineer whose brain and fingers "click" is in demand even before a producer has thought something. In other words, those console experts are in demand today who do not need a producer for artistic reasons.

Terms might be an obstacle. Some people may have difficulty in imagining that the word "engineer" suits that sort of employment. And this is true; if one lives with the average imagination, "engineer" does not properly describe the job. One has therefore created combinations of words that might come closer to what is involved. "Ballance engineer" is one possibility, "sound engineer" another one, "recording engineer" might be understood as a more general term. The latest concept which "only" dates back to the early 50s and takes into account nearly all the aspects that add to the former "engineer," is what the Germans call "tonmeister," literally the "master of tones." We say "nearly," because the concept was born out of the sublime world of the classical "ivory tower" and thus not geared to the "dirty grounds of vulgar artistry." However, the picture has changed now since

most of these well-educated experts have repeatedly experienced that there are sounds, and performers, outside the black tie celebrity scene that easily reach, or even exceed, all sorts of artistry, refinement, virtuosity, and feeling which can be had in conventional "classics"; and they have experienced the fact that jobs have been open in those dirty grounds while the ivory tower was closed.

Returning to the early 30s, we find an increasing number of achievements which made the work of the recording engineer more professional. The studios in the United States and England remained on the somewhat drier end. Here the use of dynamic and ribbon microphones spread to all applications. There was little use of condenser microphones. Standard miking was still quite close-up and mixing was straight, without any sophistication. In these days one of the most remarkable patents of all time in our industry was filed in 1931, by Alan D. Blumlein, chief engineer at EMI [1]. It contained nearly all basics we know and apply today: when cutting the 45-degree stereo groove; when using plastic record material, fine grooves, and sapphire tips; when using a dynamic stereo pickup; when listening to duplex carrier modulated stereo broadcast; when converting into sum and difference; when using a dummy head; when using adjustable coincidence microphones; and when turning a "spreader" (which widens or narrows the stereo picture) or "shuffler" (which introduces frequency-depending crosstalk thus better pinpointing stereo focus).

In Europe, particularly in Germany, the 30s saw the advent of the concert-hall type studio with recording techniques favoring lively acoustics and increasing the distance between sound sources and microphones. The most important approach in this direction was taken between 1929 and 1932 with the new building of the Reichsrundfunkgesellschaft (RRG), Berlin, which contained an 18 000-m^3 concert-hall studio, designed for even the largest number of performers. With this studio, concert-like sounds became familiar to the ears of the listening and record-buying public. Consequently the developing taste demanded more of this type of sound from disc records. The trend was stressed through the use of the sensitive condenser microphones which were favored almost exclusively at this new broadcasting center during the 30s.

The imposing large performance halls that came into existence for example, Radio City Music Hall and NBC studio A, in New York showed the same tendency, though a bit more oriented to the drier side with mostly large stage shows, big bands, musicals, and other entertainment objectives in mind.

As already mentioned, the end of the 30s saw a widespread use of the dynamic and ribbon microphones in the United States and elsewhere, and a flood of "bottles" (condenser microphones) in several European countries, mainly Scandinavia, Holland, Switzerland, and Germany. It is interesting to note that the much lesser price of the dynamic microphones must have made operators less concerned about the number put on stage, because it was the comparatively large number of microphones and mixing channels that made the most important difference between the "dynamics" and the "condenser" world through the 40s and early 50s.

At this time a number of accessories to the recording business underwent suitable improvement: continually better microphones, loudspeakers with wider range and more power, better and smaller amplifiers, and better indicators and measuring methods. This helped the recording man to better understand and appreciate what he did.

The setting up of microphones and artists became gradually systematic. The influence of directional diagrams and acoustic shades became an important part in the thinking of the musical engineer. Discussions about the "ethical" facets of recorded sound began to appear in more widely distributed periodicals and newspapers. It was no longer sufficient to have merely caught the sound, but how was also important.

Particularly in the United States and England, recording of entertainment, jazz, and swing sounds enjoyed increasing dedication and skills. A few from the long possible list of excellent performers were: André Kostelanetz, Glenn Miller, Jack Hylton, Bob Crosby, Nat Gonella, Benny Goodman, Ray Anthony, Woody Herman, Glenn Gray, Percy Faith, Stan Kenton, and Billy Butterfield. To many oldtimers in the business who still mainly think and feel with their ears, the sounds of those decades have not yet been surpassed. The full, rich, warm, and "up front" sound, always sharply contoured even in the low-pitch instruments, was, and still is, striking. It has been mostly lost in the course of the continuing evolution toward flat wide ranges and physical stainlessness. Nobody has really explained why this is so, but might it not be possible that the "oldie" microphones with their increased bottom end, mostly peaking around 80 Hz, and their "built-in" rolloff beyond 6000 Hz provided a marvelous physiological equalization to the loud sounding brass and yielding just the proper subjective shape when played back at home some 20 dB softer? I remember having tried to make up for that effect later, just after World War II, when I sat down every day with big bands and large musical-type casts for years, linking home-brew equalizers between the jacks of my gorgeous four-fader console. Believe it or not, it worked beautifully. But alas, what once worked unconsciously, even without being noted, could not be revived with systematic intention. So it is good to know that there is still something left to be re-explored. We have the physical qualities: low distortion, wide range, little noise, fairly stable amplitudes. One essential thing, musically, however, is still hanging in air: physiological matching between the acoustic volume received at the microphone and the volume at which this will reproduce within the final sound at home. Who dares to take hold of that hot iron when it worked by accident 40 years ago?

All early recording was done with only a number of microphones and level faders. Equalizers and other processors came later when making up for the unavoidable loss level with amplifiers was no longer a job to be measured in cubic feet and kilograms, not to speak of the expense that was not commonplace in those days.

Nevertheless, quite a number of achievements can be dated back to the late 30s and 40s which are today

recognized as basic and have helped recording techniques greatly: the high-frequency biased tape recorder (von Braunmühl and Weber) and the wide-range coaxial loudspeaker (Eckmiller) in 1937, the stereo "Magnetophon" in 1942, the long line of versatile and soon miniaturized condenser microphones starting in 1947, and the development of modular flat-mounted mixing desk components since 1949.

From around that year recording engineers really began to feel the technical challenge. True multimicrophony was on its way, soon providing one microphone per instrument, occcasionally even more, as the case of grand pianos and organs. Already in those days we were seeing three or four microphones in and around one single bass drum.

It often bothers the clear-headed technician how these sound wizards consider physics. How can a drum sound better with four microphones instead of one? What about phase interference, comb filter effects, doubling, etc. The answer is as old as the business: the meter is what you hear—thus the meter cannot be better than hearing. It is not by accident that the few who believe they can hear like an analyzer are almost known by name. However, these are not always the most searched after by artists.

Placing microphones in front of an "artistic sound source," as scientists love to put it, has always been, and will most probably remain, a matter of eyesight and intuition. When one starts learning about characteristics and behavior of pressure and gradients in the acoustic environment, a certain image develops which forms an almost precise idea of what to do under what circumstances. However, if the decision and actions are left in the hands of the novice a great surprise is often encountered when the "proof of the pudding" comes along: the room is boomy, though the omnidirectional sounds better than the cardioid; because of the boominess a good effect is expected from cutting the lows and boosting the highs; now when listening to the playback after this adjustment is made, it is decided that it is "better" without it; and so on. Before the worried operator understands that the control room was boomy as well, and that the monitor loudspeaker was the dull sister of an unfinished laboratory special, he gets lost in soul-saving maneuvers with a batch more microphones and neck-breaking settings on dozens of waveformers.

In the middle 50s and the beginning of the 60s, the demand for more channels and all that went with them developed into sort of an explosion. Without the transistor it is unlikely that it would have happened this way. We saw the advent of a new industry: console making.

An important part of this story is the independent studio. Without them, the outburst would not have happened either. While recording techniques, having reached good basic standards, dabbled along smoothly in the established bodies, some ten years after World War II, a new artistic longing rose with many young people contrasting with the professional exclusivity with which music had been presented during the past. A few talented ones did it. It was a sort of do-it-yourself music; dreamed-up, unconventional expressions of desire or fatigue, pleasure or distaste, praise or damnation, making the world better or turning it head over heels. In principle this was not new. The middle ages saw this when minstrels and fools had the clever task of shouting loud and unhampered that which had accumulated in the minds and souls of those who could not risk shouting. How far away are we from the middle ages?

The biggest difference in this new world of sound is electric guitars and amplification, and the possibility for this to be recorded and distributed around the world rather than to be heard only in the farm yard. The impact that this new music made was tremendous. It gave birth to a fundamental change in nearly all areas of the business. In terms of recording techniques it brought about the independent producer and the hundreds of sound workshops that followed. The giants lost their hold on this evolution because they could neither follow the redistribution of claims and revenues compared with the freelancers, nor could they cope with the peculiarities and behavior of this new creative appearance. The unions did their part to take the institutionalized studios out of the game when they insisted that the union crew must still be paid when these new groups brought along their own mixers.

The independent studio has in fact made recording history in consoles, methods, sound, and business. Today's machinery, whether pop or classically oriented, bears evidence of this influence.

From the mid-fifties on the use of condenser microphones became more common. Methods of producing reverberation were refined; even in the mono age multiple-perspective reverberation mixing of recordings of the various instrumental groups of a big band were commonplace.

Recipes for the use of certain microphone models on certain instruments, and an individual recipe for each operator, remained standard. (Remember, with the advent of the groove the first cutting styli were taken home by the operator, watched like a talisman, and put back in operation only behind carefully closed doors.) Spring- and steel-plate reverberation added to the technical arsenal, tape loop iteration was used for effects: reverberation, echoes, and shatter. The first most widely known recordings that revealed all of these effects were "Tennessee Waltz," and "The World is Waiting for the Sunrise" by Les Paul and Mary Ford taped on eight tracks by Tom Dowd in the early 50s in his New York studio. We saw that strikingly simple console in 1960, still operable, displaying nothing but flat faders with reverse operation (push for attenuation).

This time may also be seen as the advent of the last great evolution in recording techniques: the multitrack story. Unlike any other achievement, perhaps with the exception of quadraphony, multitrack has given rise to fervent controversies among those totally involved and between those peripherally involved who have to pay for it. The real professional sound connoisseur has known, since the advent of the first 1-inch tape, what good he can do with it and how to prevent its misuse which can ruin the artistic result. Multitrack, though has been used for almost anything. It has made up for improper live balance. The

whole mixdown practice results from this, without regard to what the reasons for uncertain or unfinished balance were. It has made up for inconvenient session dates, and made possible different recording locations for each tune and sequential dubbing with no loss of quality. It has enabled artists to shine on vocals or various instruments simultaneously, and to show up with sound effects not possible when recorded in a straightforward manner. It has put famed conductors in a position to round out a performance with this and that touch to the dynamic proportions that they wanted, but could not achieve during the sometimes hectic sessions.

As usual, with the multitrack technique various operational philosophies have developed. One says that the best result is if nobody notices that the session is multitracked. The balanced and monitored recording should sound as if the performance were live. This would retain the artistic attention and tension, and prevent later disappointment. Others say that the equipment is best suited to capture the "raw material" without regard to balance and all that, and that the proper shape will certainly be achieved later during a relaxed mixdown session. In this case it is only important that each of the various tracks contain a perfect performance of each group or instrument.

Looking back through almost 20 years of the use of multitrack, one is inclined to say that both concepts have their merits and their drawbacks. Most critics maintain that such complex subjects can be properly judged only in light of the individual situation. In other words, whether or not model A is good for situation X does not depend upon the critic's prejudice but on the situation. It needs a sharp eye for the essential components of the situation to be appropriately guided. Once having got a foothold, multitrack spread like fire in the bush. The early 60s saw many of the independents in full swing on eight-track. Some of the large companies joined hesitatingly.

In terms of sound the properly processed multitrack product yielded an audible credit to merits: better separation, more clearly focused contours, impeccable presence, and imposing body sounds from electronic bass and tectonic shatter from toneless bass drums. Loudspeaker development soon followed suit and tried to take advantage of the new sound adventure.

Microphone techniques meanwhile had proceeded to miniaturized forms which showed better polar patterns and even smoother frequency response (for those who wanted it). Twenty-four microphone channels for a group of eight musicians were not uncommon.

The good possibilities for separation and post mixing made it evident that acoustic crosstalk could be hazardous. Therefore, damping and overdamping became usual throughout the field. A damped studio can absorb a lot of volume. The amplifier industry moved pretty well in hand with this development. Soon there was almost no stage nor studio where peak sounds did not reach 120 phons. The long era started where some seemed to believe that watts can make up for a lack of virtuosity and artistry.

However, the experience to be gained from the Beatles through Abba is proof of the old saying that real artistry sells on any level.

With transistorization and the use of large numbers of channels, a wide variety of accessories and auxiliary equipment came into being: complex equalizers and compressor/limiters, pan pots, mute and cueing, multiple echo sends and returns, foldback with individual reverberation mix, one-per-track bus selector buttons, and many more.

Stereo made a breakthrough in almost 2 to 3 years in the early 60s. A-B (transition) techniques became widely used in the United States, and were partly used in England, Germany, and some other European countries, where, because of the work of Blumlein and Lauridsen, the coincident pair method was prevalent for some years.

One interesting aspect to those in the industry was that most large American and many independent studios at first added one monitor channel per track as multitrack and stereo techniques developed, while European studios preferred sophisticated monitor-mix circuits and two monitor loudspeakers.

There is also a variety of opinions regarding the use of many of the facilities in the consoles. Some consider these as gimmicks and reject them, relying on good documented verification of what happens in front of the microphone. In particular, we find these in the classical field where only a little of what we have said here applies. But there are also advocates for simplicity in the pop field. And one may find that their recordings are not the worst by far. There are others who do marvelous jobs in pulling out all possible and available "stops." As it has been said, it depends on whether the tool suits the work. The skilled will know.

At the height of professional interest in stereo, another sound adventure came along: quadraphony. So far this has become the most controversial achievement among those involved. From praise to condemnation, from deep philosophical investigation to bare ignorance, everything was heard. In fact, it is delicate to assume a neutral position to a new concept in sound which automatically involves all artistic aspects, when a number of experts and powerful organizations regard it only as a system, and when the artists are uninterested. In terms of the recording industry, this lasting uncertainty has at least given a healthy upswing to some makers of components which are pertinent to this technology. Today's recording man has mostly at hand a good number of four-channel monitors and a batch of more controls in front of and around him. The contemporary workshop studio in a music center can give him at least 24 inputs, 16 outputs, selectable buses, many sorts of equalization per channel, and in addition to what has already been mentioned, a wide selection of phasors, flangers, time delays, pitch shifters, speed shifters, vocoders, synthesizers, iterators, various sorts of reverberation, echo generators or repeaters, dead booths, and use in the near future of whatever analog and digital wonders that may be on the drawing boards.

Scanning the professional periodicals during the recent years, it appears as if there is a growing awareness that the road away from the basics might have stretched too far. An increasing number of wise men are heard who patiently repeat the warning that never in history have tools replaced the monument. At least, sightseers did not like

them as much.

However, observing a skilled and experienced "electroacoustical interpreter" at work on the console can be convincing to those who have ever tried to follow with only two hands, and without making a mistake, a complex musical program on a bank of faders. And this leads to the most recent achievement, which is the storage of mixing procedures and their automated repetition, which is mostly called "automated mixdown" or "storemix." Initiated in 1969, this novelty has since taken a foothold in various studios. An essential consideration in it is ergonomics since it asks more "pianistlike" skills from the operator than did many other devices before.

THE FUTURE

As in most other fields, forecasts can easily be taken as conceited or vain. However, it is not really the future that can be weighed, but rather a sort of extrapolation based upon the past. If one knows that at all times the makable has been made and the thinkable has been thought, it is not too risky to postulate that this will go on forever. Asymptotic approximations may thus occur for other than direct reasons. In studio equipment sophistication, for example, one other reason may be costs, unless the thinkable may become makable for comparatively less. So there is no reason why tracks should stop at 24 except, for example, unsolvable noise reasons. Yet technology moves ahead. A mixing desk that only carries the controls, with the fully remote-controlled electronics condensed into a compact package and kept in the convenient corner, seems to be in the air. Pulling dozens of cables through a labyrinth of doors and vestibules from a hall to a way-out control room for classical recording may also belong to the past when modern means of safe and inexpensive high-quality multichannel communication comes into practical reach.

If spectacular achievements are still to be expected at all, they will most likely be in the field of signal registration including master cutting, and monitoring transducers, the two areas where most is still left to be hoped for.

The influence of future development on the recording man and his use of microphones and acoustics does not seem to hold too many surprises. As long as acoustic instruments are played in an acoustic environment, the usual microphones, perhaps still further perfected, will be needed. Automation-assisted mixdown and splice-free electronic editing may hope fully be a reality in the not-too-distant future.

One of the most promising aspects in all these recent developments, however, is that artists are now much closely involved with technical operation than in former years. In the pop business the control-room window is no longer the distinguishing barrier between sound suppliers and sound receivers. Interests there have quite often merged and amalgamated. Engineers also play in the groups and produce, while group members sometimes know more than a little about recording equipment and can handle it perfectly.

In the classical field, famous artists engage in mixdown sessions and have not only learned a lot, but also recognize and esteem the artistic and cocreative value of the endeavors of their electroacoustic partners.

We are glad to close this outlook with the optimistic conviction that the family of artists and engineers is a sound one, that creativity is exceptionally vivid as it is vital in this field, and that recording techniques will always serve a good purpose beyond the daily routine.

The Musician and the Record

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The response of the musician to the introduction, growth and maturity of recorded sound is reviewed. As the technology evolved, the musician's fears of unemployment due to automation were eventually realized. Following the subsequent turbulent period which had severe impact on the musician, the recording industry and the public alike, an accommodation has been reached which appears to be satisfactory to all.

"To musicians, development of new methods to displace them is nothing new. They have been multiplying ever since 1929, when the film sound track drove thousands of musicians from the pits of the movie theaters."

Thus wrote James Caesar Petrillo, in 1955, of the musician's view of technological developments such as sound recordings, juke boxes, and music synthesizers. More than any other individual, this fiery labor leader, former head of the American Federation of Musicians (AFM), was to represent the professional musician in his greatest battles and ultimate accomodation with that product disparagingly called "canned music."

It was a stormy relationship at times—the musician and the record. While the record could not exist without the musician, and although the musician could certainly have survived without the record, he nevertheless has accepted the pressure of advancing technology and learned to use it to his best advantage. The ambivalence of this relationship continues to this day. A full century after Charles Cros in Paris and Thomas Edison in Menlo Park, New Jersey, started the world on the revolution of recorded sound, Hal C. Davis, the present head of the AFM, now numbering 330 000 members, echoed past sentiments by saying that "Listening to recorded music is like kissing a girl over the telephone." But Davis also demonstrates his pragmatism by adding: "We know you can't stop technological progress and the electronic reproduction of our product. We don't even want to stop technological development, but we're determined to prepare ourselves to live with it and survive in the process."

THE BEGINNING

It was not always an adversary situation. In the earliest times musicians regarded the phonograph as something of a curiosity, to be experimented with but not deserving enough to lend their names and artistic reputations to the recorded product. Complete anonymity was the rule at first. An 1895 list of plates of the United States Gramophone Company showed 86 titles in such categories as *Band Music, Instrumental Quartette, Barytone, Clarionet, Cornet, Cornet Duetts, Drum and Fife, Trombone, Piano, Indian Songs, Animals, Hebrew Melodies, Soprano, Contralto,* and *Vocal Quartette*. All performances were anonymous. Only the category called *Recitation* identified the artist: "the eminent versatile elocutionist, Mr. David C. Bangs."

After a tentative first decade of the new technology, a number of commerical organizations were established, and the musician soon began to recognize the medium as a source of additional employment opportunities. By 1900 the new patrons of this art included such names as the American Gramophone Company, Edison Phonograph Company, Columbia Phonograph Company, North Americal Phonograph Company, Automatic Phonograph Company, United States Gramophone Company, and the Berliner Gramophone Company in the United States; and Pathe Freres, Deutsche Gramophone, and Telefunken in Europe.

In 1906, the same year that Lee de Forest patented his Audion tube, the world's first disc jockey made his

appearance. On Christmas Eve of that year, a Canadian, Reginald Fessenden, experimenting at Brant Rock, Massachusetts, amazed wireless telegraph operators on board ships in the North Atlantic by transmitting musical signals for the first time. Fessenden played a violin solo himself on that occasion, and also played a phonograph recording of a woman singing. Lee de Forest also recognized the value of recordings for the emerging broadcast technology, and in 1908 broadcast phonograph records from the Eiffel Tower. Neither man could have anticipated at the time that radio someday would become mainly dependent on records and make stars out of disc jockeys. However, the start had been made and the role of the musician would never be quite the same again.

THE FORMATIVE YEARS

Recording sessions were exhausting ordeals in the early days. Musicians would spend hours positioning themselves in various locations in front of the horn in order to achieve proper tonal balances. Soloists would usually stand 3 to 4 inches away from the horn, but had to remember to duck away during *tutti* passages so as not to block the sound of the rest of the ensemble. Clever producers sometimes complicated the procedure even more by arranging to have a substitute singer literally "step in" to sing a single high note for a well-known artist who could not manage it strongly enough. By the time all this choreography had been completed, the final recording would begin. Performances had to be repeated many times in order to get enough copies for sale. Before Edison began to mass-produce molded cylinders in 1902, only several copies could be made at a time, each from its own recording machine. With the change to disc recording, the duplication process became simpler; copies could be stamped from a matrix derived from the original wax master.

Musicians also had to compromise some of their artistic freedom. Scores were often rearranged to provide better musical balance. For example, bassoons would often substitute for cellos and tubas for double basses. Without the manual or automatic gain-control flexibility of modern mixing consoles, handkerchiefs in front of the horn substituted for attenuators, and the dynamic range of performances was intentionally restricted. Edison, acting as his own record producer, was especially conscious of the limitations of the medium. He refused to record Rudolph Friml at the piano, characterizing him as a "pounder." When he used the same epitaph against Rachmaninoff, the great romantic piano virtuoso stalked away from the recording studio. It may be only coincidental, but in 1925 when Columbia issued the first commercial recording made by the electrical process, the performance was by Art Gillham, billed then as "The Whispering Pianist"—presumably not a "pounder."

The popular acceptance of the phonograph was helped considerably by the support of well-known musicians. Caruso's powerful singing voice was especially well suited to the phonograph when he began his recording career in 1902, and his example encouraged many other musicians to accept the new medium (Fig. 1). In the 1890s, John Philip Sousa's band could be heard (through earphones) on the nickel coin-operated Edison automatic phonographs found in many public places, including saloons. Although he was to be one of the most active recording artists of his time, Sousa had misgivings about the future of the phonograph, predicting "a marked deterioration in American music and musical taste, an interruption in the musical development of the country, and a host of other injuries to music in its artistic manifestation, by virtue—or rather by vice—of the multiplication of music-reproducing machines."

In the near term, Sousa's forecast turned out to be partly correct, and in a strange way that concern about the deterioration of musical taste, shared by others, may have saved the phonograph from extinction. With the rising popularity of radio broadcasting in the 1920s, the sale of records declined drastically, and many thought the phonograph was doomed. However, this was also a period when jazz was having its most rapid growth. Because broadcasters largely ignored jazz and country music in favor of more "cultural" pursuits, the recording industry survived mainly by the sale of so-called "race" records. Negro artists like Bessie Smith continued to enjoy great recording popularity until the 1930s when jazz was accepted by white musicians as well, and had become an important factor in radio programming.

If labor leader Petrillo would later rue the day when sound recording in the film industry caused the greatest unemployment of musicians in history, it was inevitable from the earliest experiments that images and sound would eventually be combined in a single entertainment medium. It began with Edison in 1893, with the use of background music on cylinders to accompany a film. Less than a decade later he had invented a complete sound movie camera, which he called the phonokinetograph, and a projector called the phonokinetoscope. By the 1920s studios began to introduce movies synchronized with Vitaphone records, usually playing background music only. Finally, in 1927 Warner Brothers released "The Jazz Singer," starring the singer Al Jolson. Although still using mainly subtitles and background music, this movie included a few scenes in which Jolson actually talked and sang.

On a later day another popular singer figured prominently in a major advance in the recording arts. In 1947

Fig. 1. Enrico Caruso recording for Victor—a self caricature. From RCA Records.

engineer John Mullin demonstrated his confiscated German military Magnetophon to Bing Crosby, who was trying to convince the sponsors of his radio show to permit prerecording of the broadcasts. Crosby's interest in magnetic recording and the initial order by the ABC network for 12 Ampex recorders marked the beginning of a new industry and a milestone in the technology of sound recording. It was to make possible the subsequent pioneering of Les Paul and Mary Ford in multitrack recording and the more recent introduction of commercial stereo and quadraphonic records.

THE RISE OF UNIONISM

As the trade union movement grew with the industrial revolution, musicians had ambivalent feelings about their own situation. The German musicians in New York City, who, in 1860, formed the Aschenbroedel (Cinderella) Club and incorporated four years later into the Musical Protective Union, denied that theirs was a trade union—they were artists, not laborers. After the Baltimore musicians organized in 1863, others followed, and in 1886 the National League of Musicians was formed. By 1896 the League numbered 101 local societies, but 19 of these, dissatisfied with activities of the League, went to the American Federation of Labor and formed the American Federation of Musicians.

At first the phonograph was not considered a serious threat by musicians; the new device was having its own survival problems. However, the situation was to change abruptly. As Petrillo later put it, "The deluge came in late October, 1929, when the stockmarket crashed. While businessmen were reading doom on the tickertape, another kind of tape was beginning to spell disaster for the musicians. The machine had caught up with musicians. It was the sound track. This tiny . . . strip on the edge of the celluloid movie film meant that music created by living men could now be recreated mechanically. Thus, musicians were the first victims of the electronic tube which has since opened the door to automation."

The AFM responded quickly but ineffectually. A 1929 nationwide advertising campaign promoting live music cost $1 100 000 but did not result in the rehiring of many musicians. Thus, as the rest of the world gradually recovered from the great Depression, musicians continued to suffer serious unemployment. The sound track replaced them in the orchestra pits of the theaters, and the phonograph, threatening even the staple of network radio, replaced them at the local broadcast stations.

AFM frustration with recorded sound continued throughout the 1930s until the Chicago musicians placed a ban on recording services by their members in 1937. The ban lasted for 18 months, and although it, too, did not solve the basic problem, it gave the AFM encouragement for further militant action on a continental-wide basis. Finally, in June, 1942, under broad authorizations granted by the AFM conventions in 1941 and 1942, Petrillo placed a ban on all union recording and transcription activity in the United States and Canada. Musicians in other countries quickly lent their support, especially in Great Britain, where union musicians were successful in preventing the export of musical recordings.

At first the ban was not too burdensome on either the recording or the broadcast industry. A large library of recordings already existed, and a shortage of raw materials would have limited the output of the manufactured product in any case. In February, 1943, at an attempt at negotiation, Petrillo proposed that the recording companies pay a fee for each record and transcription made by union members. The monies thus collected were to be put into a fund to be used for the reduction of unemployment among musicians. This proposal was rejected in principle by the recording companies, and the ban was to continue for a total of 29 months, in spite of pleas by the U. S. Government and President Franklin D. Roosevelt.

ACCOMMODATION

As the recording ban continued, there was a small amount of recording activity not prohibited by the Union. Since singers were not included in the ban, companies increased their use of vocal arrangements, substituting choruses for instrumental backgrounds. Recording of music with instruments not then covered by the Union rules or contracts—such as harmonicas, ocarinas, and one-man bands—continued to be made, but they found little popular appeal.

After 15 months, Decca Records agreed to the Union demands and in September 1943 signed an agreement. Gradually most of the other record and transcription companies accepted similar terms and also signed. However, Columbia, RCA, and the NBC Transcription Fund continued to balk at the principle of making payments to the Union. These three were able to hold out for more than another year after Decca signed, partly out of concern that the Union might make similar royalty payment demands on their parent radio networks. But their competitive positions were deteriorating and the possibility was increasing that many of their artists would switch to other companies. The imminence of such changes became quite apparent when violinist Jascha Heifetz ended his long exclusive association with RCA Victor and signed with Decca. Finally, in November, 1944, the last three holdouts agreed to terms and the bitter dispute ended.

The contracts signed by all companies were similar. In addition to prescribing wages for recording performances, they also provided for direct payments to the Union for every record and transcription produced. Under the terms of the Recording and Transcription Fund, these payments were to be used for the direct employment of musicians. It was one of the first union welfare funds, but one with a difference—musicians would have to work for their share of the benefits.

Unfortunately for all parties concerned, the Recording and Transcription Fund did not meet the newly imposed requirements of the 1947 Labor Management Relations Act (Taft–Hartley). This law required that control over expenditures of welfare funds be exercised by representatives of the Union and of the employers, and that the funds be used exclusively for the benefit of the employees (and their families) making the contribution. Petrillo would accept neither of these constraints and another ban was

imposed, this one lasting from January to December 1948.

The 1948 ban was settled by the substitution of another fund which avoided the restrictions of the Taft–Hartley Act by being removed completely from Union supervision. The new 1949 Music Performance Trust Fund (MPTF) was to provide employment for instrumental musicians, whether or not members of the Union, and to promote the appreciation of live instrumental music by the general public. This fund, which continues in effect to this day under the administration and control of an independent industry-designated trustee, receives semiannual payments from recording companies based on their sales of phonograph records. The proceeds are exclusively devoted to the presentation of admission-free live public performances of music in communities in the United States and Canada, such as concerts in parks, veteran's hospitals, schools, and similar places.

The MPTF was joined in 1964 by the Phonograph Record Manufacturer's Special Payments Fund. Whereas the MPTF is for the benefit of the public and all musicians, the Special Payments Fund makes general royalty payments to those musicians who make recordings. This latter fund, administered by a prominent trust company, is paid into by phonograph record companies on the basis of the number of records sold each year. The fund makes annual payments each year to all musicians who have participated in recording sessions, in proportion to the number of such sessions they have performed.

Since its inception, the MPTF has spent over $144 000 000 (see Fig. 2) to present nearly 1 000 000 live performances in the United States and Canada. Thousands of businesses, schools, government agencies, and other establishments have invested an additional $50 000 000 to cosponsor many of these live musical events. Under the terms of the AFM recording contract, each record manufacturer makes contributions to the fund as a percentage of record sales based on price. The present rate ranges from 0.5% to 0.6% of the suggested retail price of each record and tape sold. In 1976, 182 companies contributed nearly $12 000 000, and the fund and its cosponsoring organizations sponsored approximately 52 000 musical performances.

Clearly, at this late date there are few casualties of unemployment in broadcast studios or silent movie houses who can justly claim a right to continuing musical welfare support. What began in 1942 as a union welfare fund has moved to the public sector where it now thrives as a cultural force. In many areas of the United States and Canada, except for student performances and dances, MPTF-supported programs are the only source of live music available to the public.

RETROSPECTIVE

The changes that the technology of recorded sound has brought to the musical world—to performers and audiences as well—are numerous and significant. As a mass-produced, popularly priced entertainment medium, the record has made the entire literature of music available to listeners at home. It has created an interest in music where none might have otherwise existed and has provided audiences for composers and performers who might have otherwise remained unnoticed.

Musical instrument technology also has been influenced by the available recording techniques, and in some cases instruments have been developed for use exclusively in recording. Probably the first was the Stroh violin introduced in England in 1901. To overcome the difficulty of recording weak instruments by the early acoustic process,

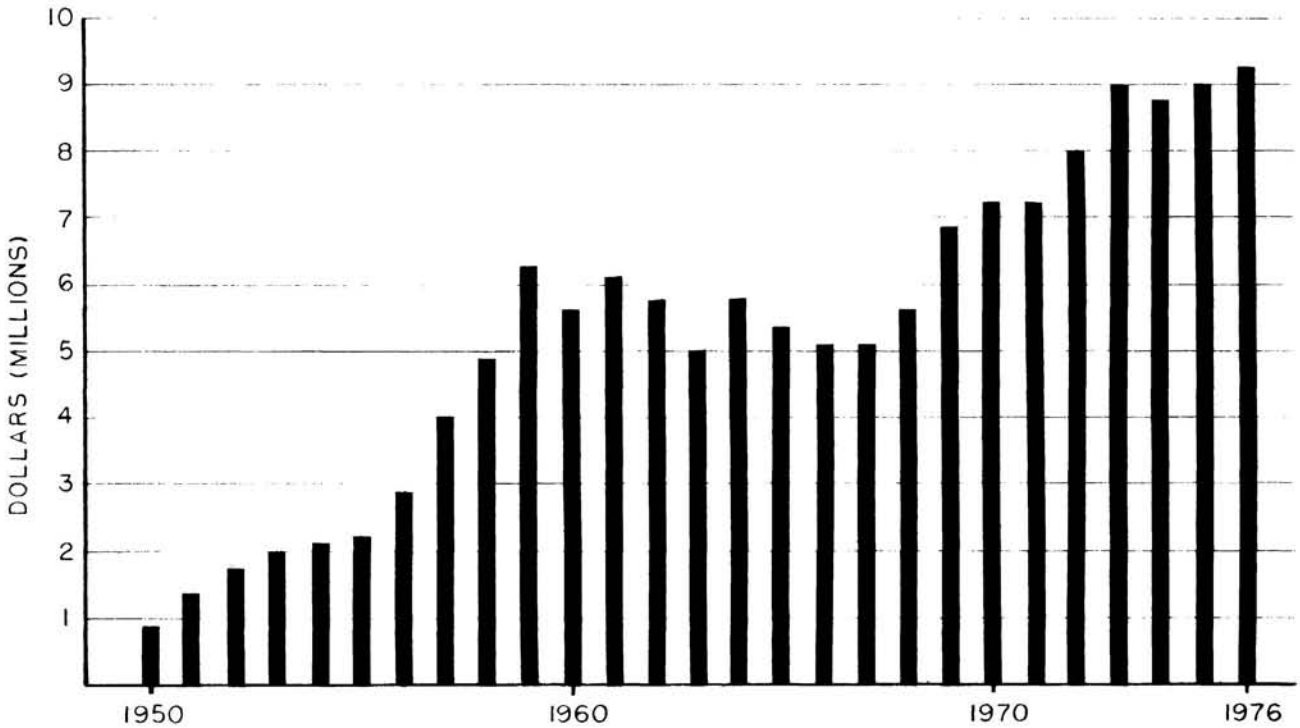

Fig. 2. Yearly MPTF Allocations for Services of Performing Musicians

this device used a metal resonator coupled to a brass horn, in place of the wooden body of a violin, to achieve a louder, more penetrating sound. More recently we have seen the development of the synthesizer, an instrument which, along with a multitrack tape recorder, at first required only a composer and not necessarily a performer in the usual sense. Today, as synthesizers have evolved into sophisticated polyphonic devices and become legitimate performing instruments, the control board itself at the recording studio has almost become another "nonperforming" instrument.

The musician, too, has changed under influence of the record. With near-flawless performances on recordings now commonplace, the performing musician must strive for similar quality in concerts. The public expectation of high quality has undoubtedly helped raise the standards of live performances. In the recording studio, on the other hand, standards of performance have gone in two directions. There exists now a new elite class of "studio musicians," versatile in their abilities and exceptionally well qualified to quickly meet the demands of any musical score. There exists also a class of recording musicians who can, in the concert sense, hardly perform at all. The convenience of multitrack recording, with all its editing and signal-processing capabilities, has provided them with opportunities which would have been unavailable without such technology. They are able to capitalize on their talents years before their fledgling technical proficiency would have otherwise permitted.

Clearly, the musician has learned to live with the record. He has, as Hal Davis admits, recognized the force of technological progress and prepared himself for it. He has even survived!

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The Great Artists

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There are artists who exceptionally justify the existence of the recording industry. With no attempt to examine them all, or even name them, some of the characteristics which they seem to have in common are explored. Whether they are cause or effect may not always be evident, because each is unique as is his particular art. But similarities of nature exist, and with a few personal reminiscences, I hope to reveal some of the structure of the great artist.

At 3 o'clock on Saturday afternoon, the 21st of February, 1942, New York's Town Hall was the setting for, at the time, a curious event. The mood of the World War II period made the event seem perhaps even incongruous. The assembled audience, mostly musical cognoscenti, observed a rather severe, piano-like instrument on the stage and a heavily padded high-backed chair facing the keyboards—two keyboards, one above the other. They looked at the program. It was a mystery—one selection.

The houselights dimmed, a hushed, long few moments, the stage door opened slowly. And as if propelled by some unknown force, a tiny figure of Lalique-like fragility glided very deliberately across the stage. When she arranged her red velvet robed figure at the contraption, she exposed soft slippers on feet that looked impractical for any purpose. During an almost apprehensive silence, she clasped her hands, closed enormous, deep-set, fathomless eyes, and with head erect seemed to be either rapt in prayer or seeking energy from some spiritual pool.

When the hands finally unfolded, they gave no promise of sufficient strength to manipulate the curious box. A motion of her feet drew attention to an array of seven piano-like pedals. Almost imperceptibly the feet moved swiftly, securely to make noiseless adjustments. Without apparent warning, a sound filled the quiet space—a sound of such compelling eloquence, such refined clarity, such universal beauty that the senses seemed to fail—the sound being perceived by some direct contact with the spirit.

Wanda Landowska had just started the *Aria* of Bach's *Goldberg Variations* on her Pleyel harpsichord. By the time she finished the hour-long work, she had transported that fortunate audience along artistic and sonic avenues that revealed one of the truly great keyboard masterworks, the incredibly rich sonic resources of the harpsichord and her own incomparable genius.

It was a performance of more than music—it was an act of monumental courage. At almost 63, Landowska was facing a world she had not even visited in 14 years, 14 hostile years for the United States, years of depression, panic, war—a long period of distraction from anything so remote and tenuous as ancient music played on an antique instrument by a wisp of humanity. If the great impression she had made on Americans during her concert tours between 1923 and 1928 had evaporated during her absence, she was really starting a new career. But she would gamble that career and her future on one relatively unknown composition, performed on an unfamiliar instrument at a profoundly depressing moment in her own life as well as that of all mankind.

Driven in 1940 by the approaching Germans from her beautiful home and famous school at St.-Leu-la-Forêt outside of Paris, Landowska finally reached America on December 7, 1941. She had escaped with a harpsichord (donated by a devoted pupil) and very little else except her insistence to survive. It was a desperate moment. She needed money, she needed to get back to work, but mostly, she needed to give a recital. And no manager would sponsor her. Friends came to her aid, rented Town Hall, sold tickets, promoted the concert. But they advised her to play a popular, varied program. Landowska had

other ideas. "I shall give a very great concert. It must be so. I will play only the *Goldberg Variations*. And it will be remembered."

When I first began to work intimately with her eight years later, as the director of her recording activity, the trauma of that gamble and the detailed logic of her decision were obscured by the great success it generated for the following years. Her past was never important to her. She was working hard and making elaborate plans for the future. At 71 she was recording Bach's complete *Well Tempered Clavier,* which she called her last will and testament. During her almost ten remaining years, we seldom touched upon that critical point in 1942, she preferred to look always forward, planning work into eternity. But when she spoke of the *Goldberg*, it had a profound meaning which suggested not the result of that incredible act but the reason for her certainty that through that masterpiece she could make a new life in a new world.

When RCA released her recording of that work, no such anticipation of new life for her was contemplated. The recording ban imposed by the AFM was lifted in 1944 (after a hiatus of two years), and RCA was frantically piling up inventories of current hits. Landowska's own declaration of independence that afternoon in Town Hall was finally consecrated on disc in 1945. RCA expected a connoisseur response, nothing more, and pressed up a modest 3000 albums. But the frail Polish lady was vindicated again. RCA scrambled to supply 30 000 customers with sets within three months, and today, some thirty years later, the recording enjoys a solid position in the catalog. A success story? Yes, but one that exposes the nerve ends of great artists—the woof and warp of their fabric. It's the evidence of some primordial gene that propels the human organism into a white heat of dedication, motivation, and persistence. And that gene is mightily uncommon.

Perhaps the common conception of a great musical artist is that of someone who performs in his chosen artistic medium on an exceedingly high and consistent level. And that is one of the qualifications but by no means the most important one. Greatness lies in adding some unique and compelling quality to a body of musical expression. And that quality can only emerge from originality and the persistence to express it. No, probably the word is "insistence"—a rigid demand on every human resource that results in a totally convincing expression.

Is this "talent", that instinctive common denominator of artistic expression? I think not. There are talented performers in every field, some who have conquered their instruments, vocal chords, or conducting ability to a degree greater than some of the great artists. Vladimir Horowitz, generally considered to be in the greatest command of the piano, has often pointed out instances where other pianists can play certain music which he cannot. Technical manipulation of an instrument is only the means to a musical end. Of course, great artists invest vast amounts of time and energy in developing and keeping their technical facilities. Jascha Heifetz still works every day as he has since he was three years old. At 76 he has stopped concertizing but keeps his technique in trim for his own satisfaction and the enjoyment of evenings of chamber music with colleagues and students. His almost infallible technique was always used to serve his special musical intentions. And he judged his performances and recordings rigorously on that basis. Slight defects in intonation or ensemble were ignored in his recordings if a "take" carried his musical message. It bothered the perfectionist in him a little, but not wanting to take the chance of disturbing the musical line by splicing, I often encouraged him to accept the "take" as played. "A little technical defect will make all the other violinists very happy" was one of my ploys.

"Technique," Horowitz says, "is the facility to express music in the way you feel." Which is at once a revelation of his own approach to technical problems and the suggestion that he can play anything he really wants to play. And he has wanted to play some incredibly difficult works! His reputation is not unjustified. His technique is the result of working out his own musical rhetoric, and his identification as a great artist is based on his unique contribution to the art of pianistic expression. The indelible mark of his own personality emerges with crystalline clarity, endeavoring constantly to unearth and communicate the meaning of the musical message hidden in the composer's notation.

Music is such a paradox. Composers hear sounds in their imagination, write down rather incomplete directions to produce those sounds, and rely on strong, independent personalities to follow the sketch to create the composer's

Vladimir Horowitz started a period of rest from the concert hall in 1953 that stretched to 12 years. But we recorded often during that period, sometimes in his living room. This was Carnegie Hall in 1957.

masterpiece. Of course, it's a symbiotic relationship, but it's somewhat analogous to a painter making a charcoal drawing of a picture, instructing what hues he wishes, and allowing someone else to fill in the colors, shadings, and even change form to satisfy the colorist's concept of the picture.

A great artist is not actually a unique interpreter of the composer's intentions. Those musical directions are so inadequately expressed that the artist must imbed himself in the composer's culture, his other works, his letters, every different view of a composer's expression in pursuit of the musical character of the composer. Armed with those intellectual tools, the artist "opens up the notes"—the way Horowitz puts it—to discover the composer's inner ear. Putting his own creative drive in gear, the artist expresses his concept of the music. Is that an "interpretation"? Is he translating from one language to another? I submit that there is great creative substance involved in expressing a composition in unique personalized sound.

There is, of course, great controversy over the "right" way to play something. And this is one of the prime areas where a great artist reveals other qualities of his personality. When Heifetz walks on stage, views his audience with monumental authority, and assumes the posture of confident mastery of his art, everyone present is immediately riveted into the proper atmosphere to listen very seriously to what he has to say musically. Something important is about to take place, and I am convinced that I will be transported musically to sublime regions. I will hear these works "right."

To some, this is showmanship—even Heifetz calls it that. But it cannot be so calculated in the usual sense of that word. I prefer to think of it as a charisma—a special grace that creates a mood of acceptance. Heifetz retains his aura of elegant dedication throughout a performance, even to backstage amenities. His humor, though, sometimes breaks through his endeavors to receive the public with courteous detachment. A very effusive backstage visitor once pleaded with him, "How can I tell you how beautiful your performance was?" Heifetz gave a rare grin and mischievously said, "In English."

Jascha Heifetz's formality during concerts is well known. But an atmosphere of relaxed dedication prevailed during his recording sessions. The RCA Hollywood studio was the setting for this almost frivolous moment in 1965. Ivan Fisher the engineer is at the left and Brooks Smith is the pianist.

String instruments have such special technical problems, almost as elusive as vocal chords. Professional violinists rate their colleagues on various scales of attainment, but invariably invent a new and superior category for Heifetz. Recording with him for over twenty-five years has been a great and glorious lesson in art and humanity. To cope with that highly developed motivational gene at work in a blinding array of situations is almost more than an average person can deal with.

The intense creative drive a great artist possesses demands that he observe everything with a questioning attitude. "Does it conform to my concept?" "Is it my original thought?" "Do I accept it, modify it, reject it?" It's a constant inward looking, and it allows little space for the opinions of others. In society's structure, such a characteristic would be classified as an incredible ego, and as life progresses, it makes more enemies than friends. It is perhaps the plight of the genius, and it probably explains why great artists generally lead lonely lives—massive in activities and personal contacts, perilously short on meaningful human involvements. The dimensions of their lives are so fitted into the centricity of their art that other beings are relegated to revolve around the periphery. Who accepts that role? Some astute artist once said, "Great artists have too many wives and too many children and not enough friends."

And then there's the legendary artistic temperament—that supposedly characteristic quality that accounts for the apparently irrational behavior of great artists. As intense as they are in their dedication to their art, can they be expected to be less so in their human contacts? But the source of their expressions of dissatisfaction is their own highly developed sense of responsibility—they blame themselves for not getting what that motivational gene demands. Toscanini's exhibitions of displeasure are famous and serve as a good example. Even in the dress rehearsal for his final concert with the NBC Symphony in 1954, after trying repeatedly to get his brass section to produce a desired effect, he roared, "Shame—shame on you," and left the podium. And as he walked off the stage, he quietly uttered, "Shame on me."

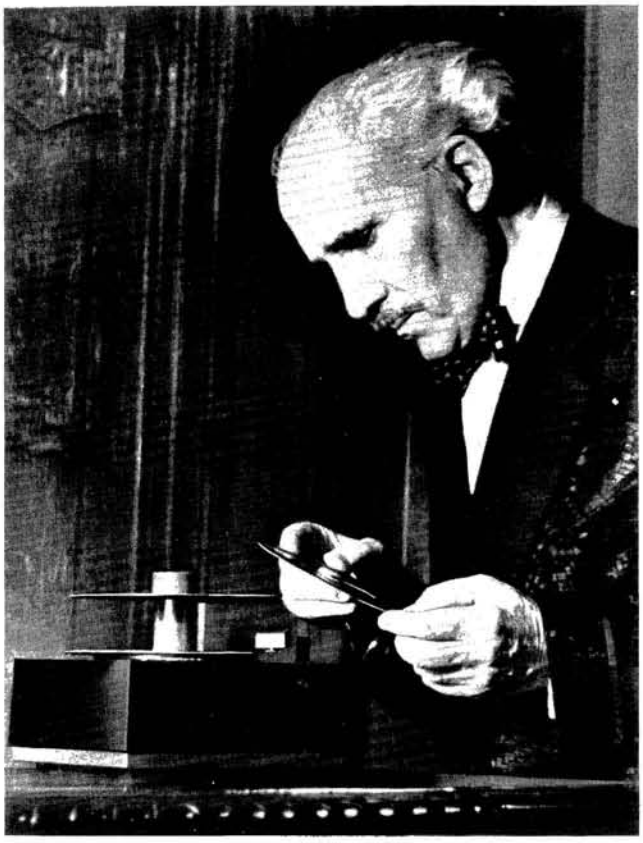
Great artists lose many human rights in their self-imposed dedicational imprisonment, but the public is the beneficiary of that loss. They truly suffer, and they have no choice. But they survive, often extraordinarily. Arthur Rubinstein is now past his 90th birthday, Leopold Stokowski past his 95th. They were two charismatic great artists—a pianist who only found his niche in life after 40 and an organist-cum-conductor who practically invented sound.

Rubinstein is a kind of exception to prove a rule. Possessing a native talent for the piano and a passion for the social advantages of the life of an artist, his motivation did not elevate him to a conspicuous stature until faced with a need. It was called "responsibility," and it came in the form of a wife and children. As a testament to his creative energies, after 40 he refined his talents, developed his pianistic heroic qualities, and became renowned for

performances of the music of his countryman, Chopin. A more shrewdly calculating artist probably does not exist, and his greatness is a tribute to a very refined sense of discrimination. He always reviewed the first "take" of his recording of a work with the comment, "Now I will have my lesson." He submitted that a student past 14 could best use a tape recorder rather than a teacher. By that age he should have the proper basis for his technical facility. If he could hear and correct his mistakes and judge the validity of his performance, that was all he needed. If he couldn't, no teacher could help him become an artist!

The other nonagenarian framed his career in sound dramatized by perhaps the greatest charisma on record. It was the kind of aura that penetrated even the sonic record. Originally an organist trained in pulling out stops to energize various ranks of pipes to achieve sonic effects, Stokowski handled his Philadelphia Orchestra (and every orchestra since) with the same expertise. He literally called himself a sonic painter, and after building the sections of his orchestra with the same precision ranks of organ pipes would be constructed, he introduced the most exotic orchestral sound ever known in performances of compelling persuasion. He was strongly aware of acoustic properties of auditoriums and their contribution to orchestral sound perception, and although not a trained scientist, he instinctively knew what to modify to correct sonic flaws and enhance projection. His recordings (a 60-year history) have all been attendant to his innate sense of sound. He directed microphone placement when certain orchestral elements required reinforcement and even introduced dynamic variations into his recordings electronically after the initial taping was completed. No patience for temperament, his ship was operated efficiently. On stage was the time for creating a visual mood—in the recording studio, we work.

Arthur Rubinstein enjoys the good life, including the best cigars—this one during a break in his recording in Rome in 1965.



Although Arturo Toscanini had little awareness of recording devices (he blamed himself for taking the wrong tempo if a turntable was off speed), he was fascinated by the new 45-r/min discs in 1950.

But the atmosphere of work pervades the recording of great artists. It is always an object to be accomplished and therefore pursued with the conviction he gives to all his pursuits. From those assisting him he wants immediate efficiency and the same concentration of effort he commands from himself. Most do not like to record. It is a totally foreign environment—no audience, an unyielding studio, unresponsive microphones, recording devices with total memory (that's perhaps the worst). But the challenge is there, and it must be met and done as well as the other challenges in their lives.

In general, the great artist is the easiest to work with. He's secure, prepared, arrives promptly, and works hard. He tends to blame himself rather than a recording process (although Mischa Elman accused me of having a special microphone for Heifetz' E string), and he keeps trying for his own unique performance. Exception: it wasn't a good idea to play back during a session for Toscanini—he'd get depressed and leave. Generally, a great artist doesn't listen to his own recordings once they are finished and on the market. Artistic expression is an elusive function of the moment, and a recording is always the same. They are constantly restudying their repertoire and finding ex-

panded meanings. Vocal artists, however, generally enjoy their recordings, because, I suspect, a properly edited recording can give them a sense of having captured their vocal production in its true estate. Some artists look at recording as a special performance designed for the living room rather than a concert hall. They recognize that repeated auditions are implicit and any recognizable flaw will take on undue prominence, working ultimately against the enjoyment of the composition.

Some performers view recording with fascination, however, but it's more technical than aesthetic. The idea of accomplishing some desirable artistic purpose through recording that would at best be problematic in performance is a source of increased power. Tape and its splicing facility, tracking various musical elements in sequence, and the array of sound-manipulating devices have led to delusions of artistic grandeur. All these technical tools can enhance an expression, but they can in no way create one. Fortunately, the elusive act of creation still, and probably always will lie in the psyche of the human performer.

But recordings are a vital adjunct to the performing artist's career, not only as a permanent document of his creative personality, but to reach audiences that may not have access to personal appearances. They also furnish the artist with supplementary income. Caruso's records were a major source of his income and even gave Victor a gross income of 2.5 million per year in the early 1920s. Vladimir Horowitz bought his New York town house with royalties from his recording with Toscanini of Tchaikovsky's First Piano Concerto. And the great artists of popular music have profited astronomically from a few hours in the recording studio.

Even though art is the great artist's motivation, there is no absence of business sense. It seems to be another characteristic they have in common. They all realize that the consumer appreciation of a product probably lies in direct proportion to the price he pays to enjoy it. The great Russian bass Feodor Chaliapin was asked to sing at a social gathering and when informed that there would be no fee, replied, "Only the birds sing for nothing." Which is not to imply that great artists, or lesser ones either, do not contribute their services for a wide variety of charitable and benefit purposes. If Heifetz had received a fee for all the benefit concerts he gave for U.S. troops during World War II alone, his financial life would be much more secure. In one war bond concert in 1943 given by Toscanini and Horowitz, eleven million dollars in bonds were sold. Benefit appearances are a necessary part of an artist's life, and certainly the greater the artist, the greater the benefit.

Fees are broadly regulated by the stature of an artist, and his management usually negotiates them with orchestral associations and concert presentation organizations. Artists are sometimes contacted directly for special personal appearances, and their personal feelings are given an opportunity to express themselves. The great violinist Fritz Kreisler was asked many years ago to play at an official dinner at the White House, the story goes. Since his participation was an artistic one, he was asked his fee. He responded that his usual fee was $5000, but if he was expected to mingle with the guests, it would be $10 000. He was known to be a very private man.

In recent years some of the most prestigious artists have been presenting themselves. They retain a management that receives a percentage of the gross to arrange details, book concert halls, and decide with the artist on the scale of ticket prices. Another cut goes to the hall for rental and advertising, and the rest, about 75%, goes to the artist. He, of course, takes the risk, but recognizing his own capacity to draw a large crowd, a great artist can always walk away with a substantially better check than just a guaranteed fee. Horowitz is the most successful of the classical artists who take such a risk—small risk, for he never plays to less than a full house. He can gross in twenty-five concerts a year what it would take some other pianists a hundred to make. Possibly he generates four times the musical excitement in his concerts. In any event, he's well worth the price of admission.

Other artists have incorporated themselves, collecting production teams that produce concerts, recordings, and television programs. Leonard Bernstein, the great conductor and composer, is the commodity of his own corporation, and it is an eminently salable product.

These new jet-age methods of concert organization take cognizance of the popular recognition of an artist and allow him the freedom to profit financially in proportion to his stature as a public figure. The literal jet age, though, is not beneficial to all artists. In the past, boats and trains gave them periods of enforced repose between engagements to collect their creative juices and gradually adjust to different time zones which affected their biological rhythms. This was especially necessary to vocal artists

Leontyne Price has a charisma that projects her great art into the soul of her audience, both in person and on records.

whose physical powers were (and still are) taxed excessively with each performance. Today, however, artists can perform around the world in the space of a few days. And some do. The criticism some vocalists receive, even from their colleagues, for accepting engagements in close succession at various points on our globe appears justifiable, but a singer's psyche is constantly bombarded by one major concern—*La Voce*. The Voice (never "my voice") exists as a curiously disembodied entity with a completely detatched life of its own. Singers know that time and associated age are the voice's adversaries, and many feel that they must take advantage of it while it is at the peak of its prowess. That this contributes to an early decline of vocal quality and control is the contention of many singers, critics, and knowledgeable bystanders. But evidence aside, the motivation of the true arist is a personal involvement. He got where he is without a fear of the evidential probability that he wouldn't. So he makes his own decisions based on the instinct that brought him to the apex of his profession.

Does he really *know* everything there is to be known about his art, his instrument? Or does he work purely on instinct? Landowska, one of the great scholars of her art and the harpsichord (she specified the operational characteristics for the modern instrument), emersed herself in the cultural and artistic milieu of the composer and his time, meticulously worked out registration, fingerings, dynamics, tempi, ornamentation. Then, as she simplified it, "I forget it all and just play."—meaning, I suppose, that preparation and knowledge are vital grounding for the artistic temperament to communicate in sound but that the ultimate is from the soul.

Some of the statistics about an instrument we all accept as common knowledge can somehow mysteriously escape a great artist. Horowitz once received a note from Paul Muni thanking him for the compliments Horowitz sent after seeing him in a Broadway play, and he added, "But I'm sure I will never create the electricity you do seated at the 88." Horowitz didn't understand the reference, thinking it might have had something to do with an automobile popular at the time. He questioned his wife, Wanda (daughter of Toscanini), who felt sure it had something to do with the piano. Finally, their daughter Sonia rightly estimated that it referred to the number of keys on the piano and asked her father how many there are. "I don't know—I never counted them," he admitted.

The great conductor Pierre Monteux was unique as an artist but also in his preference for hearing his recordings played back at "background music" levels. Richard Mohr, Producer, at left and Ray Hall, Engineer, at right. Boston Symphony Hall in 1953.

The strength of individuality expressed by great artists is a reflection of their certainty that what they are doing is the only thing that is right. Doubts? Yes, sometimes their instincts question the musical validity of a composer's instruction. But they know that composers of the past had different sounds in their ears, different audiences, concert halls, even different instruments to deal with. Modern translations of classical compositions written without awareness of today's sound potential must temper the composer's explicit directions to reveal the musical values implicit. Yet, there is often a struggle between judgment and notation. One profoundly significant one I observed was during the playback of Toscanini's recording of Beethoven's Ninth Symphony. We were listening to the final tape at his home in Riverdale, and he followed his score carefully, making no comment until we reached the slow movement. A thoughtful frown covered his majestic face, and he asked for a pocket metronome to check the tempo of his performance against that which Beethoven had indicated. He held the watch-like device close to his eyes and adjusted it while we played the movement again. He gestured to stop the recording and sat brooding for a long moment. Almost inaudibly he sighed and said, "Walter (Bruno Walter, a great conductor and interpreter of Beethoven) plays it at 66 (beats per minute). Beethoven wants 60. Mine is 60. Perhaps Walter is right." Another long probing pause and finally, with a resigned gesture, he said, "I'd rather be wrong with Beethoven." But it is certain that if he had strongly felt the faster tempo could express the music most effectively, he would have taken it.

When artistic judgment is not received with general critical approval, it is considered taking liberties with the score. Yet all artists filter the written dots and directions through their own personalities. Some great singers are notoriously free with note values and transpositions. Even the great Caruso transposed certain arias to a more comfortable range of his voice. He didn't have a very secure high C, and some arias calling for that sustained note would, at his request, be lowered a half tone or a full tone for performance. Yet no one ever suggested that his rendition of those arias was less than magnificent. Some singers (and other performers as well) exercise little musical judgment in their decisions to ignore a score instruction or invent a "personal interpretation" designed to show off a technical quality they possess at the expense of the music.

Of course the opinion of musical validity is a highly personal one, and there isn't an artist who was never subjected to critical barbs. Strangely enough, most negative comments great artists get from the journalistic critical community are in response to their recordings. It is almost as if more than one audition of a performance is

required for critics to find something to complain about. Great artists are sometimes prime targets for the insecure critic, especially record critics. It seems to give them a sense of power to try to reduce the stature of the giants. Of course they can't, and they succeed only in diminishing their own credibility by their exhalted comments. José Iturbi, a great pianist with an earthy Spanish perspective, compared such comments to monkeys climbing up trees: the higher they get, the better you can see their backsides.

This centennial of recorded sound pays tribute to the artist, great and otherwise. Although the great ones will be celebrated for consecrating their significance to a record groove, all artists—classical, popular, rock, country, soul, whatever the category—and their human artistic, communicative effort are recognized. If it touches another human and elicits a response, it has meaning. We hail the great artist for reaching wide audiences over long periods of time; we do not diminish those who may have only a moment of supreme glory. Perhaps consistency or longevity is a virtue, but we do not deny the art if it is fleeting and may never have seen the inside of a recording studio. Great artists are monumental exceptions. Their approach to every facet of art and life is peculiar to their indelible personalities. But they do not contradict the existence of those who have less intense and less visible, or audible, manifestations of their art. But we do give great and profound thanks to the great artists for touching perfection in their art and giving us, in addition, the courage to hope for a movement away from mediocrity—in life as well as art.

Records of the Future

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The nature of our future phonograph records will probably be tied strongly to future technical innovations. Right now the most dramatic technical change for the long term would seem to be digital audio. The concurrent evolutions in computer technologies and consumer video recording might point to the advent of digital audio records. This paper outlines the possibilities in general terms.

INTRODUCTION: In any discussion of what records of the future might be like, it would be awkward to avoid also discussing the future of recording and its allied technologies. Involved are such subjects as how will recording take place, in what form will the sound be written down, how will the artists and music be affected, how will the sound be processed as it is recorded and when it is played back, etc. Indeed, these issues will play an important role in shaping our records of the future and vice versa.

However, the central and most intriguing question remains—what will the records themselves be like? What will be their size and shape? What and how much will they contain? What will be their quality? How long will they last? How will they be manufactured and packaged? How will they be distributed and sold?

If one looks to history for answers to these questions, the general trend seems surprising but clear. Records have not changed in any really basic way since the turn of the century. In fact, Emile Berliners' disc record has been one of man's more robust inventions. And why should we expect things to change more rapidly between now and 2050 A.D. than they have been? It is quite possible that they might not, but on the other hand, there are some strong forces that suggest that they will, and in a very radical way.

The most obvious of these forces is the emergence of digital audio and the development, in several forms, of the concept of the video disc. Coupled with others, these forces have induced much speculation in the audio industry concerning the advent of a digital record. In fact, many believe that such a record of the future is inevitable the remaining question being when will it be introduced. In an attempt to clarify this matter, the following presents a conceptual summary of how digital audio and the recording industry might interact.

DIGITAL AUDIO

The use of digital methods for processing and recording music quality audio has been receiving rapidly increasing attention since about 1970. This society has included technical sessions concerning digital techniques in its regular conventions with increasing regularity. A complement of products employing digital signals are now available in both the consumer and professional markets. Such products include delay systems, time base manipulators, reverberation units, and (more recently) recorders. That at least some of these systems have been employed in the making of conventional recordings is a foregone conclusion. Moreover, some recordings have been released in which digital tape recording or sophisticated digital signal processing played a dominant role in their production.

Nevertheless, digital audio is still quite new. In this light, a brief description of what digital audio is and a list of its most important characteristics is in order.

Audio means sound in the form of signals, usually electric, magnetic, mechanical, or optical. Conventionally, these signals take on a shape in direct analogy to the sound waves themselves. Thus, the name analog audio. In order to form digital audio, analog audio is formed first. The analog audio waves are then sampled at a very rapid

and regular rate, producing a sequence of values. The act of sampling is identical to placing a set of points on a graph. Each value is then converted to numerical form, thus producing a *digital* sample. The more digits used for the numerical representation of a sample value, the more accurate the digital audio becomes. The sequence of digital samples is then concatenated into a sequence of digits. This sequence of digits is digital audio.

In order to hear digital audio it must first be converted into analog audio. This is done by reforming the digital samples from the sequence of digits, using each digital sample to control the successive outputs of a voltage generator, and then smoothing that output with the electronic equivalent of a French curve, namely, an electric low-pass filter.

It has long been well known that analog signals such as analog audio can be converted to digital form in the manner just described. What is most surprising about the fact is that, except for the use of a finite number of digits to represent each sample, the reconstructed audio can in theory be made to be *exactly* the same as the original, provided some very simple conditions are met. These conditions are that the audio signal be sampled faster than twice per cycle of the highest frequency component contained within it, and that the low-pass filter be ideal. In practice, these conditions can be approached with amazing precision, permitting the most rigorous audio fidelity standards to be met and exceeded. Furthermore, when proper methods are utilized, the effect of using a finite number of digits for each sample can be made to be wholly equivalent to the addition of signal-independent random noise, the amplitude of which can be forced to any desirably low level. In practice, noise levels less than 90dB below maximum signal levels have been routinely obtained.

The task of instrumenting high-quality conversion of analog audio to digital audio and back again is not a trivial one. A great deal of care must be taken to avoid about a dozen subtile engineering pitfalls. Some of these pitfalls have caused misunderstandings to arise about the basic requirements for forming ultrahigh-quality digital audio. However, both theory and extensive experience and testing have proven the basic requirements stated earlier to be valid in practice.

In considering the characteristics of digital audio, one might ask: what is it good for? The most obvious answer is that it provides the highest quality method for the transmission, processing, and recording of sound. In fact, the quality is *very* much higher than other known methods will provide. As a specific example consider that digital tape recordings have been demonstrated that cannot be distinguished from a direct connection to very-high-quality microphone sources, except for the brief delay encountered while tape travels from the record head to the playback head.

However, it may be that high quality is not the most important advantage of digital audio. Due to their discrete nature, digital audio signals can almost always be copied without distortion of any kind. The situation is comparable to copying written text. Since the number of standard characters used in writing is small, one can overcome degradation simply by reading the characters and writing them over again in standard form. Old disintegrating documents can usually be completely rejuvenated in this way without error. For digital audio each digit is a character capable of being copied in standard form with as small a chance of error as one wishes to select. What is more, vanishingly small chances of error can easily be achieved. The implications are obvious. If assembled using digital audio, recorded archives of sound need not suffer the degradation of time now responsible for the steady loss of valuable recorded material, both historic and musical. And when multiple copies of a recording are to be distributed, no difference between the 1 000 000th copy and the original need be expected. If the stability of archives and quality control of products are of any importance to recording companies, these issues should be of interest on a basis independent of the sound quality of the original material.

Another important advantage of digital audio is the complex signal processing it allows. Analog circuits are incapable of performing signal processing tasks beyond a certain complexity. This is so because analog circuits function in an imprecise manner. When increasing numbers of analog circuits are assembled for the performance of complex tasks, this imprecision accumulates to a point where the desired results can no longer be obtained. Many technically correct processing ideas have not found use due to this limitation. Digital audio and digital processors can change this situation and permit the exploitation of new ideas as well. The industry has already seen examples of this in the delay systems, time base manipulators, and reverberation units mentioned earlier. Some recent commercial restorations of old acoustic recordings by the author would not have been possible otherwise. The future promises even more sophisticated systems for use in both the recording studio and the home. In addition, the same technology which has produced programmable hand calculators may eventually permit the flexible reconfiguration of these systems by the user.

Still another promising area, now emerging, is the use of digital audio in psychoacoustic experimentation. The generation and control of high-quality test sounds of complex nature is made possible, and even simple, using digital audio. Answers to such questions as, "How much phase shift can really be heard?" or "What are the subjective effects of various forms of audio degradation and distortion when taken one by one in pure form?" come within practical reach. Even more important, the construction of large ultrahigh-quality libraries of recordings to be used in the testing of products for market acceptance becomes possible for the first time.

In addition to the above advantageous characteristics digital audio has some apparent disadvantages, at least for the present. The most important of these seem to be the large amount of storage space required to record using digital audio and the fact that digital processing and conversion circuits are complex and thus more expensive than typical analog circuits currently in common use. Fortunately, advances in technology, especially in the area

of integrated circuits and high-density storage systems, are changing the severity of these disadvantages. In fact, with time these disadvantages will probably be reversed and become advantages instead. If this happens, the advantage in storage space will become a very exciting characteristic indeed.

In order to clarify the storage space situation, consider an application involving ultrahigh performance. Assuming that a 20-kHz bandwidth with a dynamic range of 95 dB is to be sustained, one can quickly estimate the digit rate required. Suppose sampling is to be performed at 42.5 kHz to allow a practical margin beyond the required two samples per cycle of the highest frequency component. Also, suppose that binary digits are to be used as is common practice in digital electronics. This demands that 16 binary digits (bits) be used in each sample taken. We then compute the bit rate to be

$$R_b = 42\,500 \times 16 = 680\,000 \text{ bits per second.}$$

In turn, if an hour of stereo sound were to be recorded, the total number of bits involved would be

$$3600 \times R_b \times 2 = 4\,896\,000\,000 \text{ bits.}$$

This staggering amount of information would all have to be written in a small area if a digital record made in this way were to be practical. Even so, this quantity of data and more can, for example, easily be written on a 10½ inch reel of 1 inch instrumentation tape using today's off-the-shelf technology. Moreover, when recording is not required, such as in a processor for creating reverberant effects, only a small fraction of this quantity of information need be retained for processing at any given instant. This relatively modest requirement for storage is what has permitted practical processors to appear on the market before practical recording systems.

We will return to the subject of digital recording later. First, let us discuss the impact of digital audio on the present recording medium.

DISCS OF THE FUTURE

The audio disc as we know it will probably be with us for some time. It will undoubtedly continue to change in an evolutionary fashion. Some of these changes will be brought about by the advent of digital audio.

As we have already mentioned, digital signal processing is beginning to be used for the restoration of old recordings so that they can be re-released in an enhanced form. So far the object has been to remove the resonant and reverberant colorations which tend to hid the true musical content of acoustic recordings. Consumer interest in the results have been high. As the technology evolves, other forms of imperfection will become the targets for elimination. One obvious example is surface scratch which, strangely enough, is much harder to reduce in a musically acceptable fashion than is generally appreciated. As techniques advance, knowledge about music and the nature of human hearing seem to play an increasing role in the formulation of satisfactory restoration methods.

It is natural to assume that digital methods will play an increasing role in the production of newly recorded material as well as in the enhancement of old. In fact, a number of recordings have already been produced in Japan, by the Nippon Columbia Company, in which the audio signals were taken from the microphone up to the cutting lathe in digital form. Practical digital audio tape recorders are just now appearing. Their use in the recording, mixing, and mastering of conventional disc recordings is upon us. The advent of flexible, fully automated, digitized studios is a logical next step.

Besides permitting the more convenient and rapid production of records, digital recording and mastering can greatly broaden the availability of the high sound quality sought by consumers interested in the growing number of records made by recording directly onto the lacquer disc as the music is being performed.

As the synthesizer becomes more evident on the musical scene, digital signal generators are seeing increased use in their construction. And not far in the background is still another form of music making, called computer music. Computer music audio is constructed directly as digital signals, usually as the result of the efforts of a single individual who acts as instrument designer, composer, and performer. A natural evolution involving more of this kind of music on records of the future seems certain.

One can expect that the nature of discs will be changed by the advent of digital audio. The effect will be primarily in the quality of the sound and secondarily in the kind of music recorded. In addition, the effectiveness and speed with which discs are to be produced will probably be significantly aided using digital processing and recording. However, the full impact of digital audio on records will come by a route other than through the conventional disc.

NEW MEDIA FOR RECORDS

It is obvious that, if digital audio can be used to make conventional records, the digits can in principle be written directly onto a suitable medium, thus producing a digital record. Unfortunately, the practical problems implied are very difficult. The basic difficulty is, of course, the number of digits which must be written to form a single record. As we estimated earlier, an hour of stereo could involve as many as 5 billion binary digits. Even if this could be reduced by a factor of 5, which is unlikely if high-fidelity music quality is to be maintained, a billion bits is a large amount of information to be written on a surface or in a volume small enough to be used as a consumer record. Furthermore, the task of reading this large amount of information with a device simple and inexpensive enough to be sold as a consumer player is comparably difficult.

Nevertheless, there are several media now appearing in various stages of practical development which could support such digital audio records. Most of these have been developed not to further audio, but to produce a vehicle for recorded consumer television. Because television requires a very large bandwidth compared to audio, converting a video recording medium to high-quality

digital audio, which requires about 70 times the bandwidth of analog audio, appears feasible.

In geometric terms suppose we were to require that all 5 billion binary digits had to be written on 10 square inches of material. This would require 500 million bits to be written in each square inch. In a rectangular form this would mean writing bits on centers spaced about 25 000 to the inch. This is small but still twice as large as the average wavelength of visible light, and 10 square inches is equivalent to a square only slightly larger than 3 inches on a side. In contrast a 12-inch disc typically has about ten times as much surface area on one side, label excluded.

Depending upon how these technologies emerge and mature, as far as size and shape are concerned, one can envision digital records as anything from pocket-sized to approximately the same as current discs. It is not outrageous to imagine carrying several hours of music in a box the size of a deck of cards. As an extra bonus, it might be expected that such records be far more durable and resistant to wear than what has been known so far.

As far as playing is concerned, there will probably be little change from current practice. The present format is quite well adapted to the musical traditions as far as performance duration is concerned, and it seems fitting that records fit the music and not vice versa.

Not only will the records of the future themselves be different, so will their players. It is logical to expect a playback unit similar in cost to a present-day medium- or high-quality turntable. Prototype players for the playback of home television recordings may provide some guidance to the possibilities. Indeed, one might expect a more compact unit than is presently common to match a possibly more compact record. Of course, such players would be compatible with current electronic and loudspeaker systems as players for LP records were in the late 1940s. However, in contrast, the players for digital records would not play conventional discs.

Providing further advancement is the very excellent possiblity that players for digital records would contain, at least in more sophisticated models, digital processors capable of manipulating the sound in far more elegant ways than present electronics will allow. It would seem advisable that auxiliary information be written on the record to help guide such processing, at least to the extent of permitting flexible automatic cueing.

It goes almost without saying that technical changes of this order would have a profound effect on such equally important issues as manufacturing, packaging, distribution, and sales. In fact, it is pragmatic to assume that the advantages and disadvantages in these areas will have a stronger effect upon the nature of these records than technical factors. The tradeoffs are not presently obvious. For example, a smaller record might be much easier to distribute, display, and handle; but it could cost more to make. And what about quality? Will better audio quality, yes, even very much better audio quality, sell significantly more records? And what about the effect upon music and the artists? If we do see a dramatically new vehicle for records, will it alter the traditions of performance and composition in the same way as the pocket and automobile radio?

No matter what the answers to these questions might be, it is clear that audio has a more exciting future coming up. The potential for creativity and innovation is high on all fronts, presenting a challenge for growth to all members of the profession from artist to retailer.

100 Years of Phonography

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For many inventions 100 years have passed since their origin and publication. Many of them have fallen into oblivion; many are long dead and only valued among experts; and there are some that are still very much alive. No wonder that for them a 100th anniversary is a special occasion to commemorate them all over the world. The invention of phonography is among these successful events.

It is often said that success has many fathers and failure is an orphan. It is similar with inventions—in general it is the person that realizes an idea who becomes a celebrity and not the pioneers or those who failed to realize what might have been a good concept. Yet, the person who will be praised as inventor later on may have learned a lot from the pioneers' mistakes. The names of Bell, Bourseuil, and Cros, who executed an essential part of the preliminary work, must be included in the history of phonography, but the actual founders of practical phonography are Edison and Berliner.

For good reasons, posterity hails Edison as the man of genius for two of his most outstanding developments: the electric bulb and the apparatus for recording and reproducing sound. Even though they were chiefly rolls (cylinders) with vertical recording that came on the market during the early years, Edison already suggested the disc record, a plane sound carrier. Edison, like many other indefatigable geniuses, seemed to have been content with the solution of the principle, and he seemed to have become so totally engaged in solving the problem of the bulb, that he did not pursue further development himself. The credit for anticipating the disc record as a suitable mass medium for the supply of artistic information and for making decisive proposals to realize his idea is due to Emile Berliner. He recognized the advantages of lateral recording, which he did not invent but introduced (thus lateral recording has been called "Berliner recording" in his honor). He gave instructions on the principle regarding the stamping procedure, and he submitted his first ideas on copyright. So in posterity's view it is more the practitioner Berliner than Edison who is considered the father of phonography, although the basic solution originated from Edison.

In reviewing the progress realized within 100 years, it might sometimes be difficult for us to understand and appreciate the realization of that new and—according to the status of technique of that time—imperfect invention. No doubt that the audience must have been interested and taken pleasure in it, though it was also able to hear and recognize the discrepancy between the original music and its recording. Today we can only sense the astonishment at the miracle of capturing and reproducing sound and understand why it was more intense than criticism, and why imagination was stronger than reality.

The copy of a speech which Berliner made at the Franklin Institute in Philadelphia in May 1888 has been preserved. It is testimony to his honesty in that he named Charles Cros to have been the first who had the practical idea to record and reproduce sounds. But nobody had known of it in his time. Cros, who was obviously short of means, confined himself to deposit his lines of reasoning in a sealed letter at the French Academy of Science. When the letter was opened in December 1877, Edison had already made a name for himself with his phonograph. Anyway, the name of Cros is still alive in our conscience. There is a coveted record prize in his name in France.

The important stages of the ensuing evolution can be briefly summarized. The introduction of electroacoustics in the 1920s opened a door that allowed at least the sound source to be freed from its constriction in front of the acoustic horn. This was immense progress, but in view of the standard of linear and nonlinear distortion, bandwidth, and noise level that was attained, it was rather a request for improvement than a satisfactory solution. Nevertheless, the fact that leading musicians of that time spoke of recordings being "true to nature that cannot be surpassed any more" makes the descendent waver between shaking his head and being touched.

The next important step was made possible by P. Goldmark's proposal to introduce plastics as carrier materials leading to a sound track the geometry of which could be considerably reduced, thus permitting increased playing time. In this connection it was not only a door that was opened, but a wall that was demolished. The immense improvements that were realized during the following years are based on this idea. The stereo technique that has now been practiced for two decades offers the possibility of a sound source which can be increasingly adapted to our biologically-rooted hearing ability, provided the apparatus now available is used appropriately. This applies mainly to space-limited rooms, and the medium has been tailored to this purpose. The margin that was realized by this technique was and still is sufficient to develop medium-specific recording practices and a sound culture which, according to artistic laws, liberate the product from being just a substitute for the concert hall.

No doubt it is more worthwhile and especially more spectacular to clear away gross defects than to do the polishing up that remains. So we cannot deny that the field of development of economically interesting activities is limited accordingly. On the other side, inactivity is dangerous, so the search for new ways is understandable.

The writer has already tried to explain elsewhere that quadraphony does not belong to these new ways, and he has also pointed out the cons of quadraphony. As it has turned out, up to now he seems to be right.

When speaking of phonography one can no longer refer only to the disc record. There is also magnetic tape which serves as an auxiliary means and which becomes more and more a rival of the disc. At the turn of the century, the Danish engineer Poulsen had developed a method of magnetizing a steel wire in the rhythm of speech waves. This method, too, has had predecessors, and the names which are connected with its further development are only known to insiders. But its usefulness was achieved only in the 30s, when activities with magnetic tape instead of wire proved successful and, moreover, with the invention of the ring head by Schüller and of high-frequency biasing by von Braunmühl-Weber.

Since that time magnetic tape has become necessary as an auxiliary means of the disc record: direct recordings without the use of magnetic tape have become impractical because they lack the advantages of immediate control and correction. The technique of an amplitude-dependent groove distance (spacing) with an optimum increase of playing time, which is applied all over the world, was perfected relatively late, the original idea of a magnetic tape having been formulated in a patent specification in 1928. (Here the Deutsche Grammophon Gesellschaft has done the pioneer work.)

On the other hand, tape has also virtually become a competitor of the disc record, since the introduction of the cassette. Its small dimensions and easier handling as compared with the disc record permit mobile use and make it more and more popular. Due to the Dolby system the quality of cassettes is continually being improved in an attempt to live up to that of the disc record. This system permits especially an improvement in the signal-to-noise ratio and thus the bandwidth. In view of given price considerations and tape properties, the original defects chiefly came from the small dimensions of the cassettes and the playing time desired. There is one thing that cannot be denied: up to now the disc record is still unbeaten when its high reproduction quality is compared to its cost of manufacture.

Whether or not the disc record will be replaced by another sound carrier surely has no bearing that is detrimental to the phonographic concept. The essential thing in this connection is, of course, the information itself and not the carrier of the information. Although the disc record stands for an extremely popular presentation of artistic activity, we cannot shut our eyes to the fact that the technique is also ruled by a kind of biological regularity: successful renderings of a technical idea are often replaced by a better adapted new invention before they have reached their culmination point—otherwise there is the risk of dying out.

However, in this connection there can be no question of dying out; it is rather an instinctive want that is satisfied, and this may be worth some reflection. In a comparable space of time other important inventions affecting people are, to name but a few, the development of the locomotive engine by Stephenson, the development of the combustion engine by Otto, the discovery of the dynamo electric principle by Siemens, and of the electromagnetic waves by Hertz. Today the most important branches of industry are based on them. Their objective is chiefly of an economical nature, and this is what differentiates them from the structure of business generally called the "phonographic industry." Of course, the inner structure of any activity must have an economically-oriented core. But the purpose of this activity is solely to give the customer a chance of acquiring pleasure and enjoyment, which people desire. So it is not a matter of selling tangible goods (the necessary instruments excepted), but of idealistic goods, of artistic information, and even of illusions. The trends of taste in the cultural field of the Western hemisphere have a joint basis, and since music—for it is music that is involved, music of all shades and artistic diversity—hardly makes demands on the intellect to produce an effect, but satisfies the emotional need, its success in the world is unique. There is nothing that might "sell" more easily than emotions which, free from any linguistic barrier, find so many receivers by many different channels. Moreover, it is the interpretation and the interpreter that play an important role, too. The range of contemporary people's taste seems to be wide enough to make not only new creations popular, but to give specific attractiveness to existing and famous compositions. So the emotional satisfaction and necessity of interpretation are equally essential roots not only of the public musical life, but also of phonography. When using these in "marketing," specific temptations are included which, however, as success has shown, have not affected the original longing of man for inward pleasure. As long as this attitude of man prevails, phonography will continue to flourish, whether with new technical realizations or with those already existing.

The White House Record Library*

Centennial Issue...

Foreword

In 1969, the Recording Industry Association of America (RIAA) offered to provide the White House with a collection of American recordings to reflect the wide range of American interest in recorded music, as well as drama, prose and poetry. The RIAA also offered to provide the necessary record-playing equipment. The Library and equipment would be an official gift to the White House.

Mrs. Richard Nixon was enthusiastic about the offer and proposed it to the Committee for the Preservation of the White House, the official body that oversees the historical preservation and development of the First Family's home.

With the Committee's concurrence, Mrs. Nixon announced plans for a White House Record Library in January 1970. It was also decided that a duplicate of the White House Library collection would be established at another Washington location so the public could enjoy the recordings.

To make the selections, Mrs. Nixon named a special commission of five members, each with expertise in a particular field. The Commission began its extensive research in the spring of 1970, working with selected advisors.

At a presentation ceremony in March, 1973, Mrs. Nixon accepted the Library on behalf of the White House Historical Association, and another historic legacy for future generations was added to the White House.

Classical Recordings

For the purposes of the White House Record Library, "classical" may be defined as, broadly speaking, whatever does not qualify under the headings of popular, jazz, folk or spoken word, the other four categories represented in the total collection.

Yet it could not, and still be representative of the country in which it has emerged, exclude such popular works as George Gershwin's "Rhapsody in Blue," or the spoken word in Aaron Copland's "Lincoln Portrait," or a jazz-based work such as Darius Milhaud's "Le Creation du Monde," or the kind of folk qualities embodied in Robert Russell Bennett's "Commemoration Symphony" based on material of Stephen Foster. What affiliates all these works is their inclusion in what is, generically, a concert hall repertory.

Everything included herein is designed as part of a functional, listening collection, one intended for the pleasure of the occupants of the White House, whoever they might be. If five of the last six such occupants may be considered typical, this would include not only a President and his wife, but children as well. It is not a collection of esoterica, rareties or historic materials. Within view of White House itself is one of the world's greatest repositories of such materials, the Library of Congress. Why presume to duplicate what can be found in abundance so close by? At the same time, it is a fair guess that, if a President were moved impulsively to provide pleasure to a dinner guest with music from his native land, he will find herein something appropriate to almost every major nation.

Generally speaking, it has been the collector's intent to seek out the most "highly recommendable" version of any selection deemed worthy of inclusion. But narrow considerations of scholarship have not been allowed to outweigh in importance the claims of common sense. There may, for example, be a version of Bizet's L'Arlesienne suites which enjoy some slender superiority over those performed by the Cleveland Orchestra under the direction of George Szell. But this record provides on its second side an outstanding performance of Edvard Grieg's Peer Gynt music. Taken together, the two sides provide a happy solution to a double problem while by-passing duplication of either.

For this among other reasons, the quantity of selections in the classical collection is rather more than two thousand, as couplings have been chosen wherever possible to provide diversity without duplication. It may also be noted that operas are, in the main, presented in the form of abridgements or excerpts. It is the reasoning of the panel chairman that a President will rarely have the opportunity to devote two or more hours of listening time to a single work, and that shelf space could be utilized to greater advantage by stressing variety rather than length.

Nothing has been included simply because it is written or performed by an American musician, nor has anything been barred for that reason. In instances of substantially equal interpretative excellence, favor has frequently though not invariably gone to native performers and orchestras. It is, inferentially, their House as well as yours and mine, and the pride of sharing a place within its walls should not be granted or denied for chauvinistic reasons.

Irving Kolodin

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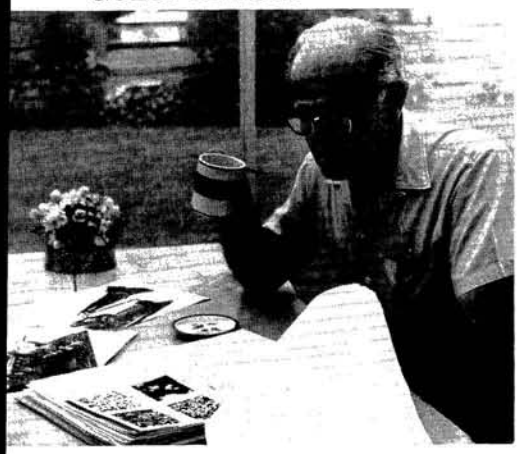
Centennial Issue...

GUEST EDITOR:



Warren Rex Isom was born in Mitchell, Indiana. He received a B.S. degree from Butler University, and masters degrees from the George Washington University, and Harvard University.

He had been in the engineering department of RCA since 1944 and held the title of chief engineer of RCA Records from 1966 until his retirement in 1976. He is technical advisor on sound recording matters to the United States National Committee of the International Electrotechnical Commission. The professional career of Mr. Isom has encompassed the field of recording including work on wire, film, magnetic, Kinescope, predetection space and disc recording. He holds 21 United States patents in the field.

A member of Phi Kappa Phi and President of the Audio Engineering Society for 1976/77, Mr. Isom holds membership in the Institute of Electrical and Electronics Engineers and the Society of Motion Picture and Television Engineers. He was named an Engineer of Distinction by the Engineers Joint Council.

Maurice L. Alexander was born in Mansfield, Illinois in 1913. At the University of Illinois he assisted in experiments on television scanning systems. He received a B.S. degree in electrical engineering in 1934, then worked for Philco in the field until 1941. He later joined Farnsworth Television and Radio Corporation as senior engineer in automobile radio design, working on practical applications for the ratio detector circuit and used it in one of the first FM automobile receivers. He developed the first successful signal-seeking automobile radio for Chevrolet.

Mr. Alexander joined the Crosley Division of Avco Manufacturing Corp. in 1951 as manager of their receiving and picture tube plant in Batavia, Illinois. He established a laboratory for making transistors and a pilot plant for producing color tubes, both shadow-mask and chromatrons. He was later named radio and television product manager. In 1956 he joined the Magnavox Company as manager of the color television manufacturing plant in Evanston, Illinois. He was later named quality control manager for the Magnavox Company of Tennessee, then product engineer, chief radio engineer, chief electronic organ engineer, and chief engineer for monochrome TV and remote control. He has been assigned to the area of competitive analysis since 1968.

•

William S. Bachman was born in Williamsport, Pennsylvania in 1908. He graduated from Cornell University in 1932 with an E.E. degree. In 1934 he joined the radio receiver engineering department of General Electric Co. at Bridgeport, Connecticut, where he worked on loudspeakers, receivers and phonograph combinations. He designed the General Electric variable reluctance pickup and received the Coffin award for work on feedback amplifiers. In 1946 he joined Columbia Records as director of research. In this capacity he contributed to the development of long-playing records, the heated stylus master recording technique, viscous-damped reproducer arms, and program-controlled groove spacing equipment. In 1960 he was appointed vice president for engineering, research, and development. He has served as chairman of the engineering committee of the Recording Industry Association of America, and as a member of the standards committees of the Audio Engineering Society, Electronic Industries Association, and

Trident, London, United Kingdom (Centredisc Limited): Trident companies operate recording studios, mobile broadcast-standard video units, static television studios including full video postproduction editing and film-to-video conversions in all standards; manufacture electronic equipment including mixers etc.; and are involved in record production, music publishing and artist management.

U.S. Pioneer Electronics Corp., Moonachie, New Jersey (Pioneer Electronic Corporation): Distribute consumer high-fidelity equipment and components for home, semiprofessional or studio use manufactured by Pioneer Electronic Corporation, Tokyo, and U.S. Pioneer. Products include loudspeakers, turntables, reel-to-reel tape decks, cassette decks, headsets, amplifiers and preamplifiers. The company started in Japan in 1938 and was incorporated there in 1947 as Fukuin Denki Kabushiki Kaisha. In 1961 it became Pioneer Electronics Corporation. Its United States subsidiary was established in 1966 and became known as U.S. Pioneer Electronics Corporation in 1970.

United Recording Electronics Industries (UREI), Sun Valley, California (A subsidiary of United Recording Corporation, Hollywood): Manufacture of audio signal processing and audio measurement equipment designed for sound recording, broadcasting, commercial sound and public address systems. Products include peak and RMS limiters and compressors, graphic and parametric equalizers, active and room equalization filters; response measuring systems and plotters; Time Aligned™ studio monitor loudspeakers and crossover networks. A division, Teletronix Information Systems, manufactures specialized hardware and software libraries for dissemination of pre-recorded information by telephone. UREI was established in 1958.

White Instruments, Inc., Austin, Texas: Design and manufacture of package equalizers, plug-in equalizers, both narrow-band and broad-band filters, passive as well as active filters and real-time analyzers for use in equalizing sound reinforcement systems. Established in 1952.

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ture, and broadcast studios. The company also maintains a studio in Hollywood, California, for the sale and demonstration of a complete line of professional audio equipment for recording studios, sound contractors and broadcast studios. Founded in 1964.

Stanton Magnetics Incorporated, Plainview, New York: Design, manufacture and production of professional phonograph cartridges, the company's main product. Research is devoted to professional and consumer audio fields. The firm also manufactures headphones, turntables, arms and other accessories.

Studer Revox America, Inc., Nashville, Tennessee (Formerly Willi Studer America, Inc.): Sale and service of professional and high-fidelity audio products manufactured by Willi Studer Firma, Regensdorf, Switzerland. Products include Studer tape recorders, mixing desks and power amplifiers and Revox brand high-fidelity stereo components.

Studio Maintenance Service, Inc., Santa Monica, California: Design and build recording studios and associated installations, as well as maintain existing systems. Sale and service of major brands of audio and video equipment. Representatives of Trident Audio Developments consoles on the U.S. West Coast.

Sunn Musical Equipment Company, Tualatin, Oregon and Williamstown, Kentucky (Hartzell Corporation): Design and manufacture of professional musical amplification equipment and sound reinforcement equipment, including preamplifier audio mixers, power amplifiers and loudspeaker system components.

Superscope, Inc., Sunnyvale, California: Manufacture and distribution (with its subsidiaries and affiliates) of consumer audio electronic products. Since entering the industry in 1957 as exclusive United States distributor of Sony tape recorders, the Company has developed and expanded its Marantz and Superscope product lines to become a worldwide manufacturer and distributor of audio home entertainment equipment, including stereophonic and monaural audio tape recorders, stereophonic high-fidelity components, loudspeakers, microphones and accessories, and blank and prerecorded audio tape.

TEAC Corporation of America (TCA), Montebello, California: Marketing in the United States of open-reel and cassette decks (TEAC Audio series); mixers, recorder-reproducers, optional modules and signal processors for professional and semiprofessional music markets (TEAC Tascam series); tuners, amplifiers and other components (Accuphase line); high-end open-reel and cassette decks (TEAC Esoteric series); belt-drive and direct-drive Micro Seiki turntables; microphones, high-fidelity accessories and specialized sound reproduction equipment; and high-fidelity products for TEAC International (overseas markets).

Tandberg of America, Inc., Armonk, New York (Subsidiary of Tandbergs Radiofabrikk, A/S): Marketing in the United States of stereo products including reel-to-reel tape recorders, cassette recorders, receivers, tuners, amplifiers, loudspeakers, as well as electronic teaching systems (learning laboratories). Also, manufacture of 4-channel analog instrumentation recorders, and professional digital peripheral data equipment. Company was founded in 1933 and established in the United States in 1955.

Teledyne Acoustic Research, Norwood, Massachusetts: Research, design, manufacture and worldwide distribution of loudspeakers and turntables for consumer and professional market. Acoustic Research was founded in 1954 and became Teledyne Acoustic Research in 1967.

3M Company, Magnetic Audio/Video Products Division, Saint Paul, Minnesota: Design, development and production of professional audio recording tapes, studio mastering tapes and audio accessories, including polyester-backed, low-noise oxide magnetic tapes for general use, voice recording; high-output, low-noise oxide master tapes for both voice and music; low-print tapes with additional protection against print-through; and most recently, studio mastering tapes providing greater sensitivity and output to meet new hardware developments.

Scully Recording Instruments, Mountain View, California (Dictaphone Corporation, Audio/Electronics Division): Design and manufacture of professional tape recorders and reproducers, both mono and multitrack, for broadcast and master recording; communications and broadcast logging recorders, 1 to 40 track with digital time code generators and readers.

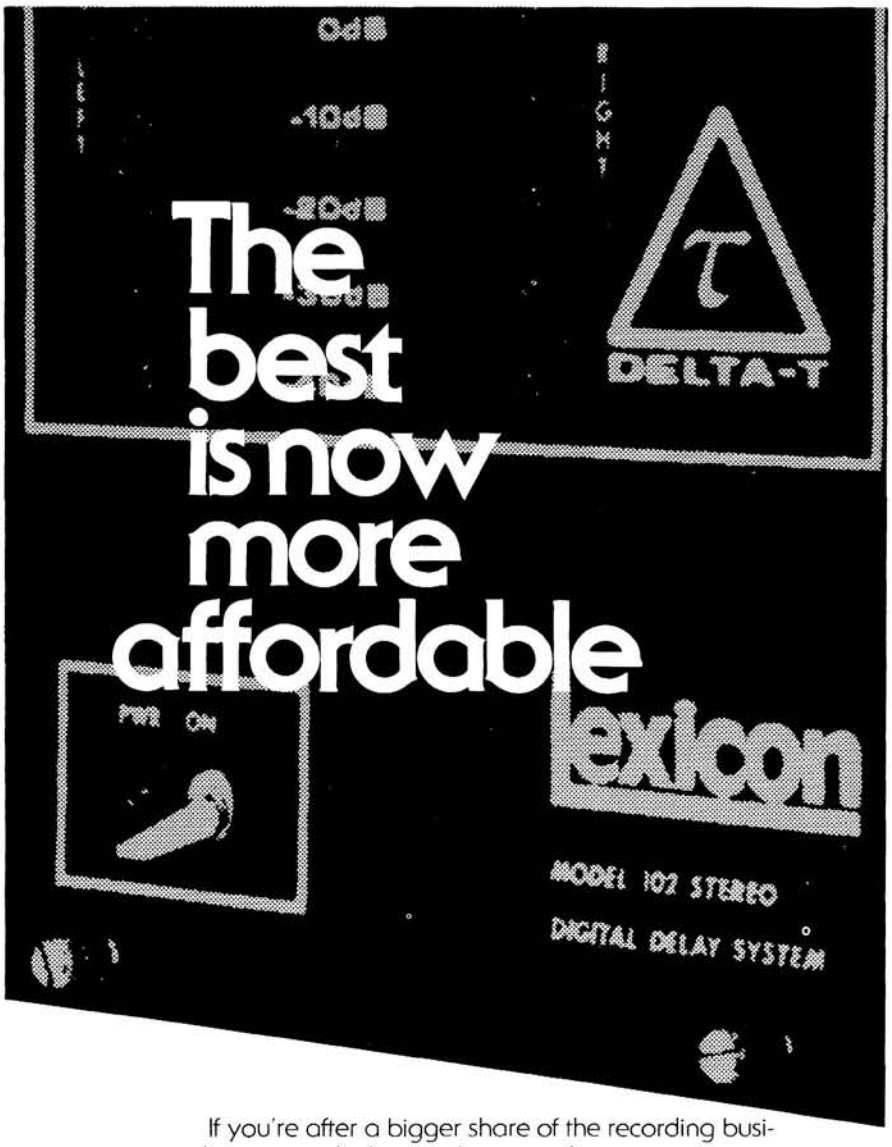
Sennheiser Electronic Corporation (N.Y.), New York, New York: Distribution of professional audio products developed and manufactured by Sennheiser Electronic K. G. of West Germany. Products include dynamic and condenser microphones and associated accessories, audio test instruments, studio monitors, loudspeakers and headphones.

Shure Brothers Incorporated, Evanston, Illinois: Manufacture of microphones for broadcasting, sound reinforcement, professional entertainment, professional recording and mobile communications; high-fidelity phonograph cartridges and components; sound systems; sound reinforcement consoles, amplifiers, equalizers, loudspeakers, professional and sound reinforcement microphone mixers, preamplifiers and other electronic components. Founded in 1925.

Soundcraft Electronics Ltd., London, United Kingdom: Design, manufacture and distribution of professional sound mixing consoles for recording studio, broadcast, and sound reinforcement use.

Soundolier, Inc., St. Louis, Missouri: Design and manufacture of commercial sound products including loudspeakers, baffles, enclosures, power supplies, telephone systems, audio masking systems, equipment cabinets and other accessories for the commercial sound field. Established in 1956.

Spectra Sonics, Odgen, Utah: Design and manufacture of professional audio amplifiers, power amplifiers, microphone/program equalizers, electronic filters, compressor/limiter systems, attenuators, quadraphonic pan controls, regulated and unregulated power supplies, audio control consoles, and sound reinforcement systems; professional quality audio products for recording, disc mastering, motion pic-



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Polygram Record Group, New York, New York (Phonogram, Inc., Polydor Incorporated, Phono-disc Incorporated): Production, marketing and distribution of phonograph records and tapes. Formed in 1972.

Media Services Section, Public Service Commission of Canada, Ottawa, Ont., Canada: Provide technical and pedagogical support through audio-visual means to assist the training activities performed by the Staff Development Branch for the Federal Government of Canada. Services provided include design, development, technical realization and reproduction of original audio-visual software from a client's script. Responsibilities include concert and conference recordings, quality assurance of software and hardware, and maintenance and repair services for all audio-visual equipment used by the Staff Development Branch.

RCA Records, New York, New York (The RCA Corporation): Engaged in all aspects of the recorded music business, extending from research, development and engineering of recording studios, recording equipment and techniques, studio techniques, mastering facilities and mastering, production equipment for its factories and distribution equipment for its warehouses, and quality monitoring of product activities for each of its principal product lines.

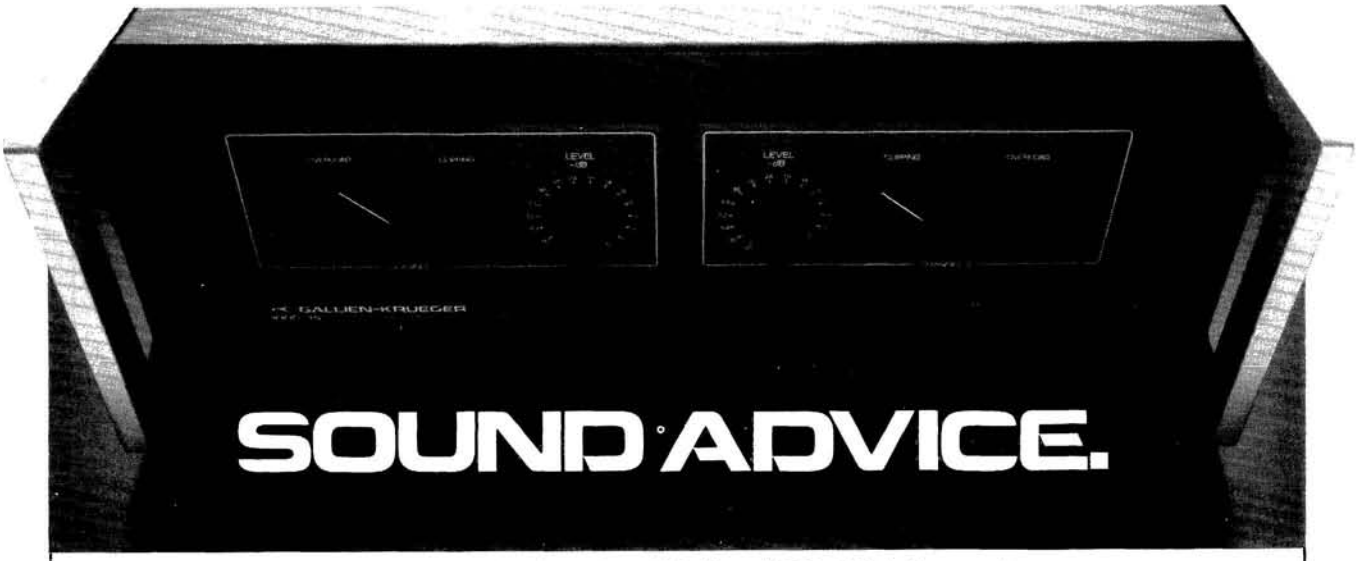
Rauland-Borg Corporation, Chicago, Illinois: Development and manufacture of professional audio systems and components, including amplifiers, mixer-amplifiers, equalizers, and loudspeaker systems; industrial sound equipment; school sound centers; administrative telephone systems; intercom systems; and communications systems for health care facilities. Started in the 1920s, the company assumed its present name in 1948.

Roanwell Corporation, New York, New York: Design and manufacture of voice communications terminal equipment such as handsets, hand-held microphones, standard and miniature headsets, secure voice telephones, vocoder handsets and related apparatus. Equipment is furnished with either conventional or noise canceling (Confidencer®) microphones, to the telephone, television, radio and government communications markets. Established in 1948.

SME Limited, Steyning, Sussex, United Kingdom: Design, manufacture and marketing of phonograph pickup arms for professional and consumer use. Started in 1946, the company assumed its present name in 1959.

Sagamore Publishing Co., Inc., Plainview, New York: Publishers of *db—The Sound Engineering Magazine,* a monthly publication devoted to the professional audio industry, as well as technical books for those working in the audio engineering field.

Scenic Sounds Equipment, London, United Kingdom: Market and service of professional audio equipment to the European recording, broadcasting and industrial electronic sectors. Products include the professional range of dbx Inc., Schalltechnik Schoeps, MICMIX Inc., Orban/Parasound, and control room and studio acoustical design services of Eastlake Audio S.A.



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Martin Audio/Video Corporation, New York, New York: Design, marketing and service of custom-design recording studio hardware, and audio-video components; marketing parts for electronics and industrial industry. Founded in 1964.

National Public Radio, Washington, D.C.: Nationwide U.S. interconnected public radio system, with more than 200 noncommercial public radio stations, serving communities in 40 states, Puerto Rico, and the District of Columbia. Programs are distributed to member stations by long-lines interconnection and tape; a domestic satellite distribution system is now in the development stages. NPR was established in 1970.

Georg Neumann GmbH, Berlin, Germany: Manufacture of transistor condenser microphones and accessories, disc-cutting equipment and accessories, mixing console units, mixing consoles and video disc-cutting equipment. Established in 1928.

Rupert Neve Incorporated, Bethel, Connecticut (Subsidiary of Neve Electronic Holdings Limited of Cambridge, United Kingdom): Exclusive U.S. sales and service representative of the Neve group of companies, who manufacture sound mixing consoles and processing equipment for broadcasting, music recording and film facilities. The Neve organization was founded in England in 1962, and incorporated in 1965; Rupert Neve Incorporated and Rupert Neve of Canada Limited have been marketing their products in North America since 1971.

The Orange County Electronics Corporation Ltd., Winnipeg, Manitoba, Canada: Design and manufacture of audio processing and monitoring equipment including compressors, limiters, expanders, parametric equalizers, stressors, monitor amplifiers and professional monitor systems. Founded in 1972.

Otari Electric Co., Ltd., Tokyo, Japan: Manufacture of professional studio tape recorders, high-speed tape duplicating systems, cassette copying machines, quality control monitor players, magnetic audio tape loading machines, and video tape loading machines.

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national): Design and manufacture of loudspeakers and loudspeaker systems, mixers, power amplifiers and accessories for studio, sound reinforcement, musical instrument and home entertainment systems. Established in 1946.

Jensen Sound Laboratories, Schiller Park, Illinois: Design, manufacture and international marketing of loudspeakers and loudspeaker systems for home, automotive and citizen-band radio use, and of a line of stereo headphones. Established in 1927.

KEF Electronics Ltd., Tovil, Maidstone, Kent, United Kingdom: Research, design and manufacture of loudspeakers, drive units and complete loudspeaker systems for consumer and professional applications.

Knowles Electronics, Inc., Franklin Park, Illinois: Design, development and manufacture of subminiature electroacoustic transducers used as microphones and receivers in such applications as pocket pagers, dictating machines, hearing aids, telephone headsets, sound level meters and small transceivers. Founded in 1954. A subsidiary, Industrial Research Products, Inc., established in 1946, manufactures audio digital time-delay units for sound reinforcement systems and recording studios, as well as an anthropometric manikin and an eardrum simulator.

Koss Corporation, Milwaukee, Wisconsin: Design and production of high-fidelity stereophones for private music listening and electroacoustic products for consumer audio use.

Kustom Electronics, Inc., Chanute, Kansas: Design and manufacture of network sound reinforcement components, including professional mixing consoles, power amplifiers, bass loudspeaker cabinets, mid-high frequency transducers and horns.

Link House Publications, Ltd., Croydon, United Kingdom: Publisher of the monthly magazine, *Studio Sound & Broadcast Engineering,* which is concerned with all aspects of commercial recording, studio engineering, and related topics, and *Hi-Fi News & Record Review,* also published monthly, devoted partly to domestic sound reproduction and partly to record reviewing and musical matters—mainly but not exclusively in the classical field.

London Records, Inc., New York, New York (The Decca Record Co., Ltd.): Distribution of records made by parent company; manufacture and distribution of records in United States.

MCI, Inc., Fort Lauderdale, Florida: Design and manufacture of audio mixing desks, both manual and automated; master tape recorders for broadcasting and professional recording studios; auto locators; slave drivers; light meters; phase meters; and conductive plastic faders with either audio taper or VCA taper. Established in 1955.

Magnetic Reference Laboratory, Inc., Mountain View, California: Research, development and manufacture of precision reproducer calibration test tapes designed for applications in manufacturing, maintenance and design of audio tape recorders in studio, broadcasting, duplicating and consumer applications.

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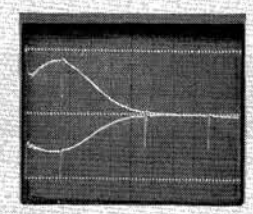
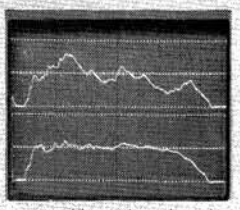
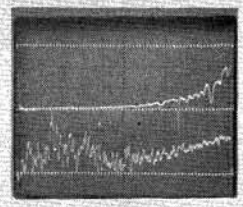
Oscilloscope photographs of some typical examples of plots made using the 4400 and an oscilloscope.



Swept sine wave frequency response plot of the reciprocal action of a low frequency equalizer. The small negative spikes are markers at 62Hz, 1kHz and 8kHz. The amplitude window between the top and bottom reference lines is 30dB; the horizontal axis is log 20Hz to 20kHz.



Frequency response of the speaker and room in a monitor system. The top trace, with 40dB window between reference lines, is before equalization; the bottom trace after equalization. The source was pink noise and the plots were made using the spectrum analysis mode with a ⅓-octave bandwidth.



Spectral analysis of the noise floor of a tape recorder playing back erased tape. A 2% filter bandwidth was used. Bottom reference line is −90dBm, top −30dBm. Second trace is phase shift versus frequency between two reproduced tracks. Top reference line is +180°, middle 0° and bottom −180°. The marker is at 4kHz in the 20Hz to 20kHz sweep.

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General Gramophone Publications Ltd., Harrow, Middlesex, United Kingdom: Publishers since 1923 of the record and audio magazine, *Gramophone;* of *Cassettes & Cartridges,* launched in 1973; and of a range of catalogs and books, including *Gramophone Classical Catalogue.*

Goodmans Loudspeakers Ltd., Havant, United Kingdom: Development and manufacture of loudspeaker systems and drive units for all applications, and marketing of range of high-fidelity equipment. Established in 1931; Havant factory opened in 1971.

Gotham Audio Corporation, New York, New York and Hollywood, California: Exclusive representative for professional audio equipment manufactured by EMT, Europafilm, Klein + Hummel, Lyrec, Neumann, NTP, Pyral, Telefunken and Woelke. Products include condenser microphones, stereo disc-cutting systems, reverberation and delay systems, master tape recorders, noise reduction systems, audio processing devices, meters, audio test equipment, master lacquer blanks, and miniature audio input transformers. Founded in 1957.

Grampian Reproducers Limited, London, United Kingdom: Manufacture of industrial audio systems comprising power amplifier rack consoles with varying inputs and programmable outputs, mains/battery amplifiers, loudspeakers and microphones. Established in 1932.

Harrison Systems, Inc., Nashville, Tennessee: Research, development and manufacture of professional audio equipment for use in multitrack recording.

Harvey Radio Company, Inc., New York, New York (Harvey Group, Inc.): Sales and service of professional audio equipment, including tape recorders, mixers, equalizers, amplifiers, monitoring equipment, microphones and accessories, recording tape and loudspeakers.

IMF Electronics, High Wycombe, Buckinghamshire, United Kingdom: Design, development and manufacture of loudspeaker systems for high fidelity use, both professionally and domestically.

ITT Consumer Products (U.K.) Ltd., Sidcup, Kent, United Kingdom (Parent Company: International Telephone and Telegraph Corporation): Manufacture and marketing of radio, audio and television products for the consumer market, including the design and manufacture of loudspeaker systems.

Infonics, Inc., Michigan City, Indiana: Design and development of high-speed, in-cassette audio tape duplicators for educational and commercial use.

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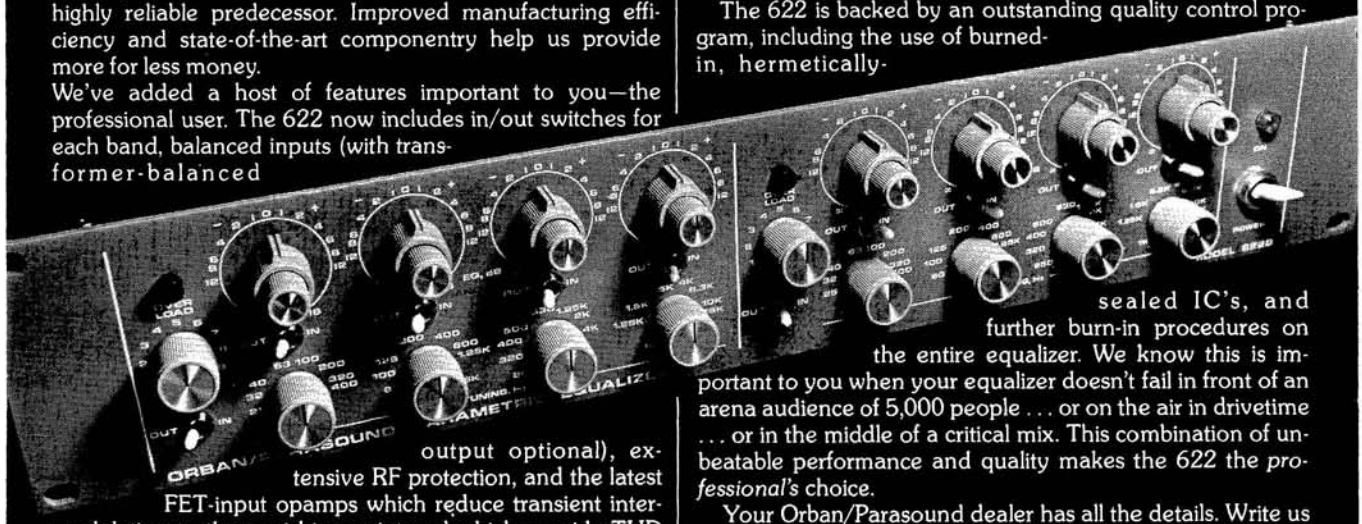

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So, if you want high quality and reliability in *all* your professional applications, go TDK all the way. Let us show you how TDK professional products can upgrade the quality of your products—and save you time, too. For further information, write us or call (516) 746-0880.

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World leader in recording tape technology.

TDK Electronics Corp., 755 Eastgate Boulevard, Garden City, New York 11530. In Canada, contact Superior Electronics Industries, Ltd.

of present-day CBS Records. Purchased by W. Paley in 1938. Name was then changed from American Record Corp. to Columbia Recording Corp.

CBS Technology Center, Stamford, Connecticut (CBS Incorporated): Research and technology development in the fields of television, radio broadcasting, high-density recording, audio systems technology and sound reproduction technology. Developments in audio engineering are related to disc and magnetic tape sound recording and reproduction, studio acoustics, broadcasting, musical instruments, loudspeakers and microphones.

Cetec Audio, North Hollywood, California (Cetec Corporation): Design and manufacture of Gauss high-speed tape duplicator, Gauss loudspeakers, audio consoles and mixing units for broadcast, television, recording and live performance, and cassette copier.

Chartwell Electro-Acoustics Limited, Mitcham, Surrey, United Kingdom: Design and manufacture of loudspeaker systems, loudspeaker components and drive units with bextrene and special plastic cones, for professional studios, broadcasting corporations and consumers both domestically and internationally.

Compteurs Schlumberger, Audio Professional Department, Rueil-Malmaison, France: Development, production, sale and installation of professional audio equipment for radio and television broadcasting, film studios, recording studios, and remote recording vehicles. Products include lightweight remote mixers, traditional and computerized sound recording and mixing consoles, studio mastering and perfo. recorders, amplifiers, static switching grids, remote recording vehicles and OB vans.

Dolby Laboratories, Inc., San Francisco, California: Design and manufacture of Dolby A-type noise reduction equipment for music recording, broadcast, television and motion picture sound and Dolby B-system for cassette recording and FM transmission.

Dukane Corporation, St. Charles, Illinois: Design and manufacture of internal communications and sound systems for institutional, industrial, commercial and municipal facilities.

EMI Ltd., London, United Kingdom: Manufacture and distribution of disc and tape records; design, manufacture and distribution of medical, industrial and defense electronics; and production and distribution of motion pictures. Firm also operates cinemas, hotels, restaurants and other major entertainment establishments. It was formed in 1931 by the merger of two parent companies: The Gramophone Company, registered in England in 1898 and The Columbia Graphophone Company, registered in England in 1900, having previously operated in Berlin and Paris for a number of years.

Electro-Voice, Inc., Buchanan, Michigan (a Gulton Company): Design and manufacture of professional and general purpose microphones, loudspeakers, public address systems, sound reinforcement products and high-fidelity component loudspeakers and loudspeaker systems.

Empire Scientific Corporation, Garden City, New York: Research, de-

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ment and manufacture of conductive plastic faders, quadrasonic panners and automated consoles, also designs and builds complete console systems using these components.

B & K Instruments, Inc., Cleveland, Ohio (U.S. Subsidiary of Bruel & Kjaer, Naerum, Denmark): Importation and distribution of precision microphones, distortion analyzers, sound level meters, graphic level recorders, one-third octave and narrow-band serial and real-time analyzers in the frequency range of 1.6 to 100 000 Hz. Parent company established 1946, U.S. company established 1958.

B & W Loudspeakers Limited, Worthing, West Sussex, United Kingdom: Research, design and manufacture of complete loudspeaker systems for consumer and professional use.

Bang & Olufsen (U.K.) Limited, Gloucester, United Kingdom: Marketing and distribution of professional audio and television products manufactured by the parent company in Denmark. Products include loudspeakers, pickups, record players, cassette recorder decks; music centers, AM/FM stereo receivers, portable radios, headphones and CTV sets.

F. W. O. Bauch Limited, Boreham Wood, Hertfordshire, United Kingdom: U.K. distribution of studio recording equipment manufactured by Studer, Revox, Neumann, EMT, Klein + Hummel, Albrecht, Danner, Europafilm, UREI, Lexicon, Allison Research, Seydel, MRL, Transco, Arp, and Switchcraft.

Bell Telephone Laboratories, Murray Hill, New Jersey (American Telephone and Telegraph Company): Research and development arm of AT&T, responsible for creation of new science and technology required for telephonic communication and its application to development of telephones, transmission facilities and switching equipment.

Bose Corporation, Framingham, Massachusetts: Design and manufacture of audio reproduction and amplification equipment for professionals and consumers. Professional products are intended for use in sound reinforcement and portable playback applications. Established in 1964.

Bozak, Inc., Darien, Connecticut: Design and manufacture of loudspeakers including 2- and 3-way multiple array line loudspeaker systems and associated audio electronic equipment including 6- and 10-input mono and stereo mixer preamplifiers, power amplifiers ranging from 50 to 150 watts and accessories such as power controls and monitor panels. Established in 1949.

British Industries Company, Westbury, New York (Division of Avnet, Inc.): Design, development and manufacture in the United States of B.I.C. multiple play manual turntables and B.I.C. Venturi loudspeaker systems; distribution of English-made Multicore solders and chemicals.

CBS Records, New York, New York (Div. of CBS Inc.): Research, development, recording and manufacturing of records and tapes. Recording studios in New York City, San Francisco, California and Nashville, Tennessee. Manufacturing facilities in Pitman, New Jersey, Terre Haute, Indiana and Santa Maria, California. Columbia label first marketed in 1890 by the American Graphophone Co., ancestor

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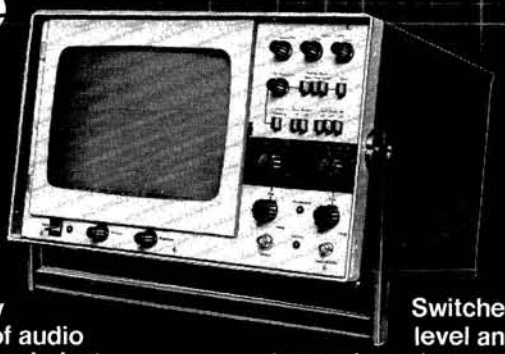

The RA200 Test Set quickly gives you accurate traces of audio system frequency responses. In just a few seconds, this self-contained instrument clearly displays response as a gain/frequency plot on a long-persistence CRT. Outputs are provided for operating an X-Y plotter. Whether you use the internal sweep oscillator, or an external signal, the RA200 requires no synchronisation and adjusts automatically to the incoming frequency. It covers 20Hz to 200kHz, with resolution down to 0.1dB over a very wide dynamic range.

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Company
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Corporation): Design, manufacture and worldwide distribution of compression drivers and components for professional loudspeaker systems; environment-resistant loudspeakers for use in sound reinforcement, background music, and alarm signalling installations; and floor, desk, boom microphone stands and accessories for professional and commercial applications.

Audio Consultants, Inc., Nashville, Tennessee: Design, turnkey construction, and installation of professional recording studios and related facilities, including live performance halls and audio production facilities for radio and television broadcasting; sales, installation, and service of professional recording and mixing consoles, professional tape recorders and related audio equipment.

Audio Designs and Manufacturing, Inc. (ADM), Roseville, Michigan: Design and manufacture of stock and custom professional audio consoles and associated components for recording, broadcasting, film mix and sound reinforcement applications. Firm's worldwide representation outside of the continental United States is through Ampex International of Redwood City, California. Trade names are: Slidex, Audex, Fadex, Predex and Vue-Scan. Established in 1966.

Audio Dynamics Corporation, New Milford, Connecticut (BSR [USA] Limited): Design, development, manufacture and distribution of magnetic phonograph cartridges, tonearms, frequency equalizers, sound level meters and the ACCUTRAC professional turntable. ADC was established in 1960.

Audio Magazine, Philadelphia, Pennsylvania: Monthly publication, established as Audio Engineering in 1947, includes articles on theory and design of audio equipment, test reports on current products for both consumer and professional, and columns about industry events, product trends, and recent record and tape releases.

Audio-Technica U.S., Inc., Fairlawn, Ohio: Development and marketing of products for the consumer electronics industry, including magnetic phonograph cartridges and styli, headphones, microphones, audio accessories, and direct-to-disc recordings.

Audiotechniques, Inc., Stamford, Connecticut: Distribution of professional audio products for the recording and broadcasting industry, specializing in recording equipment installation, system design and service. A division of the company, Audiomarketing, Inc., manufactures monitor systems for studios, and imports and distributes recording equipment.

Auditronics, Inc., Memphis, Tennessee: Manufacture of audio control consoles with 8-, 16- and 24-track capability, designed for sound reinforcement, multichannel recording, location recording and broadcasting, stereo broadcasting, radio and television production and on-air work, and motion picture recording.

Automated Processes, Inc., Huntington, New York: Development and manufacture of audio components, synchronizers and accessories for recording, broadcasting, sound reinforcement and motion picture production. Firm has pioneered in develop-

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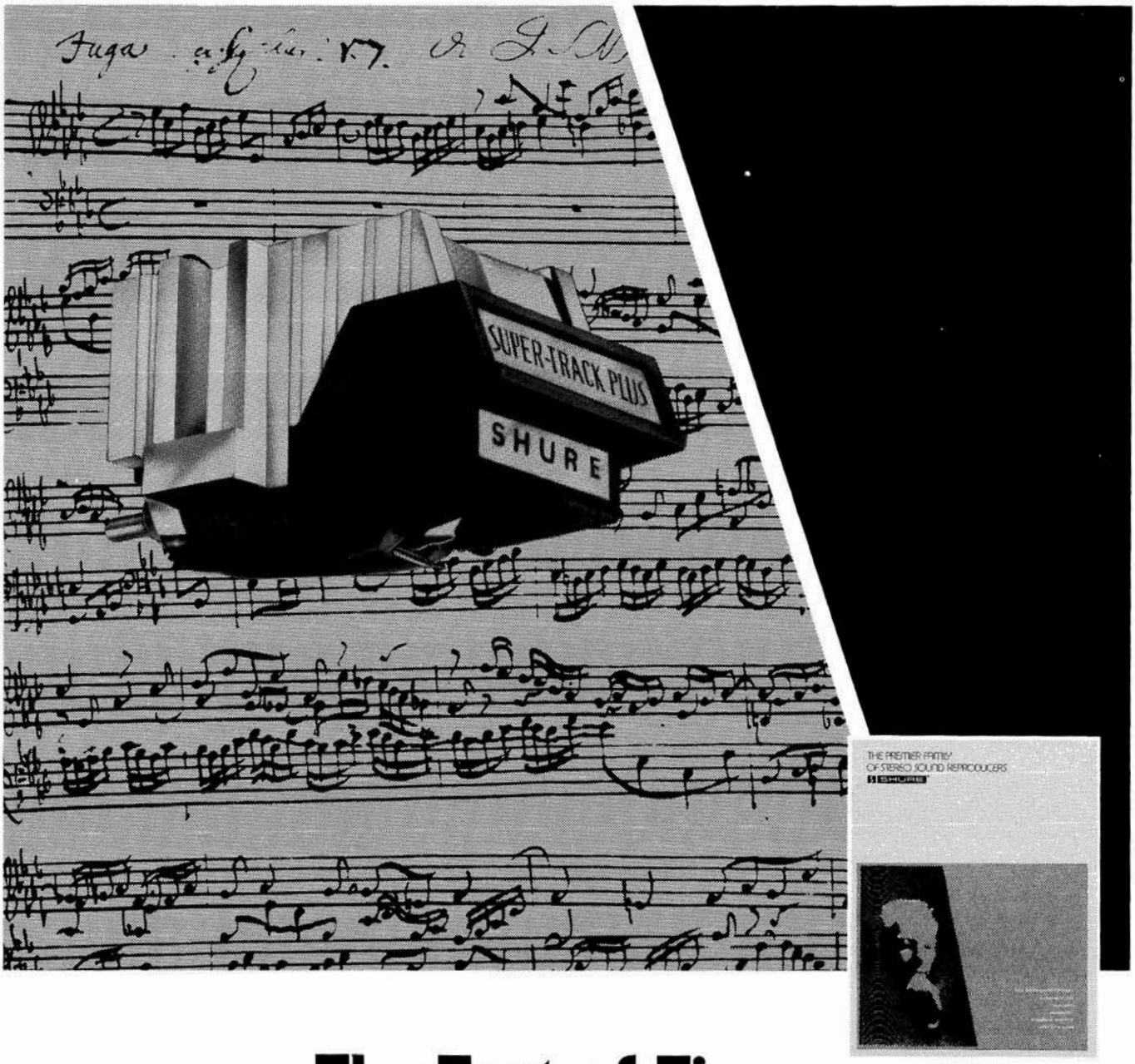

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Critics were most generous in their praise when the Shure V-15 Type III phono cartridge was first introduced. The ultimate test, however, has been time. The engineering innovations, the uniform quality and superb performance of the V-15 Type III have made it the audiophile's choice as the source of sound for the finest music systems both here and abroad.

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MODEL V-15 TYPE III
Tracking Force Range: ¾ to 1¼ grams
Frequency Response: 10 to 25,000 Hz
Typical Tracking (in cm/sec peak recorded velocity at 1 gram:)
400 Hz . 26 cm/sec 1,000 Hz . 38 cm/sec
5,000 Hz . 35 cm/sec 10,000 Hz . 26 cm/sec
Channel Separation (Minimum): 25 dB at 1 KHz; 15 dB at 10 KHz
Stylus: Model VN35E Biradial Elliptical, 5 x 18 microns (.0002 x .0007 inches)
Also available: Model V-15 III G with the VN3-G Spherical stylus, 15 microns (.0006 inches)
Model VN78E Biradial Elliptical stylus, 13 x 63 microns (.0005 x .0025 inches) for mono 78 rpm.

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Review of Society's Sustaining Members

Centennial Issue...

Editor's Note: *Because many of our Sustaining Members have been supporting the Society for a number of years, and their activities, in many cases, have expanded and/or shifted in emphasis, it is appropriate to publish here restated descriptions of their products and services. The following edited review includes also capsule profiles of the products and services of the many new companies which have more recently been added to the roster.*

Acoustic Research, Norwood, Massachusetts: Research, design and manufacture of high-fidelity loudspeakers and turntables for consumer and professional use.

Acoustic Transducer Co., Ltd., Chiswick, London, United Kingdom: Design, development and production of loudspeaker drive units and monitor loudspeaker systems for professional use. Marketing of professional power amplifiers and mixing consoles. Established in 1974.

The Acoustical Manufacturing Co., Ltd., Huntingdon, Cambridgeshire, United Kingdom: Research, design and manufacture of amplifiers, tuners and loudspeakers under the trade name QUAD, for consumer and professional use.

AKG Acoustics, Mahwah, New Jersey (North American Philips Corporation): Research, manufacture and distribution of professional condenser, electret and dynamic microphones, tortional transmission lines, reverberation systems and digital time delay units for sound reinforcement, public address, broadcast, studio and recording applications, headphones and phono cartridges.

AKG Akustische und Kino-Geraete Ges. m.b.H., Vienna, Austria: Research, development and manufacture of primarily professional audio equipment, such as microphones, headphones, phonograph pickup cartridges, artificial reverberation units, digital time delay units and ultrasonics (mainly for information transfer), as well as dynamic microphone capsules for standard telephone subscriber sets.

Allison Research, Inc., Nashville, Tennessee: Design and manufacture of programmable mixing equipment, voltage-controlled amplifiers, limiters and expanders.

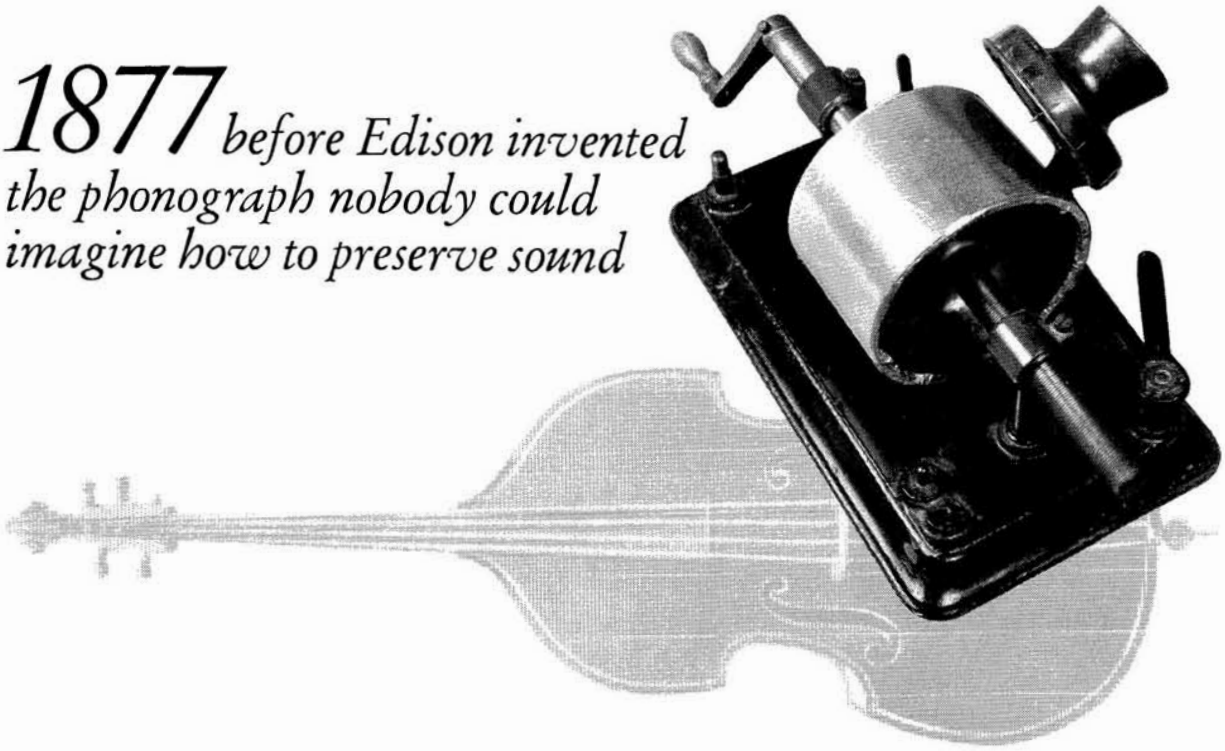
Altec Sound Products Division, Anaheim, California (Altec Corporation): Design, manufacture and distribution of a wide variety of industrial, professional, commercial and consumer sound systems. Products are distributed domestically and internationally under Altec, Altec/Lansing and University Sound brand names. Firm was established in 1936 and purchased the Lansing Manufacturing Co. in 1941.

Ampex Corporation, Redwood City, California: Design and manufacture of magnetic recording products for audio, video, scientific and computer applications. Products include 8-, 16- and 24-channel recorders, 1-, 2- and 4-channel studio machines, mono and stereo portable recorders and audio and video blank recording tape. Firm also distributes EECO line of transport control products for synchronizing audio and/or video recorders.

Armstrong Audio Limited, London, United Kingdom: Development, manufacture and distribution of amplifiers, tuners, receivers and loudspeakers. Originally established as Armstrong Wireless and Television Co. Ltd. in 1930 and changed to its present name in 1962.

Atlas Sound, Parsippany, New Jersey (American Trading and Production

1877 before Edison invented the phonograph nobody could imagine how to preserve sound

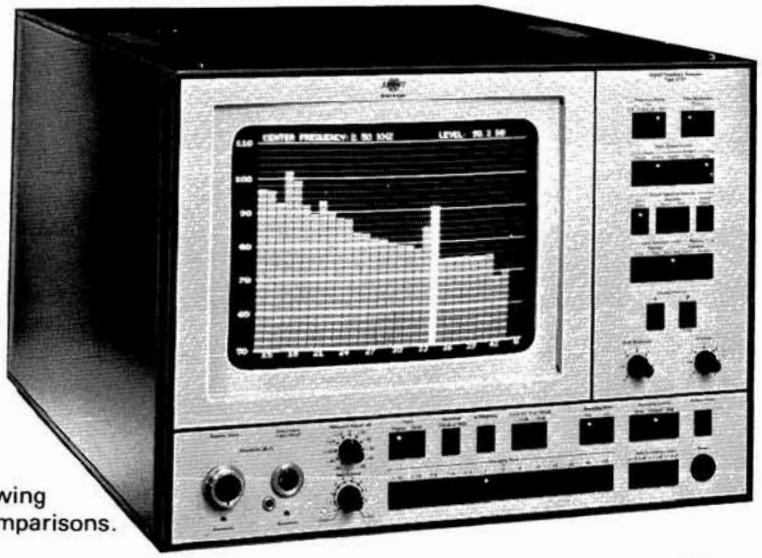


1977 quite a few things have happened since then, and Brüel & Kjaer is proud to have supplied over the past 35 years many of the instruments that helped contribute to progress in the audio engineering field.

Today we spend all our efforts in developing the instruments which will help make your future visions come true.

Our latest development is the Third Octave Real Time Analyzer, Type 2131. Being all digital, we gave it an IEC interface so you can conveniently control it with the programmable calculator or computer of your choice. Here's where it pays off: High speed production testing of loudspeakers for frequency response and "rattle". Automatic measurement of loudspeaker directivity and sound power output. And simultaneous reverberation time measurement in all filter bands.

Other features include 1/12 octave analysis under computer control, large screen display for room equalization viewing and memory storage for two channel comparisons.



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separate entries under the composer and title, without additional reference to the other works, if any, on the same record,

Opus numbers are given here when used by the composer, as well as dates of compositions in many cases. However, the works of certain classical composers are usually identified not by the composers' own opus numbers, but by a special Thematic Index which is the work of another person. Those in general use today are identified in this catalog by the initial of the musicologist who compiled the index (not by the title of his book) as follows:

W. [Wotquenne] C. P. E. Bach
S. [Schmieder] J. S. Bach
K. [Köchel] Mozart
D. [Deutsch] Schubert
P. [Pincherle] Vivaldi

Records in the Musicals, Movies section are further identified as to Original Cast [OC] and Soundtrack [ST].

For purposes of standardization, clarity and accuracy, composer and title spellings, dates, arrangement and other details, this Catalog (except for the Spoken Word section) follows the established practices in format and detail used by the monthly *Schwann Record & Tape Guide* which, in turn, relies upon *Baker's Biographical Dictionary of Musicians* (ed. Nicolas Slonimsky) as the principal and most reliably accurate source of information, together with major European encyclopedias.

William Schwann

List of Record Labels and Abbreviations used in these listings

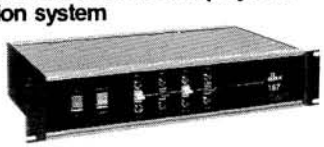
A & M
Abbey
ABC
Alshire
Amos
Angel (Ang.)
Archive of Folk & Jazz Music (Arc. Folk.)
Argo
Atco
Atlantic (At.)
Audio Fidelity (Audio Fi.)
Audio Rarities
Bach Guild (Bach)
Bell
Blue Note (Blue)
Blues Time (Blues T.)
Bluesway (Blues.)
Broadside (Broad.)
Buddah (Bud.)
Buena Vista (Buena)
Cadet
Caedmon (Caed.)
Camden (Camd.)
Capitol (Cap.)
Carillon
CBS News
Century (Cent.)
Chart
Checker
Chess
CMS
Columbia (Col.)
Columbia Special Products (CSP)
Concert-Disc (Con.-Disc)
Contemporary (Contem.)
Cook
Coral
Creative World
Creed
Composer's Recordings, Inc. (CRI)
Decca (Dec.)
Delmark (Del.)
Deram
Desto
Deutsche Grammophon (DG)
Dot
Dover
Dunhill (Dun.)
Dyer-Bennet
Elektra (Elek.)
Epic
Everest (Ev.)
Evolution (Evo.)
Expanding Cinema
Fantasy (Fan.)
Flying Dutchman (Fly.)
Folk-Legacy (Folk-Leg.)
Folkways (Folk.)
Fontana (Fon.)
GHB
Good Time Jazz (GTJ)
Gordy (Gor.)
Harmony (Har.)
Harvard Vocarium
Heliodor (Hel.)
Hickory (Hick.)
HiFirecords (HiFi)
Hob
Imperial (Imper.)
Impulse
JCOA
Jupiter
Kapp
Kenwood (Ken.)
Key
King
Liberty (Lib.)
Library of Congress
Limelight (Lime.)
Living Shakespeare
London (Lon.)
Louisville (Lou.)
Mainstream (Main.)
Master Jazz (Mas. J.)
Melodiya/Angel (Mel./Ang.)
Mercury (Mer.)
MGM
Milestone (Mile.)
Monitor (Mon.)
Monmouth-Evergreen (Mon.-Ev.)
Monument (Monu.)
Motown (Mo.)
Musicor (Musi.)
Nashboro (Nashb.)
Neighborhood
Nonesuch (None.)
Odyssey (Odys.)
Oiseau-Lyre (Oiseau)
Pacific Jazz (Pac.Jazz)
Parrot (Par.)
Pavillon (Pav.)
Peacock (Pea.)
Period (Per.)
Philips (Phi.)
Plantation (Plant.)
Polydor (Pol.)
Prestige (Prest.)
Project 3 (Proj.)
PSO
Ranwood (Ran.)
RCA Victor (RCA)
Readers Digest (RD)
Reprise
Richmond (Rich.)
Rivergate (Riv.)
Roach
Rococo
Roulette (Rou.)
Saturn (Sat.)
Savoy
Scepter (Scep.)
Scottish Records
Seraphim (Sera.)
Silhouettes in Courage (Sil.)
Skylite (Sky.)
Smash
Solid State (Solid)
Song
Soul City
Spoken Arts (Sp.Arts)
Spoken Word (Sp.Word)
Starday
Sun
Tamla (Tam.)
Tangerine (Tan.)
Tetragrammaton
Tradition (Trad.)
Uni
United Artists (U.Artists)
Vanguard (Van.)
Verve
Verve/Forecase (Verve/Fore.)
Vocalion (Voc.)
Warner Bros. (War.)
Westminster (West.)

dbx noise reduction & signal processing

Tape noise reduction for the professional studio

216 16-channel simultaneous record/playback noise reduction system

187 4-channel switchable record/playback noise reduction system



K9-22 single-channel noise reduction card replacement for Dolby "A"

- 30dB noise reduction with 10dB more headroom
- Reduces tape hiss to inaudibility
- Preserves full dynamic range
- Cable assemblies furnished ready to plug in
- Spare two-channel 310D module included
- Available on modular basis for as few as four channels, expandable to 24 or 32 channels
- Electrically interchangeable and fully compatible with dbx 216 and other professional studio systems
- Remote control switching capability
- Direct plug in replacement for the Dolby® CAT 22 card; converts Dolby 361, M16 or M24 to dbx noise reduction
- Fully compatible with other dbx professional noise reduction systems
- Less than half the cost of a free standing noise reduction system
- Carrying case available for easy portability

Tape noise reduction for the semi-professional studio

157 2-channel simultaneous record/playback noise reduction system

158 8-channel modular simultaneous tape noise reduction system

- Single-ended inputs and outputs terminated in RCA type phono connectors to interface with semi-professional recorders, mixers, etc.
- Small package for ease of portability
- Excellent choice for the small studio or location recordist
- 30dB noise reduction with 10dB additional headroom
- Fully compatible with dbx professional studio systems
- Inexpensive noise reduction system with professional performance
- Work with both pro and semi-pro recorders
- 158 comes with main frame and as few as 2 or as many as 8 channel modules
- Spare 158 module free with purchase of complete 8-channel system
- Multiple 158's can be used for 16 or 24 track recording
- Rack mount option available for all dbx 150 and 160 series models

Compressor/limiters

160 single channel compressor/limiter

162 true stereo compressor/limiter

- True rms level detection
- Compression ratio variable from 1:1 to infinity
- Threshold variable from -38 to +12dBm
- Low distortion even at high compression ratios
- Wide dynamic range and low noise

For complete information on these and other dbx signal processing systems, circle reader service number or contact:

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dbx

Henry V
The Marlowe Society 4-Argo **OSA-1415** **[E26]**

Henry VIII. Shakespeare
With Russell Thorndike, Christopher Casson and William Styles Sp. Arts 881 **[E26]**

The Importance of Being Earnest by Oscar Wilde
With Gladys Cooper, Joan Greenwood, Richard Johnson, Alec McCowan and Lynn Redgrave 3-Caed. **STRS-329** **[E27]**

Jean Genet
Readings by Jean Genet, Max Adrian, Alan Webb, Brenda Bruce, Nigel Davenport and Sheila Burrell Caed. **TCS-1134** **[E27]**

John Barrymore Reads Shakespeare With Commentary
Richard III, Twelfth Night, Macbeth, Hamlet 2-Audio Rarities 2280, 3380 **[E27]**

King Lear. Shakespeare
With Sir Donald Wolfit and Rosalind Iden The Living Shakespeare **SKL-354** **[E27]**

Laurence Olivier in Othello. Shakespeare
With Laurence Olivier, Maggie Smith, Frank Finlay and Joyce Redman 4-RCA **VDS-100** **[E28]**

Love for Love by William Congreve
With Laurence Olivier, Joyce Redman 3-RCA **VDS-112** **[E28]**

A Midsummer Night's Dream. Shakespeare
With Paul Scofield, Jay Parker et al. 3-Caed. **SRS-208** **[E29]**

Moon for the Misbegotten by Eugene O'Neill
Salome Jens, Mitchell Ryan, W. B. Brydon 3-Caed. **TRS-333** **[E29]**

Much Ado About Nothing. Shakespeare
With Maggie Smith, Robert Stephens and Albert Finney 3-RCA **VDS-104** **[E30]**

Peter Weiss: Marat-Sade
With Patrick Magee et al. 3-Caed. **TRS-312** **[E30]**

Riders to the Sea and In the Shadow of the Glen by J. M. Synge
Eireann Players of Dublin Sp. Arts 743 **[E31]**

Romeo and Juliet. Shakespeare
With Albert Finney, Claire Bloom and Dame Edith Evans 3-Caed. **TSR-228** **[E31]**

Saint Joan by G. B. Shaw
With Siobhan McKenna, Donald Pleasance, Robert Stephens, Alec McCowan et al. 4-Caed. **TRS-311** **[E31]**

Shakespeare's Julius Caesar
Hilton Edwards and Michael MacLiammoir, A Dublin Gate Theatre Production Sp. Arts 809 **[E32]**

Uncle Vanya. By Anton Chekov
With Laurence Olivier, Michael Redgrave, Joan Plowright 2-Caed. **TRS-303** **[E32]**

Who's Afraid of Virginia Woolf by Edward Albee
With Uta Hagen, Arthur Hill, George Grizzard and Melinda Dillon 4-Col. **DOS-687** **[E32]**

Endgame: Samuel Beckett
With Lester Rawlins, Gerald Hiken, P. J. Kelly, Nydia Westman 2-Sp. Arts **EVR 003** **[E33]**

The Rose Tattoo by Tennessee Williams
With Maureen Stapleton and Harry Guardino 3-Caed. **TRS-324** **[E33]**

Humor, Nostalgia

Allan Sherman War. **S-1475** **[E34]**

Anna Russell Sings! Again? Col. ML-4733 **[E34]**

Bill Cosby—Revenge War. **S-1691** **[E34]**

Bob Newhart War. **S-1588** **[E34]**

Bruce, Lenny—Togetherness Fan. **7007** **[E34]**

Freberg, Stan—Presents the United States of America Cap. **SW-1573** **[E34]**

Frye, David—I Am the President Elek. **75006** **[E34]**

Great Moments in Radio, Vol. 1
Narrated by Jack Benny: News, Soap Operas, Comedy, Commercials, Adventure Evo. 2001 **[E34]**

Great Moments in Radio Vol. 2
Narrated by Jack Benny, The Great Radio Comedians, Radio Adventure and Drama, On-the-Spot Coverage of Sports, the Classic News Broadcasts Evo. 2009 **[E34]**

Mabley, Moms—Funniest Woman Chess 1447 **[E35]**

The Marx Brothers
Their original voice tracks from their greatest movies, Groucho, Chico and Harpo Marx Dec. **79168** **[E35]**

Mike Nichols and Elaine May
Best Mer. **60997** **[E35]**

Steinberg, David—Disguised as a Normal Person Elek. **74065** **[E35]**

Shelley Berman—Inside Verve **615003** **[E35]**

W.C. Fields on Radio with Edgar Bergen & Charlie McCarthy Col. **CS-9890** **[E35]**

Wilson, Flip—Cowboys At. S-8149 **[E35]**

Key and Explanatory Notes

Capital letters indicate major keys [G = G major]
Small letters indicate minor keys [a = A minor]

Numbers in brackets [A-13] following record label number identify the location of the record in the White House Record Library. A stands for classical; B for popular; C for country, folk & gospel; D for jazz, and E for spoken word. **Bold face** numbers indicate stereo records. Light face numbers indicate mono records. Electronically reprocessed "stereo" records made from mono originals are identified by an "E" following the record number.

All compositions in the classical section, as selected by the committee which chose these records, are given

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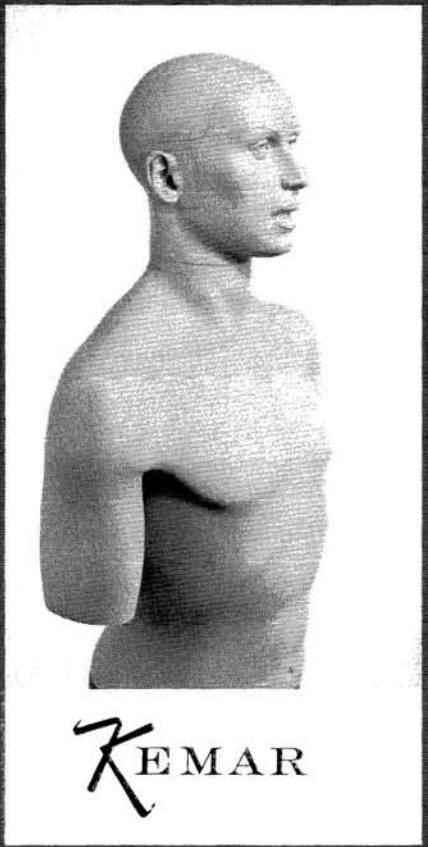

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The Jungle Books by Rudyard Kipling
Read by Christopher Casson and Eve Watkinson — 2-Sp. Arts 933,929 **[E19,20]**

Lewis Carroll's Alice in Wonderland
With Margaretta Scott and Jane Asher — 2-Argo 145/6 **[E20]**

The Man Without a Country
Read by Edward G. Robinson — Caed. TC-1178 **[E20]**

Miracles: Poems Written by Children
Collected by Richard Lewis. Read by Julie Harris and Roddy McDowall — Caed. TC-1227 **[E20]**

Mother Goose
Cyril Ritchard, Celeste Holm, Boris Karloff — Caed. TC-1091 **[E20]**

Silas Marner (abridged)
As read by Judith Anderson — 2-Caed. TC-2024 **[E20]**

Tales from Shakespeare by Charles and Mary Lamb: The Taming of the Shrew and Macbeth — Sp. Arts 976 **[E20]**

Treasury of Lewis Carroll
Read, Sung and Arranged By Christoper Casson — Sp. Arts 897 **[E21]**

Treasury of Nursery Rhymes
Read by Christopher Casson accompanied by Gaelic Harp — Sp. Arts 304 **[E21]**

The Wind in the Willows by Kenneth Grahame — 2-Argo **RG-221/2** **[E21]**

Plays

Antony and Cleopatra, Shakespeare
With Anthony Quayle and Pamela Brown — 3-Caed. **SRS-235** **[E21]**

Babes in the Wood—A Family Entertainment.
An authentic English Pantomime by V.C. Clinton-Baddeley, 45 RPM — Jupiter **JCP-35** **[E21]**

The Balcony, Jean Genet
Pamela Brown, Patrick Magee, Cyril Cusack — 3-Caed. TRS-316 **[E22]**

The Chairs
By Eugene Ionesco; with Siobhan McKenna and Cyril Cusack — 2-Caed. **STRS-323** **[E22]**

Cyrano de Bergerac by Edmond Rostand
With Sir Ralph Richardson — 3-Caed. **TRS-306** **[E23]**

Death of a Salesman
With an introduction by the author, Arthur Miller. Lee J. Cobb, Mildred Dunnock — 2-Caed. **TRS-310** **[E23]**

The Duchess of Malfi by John Webster
With Barbara Jefford, Robert Stephen, Alec McCowan, Jeremy Brett, Douglas Walmer — 3-Caed. **TRS-334** **[E24]**

Dylan Thomas Reading Shakespeare: King Lear and Webster: The Duchess of Malfi — Caed. TC-1158 **[E24]**

Five One Act Plays by W. B. Yeats
With Siobhan McKenna, Cyril Cusack, Marie Kean and Patrick Magee — 3-Caed. **TRS-315** **[E24]**

The Glass Menagerie by Tennessee Williams
With Montgomery Clift, Julie Harris, Jessica Tandy and David Wayne — 2-Caed. **TRS-301** **[E25]**

The Great White Hope by Howard Sackler
With James Earl Jones and Jane Alexander — 4-Tetragrammaton **TDL-5200** **[E25]**

Hamlet—Shakespeare Theatre Guild on the Air
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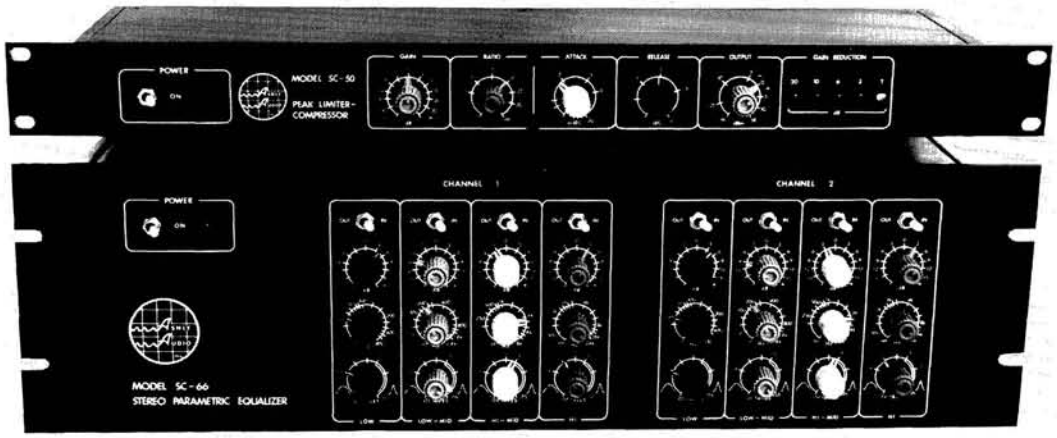

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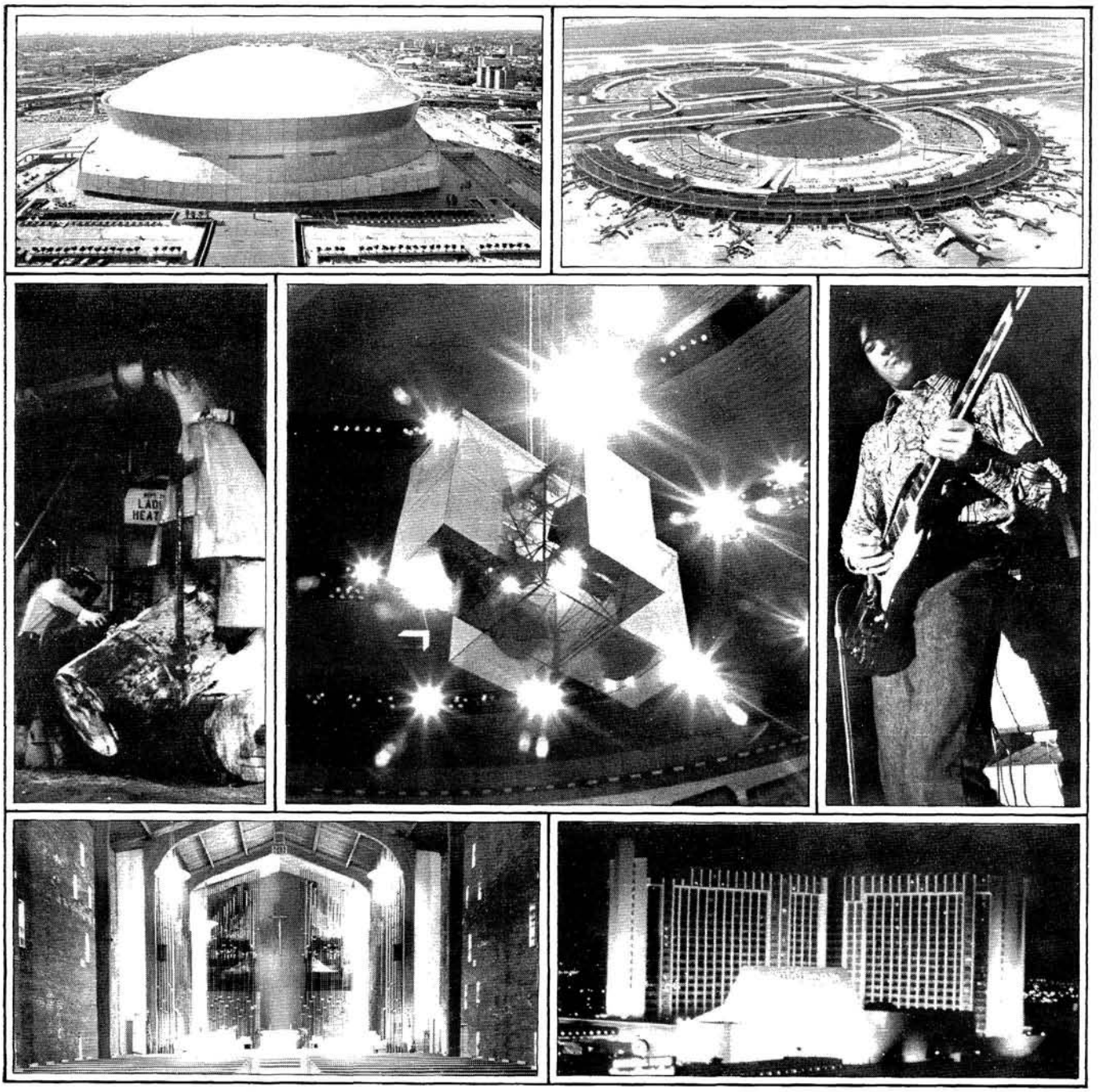

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Christian Poetry and Prose Read by Alec Guinness
Folk. FL-9893 **[E12]**

The Georgics of Virgil
Translated and read by C. Day Lewis Sp. Arts 733 **[E12]**

Gerard Manley Hopkins Read by Cyril Cusack
Caed. TC-1111 **[E12]**

A Golden Treasury of American Verse
Read by Alexander Scourby, Nancy Wickwire
Sp. Arts 772 **[E12]**

Homer: The Odyssey
Books 9-12. Translated by Richard Lattimore.
Read by Anthony Quayle 3-Caed. TC-3001 **[E12]**

The Jupiter Book of Ballads Folk. 9890 **[E13]**

Milton's Paradise Lost
Read by Anthony Quayle 2-Caed. TC-2008 **[E13]**

Old Testament Psalms and the Tale of David
Read by Judith Anderson Caed. TC-1053 **[E13]**

Poems By W. B. Yeats
Spoken according to his own directions Jupiter **OOB-2** **[E13]**

The Poetry of Coleridge
Read by Sir Ralph Richardson Caed. TC-1092 **[E13]**

Poetry of Langston Hughes
Read by Ruby Dee and Ossie Davis Caed. TC-1272 **[E13]**

Robert Burns: Tam O'Shanter and other Poems
Read by Harold Weightman Scottish Records **SR-124** **[E13]**

The Treasury of John Keats
Read by Robert Speaight and Robert Eddison
Sp. Arts 868 **[E13]**

The Treasury of George Gordon, Lord Byron
Read by Peter Orr Sp. Arts 908 **[E13]**

Prose

Alexis de Tocqueville: Democracy in America
Read by Anthony Quayle Caed. TC-2039 **[E14]**

The Autobiography of Frederick Douglass
Read by Ossie Davis Folk. FH-5522 **[E14]**

Bret Harte Read by David Kurlan Folk. FL-9740 **[E14]**

The Canterbury Tales of Geoffrey Chaucer
Presented in modern translation 4-Sp. Word **SWAI** **[E14]**

Charles Dickens: A Christmas Carol
With Sir Ralph Richardson and Paul Scofield
Caed. **TCS-50001** **[E15]**

Daniel Defoe's Molf Flanders
Read by Siobhan McKenna Caed. TC-1090 **[E15]**

Jeeves
By P.G. Wodehouse Caed. **TC-1137S** **[E15]**

An Informal Hour with J. Frank Dobie
Tales of the American Southwest Sp. Arts 722 **[E15]**

Langston Hughes: Simple
Read by Ossie Davis Caed. TC-1222 **[E15]**

James Joyce: Finnegans Wake
With Siobhan McKenna, Cyril Cusack Caed. TC-1086 **[E15]**

James Joyce: A Portrait of the Artist as a Young Man
Read by Cyril Cusack Caed. TC-1110 **[E15]**

James Joyce: Ulysses Caed. TC-1063 **[E15]**

Lotte Lenya Reading in English. The Stories of Kafka Caed. TC-1114 **[E15]**

Proust. Remembrance of Things Past: Swann in Love
Read by Sir Ralph Richardson 2-Caed. TC-2017 **[E16]**

Sir Michael Redgrave Reads Chekhov Sp. Arts 828 **[E16]**

Tales of Horror and Suspense by Ambrose Bierce
Read by Ugo Toppo CMS **513** **[E16]**

Treasury of Jonathan Swift. Gulliver's Travels.
Read by Denis Johnston Sp. Arts 856 **[E16]**

Walden by Henry David Thoreau
Read by Howard Mumford Jones Sp. Arts 832 **[E16]**

Geoffrey Chaucer Readings In Middle English by Nevill Coghill and Norman Davis Sp. Arts 919 **[E16]**

The Legend of Sleepy Hollow by Washington Irving
Read By Hurd Hatfield Sp. Arts 991 **[E16]**

Concert Readings

Ages of Man—Scenes and Sonnets from Shakespeare
Sir John Gielgud Col. OL-5390 **[E17]**

The Brontës
Margaret Webster 2-Van. **VRS-9176/7** **[E17]**

The Death of Patroclus
Adapted from Book XVI of Homer's Iliad by Christoper Logue with Vanessa Redgrave, Alan Dobie, Martin Starkie, Jerry Scully and Christopher Logue Sp. Arts 926 **[E17]**

Emlyn Williams as Charles Dickens 2-Argo **TA-507-8** **[E17]**

An Evening with Dylan Thomas Caed. TC-1157 **[E17]**

Hal Holbrook in Mark Twain Tonight Col. **OS-3080** **[E17]**

Homage to Dylan Thomas Argo **RG-29** **[E17]**

A Lovely Light. Edna St. Vincent Millay
Dorothy Stickney 2-Van. **VRS-9201/2** **[E17]**

Spoon River Anthology
By Edgar Lee Masters Col. **OS-2410** **[E18]**

Under Milk Wood by Dylan Thomas
Directed by Dylan Thomas with Dylan Thomas and the Original Cast 2-Caed. TC-2005 **[E18]**

Children's Material

Animal Tales Told in the Gullah Dialect by Albert H. Stoddard of Savannah, Georgia
3-Library of Congress AAFSL 45/46 **[E18]**

A Child's Garden of verses, by Robert Louis Stevenson
Read by Basil Langton and Nancy Wickwire
2-Sp. Arts 904/5 **[E18]**

Doctor Seuss: Happy Birthday to You Caed. TC-1287 **[E18]**

A Gathering of Great Poetry for Children
Edited by Richard Lewis and Read by Julie Harris, Cyril Ritchard, David Wayne and the poets themselves 4-Caed. TC-1235/8 **[E19]**

Great American Speeches
Various Caed. TC-2016 **[E19]**

Hans Christian Andersen: The Little Match Girl and Other Fairy Tales
Told by Boris Karloff Caed. TC-1117 **[E19]**

Jack Tales Told by Mrs. Maud Long
Library of Congress L-47 **[E19]**

The Just So Stories of Rudyard Kipling
Read by Boris Karloff Caed. TC-1038 **[E19]**

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An anthology read by the Poets
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Frank O'Connor Reading "My Oedypus Complex" and "The Drunkard" Caed. TC-1036 **[E8]**

An Informal Hour with Dorothy Parker Sp. Arts 726 **[E8]**

James Jones Reads James Jones
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Read by James Mason Caed. TC-1203 **[E12]**

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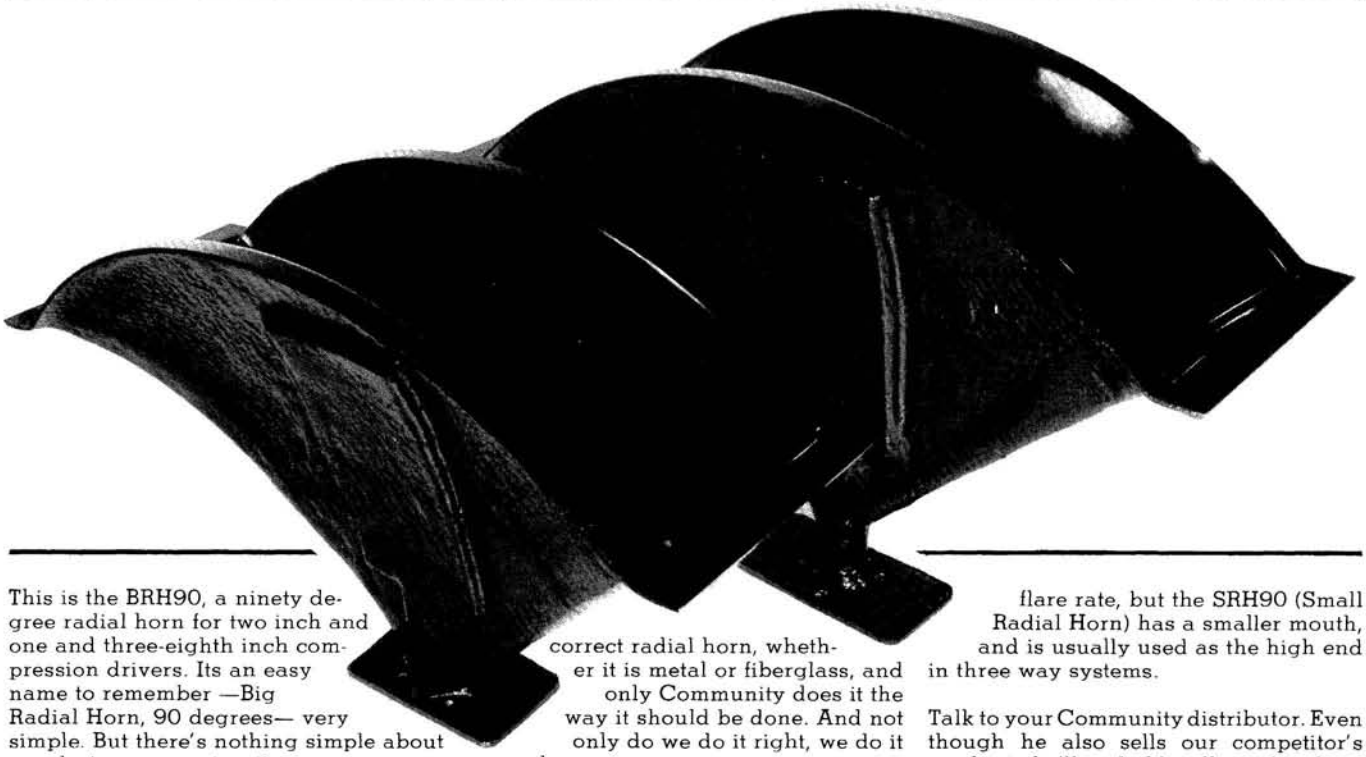
BRH90 RADIAL HORNS



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Community horns are made of fiberglass. Not sprayed-up cheaply-made fiberglass, but fiberglass hand-laminated by experts and constructed to our exact requirements for maximum acoustical accuracy, resonance-free rigidity and unparalleled strength. Our horns are absolutely weatherproof. They will *never* corrode or rust out. Nor are they ever likely to break. Not now and not forty years from now.

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We also make two 90° radials for use with one inch and screw-on drivers —the RH90 and the SRH90. Both have the same flare rate, but the SRH90 (Small Radial Horn) has a smaller mouth, and is usually used as the high end in three way systems.

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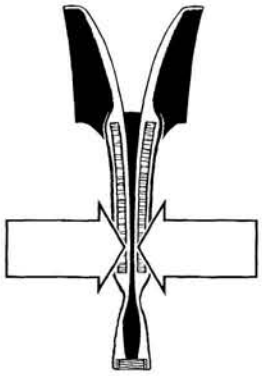

	BRH90			RH90			SRH90		
Flare Rate	240Hz			345Hz			345Hz		
Operating Range	500Hz up			600Hz up			1,000Hz up		
Size: H.	11 ⅛"			12¼"			6½"		
W.	33⅝"			30⅜"			24¾"		
D.	21"			20½"			18¾"		
Weight	25 LB.			20 LB.			12 LB.		
Finish	Black, High Gloss			"			"		
Horizontal Dispersion	KHz	-3dB	-6dB	KHz	-3dB	-6dB	KHz	-3dB	-6dB
	.6	85	95	.6	80	90	1.2	95	100
	2	90	90	2	90	100	3	90	95
	10	80	90	10	85	90	10	85	100
Vertical Dispersion	KHz	-3dB	-6dB	KHz	-3dB	-6dB	KHz	-3dB	-6dB
	.6	50	90	.6	55	100	1.2	50	70
	2	35	50	2	35	50	3	40	65
	10	20	35	10	20	35	10	20	30

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Guitar Country RCA **LSP-3429** [C4]

Autry, Gene—Country Music Hall of Fame Col. **CS-1035** [C4]
Golden Hits RCA **LSP-2623** [C4]
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Baez, Joan Van. **2077** [C5]
Any Day Now 2-Van. **79306/7** [C5]

The Ballad Hunter 5-Library of Congress AAFS L49-53 [C5]

Bare, Bobby—Best RCA **LSP-3479** [C6]

Belafonte, Harry—Streets I Walk RCA **LSP-2695** [C6]
This Is Harry 2-RCA **VPS-6024** [C6]

Bibb, Leon—In Concert Lib. **7327** [C6]

Bikel, Theodore—Songs of the Earth Elek. **7326** [C6]

Blackwood Brothers—Best RCA **LSP-2931** [C6]

Blues at Newport 2-Van. **79180/81** [C6]

Brand, Oscar—Best Trad. **2053** [C6]

Britt, Elton—16 Great Country Performances ABC **S-744** [C7]

Broonzy, Big Bill Arc. Folk **S-213** [C7]

Brother Joe May—In Church Nashb. **7093** [C7]

Brothers Four—Greatest Hits Col. **CS-8603** [C7]

The Browns—Best RCA **LSP-3561** [C7]

Buckley, Tim—Goodbye and Hello Elek. **7318** [C7]

Buffalo Springfield—Retrospective Atco **S-33-283** [C7]

Camp, Hamilton—Here's To You War. **S-1737** [C7]

Campbell, Glen—Live 2-Cap. **STBO-268** [C7]

Carawan, Guy—Songs Folk. **3544** [C8]

Carson, Martha—Sings Camd. **S-906** [C8]

Carter Family—Best Col. **CS-9119** [C8]
Original & Great Camd. **S-586** [C8]

Carter, Mother Maybelle—A Living Legend Col. **CS-9275** [C8]

Cash, Johnny—At Folsom Prison Col. **CS-9639** [C8]
At San Quentin Col. **CS-9827** [C8]
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Clark, Roy—Greatest! Cap. **SKAO-369** [C9]

Cleveland, James—Best Hob 253 [C9]
One and Only Savoy 14252 [C9]

Cline, Patsy—Greatest Hits Dec. **74854** [C9]

Collins, Judy—Fifth Album Elek. **7300** [C9]
Wildflowers Elek. **74012** [C10]

Cooke, Mme. Edna Gallmon—Memories Nashb. **7068** [C10]

Copas, Cowboy—Story 2-Starday **S-347** [C10]

Cotton, Elizabeth—Negro Songs Folk. 3526 [C10]

Cramer, Floyd—Best RCA **LSP-2888** [C10]

Dane, Barbara—Anthology of American Songs Trad. 2072 [C10]

Davis, Jimmie—How Great Thou Art Dec. **74322** [C10]
Near the Cross Dec. 8174 [C10]

Davis, Skeeter—Best RCA **LSP-3374** [C11]

Dean, Jimmy—Greatest Hits Col. **CS-9285** [C11]

Denver, John—Rhymes and Reasons RCA **LSP-4207** [C11]

Dixie Hummingbirds—Best Pea. **PLP-138** [C11]

Driftwood, Jimmy—Best Monu. **18043** [C11]
Voice of the People Monu. **18006** [C11]

Drusky, Roy—Greatest Hits, Vol. 1 Mer. **61052** [C11]

Dudley, Dave—Best Mer. **61268** [C11]

Dyer-Bennet, Richard Dyer-Bennet **1000E** [C11]

Dylan, Bob Col. **CS-8579** [C12]
John Wesley Harding Col. **CS-9604** [C12]

Early Rural String Bands RCA LPV-552 [C12]

Eighteen King Size Hits Col. **CS-9468** [C12]

Elliott, Jack—Sings Guthrie and Rodgers Mon. **S-380** [C12]

Estes, Sleepy John—Broke and Hungry Del. **9608** [C12]

Everly Brothers—Sing Great Country Hits War. **S-1513** [C12]

Fariña, Mimi & Richard—Reflections in a Crystal Wind Van. **79204** [C12]

Flatt & Scruggs—Greatest Hits Col. **CS-9370** [C12]

Foley, Red—Story 2-Dec. **DXS-7177** [C13]

Ford, Tennessee Ernie—Sixteen Tons Cap. **DT-1380E** [C13]

Forrester, Howdy—Big Howdy U. Artists **6295** [C13]

Franklin, Aretha—Amazing Grace, w. James Cleveland 2-At. **2-906** [C13]

Frizzell, Lefty—Greatest Hits Col. **CS-9288** [C13]

Gentry, Bobbie—Ode to Billie Joe Cap. **ST-2830** [C13]

Gibson, Bob—Where I'm Bound Elek. **7239** [C13]

Gibson, Don—Best RCA **LSP-3376** [C13]

Golden Gems of Gospel Pea. **PLP-140** [C14]

Gospel Song Styles of 12 Great Artists RCA **LSP-3721** [C14]

Great Golden Gospel Hits 3-Savoy 14069, 14104, 14165 [C14]

Greene, Jack—Until My Dreams Come True Dec. **75086** [C14]

Griffin, Bessie—Gospel Soul of Savoy **S-14233** [C14]

Guthrie, Arlo—Alice's Restaurant Reprise **S-6267** [C14]

Guthrie, Woody—The Early Years Trad. **2088** [C14]

Haggard, Merle Cap. **SKAO-2951** [C14]

Hammond, John—I Can Tell At. **S-8152** [C15]

Hardin, Tim—Best Verve/Fore. **S-3078** [C15]

Hartford, John—Gentle On My Mind RCA **LSP-4068** [C15]

Havens, Richie—Somethingelse Again MGM **4699** [C15]

Hawkins, Edwin Singers—Let Us Go To The House of The Lord Pav. **1001** [C15]

Hill, Goldie—Sings Country Voc. **73831** [C15]

Holcomb, Jack—Sings Gospel RCA **LSP-2868** [C15]

Homer & Jethro—Best RCA **LSP-3474** [C15]

Hooker, John Lee—At Café Au Go Go Blues. **S-6002** [C15]

Horton, Johnny—Greatest Hits Col. **CS-8396** [C15]

Houston, Cisco—Legendary Van. **73006** [C16]

Houston, David—Greatest Hits Epic **BN-26342** [C16]

Howard, Harlan—All Time Favorite Country Songwriter Monu. 8038 [C16]

Hurt, Mississippi John—Immortal Van. **79248** [C16]

Husky, Ferlin—Best Cap. **SKAO-143** [C16]

Ian & Sylvia—Northern Journey Van. **79154** [C16]

Indian Songs of Today Library of Congress AAFS L36 [C16]

Ives, Burl—Greatest Hits Dec. **74850** [C16]
Times They Are A-Changin' Col. **CS-9675** [C16]

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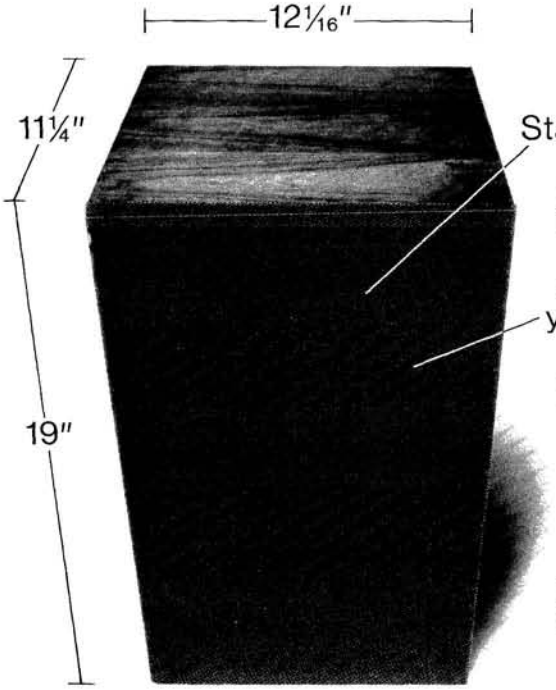

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Unsinkable Molly Brown [ST]	MGM **S-4232ST**	**[B67]**	**West Side Story** [OC]	Col. **OS-2001**	**[B67]**
Vagabond King—Lanza	RCA **LSC-2509**	**[B67]**	**Wizard of Oz** [ST]	MGM **S-3996ST**	**[B67]**

Folk, Country and Gospel Recordings

The interrelated forms of folk, country and gospel music have their roots in the past but are peculiarly relevant to the present. Much of the song material stems from bygone generations but nevertheless influences contemporary popular music in a major way. It could not be otherwise, for the validity and vitality of these basic song forms is unmatched. They represent the aspirations of the people; they mirror the trials and tribulations of men and women; their melody lines have a haunting loveliness and their lyrics are at once poetic and realistic.

Together, these musical forms illustrate the richness of the fabric of Musical Americana.

This record collection attempts to provide the listener with a sampling of this cultural heritage. There is included, for instance, pristine folk material, as in the Alan Lomax Southern Heritage Series, as well as records exemplifying the beginnings of the commercial recording era during the 1920's and 1930's illustrated by Harry Smith's Anthology of American Folk Music. The folk list also includes material by such artists as John Jacob Niles, Richard Dyer-Bennett and Burl Ives; the folk blues of Muddy Waters, Leadbelly and other great black artists; and examples of the contributions of such noted talents as Pete Seeger, Woody Guthrie, Jean Ritchie and many more. Finally, the folk list includes a representative sampling of such modern artists as Bob Dylan and Joan Baez, among others.

The country list is similarly broad. It includes a generous amount of traditional material as illustrated by the records of Jimmie Rodgers, the father of the country field, the Carter Family, and many other giants of this musical genre.

Both Rodgers and the Carter Family were discovered by Ralph Peer, who in the late 1920's and early 1930's pioneered in both the country and blues areas of American music. Peer was the prototype of the commercial recording man who possessed vision and taste—and in the 1940's, 1950's and on into the 1960's his work was continued by such men as Art Satherly, David Kapp, Don Law, Frank Walker, Steve Sholes, Ken Nelson, Paul Cohen, Owen Bradley and others who devoted years to the building of the country music field.

During their lifetime, country music changed, losing some of its purity but at the same time enriching the popular music idiom with its great songs and artists. Thus, modern country record arrangements may use horns, drums, electronic instruments, choral groups and other elements which were taboo in an earlier era. These changes were occasioned by many developments: the improvement in communications; population migrations during World War II, which resulted in residents of the rural South moving to other sections of the nation to work in defense plants; changes in the technology of farming and mining, which initiated additional population migrations. Thus, country music, once a self-contained cultural entity, influenced and in turn was influenced by other musical forms.

Recordings included in this section mirror this gradual change in country music and prove that a musical idiom is dynamic, not static. In general, the lyrics of country music have a basic sincerity and truth, and much of the material reflects the rural southerner's closeness to God.

This dedication to things spiritual is, of course, a paramount expression of the gospel field. Artists such as James Cleveland, the Blackwood Brothers and the remainder of the gospel list are truly dedicated to the work of the Lord. As in the instances of folk and country, the gospel field has had a tremendous impact on the broad field of contemporary popular music. This is indicated by the fact that the satisfying gospel chord progressions and the style of performance have become virtually an integral part of the music of such major artists as Aretha Franklin, Ray Charles, and countless others whose records cut across all categories and sell in the broad pop market.

Paul Ackerman

COUNTRY-FOLK-GOSPEL RECORDINGS

Acuff, Roy—Best	Cap. **DT-1870E**	**[C1]**
A Living Legend	Hick. **S-145**	**[C1]**
Wabash Cannonball	Hick. **S-125**	**[C1]**
Afro-American Spirituals, Work Songs, and Ballads	Library of Congress AAFS L3	**[C1]**
Almanac Singers—Talking Union	Folk. 5285	**[C1]**
American Sea Songs and Shanties	Library of Congress AAFS L26	**[C1]**
Anderson, Bill—Greatest Hits	Dec. **74859**	**[C1]**
Anderson, Eric	War. **S-1806**	**[C1]**
Anderson, Liz—Country Style	RCA **LSP-4118**	**[C1]**
Anderson, Lynn—Best	Chart **CHS-1009**	**[C2]**
Anglo-American Ballads	Library of Congress AAFS L1	**[C2]**
Anthology of American Folk Music (Vols. 1,2,3)	6-Folk. 2591-2-3	**[C2,3]**

An open letter to Thomas A. Edison

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Dear Tom,

All of us at the Audiotechniques' group want to thank you for the phonograph. It was a great idea, and without it we all might be selling insurance.

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So, Tom, we'd like to invite you to attend our centennial celebration in 2072. (On second thought, we'll probably join you in looking in on the party together). Until then...

Best regards,

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Kathleen Kuliner
Bob Berliner
Hank Brown
Richard Faszczewski
Audrey Anderson
Susan Kruisel
David Berliner
James McIpe
Cathy Toal
Phyllis Fortuna
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Thomas, John Charles—An Affectionate Recollection RCA LPV-515 [B53]

Thornhill, Claude—Snowfall, a Memory of Claude Mon.-Ev. **6606** [B53]

Those Wonderful Girls of Stage, Screen & Radio 2-Epic **B2N-159** [B53]

Those Wonderful Guys of Stage, Screen & Radio 2-Epic **B2N-164** [B53]

Tillotson, Johnny—Very Best MGM **4814** [B54]

Trapp Family—Sound of Folk Music Camd. **S-904** [B54]

Vale, Jerry—Greatest Hits Col. **CS-8778** [B54]

Valente, Caterina—Golden Favorites Dec. **74504** [B54]
Sweet Beat Lon. **536** [B54]

Vaughan, Sarah—Golden Hits Mer. **60645** [B54]

Vaughn, Billy—Sail Along Silvery Moon Dot **25100** [B54]

Ventures—Golden Greats Lib. **8053** [B54]

Vinton, Bobby—Greatest Hits Epic **BN-26098** [B54]

Waring, Fred—Waring's Pennsylvanians RCA LPV-554 [B54]

Warwick, Dionne—Promises, Promises Scep. **S-571** [B55]
Golden Hits, Vol. 1 Scep. **565** [B55]
Golden Hits, Vol. 2 Scep. **S-577** [B55]
I'll Never Fall In Love Again Scep. **S-581** [B55]

Washington, Dinah—Unforgettable Mer. **60232** [B55]

Welk, Lawrence—Memories Ran. **8044** [B55]

Whiteman, Paul—Featuring Bing Crosby Col. CL-2830 [B55]
Vol. 1 RCA LPV-555 [B55]
Vol. 2 RCA LPV-570 [B55]

Who—Tommy 2-Dec. **DXSW-7205** [B55]

Wilber, Bob & Maxine Sullivan—Music of Hoagy Carmichael Mon.-Ev. **6917** [B56]

Wiley, Lee—Back Home Again Mon.-Ev. **7041** [B56]
Rodgers & Hart/Harold Arlen Mon-Ev. **6807** [B56]
Sings Gershwin & Porter Mon.-Ev. **7034** [B56]

Williams, Andy—Days of Wine & Roses Col. **CS-8815** [B56]
Greatest Hits Col. **KCS-9979** [B56]

Williams, Roger—Autumn Leaves Kapp **3452** [B56]
Golden Hits Kapp **3530** [B56]

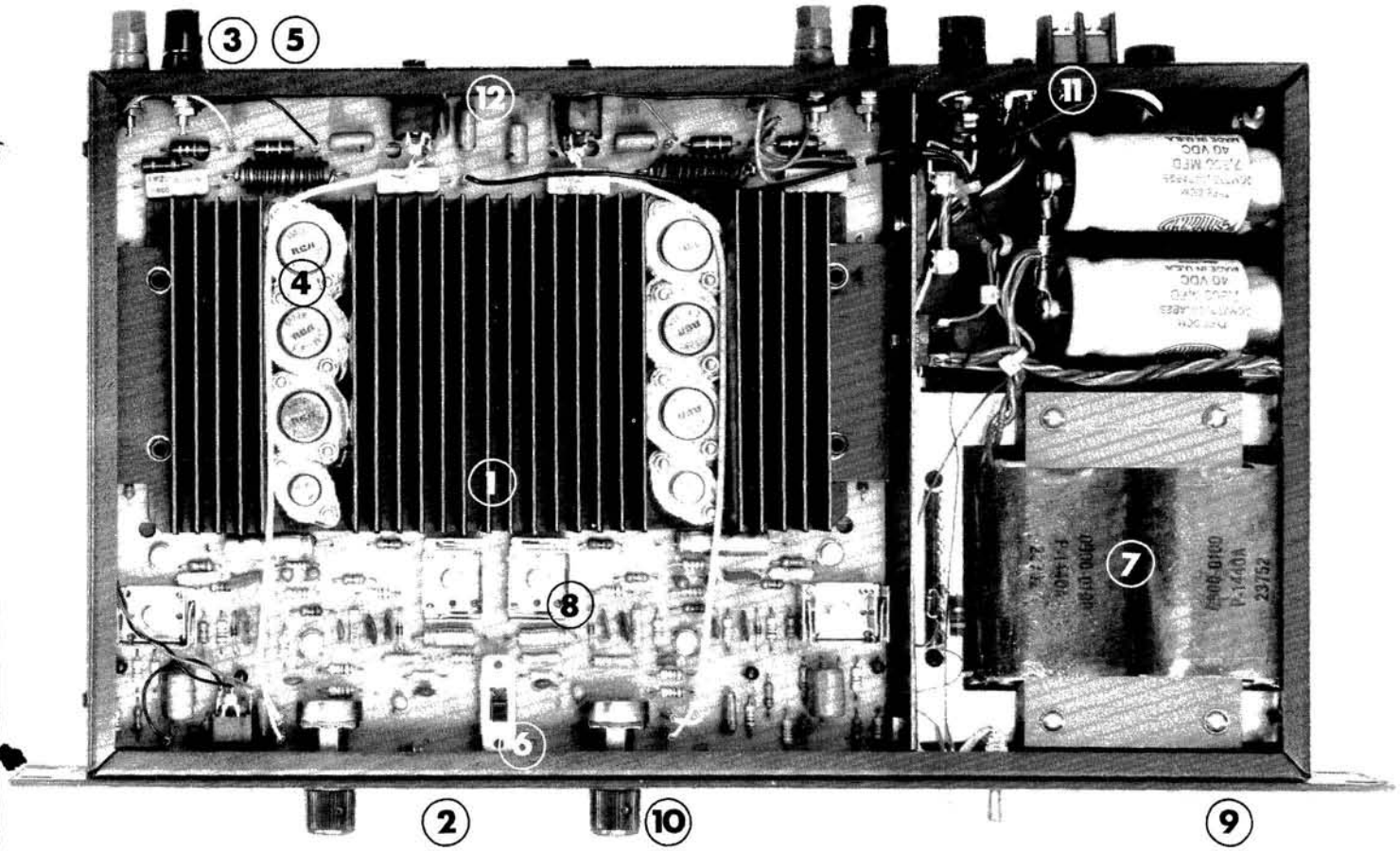
Wilson, Nancy—Best Cap. **SKAO-2947** [B56]

Winterhalter, Hugo—All Time Movie Greats 2-Musi. **M2S-3160** [B57]

Youmans, Vincent—Through the Years Mon.-Ev. **S-6401-2** [B57]

Musicals, Movies

Applause [OC] ABC **OCS-11** [B58]
Babes in Toyland Buena **S-4022** [B58]
Bells Are Ringing [OC] Col. **OS-2006** [B58]
Black Orpheus [ST] Fon. **67520** [B58]
Born Free [ST] MGM **S-4368** [B58]
Boys from Syracuse CSP **COS-2580** [B58]
Breakfast at Tiffany's RCA **LSP-2362** [B58]
Brigadoon [OC] RCA **LSO-1001E** [B58]
Bye Bye Birdie [OC] CSP **COS-2025** [B59]
Cabaret [OC] Col. **KOS-3040** [B59]
Camelot [OC] Col. **OS-2031** [B59]
Can-Can Cap. **DW-452E** [B59]
Carmen Jones [OC] Dec. **79021E** [B59]
Carousel [OC] Dec. **79020E** [B59]
Countess Maritza West. **8159** [B59]
Damn Yankees [OC] RCA **LSO-1021E** [B59]
Dr. Zhivago [ST] MGM **S-1E6ST** [B59]
Exodus [ST] RCA **LSO-1058** [B60]
Fanny [OC] RCA **LSO-1015E** [B60]
Fantasticks [OC] MGM **S-3872OC** [B60]
Fiddler on the Roof [OC] RCA **LSO-1093** [B60]
Finian's Rainbow [OC] RCA **LSO-1057** [B60]
Fiorello [OC] Cap. **SWAO-1321** [B60]
For Whom the Bell Tolls War. **S-1201E** [B60]
Funny Girl [OC] Cap. **STAO-2059** [B60]
George M. [OC] Col. **KOS-3200** [B61]
Gigi [ST] MGM **S-3641ST** [B61]
Girl Crazy CSP **COS-2560** [B61]
Golden Boy [OC] Cap. **SVAS-2124** [B61]
Gone With the Wind [ST] MGM **S-1E10ST** [B61]
Graduate [ST] Col. **OS-3180** [B61]
Guys & Dolls [OC] Dec. **79023E** [B61]
Gypsy [OC] Col. **OS-2017** [B61]
Hair [OC] RCA **LSO-1143** [B62]
Happy Time RCA **LSO-1144** [B62]
Hello, Dolly [OC] RCA **LSOD-1087** [B62]
I Do! I Do! [OC] RCA **LSO-1128** [B62]
The King and I [OC] Dec. **79008E** [B62]
Kismet RCA **LSO-1112** [B62]
Kiss Me Kate Col. **OS-2300E** [B62]
Lew Leslie's Blackbirds of 1928 Col. OL-6770 [B62]
L'il Abner [OC] Col. **OS-2021** [B62]
Lost in the Stars [OC] Dec. **79120E** [B63]
Mame [OC] Col. **KOS-3000** [B63]
A Man & a Woman [ST] U. Artists **5147** [B63]
Man of La Mancha [OC] Kapp **S-5505** [B63]
Mary Poppins [ST] Buena **S-4026** [B63]
Merry Widow West. **8159** [B59]
Midnight Cowboy [ST] U. Artists **5198** [B63]
Mondo Cane [ST] U. Artists **5105** [B63]
Most Happy Fella Col. **OS-2330E** [B63]
Music Man [OC] Cap. **SW-990** [B64]
My Fair Lady [OC] Col. **OS-2015** [B64]
Never On Sunday [ST] U. Artists **5070** [B64]
Oh, Kay! Col. **OS-2550** [B64]
Oklahoma [OC] Dec. **79017E** [B64]
Oliver Cap. **ST-1784** [B64]
On a Clear Day You Can See Forever [OC] RCA **LSOD-2006** [B64]
Originals, Musical Comedy (1909–'35) RCA LPV-560 [B64]
Pajama Game [OC] Col. OL-4840 [B64]
Peter Pan [OC] RCA **LSO-1019E** [B65]
Pink Panther RCA **LSP-2795** [B65]
Promises, Promises [OC] U. Artists **9902** [B65]
Romeo & Juliet [ST] Cap. **ST-2993** [B65]
1776 [OC] Col. **BOS-3310** [B65]
Showboat RCA **LSO-1505** [B65]
Song of Norway [OC] Dec. **79019E** [B65]
Sound of Music [OC] Col. **KOS-2020** [B65]
South Pacific Col. **OS-2040E** [B65]
Student Prince Col. **OS-2380** [B66]
Thoroughly Modern Millie Dec. **71500** [B66]
Three Penny Opera 2-Col. **02S-201** [B66]
2001:A Space Odyssey [ST] MGM **S-1E13STX** [B66]
Umbrellas of Cherbourg [ST] Phi. **PCC-616** [B67]



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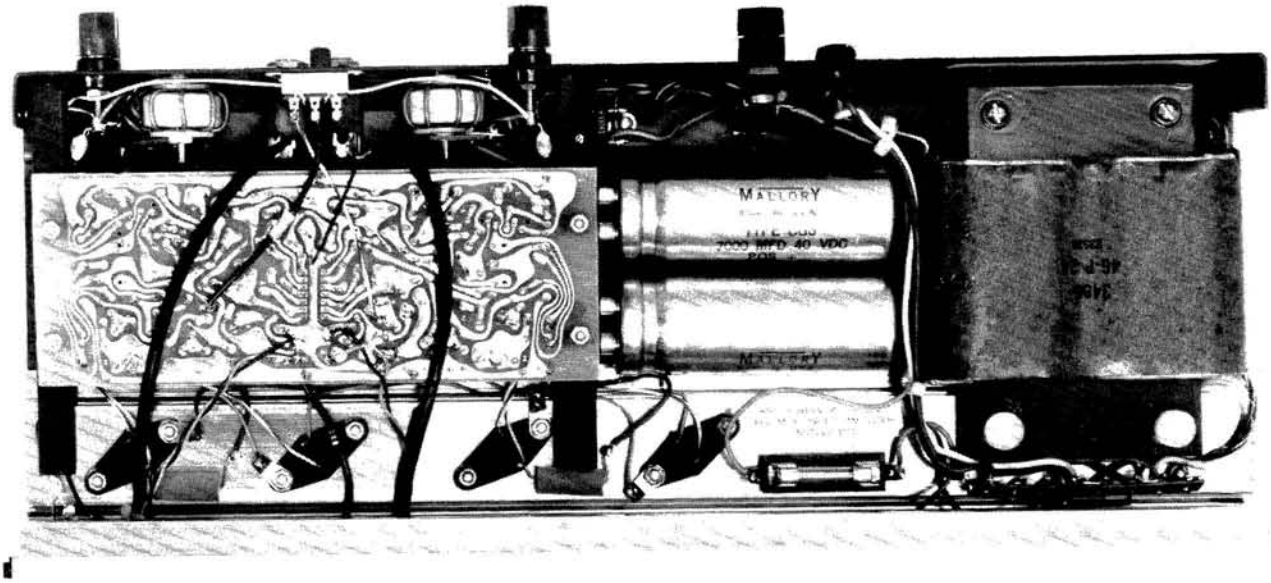

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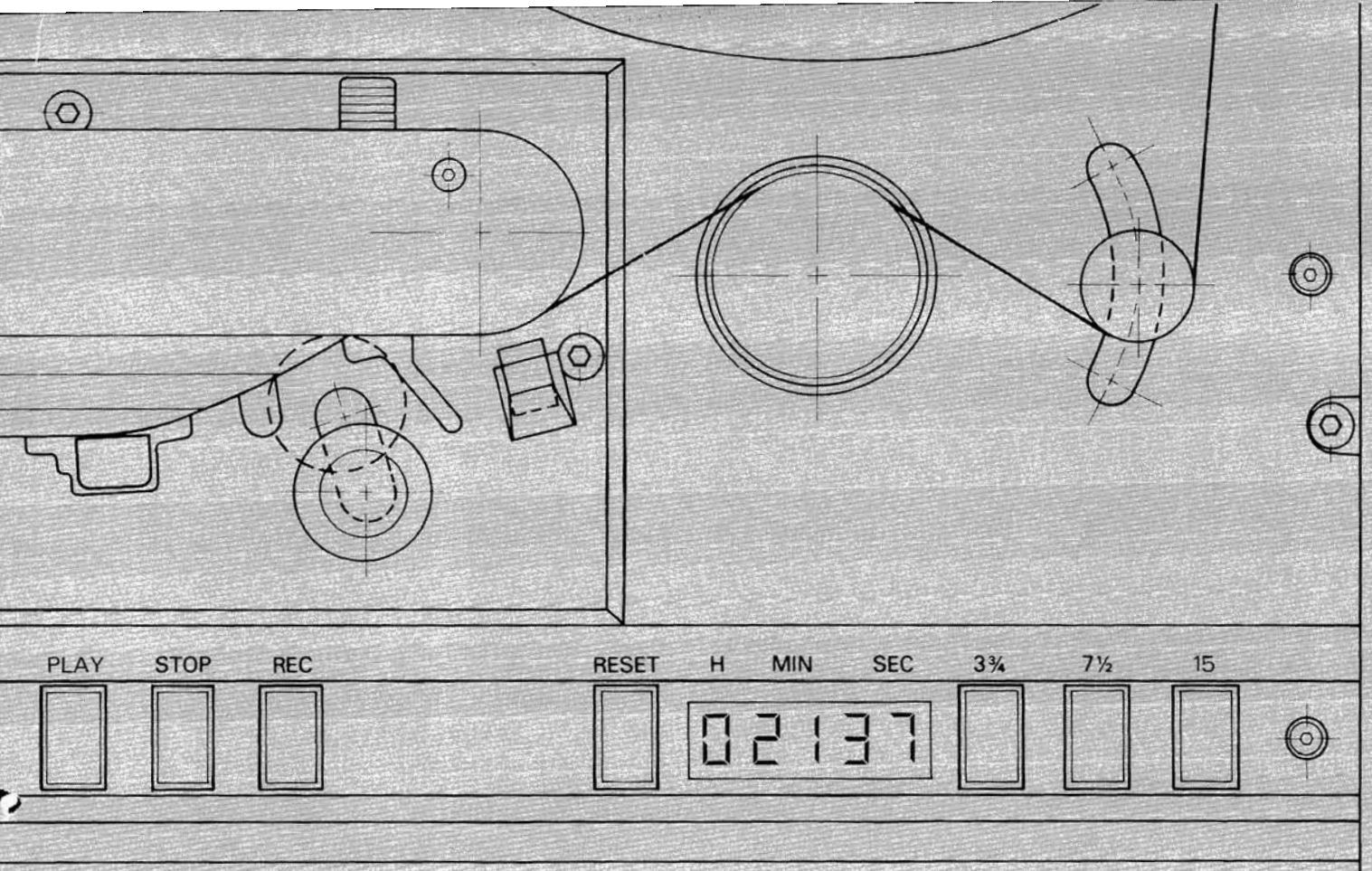

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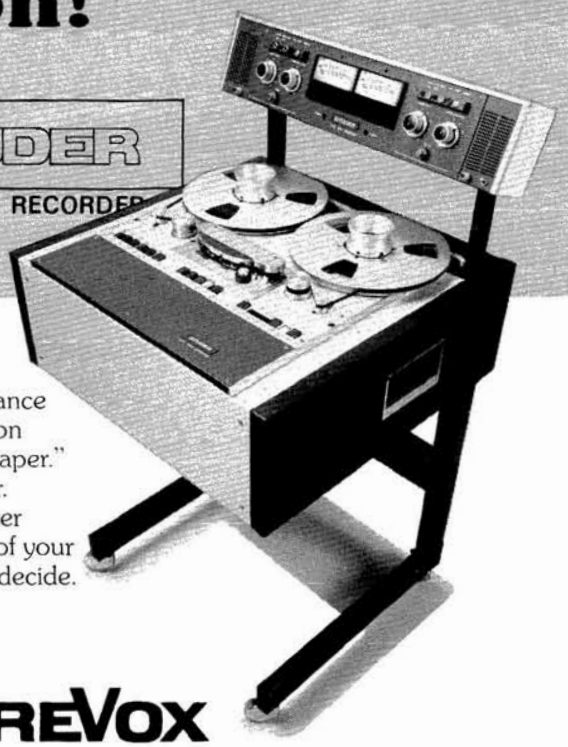

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Mann, Herbie—Best	At. **S-1544**	**[B34]**
Manne, Shelly & André Previn—My Fair Lady	Contem. **7527**	**[B34]**
Mantovani—Music of Berlin & Friml	Lon. **166**	**[B34]**
Music of Herbert & Romberg	Lon. **165**	**[B34]**
Martin, Dean—Greatest Hits, Vol. 1	Reprise **S-6301**	**[B34]**
Martino, Al—Best	Cap. **SKAO-2946**	**[B34]**
Mathis, Johnny—Johnny's Greatest Hits	Col. **CS-8634**	**[B34]**
More Greatest Hits	Col. **CS-8150**	**[B34]**
Newest Hits	Col **CS-8816**	**[B35]**
Matlock, Matty—Dixieland Story, Vols. 1 & 2	2-War. **S-1317/8**	**[B35]**
McCormack, John—Sings Irish Songs	Camd. **S-407**	**[B35]**
McEachern, Murray—Music for Sleepwalkers	Key 711	**[B35]**
McKuen, Rod—At Carnegie Hall	2-War. **S-1794**	**[B35]**
McRae, Carmen—Great American Songbook	2-At. **2-904**	**[B35]**
Portrait of Carmen	At. **S-8165**	**[B35]**
Melanie—Candles In The Rain	Bud. **BDS-5060**	**[B36]**
Gather Me	Neighborhood **47001**	**[B36]**
Mendes, Sergio—& Brazil '66	A&M **4116**	**[B36]**
Beat of Brazil	At. **S-1480**	**[B36]**
Fool on the Hill	A&M **X-4160**	**[B36]**
Greatest Hits	A&M **4252**	**[B36]**
Mercer, Mabel & Bobby Short—At Town Hall	2-At. **S-604**	**[B36]**
Miller, Glenn—Air Force Band	5-RCA LPM-6700	**[B37]**
Memorial ('44–'69)	2-RCA VPM-6019	**[B37]**
Unforgettable Glenn Miller	6-RDA 64-A	**[B38]**
Miller, Mitch—Fireside Sing Along	Har. **11241**	**[B39]**
Mills Brothers—Best	2-Dec. **DXS-7193**	**[B39]**
Such Sweet Singing	Voc. **73859**	**[B39]**
Mitchell, Joni—Clouds	Reprise **S-6341**	**[B39]**
Monroe, Vaughn—Best	RCA **LSP-3817**	**[B39]**
Montgomery, Wes—A Day in the Life	A&M **3001**	**[B39]**
Greatest Hits	A&M **4247**	**[B39]**
Morgan, Russ—Best	2-Dec. **DXS-7196**	**[B39]**
Does Your Heart Beat for Me?	Dec. **74503**	**[B40]**
Mormon Tabernacle Choir—The Lord's Prayer	Col. **MS-6068**	**[B40]**
Mothers of Invention—We're Only in it for the Money	Verve **65045**	**[B40]**
Murad, Jerry, Harmonicats—Peg O' My Heart	Col. **CS-8437**	**[B40]**
Murray, Anne—Snowbird	Cap. **ST-579**	**[B40]**
Nabors, Jim—By Request	Col. **CS-9465**	**[B40]**
Nashville Brass—Play the Nashville Sound	RCA **LSP-4059**	**[B40]**
Native American Ballads	RCA LPV-548	**[B40]**
Newton, Wayne—Best	Cap. **ST-2797**	**[B41]**
Nilsson—Harry	RCA **LSP-4197**	**[B41]**
1926	RCA LPV-557	**[B41]**
1927	RCA LPV-545	**[B41]**
1928	RCA LPV-523	**[B41]**
Noble, Ray—Slumming on Park Ave.	RCA LPV-536	**[B41]**
Nyro, Laura—New York Tendaberry	Col. **KCS-9737**	**[B41]**
Olsen, George—George Olsen and his Music	RCA LPV-549	**[B41]**
101 Strings—Play Victor Herbert	Alshire **S-5209**	**[B41]**
Original Sound of the 20's	3-Col. C3L-35	**[B42]**
Osmond Bros.—Phase III	MGM **1SE-4796**	**[B42]**
Osmond, Donny—To You With Love	MGM **4797**	**[B42]**
Page, Patti—Golden Hits	Mer. **60495**	**[B42]**
Peter, Paul & Mary—Best (10 Years Together)	War. **BS-2552**	**[B42]**
Pickett, Wilson—Best	At. **S-8151**	**[B42]**
Pollack, Ben—Pick-A-Rib Boys–Dixieland	Savoy 12090	**[B42]**
Powell, Dick—In Hollywood (1933–5)	2-Col. C2L-44	**[B43]**
Prado, Perez—Big Hits by Prado	RCA **LSP-2104**	**[B43]**
Presley, Elvis—Golden Records, Vol. 2	RCA **LSP-2075**	**[B43]**
TV Special	RCA LPM-4088	**[B43]**
Prysock, Arthur—Best	Verve **65011**	**[B43]**
Best, Vol. 2	Verve **65038**	**[B43]**
Puckett, Gary & Union Gap	Col. **CS-9612**	**[B43]**
Greatest Hits	Col. **CS-1042**	**[B43]**
Randolph, Boots—Yakety Sax	Monu. **18002**	**[B43]**
Rawls, Lou—Best	Cap. **SKAO-2948**	**[B44]**
Redding, Otis—At the Whiskey à Go-Go	Atco **S-33-265**	**[B44]**
Redman, Don—Master of the Big Band	RCA LPV-520	**[B44]**
Rich, Buddy—Mercy, Mercy	Pac. Jazz **20133**	**[B44]**
Righteous Bros.—Greatest Hits	Verve **65020**	**[B44]**
Rock Begins—Vols. 1 & 2	2-Atco **S-33-314/5**	**[B44]**
Rodgers, Richard—Music of	Camd. **S-2458**	**[B44]**
Rogers, Kenny & First Edition—Greatest Hits	Reprise **S-6437**	**[B45]**
Rolling Stones—Satanic Majesties	Lon. **NPS-2**	**[B45]**
Sandpipers—Greatest Hits	A&M **4246**	**[B45]**
Schifrin, Lalo—Mission Impossible	Dot **25831**	**[B45]**
Shaw, Artie—Best	RCA **LSP-3675**	**[B45]**
Swing With Artie Shaw	4-RDA 89-A	**[B46]**
Shaw, Robert, Chorale—Joy to the World	Camd. **S-448**	**[B47]**
With Love From a Chorus	RCA LM-1815	**[B47]**
Shea, George Beverly—Best, Vol. 2	RCA **LSP-3904**	**[B47]**
Shearing, George—Best	Cap. **ST-2104**	**[B47]**
Shirelles—Greatest Hits	Scep. **S-507**	**[B47]**
Simon & Garfunkel—Bookends	Col. **KCS-9529**	**[B47]**
Simone, Nina—Best	RCA **LSP-4374**	**[B47]**
Black Gold	RCA **LSP-4248**	**[B47]**
Sinatra, Frank—Essential	3-Col. **S3S-842**	**[B48]**
Great Years	3-Cap. **STCO-1762**	**[B48]**
Greatest Hits	Reprise **S-1025**	**[B48]**
September of My Years	Reprise **S-1014**	**[B48]**
Sinatra, Nancy—Greatest Hits	Reprise **S-6409**	**[B48]**
Slatkin, Felix—Hoedown!	Lib. **14024**	**[B49]**
Sly & The Family Stone—Stand	Epic **BN-26456**	**[B49]**
Smith, Jimmy—Best	Verve **68721**	**[B49]**
Smith, Kate—Best	RCA **LSP-3970**	**[B49]**
Sonny & Cher—Live	Kapp **5554**	**[B49]**
Sousa, John Phillip—John Phillip Sousa Conducts His Own Marches	Ev. **3260**	**[B49]**
Stars of Steel Guitar	Starday **S-350**	**[B50]**
Stars of the Silver Screen	RCA LPV-538	**[B50]**
Streisand, Barbra—People	Col. **CS-9015**	**[B50]**
Sullivan, Maxine & Bob Wilber	Mon.-Ev. **6919**	**[B50]**
Supremes—Greatest Hits	2-Mo. **S-663**	**[B50]**
Swing Hits	6-RDA 76-A	**[B51]**
The Swing Years	6-RDA 21-A	**[B52]**
Swingle Singers—Bach's Hits	Phi. **600097**	**[B53]**
They Stopped the Show	Dec. **79111**	**[B53]**
Thomas, B. J.—Greatest Hits, Vol. 1	Scep. **578**	**[B53]**
Greatest Hits, Vol. 2	Scep. **597**	**[B53]**

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Everly Bros.—Very Best War. **S-1554** **[B15]**

Faith, Percy—Greatest Hits Col. **CS-8637** **[B15]**

Feliciano, José—Feliciano RCA **LSP-3957** **[B16]**

Ferguson, Maynard Col. **C-31117** **[B16]**
M. F. Horn Col. **C-30466** **[B16]**

Ferrante & Teicher—Our Golden Favorites U. Artists **6556** **[B16]**

Fifth Dimension—Age of Aquarius Soul City **92005** **[B16]**
Greatest Hits Soul City **33900** **[B16]**
Stoned Soul Picnic Soul City **92002** **[B16]**

Fitzgerald, Ella—Best of Ella 2-Dec. **DXSB-7156** **[B16]**
Ella in Berlin Verve 64041 **[B16]**
Things Ain't What They Used to Be Reprise **S-6432** **[B17]**

Flack, Roberta—Quiet Fire At. **S-1594** **[B17]**

Fountain, Pete—Dixieland Camd. **S-727** **[B17]**

Four Seasons—Edizione D'Oro, w. Valli 2-Phi. **6501** **[B17]**

Four Tops—Greatest Hits Mo. **S-662** **[B17]**

Franklin, Aretha—Aretha in Paris At. **S-8207** **[B17]**
Aretha's Gold At. **S-8227** **[B17]**

Freeman, Stan—Fascination Proj. **S-5012** **[B17]**

Garland, Judy—Carnegie Hall 2-Cap. **SWBO-1569** **[B18]**
Deluxe Set 3-Cap. **STCL-2988** **[B18]**

Garner, Erroll—Concert By The Sea Col. **CS-9821E** **[B18]**
Greatest Garner Atco 1227 **[B18]**

Gaye, Marvin—Greatest Hits Tam. **S-278** **[B18]**

Gershwin, George Alshire **S-5006** **[B18]**

Getz, Stan—Jazz Samba, w. Byrd and Jobim Verve **68432** **[B18]**

Gilberto, João—Samba de una nota Cap. **ST-2160** **[B19]**

Gleason, Jackie—Best Cap. **SW-2796** **[B19]**

Goldsboro, Bobby—Greatest Hits U. Artists **5502** **[B19]**
Honey U. Artists **6642** **[B19]**

Goodman, Benny—This Is B. Goodman 2-RCA VPM-6040 **[B19]**

Gore, Lesley—Golden Hits Mer. **61024** **[B19]**

Gormé, Eydie—Greatest Hits Col. **CS-9564** **[B19]**

Goulet, Robert—Greatest Hits Col. **CS-9815** **[B20]**

Grand Funk Railroad—Live 2-Cap. **SWBB-633** **[B20]**

Grant, Earl—Best 2-Dec. **DXS-7204** **[B20]**

Gray, Glen (Casa Loma)—Greatest Hits Dec. **75016** **[B20]**

Great Band Era 10-RDA **25-A** **[B21]**

Guess Who—Best RCA **LSPX-1004** **[B22]**

Haley, Bill, & the Comets—Greatest Hits Dec. **75027** **[B22]**

Hampton, Lionel—Golden Favorites Dec. **74296** **[B22]**

Hawaii, Music of Old Lon. **99396** **[B22]**

Hawkins, Erskine—After Hours RCA LPM-2227 **[B22]**

Hear Them Again (Crosby, Sinatra, Como, Belafonte, Horne, Morgan, Tucker, Brice, Caruso) 10-RDA 49-A **[B23]**

Hefti, Neal—Jazz Pops Reprise **96039** **[B24]**

Herman, Woody—Golden Favorites Dec. **74484E** **[B24]**

Hi-Lo's—Happen to Bossa Nova Reprise **96066** **[B24]**

Hibbler, Al—Greatest Hits Dec. **75068** **[B24]**

Hirt, Al—Best RCA **LSP-3309** **[B24]**
Best, Vol. 2 RCA **LSP-3556** **[B24]**

Ho, Don—Greatest Hits, w. Aliis Reprise **S-6357** **[B24]**

Holiday, Billie—Lady In Satin Col. **CS-8048** **[B24]**

Holly, Buddy—Greatest Hits Cor. **757492** **[B24]**

Horne, Lena—Lovely and Alive RCA **LSP-2587** **[B24]**

Howard, Eddy—Golden Hits Mer. **60562** **[B25]**

Humperdinck, Engelbert—Release Me Par. **XPAS-71012** **[B25]**

Impressions—Best ABC **S-654** **[B25]**

Ink Spots—Best 2-Dec. **DXS-7182** **[B25]**

Iron Butterfly—In-A-Gadda-Da-Vida Atco **S-33-250** **[B25]**

Jackson 5—Greatest Hits Mo. **S-741** **[B25]**

James, Harry—Greatest Hits Col. **CS-9430** **[B25]**

James, Tommy—Best Rou. **42040** **[B25]**

Jay & the Americans—Greatest Hits U. Artists **6453** **[B25]**

Jefferson Airplane—Surrealistic Pillow RCA **LSP-3766** **[B26]**
Worst RCA **LSP-4459** **[B26]**

Jenkins, Gordon—Manhattan Tower Dec. **78011** **[B26]**

Jobim, Antonio Carlos—The Composer of Desafinados Plays Verve **68547** **[B26]**

John, Elton Uni **93090** **[B26]**

Jolly, Pete—Give a Damn A&M **4184** **[B26]**
Herb Alpert Presents A&M **4145** **[B26]**

Jolson, Al—Best 2-Dec. **DXS-7169** **[B26]**

Jones, Jack—Greatest Hits Kapp **3559** **[B26]**

Jones, Spike—Best of Spike Jones & his City Slickers RCA **LSP-3849** **[B27]**

Jones, Tom—Live in Las Vegas Par. **XPAS-71031** **[B27]**

Joplin, Janis—Pearl Col. **KC-30322** **[B27]**

Jordan, Louis—Greatest Hits Dec. **75035** **[B27]**

Jugs, Washboards & Kazoos RCA LPV-540 **[B27]**

Kaempfert, Bert—Best 2-Dec. **DXS-7200** **[B27]**

Kaye, Danny—Best 2-Dec. **DXS-7175** **[B27]**

Kenton, Stan—In Stereo Creative World **1004** **[B28]**
Live At Redlands U. 2-Creative World **1015** **[B28]**
West Side Story Creative World **1007** **[B28]**

Kerr, Anita—Slightly Baroque War. **S-1665** **[B28]**

King, Wayne—Best RCA **LSP-3742** **[B28]**

Kings of Swing—In the Groove 6-RDA 45-A **[B29]**

Kinks—Greatest Hits Reprise **S-6217** **[B30]**

Krupa, Gene—Drummin' Man 2-Col. C2L-29 **[B30]**

Laine, Frankie—Golden Hits Mer. **60587** **[B30]**
Greatest Hits Amos **7009** **[B30]**

Lambert, Hendricks & Ross—Sing a Song of Basie Impulse **S-83** **[B30]**

Lang, Eddie & Joe Venuti—Stringing the Blues 2-Col. C2L-24 **[B31]**

Lanza, Mario—Best RCA **LSC-2748** **[B31]**

Lawrence, Gertrude—Star Audio Fi. 709 **[B31]**

Lawrence, Steve—Greatest Hits Col. **CS-9565** **[B31]**

Lee, Brenda—Ten Golden Years Dec. **74757** **[B31]**

Lee, Peggy—Greatest Cap. **DKAO-377E** **[B32]**
Miss Peggy Lee Har. **30024E** **[B32]**
Peggy Lee 3-Cap. **STCL-576** **[B32]**

Lettermen—Best, Vol. 1 Cap. **ST-2554** **[B32]**
Best, Vol. 2 Cap. **SKAO-138** **[B32]**

Lewis, Gary—Golden Greats Lib. **7468** **[B32]**

Lewis, Ramsey—In Crowd Cadet **S-757** **[B33]**

Lewis, Ted—Greatest Hits Dec. **74905** **[B33]**

Liberace—Mr. Showmanship! Dot **25547** **[B33]**

Lombardo, Guy—Greatest Hits Dec. **74812** **[B33]**

Lopez, Trini—Greatest Hits Reprise **S-6226** **[B33]**

Makeba, Miriam—In Concert Reprise **S-6253** **[B33]**

Mamas & the Papas—16 Greatest Hits Dun. **S-50064** **[B33]**

Mancini, Henry—Best RCA **LSP-2693** **[B33]**
This Is Henry Mancini 2-RCA **VPS-6029** **[B33]**

Mangione, Chuck—Together, w. Rochester Phil. 2-Mer. **SRM-2-7501** **[B34]**

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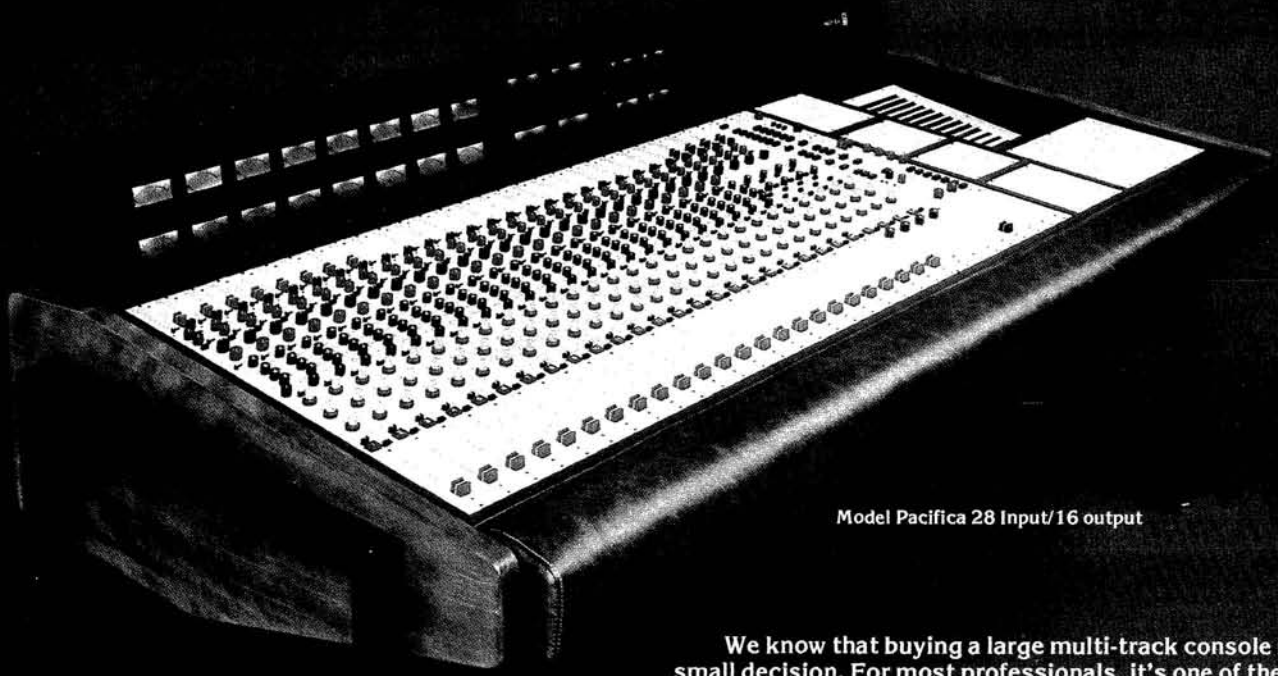

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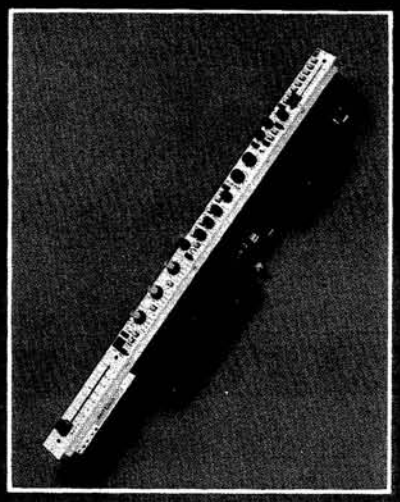

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POPULAR RECORDINGS

Adler, Larry—Discovery, w. Gould RCA **LSC-2986** [B1]
Almeida, Laurindo—Classical Current War. **S-1803** [B1]
Alpert, Herb—Greatest Hits A&M **4245** [B1]
Ames, Ed—This Is 2-RCA **VPS-6023** [B1]
Andrews, Julie—Christmas Treasure RCA **LSP-3829** [B1]
Andrews Sisters—Greatest Hits Dec. **74919** [B1]
Apaka, Alfred—Greatest Hits Cap. **DT-2088E** [B1]
Armstrong, Louis—Best 2-Dec. **DXS-7183E** [B1]
Rare Batch of Satch RCA LPM-2322 [B1]
Arnold, Eddy—Best RCA **LSP-3565** [B2]
Association—Greatest Hits War. **S-1767** [B2]
Austin, Gene—This is Gene Austin 2-RCA VPM-6056 [B2]
Bacharach, Burt—Make It Easy On Yourself A&M **4188** [B2]
Baez, Joan—One Day at a Time Van. **79310** [B2]
Bailey, Mildred—Greatest Performances, Vols 1–3 3-Col. C3L-22 [B2]
Bailey, Pearl—Pearl's Pearls RCA **LSP-4529** [B3]
Baja Marimba Band—Do You Know the Way to San José, w. Wechter A&M **4150** [B3]
Their Greatest Hits A&M **4248** [B3]
Barnet, Charlie—Vol. 2 RCA LPV-567 [B3]
Basie, Count—Basie Years 2-Rou. **102** [B3]
Beatles—Meet the Beatles Cap. **ST-2047** [B3]
Sgt. Pepper Cap. **SMAS-2653** [B3]
Bee Gees—Best Atco **S-33-292** [B3]
Belafonte, Harry—This Is 2-RCA **VPS-6024** [B4]
Bennett, Tony—Greatest Hits Col. **CS-8652** [B4]
Greatest Hits, Vol. 3 Col. **CS-9173** [B4]
Benton, Brook—Golden Hits Mer. **60607** [B4]
Berry, Chuck—Golden Decade 2-Chess **S-1514** [B4]
Best of Dixieland RCA **LSP-2982** [B4]
Blood, Sweat & Tears Col. **CS-9720** [B4]
Greatest Hits Col. **KC-31170** [B4]
Boone, Pat—Days of Wine & Roses Dot **25504** [B5]
Pat's Greatest Hits Dot **25071** [B5]
Boston Pops, Fiedler—Best RCA **LSC-2810** [B5]
Box Tops—Super Hits Bell **S-6025** [B5]
Brewer, Teresa—My Golden Favorites Cor. **757351** [B5]
Brice, Fanny & Helen Morgan RCA LPV-561 [B5]
Brothers Four—Greatest Hits Col. **CS-8603** [B5]
Brown, James—At the Apollo, Vol. 2 2-King **1022** [B5]
Brubeck, Dave—Greatest Hits Col. **CS-9284** [B5]
Butler, Jerry—Best Mer. **61281** [B6]
Byrd, Charlie—Stroke of Genius Col. **C-30380** [B6]
Campbell, Glen—Greatest Hits Cap. **SW-752** [B6]
Cantor, Eddie—Sings "Ida" and His Other Hits Camd. **S-870** [B6]
Carle, Frankie—Plays the Great Piano Hits RCA **LSP-3425** [B6]
Carlos, Walter—Switched On Bach Col. **MS-7194** [B6]
Carpenters A&M **3502** [B6]
Close To You A&M **4271** [B6]
Carr, Vikki—Don't Break My Pretty Balloon Lib. **7565** [B6]
It Must Be Him Lib. **7533** [B6]
Carroll, Barbara—Live, Her Piano & Trio War. **S-1710** [B7]
Chacksfield, Frank—Academy Award Songs 2-Lon. **CHA-S-1** [B7]
Charles, Ray—Great Hits At. **7101** [B7]
Greatest Hits ABC **S-415** [B7]
Modern Sounds ABC **S-410** [B7]
Chevalier, Maurice—Vol. 1 RCA LPV-564 [B7]
Clark, Petula—Greatest Hits-Vol. 1 War. **S-1765** [B7]
These Are My Songs War. **S-1698** [B7]
Clark, Roy—Best Dot **25986** [B7]
Cole, Nat King—Love Is The Thing Cap. **SW-824** [B8]
The Nat Cole Story 3-Cap. **SWCL-1613** [B8]
Collins, Judy—Golden Apples of the Sun Elek. **7222** [B8]
In My Life Elek. **74027** [B8]
Colombo, Russ—Love Songs RCA LPM-2072 [B8]
Como, Perry—This Is Perry Como 2-RCA **VPS-6026** [B8]
Conniff, Ray—Greatest Hits Col. **CS-9839** [B9]
Cooke, Sam—This Is 2-RCA **VPS-6027** [B9]
Coon-Sanders Nighthawks—Radio's Aces RCA LPV-511 [B9]
Coward, Noel—The Noel Coward Album 2-Col. **MG-30088** [B9]
Cream—Best Atco **S-33-291** [B9]
Disraeli Gears Atco **S-33-232** [B9]
Creedence Clearwater Revival Fan. **8382** [B9]
Crosby, Bing—Best Of 2-Dec. **DXSB-7184** [B10]
Crosby, Bob—Greatest Hits Dec. **74856** [B10]
Crosby, Stills, Nash & Young—Déjà Vu At. **7200** [B10]
Cugat, Xavier—Golden Goodies Mer. **60798** [B10]
Curb, Mike, Congregation—Hits From Glen Campbell Show MGM **S-4804** [B10]
Damone, Vic—Best Har. **11128** [B10]
Darin, Bobby—Two of a Kind, w. Mercer Atco **S-126** [B10]
Davis, Sammy Jr.—Greatest Hits Reprise **S-6291** [B11]
Day, Doris—Great Hits Col. **CS-8635** [B11]
Denny, Martin—Golden Greats Lib. **7467** [B11]
Denver, John—Poems, Prayers & Promises RCA **LSP-4499** [B11]
DeParis, Wilbur—On the Riviera At. **S-1363** [B11]
DeShannon, Jackie—Put a Little Love In Your Heart Imper. **12442** [B11]
You Won't Forget Me Imper. **12294** [B11]
Desmond, Paul—Summertime A&M **3015** [B11]
Diamond, Neil—Gold Uni **93084** [B11]
Domino, Fats—Sings a Million Record Hits Imper. **12103** [B12]
Donovan—Greatest Hits Epic **BXN-26439** [B12]
Doors Elek. **74007** [B12]
Dorsey, Jimmy—Greatest Hits Dec. **74853** [B12]
Dorsey, Tommy—Best RCA **LSP-3674** [B12]
Incomparable Tommy Dorsey 4-RDA **92-A** [B13]
This is 2-RCA VPM-6038 [B14]
Duchin, Eddy—Original Recordings Col. **CS-9420** [B14]
Dylan, Bob—Greatest Hits Col. **KCS-9463** [B14]
Greatest Hits, Vol. 2 2-Col. **KG-31120** [B14]
Eckstine, Billy—Golden Hits Mer. **60796** [B14]
Eddy, Nelson, w. Jeanette MacDonald—Favorites RCA **LSP-1738** [B14]
Edwards, Jonathan & Darlene—Songs For Sheiks & Flappers Dot **25792** [B14]
Edwards, Webley—Best of Hawaii Calls Cap. **SKAO-141** [B15]
Hawaii Calls' Greatest Hits Cap. **ST-1339** [B15]
Eighteen King-Size Rhythm & Blues Hits Col. **CS-9467** [B15]
Ellington, Duke—The Popular Duke Ellington RCA **LSP-3576** [B15]
Encores from the 30's—1930–5, Vol. 1 2-Epic **L2N-6072** [B15]
Etting, Ruth—The Original Recordings of Ruth Etting Col. ML-5050 [B15]

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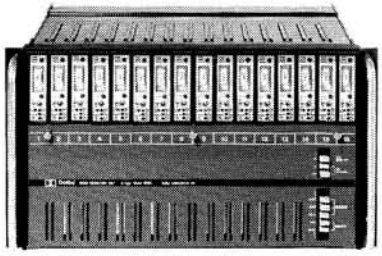
Professional Recording and Transmission Applications

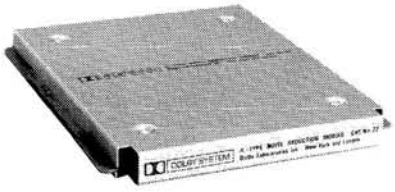
360
The Dolby 360 is a basic single-channel A-type noise reduction unit for encoding or decoding. This unit is normally used in a fixed mode such as in disc cutting or landline sending or receiving; the operating mode is manually selected.

361
The Dolby 361 is similar to the 360, providing a single channel of A-type noise reduction, but with relay switching of operating mode and tape recorder connections. The changeover can be controlled automatically by the recorder.



M-Series
The Dolby M16H A-type unit is designed specifically for professional multi-track recording, and incorporates 16 channels of noise reduction in a compact chassis only 10½ inches high. The similar M8H is an 8-track version, and the M8XH allows simple extension of the M16H for 24-track use.

Noise Reduction Module

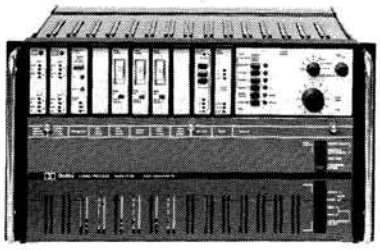


Cat. No. 22
The Dolby noise reduction module, Cat. No. 22 is the basic functional unit employed in all A-type equipment. The Cat. No. 22 is available as a spare or in quantity to OEM users for factory installation. A half-speed version of the module (Cat. No. 40) is also available.

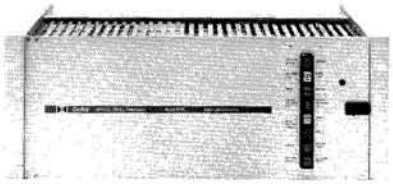
Motion Picture Industry

364
The Dolby 364 Cinema Noise Reduction Unit is intended primarily for use with Dolby A-type encoded optical sound-tracks. The 364 also includes a standard 'Academy' filter for conventional tracks, and provision for playback of magnetic sound-tracks with or without Dolby system encoding.

E2
The Dolby E2 Cinema Equalizer is a companion unit to the 364, and has been specifically designed to solve the response equalization problems of cinemas. Used with the 364 and Dolbyized optical sound-tracks, the E2 enables most cinemas to achieve modern sound reproduction standards without replacement of existing equipment.



CP100
The Dolby CP100 Cinema Processor is designed for the reproduction of all current and presently foreseeable film sound-track formats including conventional optical and magnetic tracks, Dolby encoded monaural optical tracks, Dolby encoded magnetic sound-tracks and the new stereo optical release prints. Up to three noise reduction modules can be incorporated. Typically, three channels of theatre equalization, as in the E2, will be incorporated, but facilities exist for five channels of equalization and the connection of an external quadraphonic decoder.



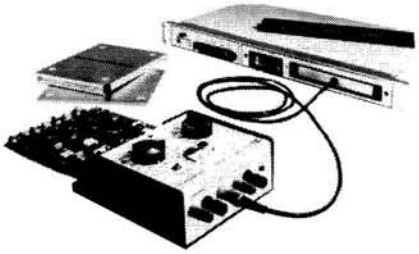
CP50
The new model CP50 is intended for the reproduction of all optical sound-track formats, Dolby encoded and conventional, mono and stereo. The unit is designed to interface with an existing fader and magnetic stereo installation; a wide range of accessories is available.

Professional Encoders for Consumer Media

330
The Dolby 330 Tape Duplication Unit is a professional quality unit with B-type (consumer) noise reduction characteristics. The unit is used for encoding duplicating master tapes in the high-speed duplication of Dolbyized cassettes, cartridges, and open-reel tapes. The 330 is a two-channel unit.

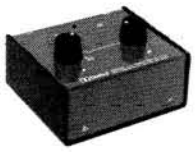
334
The 334 FM Broadcast Unit allows broadcast stations to encode stereo FM broadcasts with the Dolby B-type characteristic. The unit also provides for a reduction of high frequency pre-emphasis to 25 microseconds; this reduces the need for high frequency limiting, thus allowing a significant additional improvement in reception quality.

Test Set (A-type)



Cat. No. 35
The Dolby NRM Test Set, Cat. No. 35, permits rapid verification of performance of Cat. No. 22 Noise Reduction Modules without their removal or the need for additional test equipment.

Noise Weighting Filter



Cat. No. 98 A
Noise weighting filter to CCIR/ARM characteristic (recommended by Dolby Laboratories). Filter is used with average responding meter (ordinary millivoltmeter) allowing noise measurements to be made on tape recorders, tapes, FM tuners, etc., with results which correlate closely with the subjective effect of the noise. Filter can be used for the testing of professional and consumer equipment.

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S77/89

Die Walküre:Act 1, Scene 3
Traubel, Melchior, Toscanini, NBC Symphony — RCA **VICS-1316E** **[A54]**

Wesendonck Songs (1857-58)
Horne, Lewis, Royal Philharmonic — Lon. **26147** **[A55]**

WALDTEUFEL, EMIL (1837–1915)
Waltzes
Fiedler, Boston Pops — RCA **LSC-2548** **[A56]**

WALTON, WILLIAM (1902–
Belshazzar's Feast
Bell, Walton, Phil Orch. & Cho. — Ang. **S-35681** **[A56]**

Façade
Sitwell, Prausnitz — CSP CML-5241 **[A56]**

Partita for Orchestra
Walton, Phil. Orch. — Ang. **S-35681** **[A56]**

WARD, ROBERT (1917–
The Crucible
Bible, Brooks, Ludgin, Buckley, City Center Orchestra — 2-CRI **S-168** **[A56]**

WEBER, BEN (1916–
Symphony on Poems of William Blake, Op. 33
Galjour, Stokowski, Orchestra — CRI 120 **[A23]**

WEBER, CARL MARIA VON (1786 1826)
Concertino for Clarinet & Orchestra, Op. 26; Concerto No. 1 in f for Clarinet, Op. 73
De Peyer, Frühbeck de Burgos, New Philharmonia — Ang. **S-36589** **[A57]**

Der Freischütz
Seefried, Streich, Holm, Böhme, Jochum, Bavarian Radio Orchestra — 2 DG **2707009** **[A57]**

Overtures (Abu Hassan, Freischütz, Oberon, Euryanthe, Preciosa, Ruler of the Spirits)
Ansermet, Orchestre de la Suisse Romande — Lon. **STS-15056** **[A57]**

WEBERN, ANTON (1883–1945)
Passacaglia for Orchestra
Rudolf, Cincinnati Symphony — Dec. **710168** **[A18]**

WEILL, KURT (1900–1950)
Seven Deadly Sins (Ballet in Song) (1933)
May, Schreier, Rotzsch, Leib, Polster, Kegel, Leipzig Radio Symphony — DG **139308** **[A57]**

WOLF, HUGO (1860–1903)
Songs
Lehmann, Balogh (14 songs) — RCA **VICS-1320** **[A13]**

WUORINEN, CHARLES (1938–
Time's Encomium, for Synthesizer
Electronic Equipment — None. **71225** **[A58]**

XENAKIS, IANNIS (1922–
Eonta; Métastasis; Pithoprakta
Takahashi, Paris Contemporary Music Instr. Ens.; LeRoux, French National Radio Orchestra — Van. **C-10030** **[A58]**

YARDUMIAN, RICHARD (1917
Passacaglia, Recitatives & Fugue (Concerto for Piano)
Ogdon, Buketoff, Royal Phil. — RCA **LSC-3243** **[A30]**

Popular Recordings

It is an awesome task to try to choose a library of recordings for the White House. America is such a land of opportunity that the songs and singers to choose from are overwhelming.

Certain songs distinguish themselves by their longevity, such as "Greensleeves," "Swing Low, Sweet Chariot," "Stardust," and many others, and you can still hear Caruso, Bessie Smith and John McCormack on obscure record machines. So the real champs will punch through to the top and achieve permanence—if there is such a word—but, outside of these, we have to choose from what we hear, and not all of that is good. Most companies, being in business to make money, are inclined to put out what sells, rather than what is musically excellent.

We went through an age where "Tin Pan Alley" produced most of the popular music of America. Now we are in a resurgence of country and folk songs—an age which includes rock and many new forms of music, as well as many new writers and singers. Detroit is a big record center, and Nashville calls itself "Music City U.S.A."

Well, out of all the songs since records have come into being, we have tried to pick a representative cross-section of the songs and singers that America loved best, the favorites of their own eras—"the legends in their own time." You'll find many of your favorites in here and you'll dispute some of the choices, no doubt. But compared to over-all output, they shine like stars in the night, like jewels in the red clay.

These selections are what the man in the street sang, hummed, and danced to, what he whistled in the shower, paid his hard-earned dollar for and looks back nostalgically upon as a high point of the good times in his life. Considering the broad sweep of popular music, we have tried to find the best of what is still in print, what is not irretrievably lost, so that the inhabitants and guests of our First Mansion might be entertained by the best and most colorful of all recorded music from the day Edison first unveiled his cylindrical record. There may be inadvertent omissions and perhaps some unwarranted inclusions. A few of the recordings we wanted most were, regretfully, no longer available. Because of my unfamiliarity with the bulk of current popular releases, the distinguished Billboard reviewer, Don Ovens, kindly consented to supplement the list by including some of the more outstanding recent releases.

Our principal concern was to be objective and to provide the listener with a truly representative group of outstanding popular recordings.

All in all, I think we have succeeded.

Johnny Mercer

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Swan Lake, Op. 20 (excerpts)
Stokowski, New Philharmonia — Lon. **21008** **[A51]**

Symphony No. 4 in f, Op. 36
Ormandy, Philadelphia Orch. — 3-Col. **D3S-727** **[A51]**

Symphony No. 5 in e, Op. 64
Ormandy, Philadelphia Orch. — 3-Col. **D3S-727** **[A51]**

Symphony No. 6 in b, Op. 74, "Pathétique"
Ormandy, Philadelphia Orch. — 3-Col. **D3S-727** **[A51]**

Variations on a Rococco Theme for Cello, Op. 33
Rostropovitch, Karajan, Berlin Philharmonic — DG **139044** **[A19]**

TELEMANN, GEORG PHILIPP (1681–1767)

Musique de table (No. 5); Trio Sonata in B♭; Flute Concerto (No. 1); Sonata in f
Rampal, Veyron-Lacroix — None. **71038** **[A51]**

Suite in a for Flute and Strings
Baker, Janigro, Solisti di Zagreb — Bach **5048** **[A32]**

THOMPSON, RANDALL (1899–

Symphony No. 2
Dixon, Vienna Sym. — Desto **6406E** **[A18]**

THOMSON, VIRGIL (1896–

Mother of Us All (suite); Concerto for Cello
Silva, Janssen, Los Angeles Symphony — CSP CML-4468 **[A52]**

Plow that Broke the Plains; The River
Stokowski, Symphony of the Air — Van. **2095** **[A52]**

TORELLI, GIUSEPPE (1658–1709)

Concerto grosso, Op. 8, No. 6 in g
Karajan, Berlin Phil. — DG **2530070** **[A17]**

TURINA, JOAQUIN (1882–1949)

Danzas Fantásticas
Ansermet, Orchestre de la Suisse Romande — Lon. **6194** **[A1]**

VARÈSE, EDGARD (1883–1965)

Octandre; Poème électronique; Ionisation; Hyperprism; Intégrales; Density 21.5
Craft, Ensemble — Col. **MS-6146** **[A52]**

VAUGHAN WILLIAMS, RALPH (1872–1958)

Fantasia on a Theme by Tallis; English Folk Song Suite; Fantasia on "Greensleeves"
Boult, Vienna State Opera Orch. — West. **8111** **[A52]**
Gould Orch. — RCA **LSC-2719** **[A52]**

Symphony No. 2, "London"
Barbirolli, Hallé Orch. — Ang. **S-36478** **[A52]**

Symphony No. 4 in f; Norfolk Rhapsody
Boult, New Philharmonia Orch. — Ang. **S-36557** **[A52]**

Symphony No. 6 in e; Lark Ascending
Boult, New Philharmonia Orch. — Ang. **S-36469** **[A52]**

VERDI, GIUSEPPE (1813–1901)

Aida (excerpts)
Tebaldi, Bergonzi, Simionato, MacNeil, Karajan — Lon. **25206** **[A52]**

Arias
Caruso — RCA LM-2700 **[A52]**

Un Ballo in maschera (excerpts)
Price, Bergonzi, Merrill, Flagello, Leinsdorf — RCA **LSC-3034** **[A53]**

Duets
Bjoerling, Merrill — RCA LM-2736 **[A52]**

Ensembles
Milanov, Peerce, Warren, Moscona — RCA **VICS-1336** **[A52]**

La Forza del destino (excerpts)
Price, Tucker, Merrill, Tozzi, Schippers — RCA **LSC-2838** **[A53]**

Otello (excerpts)
Jepson, Martinelli, Tibbett, Pelletier, Metropolitan Opera Orch. & Chorus — RCA VIC-1365 **[A53]**

Requiem Mass
Nelli, Barbieri, Di Stefano, Siepi, Toscanini, NBC Symphony — 2-RCA LM-6018 **[A53]**

Rigoletto (excerpts); Overtures (I Lombardi, Luisa Miller)
Milanov, Merriman, Peerce, Warren, Moscona, Toscanini, NBC Symphony & Chorus — RCA **VICS-1314E** **[A53]**

La Traviata (excerpts)
De Los Angeles, Del Monte, Sereni, Serafin — Ang. **S-35822** **[A53]**

Il Trovatore (excerpts)
Price, Elias, Tucker, Warren, Tozzi, Basile, Rome Opera — RCA **LSC-2617** **[A53]**

VIEUXTEMPS, HENRI (1820–1881)

Concerto No. 5 in a for Violin, Op. 37
Heifetz, Sargent, New Symphony, London — RCA **LSC-2603** **[A14]**

VILLA-LOBOS, HEITOR (1887–1959)

Bachianas Brasileiras No. 5 for Soprano & 8 Celli
Sayão, Villa-Lobos, Ensemble (*Aria* only) (& Opera Arias) — Odys. 32160377 **[A54]**

Little Train of the Caipiru (from Bachianas No. 2)
Goossens, London Symphony — Ev. **3041** **[A22]**

VIVALDI, ANTONIO (1678–1741)

Concerti for Diverse Instruments
Bernstein, New York Philharmonic — Col. **MS-6131** **[A54]**

Concerto for 2 Violins, P.2
Stern, Oistrakh, Ormandy, Philadelphia Orchestra — CSP CML-5087 **[A54]**

Four Seasons, Op. 8 (P. 241, 336, 257, 442)
I Musici — Phi. **WS-9104** **[A54]**

WAGNER, RICHARD (1813–1883)

Faust Overture; Lohengrin:Preludes; Overtures (Flying Dutchman, Rienzi)
Szell, Cleveland Orchestra — Col. **MS-6884** **[A55]**

Götterdämmerung:Dawn Duet, Rhine Journey, Immolation Scene
Traubel, Melchior, Toscanini, NBC Symphony — RCA VIC-1369 **[A55]**

Götterdämmerung:Rhine Journey, Funeral Music
Furtwängler, Vienna Philharmonic — Sera. 60003 **[A55]**

Lohengrin (Highlights)
Grümmer, Ludwig, Thomas, Fischer-Dieskau, Wiener, Frick, Kempe, Vienna Phil. & State Opera Chorus — Ang. **S-36313** **[A55]**

Lohengrin:Bridal Chamber Scene
Flagstad, Melchior, McArthur, RCA Symphony — RCA LM-2618 **[A55]**

Meistersinger (selections)
Watson, Thomas, Wiener, Hotter, Keilberth, Munich National Theater — RCA **LSC-2839** **[A54]**

Parsifal:Prelude, Good Friday Music
Toscanini, NBC Symphony — RCA VIC-1278 **[A55]**

Das Rheingold (excerpts); Die Walküre (excerpts)
Flagstad, Svanholm, London, Neidlinger, Solti, Vienna Philharmonic — Lon. **25126** **[A54]**

Siegfried Idyll
Monteux, San Francisco Symphony — RCA **VICS-1457** **[A55]**

Tannhäuser:Overture; Meistersinger:Prelude; Tristan:Prelude
Szell, Cleveland Orchestra — Col. **MS-6971** **[A55]**

Tristan und Isolde (excerpts)
Nilsson, Windgassen, Böhm, Bayreuth Festival — DG **136433** **[A56]**

Tristan und Isolde:Love Duet, Act 2
Flagstad, Melchior, McArthur, San Francisco Opera Orch. — RCA LM-2618 **[A55]**

Die Walküre (excerpts)
Nilsson, Crespin, King, Hotter, Solti, Vienna Philharmonic — Lon. **26085** **[A54]**

Symphony No. 15 in A, Op. 141 (1971)
Ormandy, Philadelphia Orch. RCA **ARD-1-0014** **[A47]**

SIBELIUS, JEAN (1865–1957)
Concerto in d for Violin, Op. 47; Tapiola, Op. 112
Spivakovsky, Hannikainen, London Symphony Ev. **3045** **[A47]**
Finlandia, Op. 26; Valse Triste (from Kuolema, Op. 44); Swan of Tuonela (from 4 Legends, Op. 22); Tapiola, Op. 112
Karajan, Berlin Philharmonic DG **139016** **[A47]**
Songs
Nilsson, Bokstedt, Vienna Opera Orch. Lon. **25942** **[A24]**
Swan of Tuonela
Barbirolli, Hallé Orch. Ang. **S-36425** **[A47]**
Symphony No. 1 in e, Op. 39
Barbirolli, Hallé Orch. Ang. **S-36489** **[A47]**
Symphony No. 2 in D, Op. 43
Barbirolli, Hallé Orch. Ang. **S-36425** **[A47]**
Symphony No. 4 in a, Op. 63
Ormandy, Philadelphia Orch. CSP CML-5045 **[A48]**
Symphony No. 5 in E♭, Op. 82
Ormandy, Philadelphia Orch. CSP CML-5045 **[A48]**

SMETANA, BEDŘICH (1824–1884)
Bartered Bride: Overture, Dances
Kempe, Orch. (&Dvořák: Scherzo; Weinberger: Polka and Fugue from "Schwanda") Sera. **S-60098** **[A48]**
My Fatherland (Ma Vlast)
Kubelik, Boston Symphony 2-DG **2707054** **[A48]**
Quartet No. 1 in e, "From My Life"
Juilliard Quartet Col. **MS-7144** **[A20]**

SPOHR, LUDWIG (1784–1859)
Concerto No. 8 for Violin, "Gesangscene"
Heifetz, Solomon, RCA Victor Orch. RCA LM-2860 **[A48]**

STAINER, JOHN (1840–1901)
Crucifixion
Crooks, Tibbet, Trinity Chorus RCA VIC-1403 **[A48]**

STOCKHAUSEN, KARLHEINZ (1928–
Gruppen; Carré
Gielen, Maderna, Stockhausen, Cologne Radio Symphony, NDR Symphony DG **137002** **[A48]**

STRAUSS, JOHANN (1825–1899)
Die Fledermaus (excerpts)
Gueden, Patzak, Dermota, Krauss, Vienna Philharmonic Rich. 23045 **[A49]**
Music of Johann Strauss
Karajan, Berlin Philharmonic (& J. Strauss, Sr: Radetzky March) DG **139014** **[A49]**
Waltzes
Reiner, Chicago Symphony RCA **LSC-2500** **[A49]**

STRAUSS, RICHARD (1864–1949)
Death and Transfiguration, Op. 24
Furtwängler, Vienna Philharmonic Sera. 60094 **[A49]**
Don Juan, Op. 20
Furtwängler, Vienna Philharmonic Sera. 60094 **[A49]**
Four Last Songs
Schwarzkopf, Szell, Berlin Radio Symphony Ang. **S-36347** **[A49]**
Der Rosenkavalier (excerpts)
Schwarzkopf, Ludwig, Edelmann, Karajan, Philharmonia Orch. Ang. **S-36545** **[A49]**
Der Rosenkavalier (suite)
Ormandy, Philadelphia Orch. Col. **MS-6678** **[A49]**
Salome: Dance of the 7 Veils
Ormandy, Philadelphia Orch. Col. **MS-6678** **[A49]**
Salome: Final Scene
Welitsch, Reiner, Metropolitan Opera Orch. Odys. **32160078** **[A49]**
Sonata in E♭ for Violin & Piano, Op. 18
Heifetz, Smith RCA LM-2860 **[A48]**
Songs
Fischer-Dieskau, Moore (19) Ang. **S-36483** **[A49]**
Schwarzkopf, Szell, Berlin Radio Symphony (5) Ang. **S-36347** **[A49]**
Till Eulenspiegel, Op. 28
Ormandy, Philadelphia Orch. Col. **MS-6678** **[A49]**
Furtwängler, Vienna Philharmonic Sera. 60094 **[A49]**

STRAVINSKY, IGOR (1882–1971)
Agon (ballet) (1957)
Leinsdorf, Boston Symphony RCA **LSC-2879** **[A45]**
Le Baiser de la fée (divertimento) (1928)
Reiner, Chicago Symphony RCA **LSC-2251** **[A27]**
Concertino for 12 Instruments
Boulez, Domaine Musical Ens. Ev. **3184** **[A50]**
Ebony Concerto (1945)
Woody Herman Orch. Ev. **6009** **[A50]**
Firebird (1910)
Stravinsky, Col. Sym. Col. **MS-6328** **[A50]**
Petrouchka (complete ballet) (1911)
Monteux, Boston Symphony RCA **LSC-2376** **[A50]**
Renard (1922)
Boulez, Domaine Musical Ens. Ev. **3184** **[A50]**
Le Sacre du printemps (1913)
Stravinsky, Columbia Symphony Col. **MS-6319** **[A50]**
Song of the Nightingale (1919)
Reiner, Chicago Symphony RCA **LSC-2150** **[A38]**
Symphonies of Wind Instruments (1920)
Boulez, Domaine Musical Ens. Ev. **3184** **[A50]**
Symphony in C (1940); Symphony of Psalms (1930)
Stravinsky, CBC Symphony, Toronto Festival Chorus Col. **MS-6548** **[A50]**
Symphony in Three Movements (1945)
Goossens, London Symphony Ev. **3009** **[A50]**
Three Pieces for Clarinet (1918)
Deplus Ev. **3184** **[A50]**
Three Pieces for String Quartet (1914)
Boulez, Domaine Musical Ens. Ev. **3184** **[A50]**

SUPPÉ, FRANZ VON (1819–1895)
Overtures (Poet and Peasant, Light Cavalry, Morning Noon Night in Vienna, Pique Dame)
Solti, Vienna Philharmonic Lon. **6146** **[A50]**

TAKEMITSU, TORU (1930–
November Steps (1967)
Ozawa, Toronto Symphony 2-RCA **LSC-7051** **[A31]**

TARTINI, GIUSEPPE (1692–1770)
Sonata in g for Violin, "Devil's Trill"
Szeryng RCA **VICS-1037** **[A50]**

TCHAIKOVSKY, PETER ILYITCH (1840–1893)
Capriccio italien, Op. 45; Marche slave, Op. 31; Overture 1812, Op. 49
Bernstein, New York Philharmonic Col. **MS-6827** **[A50]**
Concerto No. 1 in b♭ for Piano & Orchestra, Op. 23
Cliburn, Kondrashin, Symphony RCA **LSC-2252** **[A51]**
Concerto in D for Violin & Orchestra, Op. 35
Szeryng, Munch, Boston Symphony RCA **VICS-1037** **[A50]**
Eugen Onegin, Op. 24 (excerpts)
Melik-Pashayev, Bolshoi Theater Per. 502 **[A51]**
Nutcracker Suites 1 and 2, Op. 71a
Ansermet, Orchestre de la Suisse Romande Lon. **6097** **[A51]**
Quartet No. 1
Drolc Quartet DG **139425** **[A10]**
Romeo and Juliet
Kondrashin, Moscow Philharmonic-Symphony Mel./Ang. **S-40090** **[A51]**
Sérénade mélancolique for Violin, Op. 26
Heifetz, Wallenstein, Los Angeles Philharmonic RCA LM-2860 **[A48]**
Sleeping Beauty, Op. 66 (excerpts)
Stokowski, New Philharmonia Lon. **21008** **[A51]**

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Quality: **SPECTRA SONICS** audio control consoles show the care and attention to detail that are the mark of the skilled American craftsman. The internal wiring, module construction, console housing, and the control display reflect the precision and distinctive craftsmanship that is characteristic of **SPECTRA SONICS.**

Capability: **SPECTRA SONICS** audio control consoles provide an immediate initial capability that may be increased to 32 inputs and 32 outputs, at minimum cost. The flexibility of the system will provide line/microphone selection, attenuation, equalization and, through assignment controls, various other combinations for the most sophisticated signal processing now required in today's studio.

Reliability: **SPECTRA SONICS** audio control consoles have an established reputation of superior reliability. Through creative design, the circuitry is developed to function well below operating limits to enhance an extended life for the components. Through empirical data on **SPECTRA SONICS** audio amplifiers, a reliability rate of 99.9% has been derived. These amplifiers are used in **SPECTRA SONICS** audio control consoles and materially contribute to system reliability.

Performance: **SPECTRA SONICS** audio control consoles are guaranteed to outperform any other console in the world in noise, frequency response, distortion, and peak overload. All consoles are provided with documented data acquired in tests of the complete system. Guaranteed performance specifications are: Frequency Response, ± ¼dB 20HZ-20kHZ; Signal/Noise Ratio (microphone input), not less than 82.5dB below +4dBM, output for a -50 input (50 ohms source); Signal/Noise Ratio (line input), not less than 87dB below +4dBM output for +4dBM input. Harmonic Distortion, less than .01% at +18dBM (1kHz); Intermodulation Distortion, less than .02% at +4dBM; Crosstalk, not less than 60dB at 20kHZ (typically 80dB).

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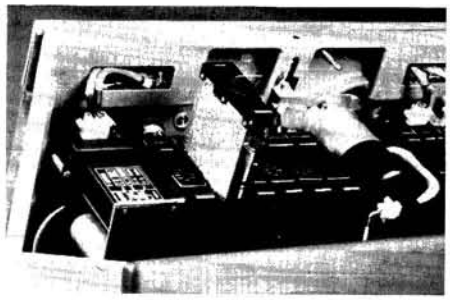

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Waller, Fats—'34–'35 RCA LPV-516 **[D28]**

Webb, Chick—Volumes 1 and 2 2-Dec. **79222/3** **[D28]**

Webster, Ben—See You at the Fair Impulse **S-65** **[D28]**

Wells, Dickie—In Paris, 1937 Prest. **S-7593** **[D28]**

Wilson, Gerald—Best of the Gerald Wilson Orchestra Pac. Jazz **20174** **[D28]**

Wilson, Teddy, Trio—In Europe, '68 Prest. **S-7696** **[D28]**

Witherspoon, Jimmy—At the Monterey Jazz Festival, 1959 HIFI **239** **[D28]**

World's Greatest Jazz Band of Yank Lawson and Bob Haggart—Extra Proj. **S-5039** **[D28]**

Jazz Collections

Be-Bop Era RCA LPV-519 **[D29]**

Chicagoans, 1928-30 Dec. **79231** **[D29]**

Encyclopedia of Jazz 4-Dec. **DXS-7140** **[D29]**

Jazz at Massey Hall Fan. **86003** **[D29]**

Jazz at the Philharmonic, Vol. 1 Stinson 23 **[D29]**

Jazz at Preservation Hall 2-At. **S-1409/10** **[D30]**

Jazz Odyssey—Vol. 1, New Orleans 3-Col. C3L-30 **[D30]**
Vol. 2, Chicago 3-Col. C3L-32 **[D30]**
Vol. 3, Harlem 3-Col. C3L-33 **[D31]**

Jazz, Volumes 1-11 11-Folk. 2801/11 **[D31,32]**

Kansas City Piano (1936-41) Dec. **79226** **[D32]**

New Wave Impulse **A-90** **[D33]**

Panassié Sessions RCA LPV-542 **[D33]**

Three Decades of Jazz, 1959-69, Vol. 1 Blue **89904** **[D33]**

Women of the Blues RCA LPV-534 **[D33]**

Spoken Word Recordings

Good spoken recordings, says the poet, William Alfred, "deepen our judgment and our pleasure, and teach us to honor language, that blessed gift which separates us from the beasts."

This list is the culmination of listening with a trained ear to thousands of available spoken records. It should be understood that not all material is suitable for this medium. The fact that a recording has been made of a great statesman, or a great poet, or a great piece of literature, does not necessarily mean that it is a good record for listening.

Selections for the list were made on the basis of excellence in execution, literary or historic worth, interest and entertainment value. Not all the selections are of equal merit. Some superior recordings could not be included because of space limitations. But here is presented a representative picture of areas of worthwhile spoken recording.

Tastes differ. However, there is something on the list which will appeal to the most diverse of temperaments and age groups, so that hearing the recordings will be a pleasurable and enriching experience for the members of the White House Family and their guests.

Be not afeared, the Isle is full of noises,
Sounds, and sweet airs, that give delight and hurt not:
Sometimes a thousand twangling instruments
Will hum about mine ears; and sometimes voices,
That if I then had wak'd after long sleep,
Will make me sleep again, and then in dreaming,
The clouds methought would open, and show riches
Ready to drop upon me, that when I wak'd
I cried to dream again.

The Tempest, III ii

Helen Roach

SPOKEN WORD RECORDINGS

Documentaries, Speeches, Lectures, Interviews

Blind Willie Johnson Folk. FG-3585 **[E1]**

Churchill, Winston: I Can Hear It Now!
Edited by Edward R. Murrow and Fred W. Friendly Col. KOL-7000 **[E1]**

Eban, Abba, Foreign Minister, Government of Israel—Address Before Security Council, United Nations, New York, June 6, 1967 Sp. Arts 986 **[E1]**

Edith Hamilton—Echoes of Greece Sp. Arts 928 **[E1]**

Edward R. Murrow—A Reporter Remembers
Vol. I, 1934-48; Vol. II, 1948-61
4-Col. 02L-332; 02L-400 **[E1,2]**

England Before the First Great War
Asquith, Lloyd George, Winston Churchill (1909), Cardinal Bourne, General Booth, Ernest Shackleton et al. Rococo 4001 **[E2]**

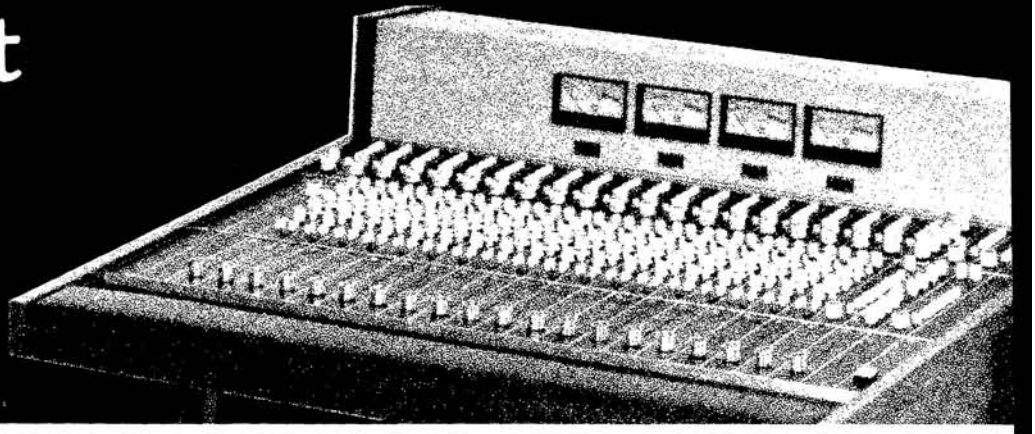
Five British Sculptors Talk: Henry Moore, Barbara Hepworth, Reg Butler, Kenneth Armitage, Lynn Chadwick Caed. 1181 **[E2]**

The Hungarian Revolution Narrated by the Commander-in-Chief of the Freedomfighter Forces, Major General Bela K. Kiraly Roach THR 1-4 **[E2]**

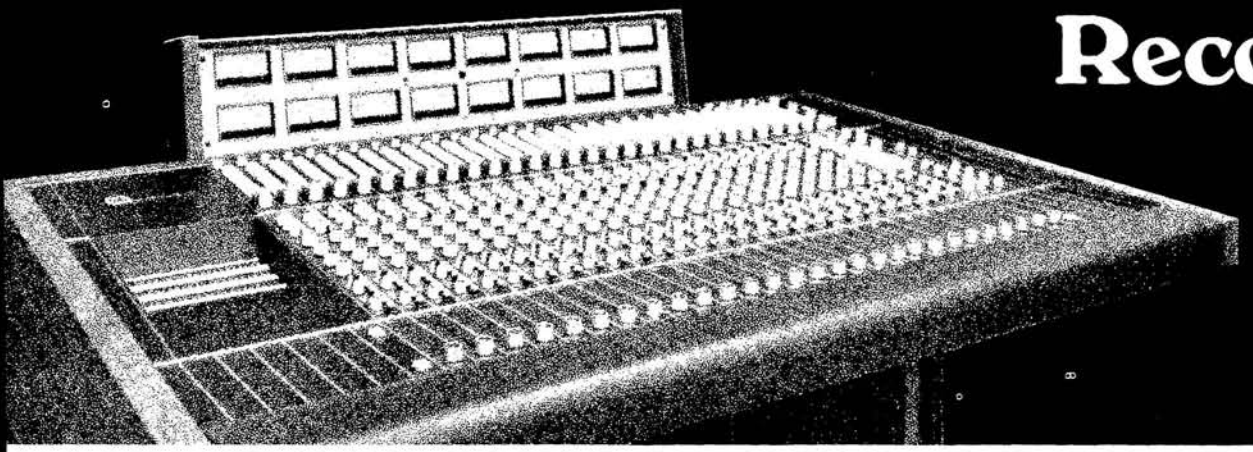
I Can Hear It Now
Prepared by Edward R. Murrow and Fred W. Friendly. Vol. I, 1933-45, Vol. II, 1945-49
2-Col. ML-4095; ML-4261 **[E2]**

John F. Kennedy: A Self-Portrait. The Gallant Warrior of the Thousand Days 2-Caed. 2021 **[E3]**

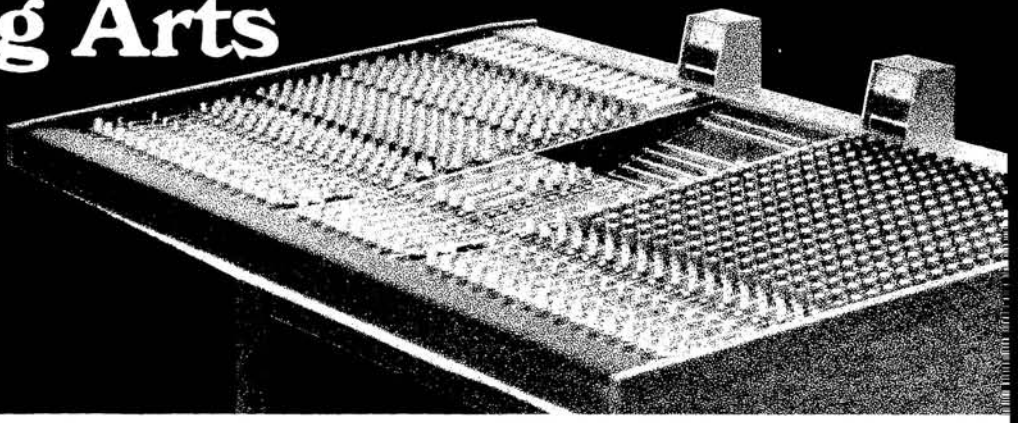
Broadcast



Recording



Performing Arts



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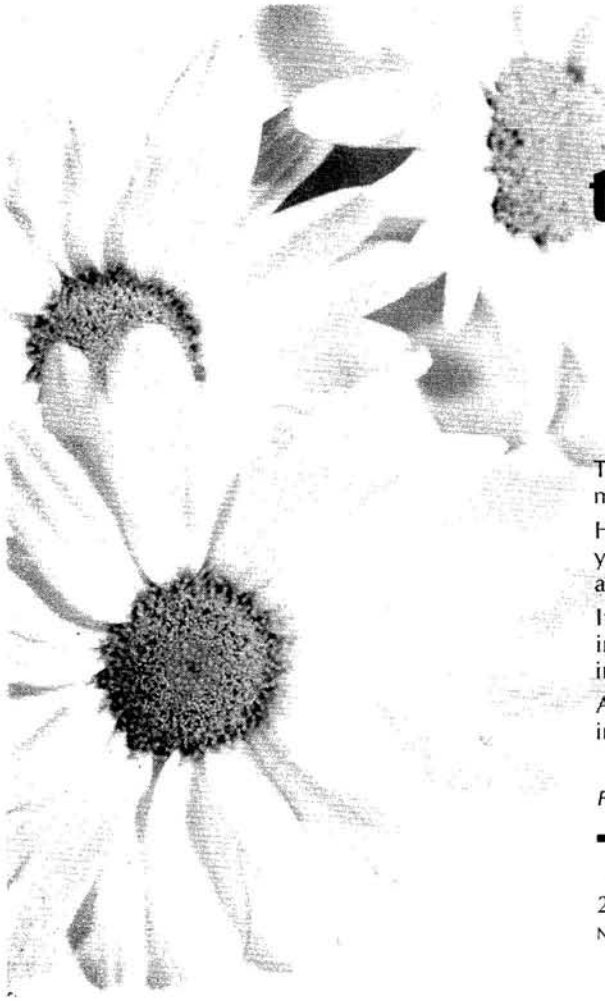
Navarro, Fats—Fats, Bud, Klook, Sonny, Kinney	Savoy 12011	[D22]
Good Bait	Riv. **S-3019**	[D22]
Nelson, Oliver—Blues and the Abstract Truth	Impulse **S-5**	[D22]
Newborn, Phineas—Please Send Me Someone to Love	Contem. **7622**	[D22]
Oliver, King—Immortal, w. Armstrong, Morton	Mile. **2006**	[D22]
In New York	RCA LPV-529	[D22]
Original Dixieland Jazz Band	RCA LPV-547	[D23]
Ory, Kid—Favorites	2-GTJ **10041/2**	[D23]
Page, Hot Lips—Feelin' High & Happy	RCA LPV-576	[D23]
Parker, Charlie—The Charlie Parker Story	Savoy 12079	[D23]
Genius	Savoy 12014	[D23]
Memorial	Savoy 12009	[D23]
Story , No. 3	Verve **68002**	[D23]
Peterson, Oscar—Soul-O!	Prest. **S-7595**	[D23]
Pettiford, Oscar—Memorial Album	Prest. **S-7813**	[D23]
Powell, Bud—Amazing, w. Navarro, Rollins, Roach	2-Blue **81503/4**	[D24]
Ra, Sun—The Magic City	Saturn **LPB-711**	[D24]
Raeburn, Boyd—Boyd Meets Stravinsky	Savoy 12040	[D24]
Man with the Horns	Savoy 12025	[D24]
Rainey, Ma—Immortal	Mile. **2001**	[D24]
Redman, Don—Master of the Big Band	RCA LPV-520	[D24]
Reinhardt, Django—Djangology	RCA LPM-2319	[D24]
Rollins, Sonny—Saxophone Colossus	Prest. **S-7326**	[D24]
Rushing, Jimmy—Listen to Blues	Van. **73007**	[D25]
The You and Me That Used To Be	RCA **LSP-4566**	[D25]
Russell, Pee Wee—Ask Me Now	Impulse **S-96**	[D25]
Memorial Album	Prest. **S-7672**	[D25]
Sete, Bola—At the Monterey Jazz Festival	Verve **68689**	[D25]
Silver, Horace—Best	Blue **84325**	[D25]
Song For My Father	Blue **84185**	[D25]
Smith, Bessie—Story, Vol. 1	Col. CL-855	[D25]
Smith, Jimmy—New Sound	Blue **81514**	[D26]
Smith, Willie "The Lion"—Memoirs	2-RCA **LSP-6016**	[D26]
Solal, Martial—On Home Ground	Mile. **S-9014**	[D26]
Spanier, Muggsy—Great Sixteen	RCA LPM-1295	[D26]
Spann, Otis—Sweet Giant of the Blues	BluesT. **29006**	[D26]
Tatum, Art—Piano Starts Here	Col. **CS-9655**	[D26]
Taylor, Cecil—Unit Structures	Blue **84237**	[D26]
Teagarden, Jack	RCA LPV-528	[D27]
Golden Horn	Dec. **74540E**	[D27]
Terry, Clark—Tonight, w. Brookmeyer	Main. **320**	[D27]
Tristano, Lennie—Crosscurrents, w. DeFranco, Buddy	Cap. M-11060	[D27]
Turner, Joe—Blues	Savoy 14012	[D27]
Boss of the Blues	At. **S-1234**	[D27]
Walker, T-Bone—Stormy Monday Blues	Blues. **S-6008**	[D27]



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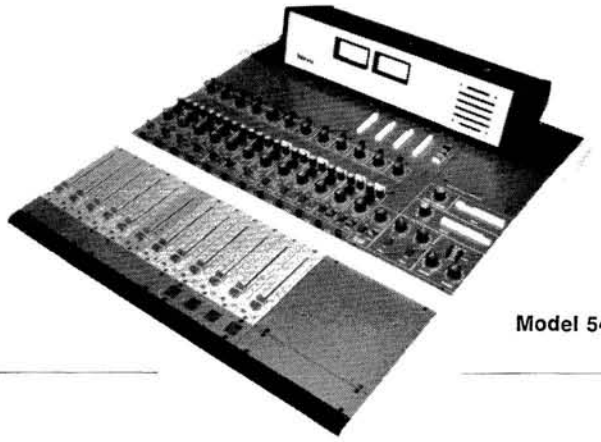
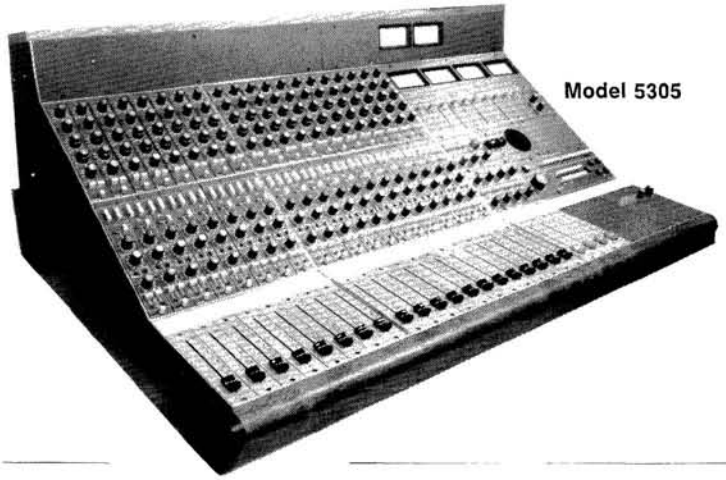


Model 5402



Model 5305

Model 5305 TV Production Console

Designed as a 4 bus 2 main output console, this model is ideal for the small to medium sized TV station for production as well as on-air use. Many optional facilities are available, enabling us to customize a console for your particular application and keep delivery lead times to a minimum. A fully fitted 12 input console with good equalization is priced at $17,950*. This is exceptionally good value in the marketplace.

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Through our leading position in the field of music recording, we are able to deliver Broadcast Multitrack Production Consoles with optimum multitrack as well as broadcast facilities. 8, 16 and 24 track consoles are often in stock, and we are eager to please customers by incorporating special facilities on short lead time. 8 track consoles start around $29,000*, 16 track around $38,000*, and 24 track around $66,000*. Check our competition, and you'll be surprised to realize our price competitive position!

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Ellington, Duke—And His Mother Called Him Bill — RCA **LSP-3906** **[D7]**
At His Very Best — RCA LPM-1715 **[D7]**
Ellington Era, Vols. 1, 2 — 6-Col. C3L-27, C3L-39 **[D7,8]**
In a Mellotone — RCA LPM-1364 **[D8]**
New Orleans Suite — At. **S-1580** **[D8]**
Second Sacred Concert — 2-Fan. **8407/8** **[D8]**

Ellis, Don—Live At Monterey — Pac. Jazz **20112** **[D8]**

Evans, Bill—At the Village Vanguard — Riv. **3006** **[D8]**
The Bill Evans Album — Col. **C-30855** **[D9]**
Undercurrent, w. Jim Hall — Solid **18018** **[D9]**

Evans, Gil—Into the Hot — Impulse **S-9** **[D9]**
Out of the Cool — Impulse **S-4** **[D9]**

Farmer, Art—Live At The Half Note — At. **S-1421** **[D9]**

Freeman, Bud—Compleat — Mon.-Ev. **7022** **[D9]**

Garland, Red—P. C. Blues — Prest. **S-7752** **[D9]**

Getz, Stan—At the Opera House, with J. J. Johnson — Verve **68490** **[D9]**
Focus — Verve **68412** **[D10]**

Gillespie, Dizzy — RCA LPV-530 **[D10]**
At the Village Vanguard — Solid **18034** **[D10]**
Groovin' High — Savoy **12020** **[D10]**

Goodman, Benny—Carnegie Hall Concert — Col. CL-814 **[D10]**
King of Swing — 2-Col. **OSL-180** **[D10]**
Small Groups — RCA LPV-521 **[D11]**

Gordon, Dexter—Our Man in Paris — Blue **84146** **[D11]**

Green, Urbie—21 Trombones — Proj. **S-5014** **[D11]**

Grey, Al—Shades of Grey — Tan. **S-1504** **[D11]**

The Guitar Album — 2-Col. **KG-31045** **[D11]**

Hackett, Bobby—Plus Vic Dickenson — Proj. **S-5034** **[D11]**

Haden, Charlie—Liberation Music — Impulse **S-9183** **[D11]**

Hall, Edmond—Celestial Express — Blue 6505 **[D12]**

Hall, Jim—Sims, Raney, Hall, Swallow, Johnson–Otra Vez — Main. **358** **[D12]**

Hampton, Lionel—Original Star Dust — Dec. **74194** **[D12]**
Vol. 1, Stompology — RCA LPV-575 **[D12]**

Hancock, Herbie—Maiden Voyage — Blue **84195** **[D12]**

Handy, John—Monterey Jazz Festival — Col. **CS-9262** **[D12]**

Harris, Barry—Magnificent! — Prest. **S-7733** **[D12]**

Hawes, Hampton—Seance — Contem. **7621** **[D12]**

Hawkins, Coleman—Body and Soul — RCA LPV-501 **[D12]**
Classic Tenors, w. Lester Young — Fly. **10146** **[D12]**
Today and Now — Impulse **S-34** **[D13]**

Henderson, Fletcher—Volumes 1 and 2 — 2-Dec. **79227/8** **[D13]**

Herman, Woody—Early Autumn — Cap. M-11034 **[D13]**
Thundering Herds — 3-Col. C3L-25 **[D13]**

Hill, Andrew—Black Fire — Blue **84151** **[D14]**

Hines, Earl—At the Apex Club, w. Jimmie Noone — Dec. **79235E** **[D14]**
Blues and Things, w. Jimmy Rushing — Mas. J. **8101** **[D14]**
Fatha Blows Best — Dec. **75048** **[D14]**
Grand Terrace Band — RCA LPV-512 **[D14]**
Southside Swing — Dec. **79221E** **[D14]**

Hodes, Art—Sittin' In, Vol. 1 — Blue 6508 **[D14]**

Hodges, Johnny—Things Ain't What They Used To Be, w. Rex Stewart — RCA LPV-533 **[D14]**

Holiday, Billie—Golden Years, Vols. 1 & 2 — 6-Col. C3L-21, C3L-40 **[D15]**
Story — 2-Dec. **DXS-7161** **[D15]**

Horn, Paul—Inside — Epic **BXN-26466** **[D16]**

Hubbard, Freddie—Breaking Point — Blue **84172** **[D16]**

Hutcherson, Bobby—Stick-Up — Blue **84244** **[D16]**

Jacquet, Illinois—The Blues, That's Me! — Prest. **S-7731** **[D16]**

Jamal, Ahmad—Poinciana — Cadet **S-719** **[D16]**

Jazz Composers Orchestra — 2-JCOA **LP-1001/2** **[D16]**

Jazz Messengers—At Cafe Bohemia, Vols. 1 & 2 — 2-Blue **81507/8** **[D17]**

Johnson, Bunk—Superior Jazz Band — G.T.J. **12048** **[D17]**

Johnson, J.J.—Looking Back — Prest. **S-7253** **[D17]**

Johnson, James P.—Father of the Stride Piano — Col. CL-1780 **[D17]**

Jones, Elvin—Heavy Sounds, w. Richard Davis — Impulse **S-9160** **[D17]**

Jones, Hank—Have You Met — Savoy 12084 **[D17]**

Jones, Quincy—Walking in Space — A&M **3023** **[D17]**

Jones, Thad-Mel Lewis—Monday Night — Solid **18048** **[D18]**

Kellaway, Roger—Spirit Feel — Pac. Jazz **20122** **[D18]**

Kelly, Wynton—Smokin' at the Half Note, w. Wes Montgomery — Verve **68633** **[D18]**

Kenton, Stan—Contemporary Concepts — Creative World **1003** **[D18]**
Cuban Fire — Creative World **1008** **[D18]**
New Concepts — Creative World **1002** **[D18]**

Kessel, Barney—Feeling Free — Contem. **7618** **[D18]**

King, B. B.—Live at the Regal — ABC **S-724** **[D18]**

Kirk, Roland—Inflated Tear — At. **1502** **[D18]**

Konitz, Lee—Subconscious-Lee — Prest. **S-7250** **[D19]**

Lateef, Yusef—Into Something — Prest. **S-7637** **[D19]**

Lewis, George—Jazz at Preservation Hall — At. **S-1411** **[D19]**

Lunceford, Jimmie—Lunceford Special — Col. **CS-9515** **[D19]**
Volumes 1, 2, 3, 4 — 4-Dec. **79237/40** **[D19]**

Manne, Shelly—My Fair Lady — Contem. **7527** **[D19]**

Martino, Pat—Baiyana (Clear Evidence) — Prest. **S-7589** **[D20]**

McLaughlin, John—The Inner Mounting Flame, w. Mahavishnu Orch. — Col. **KC-31067** **[D20]**

McShann, Jay—New York, 1208 Miles — Dec. **79236** **[D20]**

Merrill, Helen—A Shade of Difference, w. Dick Katz — Mile. **9019** **[D20]**

Mingus, Charlie—Best — At. **S-1555** **[D20]**
Let My Children Hear Music — Col. **KC-31039** **[D20]**
Mingus Ah Um — Col. **CS-8171** **[D20]**
Mingus Revisited — Lime. **86015** **[D20]**
Tijuana Moods — RCA **LSP-2533** **[D20]**

Modern Jazz Quartet—Best — At. **S-1546** **[D21]**
Modern Jazz Quartet — 2-Prest. **24005** **[D21]**

Monk, Thelonious—Genius of Modern Music — 2-Blue **81510/11** **[D21]**
Monk's Music — Riv. **S-3004** **[D21]**

Moody, James—And Brass Figures — Mile. **9005** **[D21]**

Morton, Jelly Roll—King of New Orleans Jazz — RCA LPM-1649 **[D21]**
Stomps and Joys — RCA LPV-508 **[D21]**

Moten, Bennie — RCA LPV-514 **[D21]**

Mulligan, Gerry—The Age of Steam — A & M **3036** **[D22]**
California Concert featuring Zoot Sims and Bob Brookmeyer — Pac. Jazz **20145** **[D22]**
w. Tentette — Cap. M-11029 **[D22]**

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good."

The Progress theory. "Only that which is new is good."

The Masses-Are-Always-Right theory. "Whatever is liked by the greatest number of people is good."

The Masses-Are-Always-Wrong theory. "Whatever is liked by the greatest number of people is bad. What's good is only that which is appreciated by a few people of discriminating taste; if you ask me who *they* are, I'll name you *one*, anyway." (Thus "good" jazz artists must be unpopular and underpaid. If they should build a larger audience and begin to earn a living, they become by definition "bad" jazz artists because they've sold out.)

The Jazz-Is-the-Only-Bright-Manifestation-in-a-Racist Society theory. People who believe that one haven't traveled much. More defectors go west than east.

The Only-Blacks-Can-Play theory, *versus* the Anybody-Can-Play-Jazz theory. Some of the best jazz musicians I've heard are Germans, Swedes, Poles, and Russians. Neither Germans, Swedes, Poles, Russians, nor white Americans, however, have produced an Armstrong, an Ellington, a Charlie Parker, or a John Coltrane, but were influenced by all four and by other Afro-Americans, as other Afro-Americans influenced Armstrong, Ellington, Parker, and Coltrane. Jazz doesn't run in the blood or issue from the skin; it comes from participating in a culture. And, while some are undeniably more so than others, "We are *all* Afro-Americans," as Albert Murray wrote. Whether our common culture was arrived at by sale, purchase, gift, theft, or sharing should be investigated and the findings seen; but that's a separate project from appraising the art and the character of each person as an individual, rather than judging him by his ancestors' continental origin, the kind of judgment that sustained the whole racist evil in the first place.

But to continue:

What we call "classical music" is essentially European music and what we call "jazz" is essentially American music, though both musics are played by both Europeans and Americans.

"Classical" music should be appreciated as a cathedral is, jazz as a gem is. The difference is one of scale. Either a cathedral or a gem may be either well or badly formed.

Jazz is America's classical music, Rock is—at the moment—its spring fertility-rite. Some say rock is just another form of jazz, as dixieland, swing, and bop were. My mind tells me this could be true. My heart tells me it's false. As the paper fire of rock burns lower, many rock musicians are trying to play jazz.

The jazz collection for the White House Record Library includes records that fit all these definitions—and one more definition: Jazz is also records that were unavailable when the list was completed and then were reissued the moment the list went to press.

Willis Conover

JAZZ RECORDINGS

Adderley, Julian "Cannonball"—Best	Cap. **SKAO-2939**	**[D1]**
Allen, Henry "Red"	RCA LPV-556	**[D1]**
Allison, Mose—Allison	Prest. **24002**	**[D1]**
Ammons, Gene—Jug	Prest. **S-7192**	**[D1]**
Armstrong, Louis—Plays W. C. Handy	CSP CCL-591	**[D1]**
Story-Vol. 1	Col. CL-851	**[D1]**
V. S. O. P.-Vol. 1	Epic **22019**	**[D1]**
Ayler, Albert—In Greenwich Village	2-Impulse **S-9155**	**[D1]**
Basie, Count—Best	2-Dec. **DXS-7170**	**[D2]**
Standing Ovation	Dot **25938**	**[D2]**
Super Chief	2-Col. **G-31224**	**[D2]**
Bechet, Sidney—Blue Bechet	RCA LPV-535	**[D2]**
Of New Orleans	RCA LPV-510	**[D2]**
w. Bunk Johnson, De Paris (Vols. 1 and 2)	2-Blue 1201/2	**[D2]**
Beiderbecke, Bix—Story (Vol. 1)	Col. CL-844	**[D2]**
Berigan, Bunny—Great Dance Bands of the 30's and 40's	RCA LPM-2078	**[D2]**
Bigard, Barney—w. Albert Nicholas	RCA LPV-566	**[D3]**
Blake, Eubie—86 Years	2-Col. **C2S-847**	**[D3]**
Blakey, Art—Night At Birdland	2-Blue **81521/2**	**[D3]**
Brown, Clifford—Memorial Album	Blue **81526**	**[D3]**
Three Giants, w. Sonny Rollins, Max Roach	Prest. **S-7821**	**[D3]**
Brown, Ray—That's the Way It Is, w. Milt Jackson	Impulse **S-9189**	**[D4]**
Brubeck, Dave—Time Out	Col. **CS-8192**	**[D4]**
Burrell, Kenny—Guitar Forms, w. Gil Evans	Verve **68612**	**[D4]**
Burton, Gary—Genuine Tong Funeral	RCA **LSP-3988**	**[D4]**
Byas, Don—In Paris	Prest. **S-7598**	**[D4]**
Carter, Benny—1933	Prest. **S-7643**	**[D4]**
Further Definitions	Impulse **S-12**	**[D4]**
Chaloff, Serge—Blue Serge	Cap. M-11032	**[D4]**
Charles, Ray—Live Concert	ABC **S-500**	**[D4]**
Cherry, Don—Symphony for Improvisers	Blue **84247**	**[D5]**
Christian, Charlie—1941	Arc. Folk 219	**[D5]**
w. Goodman Sextet	Col. CL-652	**[D5]**
Cole, Nat "King"—Trio Days	Cap. M-11033	**[D5]**
Coleman, Ornette—At the Golden Circle, Vol. 1	Blue **84224**	**[D5]**
Best	At. **S-1558**	**[D5]**
Coltrane, John—Best	At. **S-1541**	**[D5]**
Crescent	Impulse **S-66**	**[D5]**
Love Supreme	Impulse **S-77**	**[D5]**
Condon, Eddie—Gershwin Program	Dec. **79234**	**[D6]**
Corea, Chick—Tones for Joan's Bones	Vor. **2004**	**[D6]**
Criss, Sonny—Rockin' in Rhythm	Prest. **S-7610**	**[D6]**
Davis, Miles—Birth of the Cool	Cap. **DT-1974E**	**[D6]**
Kind of Blue	Col. **CS-8163**	**[D6]**
Modern Jazz Giants	Prest. **S-7650**	**[D6]**
Porgy and Bess, w. Gil Evans	Col. **CS-8085**	**[D6]**
Sketches of Spain, w. Gil Evans	Col. **CS-8271**	**[D6]**
Diddley, Bo—Super Blues, w. Muddy Waters, Howlin' Wolf	Checker **3008E**	**[D6]**
Dodds, Baby—Jazz à la Creole	GHB 50	**[D6]**
Dodds, Johnny	RCA LPV-558	**[D7]**
Dolphy, Eric—Out to Lunch	Blue **84163**	**[D7]**

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Smith, Connie—Best, Vol. 2 RCA **LSP-4324** **[C28]**
Connie's Country RCA **LSP-4132** **[C28]**

Snow, Hank—Best RCA **LSP-3478** **[C28]**

Songs and Ballads of the Anthracite Miners Library of Congress AAFS L16 **[C29]**

Sons of the Pioneers—Best RCA **LSP-3476** **[C29]**

Southern Folk Heritage Series 7-At. **SDHS-1** **[C30]**

Spoelstra, Mark—Five & Twenty Questions Elek. **7283** **[C31]**

Staple Singers Epic **BN-26132** **[C31]**

Statesmen—Best RCA **LSP-3925** **[C31]**

Statler Bros.—Flowers On The Wall Col. **CS-9249** **[C31]**

Stuckey, Nat—Keep Em' Country RCA **LSP-4123** **[C31]**

Sumner, J.D. & The Colorful Stamps Quartet Sky. **S-6053** **[C31]**

Tharpe, Sister Rosetta—Precious Memories Savoy 14214 **[C31]**

Tompall, Glaser Bros.—Award Winners MGM **S-4775** **[C31]**

Traditional Music At Newport 1964 Van. 79183 **[C31]**

Tubb, Ernest—Story 2-Dec. **DXS-7159** **[C32]**

Twitty, Conway—Darling, You Know I Wouldn't Lie Dec. **75105** **[C32]**

Van Ronk, Dave—With The Hudson Dusters Verve/Fore. **S-3041** **[C32]**

Wagoner, Porter—Best RCA **LSP-3560** **[C32]**

Wagoner, Porter & Dolly Parton—Just the Two of Us RCA **LSP-4039** **[C32]**

Wakely, Jimmy—Slippin' Around Dot **25711** **[C32]**

Waldo, Elizabeth, Folklorico Orch. & The St. Charles Choir—Viva California PSO **002** **[C32]**

Walker, Billy—Charlie's Shoes Har. **11414** **[C32]**
Greatest Hits Col. **CS-9798** **[C32]**

Walker, Charlie—Greatest Hits Epic **BN-26343** **[C33]**

Ward Singers—Meeting Tonight Savoy 14015 **[C33]**

Waters, Ethel—His Eye Is on the Sparrow Word 8044 **[C33]**

Waters, Muddy—More Real Blues Chess **S-1511** **[C33]**

Watson, Doc—Home Again Van. **79239** **[C33]**

Weavers—Best 2-Dec. **DXS-7173** **[C33]**

Wells, Kitty—Story 2-Dec. **DXSB-7174** **[C33]**

West, Dottie—Careless Hands RCA **LSP-4482** **[C33]**
Here Comes My Baby RCA **LSP-3368** **[C34]**

West, Hedy—Old Times & Hard Times Folk-Leg. 32 **[C34]**

White, Josh—Chain Gang Songs Elek. **7158** **[C34]**

Wilburn Bros.—Greatest Hits Dec. **75002** **[C34]**

Williams, Hank—Greatest Hits, Vol. 1 MGM **S-3918** **[C34]**
Greatest Hits, Vol. 3 MGM **S-4140** **[C34]**
Luke The Drifter MGM **S-4380** **[C34]**

Williams, Hank Jr.—Best MGM **S-4513** **[C34]**

Wills, Bob—Texas Playboys Dec. **78727** **[C34]**

Wiseman, Mac—Best Loved Gospel Hymns Dot **25373** **[C35]**

Wynette, Tammy—Your Good Girl's Gonna Go Bad Epic **BN-26305** **[C35]**

Yarbrough, Glenn—Honey And Wine RCA **LSP-3860** **[C35]**

Young, Faron—Greatest Hits Mer. **61047** **[C35]**

Young, Jesse Colin—Young Blood Mer. **61005** **[C35]**

Jazz Recordings

With jazz we are always on shaky ground. It's easy to note what is or has been popular and still easier to say what is "classical," but nobody has ever really satisfactorily answered the question, *What is jazz?*

Largely a subjective experience for both artist and audience, jazz is rooted in, and vulnerable to, acutely personal passions. The lack of a definition that *always* satisfies *all* its critics—and every observer of jazz is a critic—has led to a great variety of rigidly asserted and contradictorily exclusive definitions. I remember advising a friend who was about to join me on the board of directors of the old non-profit Newport Jazz Festival: "Just don't express any opinion at all about jazz, and you'll be all right."

There are as many ways to approach jazz as there are people approaching it:

Historically; mythologically; nostalgically; ideologically; nationally; racially; as business; as entertainment; as art.

The way people speak about jazz illustrates some of these approaches:

Guilty and apologetic. "I'm afraid I don't know very much about jazz, but I do like it."

Uninformed but anxious to hide the fact by saying the right thing. "Jazz is America's only native art form."

Inspirational. "If everybody in the world would go out on the sidewalk and play jazz together, there'd be no more wars."

Dogmatic. "This is jazz, but that isn't, and neither is that!"

Defiant. "Jazz is just a lot of noise. You call that stuff *music*?"

Tolerant. "Jazz is whatever music you listen to whenever you want to hear some jazz." (Thus Louis Armstrong, Ella Fitzgerald, Benny Goodman, etc., may be listed as both Jazz and Popular in the White House Record Library, as they are in other libraries.)

Many jazz "experts," who write about jazz instead of underwriting it, have their own passionately held theories—passionately because their theories bolster their views of life in general:

The Grass Roots theory. "Jazz is the natural expression of untutored musicians."

The Ivory Tower theory. "Jazz is so demanding an art that only schooled musicians can play it well."

The Historic Origins theory. "Only that which is old is

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Jackson, Mahalia—Best	Ken. **500**	[C16]
Bless This House	Col. **CS-8761**	[C17]
Garden of Prayer	Col. **CS-9346**	[C17]
Jackson Southernaires—Too Late	Song. **212**	[C17]
Jackson, Stonewall—Greatest Hits	Col. **CS-9177**	[C17]
Jackson, Tommy—Square Dances	Dec. **78950**	[C17]
Jackson, Wanda—Best	Cap. **ST-2883**	[C17]
James, Skip—Devil Got My Woman	Van. **79273**	[C17]
Jean, Norma—Best	RCA **LSP-4227**	[C17]
Jefferson, Blind Lemon—Immortal	Mile. **2004**	[C17]
Jennings, Waylon—Leavin' Town	RCA **LSP-3620**	[C18]
Johnnie & Jack—Here's Johnnie & Jack	Voc. **73832**	[C18]
Sing Poison Love and Other Country Favorites	Camd. **S-747**	[C18]
Johnson, Dr. C. J.—In an Oldtime Song Service	Savoy 14126	[C18]
Jones, George—Best	U. Artists **6291**	[C18]
Greatest Hits	Mer. **60621**	[C18]
Greatest Hits	Musi. 3116	[C18]
Jones, Grandpa—Sings His Greatest Hits	King **554**	[C18]
Kershaw, Doug—The Cajun Way	War. 1820	[C18]
King, Pee Wee & Band	Camd. **S-876**	[C19]
King, Pee Wee & Redd Stewart—Tennessee Waltz & Slowpoke	Nash. 2042	[C19]
Kingston Trio—Best, Vol. 1	Cap. **ST-1705**	[C19]
Best, Vol. 2	Cap. **ST-2280**	[C19]
Kristofferson, Kris—Me and Bobby McGee	Monu. **Z-30817**	[C19]
Kweskin, Jim, Jug Band—Relax Your Mind	Van. **79188**	[C19]
La Farge, Peter—As Long As the Grass Shall Grow	Folk. 2532	[C19]
Leadbelly—Last Sessions	Folk. FLW-2941	[C20]
Midnight Special	RCA LPV-505	[C20]
Lewis, Jerry Lee—She Still Comes Around	Smash **67112**	[C20]
Lewis, Jerry Lee & Gail—Together	Smash **67126**	[C20]
Lightfoot, Gordon—The Way I Feel	U. Artists **6587**	[C20]
Limeliters—Best	RCA **LSP-2889**	[C20]
Lister, Hovie & The Statesmen—New Sounds Today	Sky. **SLP-6090**	[C21]
Locklin, Hank—Best	RCA **LSP-3559**	[C21]
Loudermilk, John D.—Open Mind	RCA **LSP-4097**	[C21]
Louvin Brothers—The Family Who Prays	Cap. **DT-1061E**	[C21]
Lynn, Loretta—Greatest Hits	Dec. **75000**	[C21]
Mack, Warner—Many Moods	Dec. **74995**	[C21]
Martin, Sallie—The Living Legend	Savoy **S-14242**	[C21]
McGhee, Brownie & Sonny Terry—Long Way From Home	Blues. **S-6028**	[C21]
Mighty Clouds of Joy—The Family Circle	Pea. **114**	[C21]
Miller, Roger—Golden Hits	Smash **67073**	[C21]
Mitchell, Joni	Reprise **S-6293**	[C22]
Monroe, Bill—16 All-Time Greatest Hits	Col. **CS-1065**	[C22]
Greatest Hits	Dec. **75010**	[C22]
Morgan, George—Candy Kisses	Starday **SLP-400**	[C22]
Music From the Festival of American Folk Life	Smithsonian **100**	[C22]
Negro Blues and Hollers	Library of Congress AAFS L59	[C22]
Negro Religious Songs and Services	Library of Congress AAFS L10	[C22]
Nelson, Willie—Good Times	RCA **LSP-4057**	[C22]
New Christy Minstrels—Greatest Hits	Col. **CS-9279**	[C23]
New Lost City Ramblers—Modern Times	Folk. **31027**	[C23]
Newmann, Jimmy—Born to Love You	Dec. **75065**	[C23]
Newport Folk Festival 1959/60 (Vols. 1 and 2)	2-Folk. 2431-2	[C23]
1963	Van. **79148**	[C23]
1964	Van. **79184**	[C23]
1965	Van. **79225**	[C23]
Nightingales—Best of the Sensational Nightingales	Pea. **PLP-137**	[C23]
Niles, John Jacob—Folk Balladeer	RCA LPV-513	[C24]
Ochs, Phil—Pleasures of the Harbor	A&M **4133**	[C24]
Odetta—Sings Folk Songs	RCA **LSP-2643**	[C24]
Orbison, Roy—Very Best	Monu. **18045**	[C24]
Original Blind Boys of Alabama	Savoy 14044	[C24]
Owens, Buck—Best	Cap. **ST-2105**	[C24]
Best, Vol. 2	Cap. **ST-2897**	[C24]
Paxton, Tom—Outward Bound	Elek. **7317**	[C24]
Pearl, Minnie—Country Music Story	Starday **S-380**	[C24]
Pennywhistlers—Cool Day & Crooked Corn	None. **72024**	[C24]
Peter, Paul & Mary—In The Wind	War. **S-1507**	[C25]
Pierce, Webb—Story	2-Dec. **DXS-7181**	[C25]
Presley, Elvis—How Great Thou Art	RCA **LSP-3758**	[C25]
Price, Ray—Greatest Hits	Col. **CS-8866**	[C25]
Pride, Charlie—Best	RCA **LSP-4223**	[C25]
The Raymond Raspberry Singers	Savoy 14040	[C25]
Reed, Jerry—Alabama Wild Man	RCA **LSP-4069**	[C25]
Best	RCA **LSP-4729**	[C25]
Reeves, Jim—Best	RCA **LSP-2890**	[C26]
Best, Vol. 2	RCA **LSP-3482**	[C26]
Rich, Charlie—Lonely Weekends	Sun **110**	[C26]
Riley, Jeannie C.—Harper Valley P.T.A.	Plant. **S-1**	[C26]
Ritchie, Jean—The Ritchie Family of Kentucky	Folk. 2316	[C26]
Robbins, Marty—More Greatest Hits	Col. **CS-8435**	[C26]
Robinson, Rev. Cleophus—Best	Pea. **135**	[C26]
Robison, Carson—Square Dances	RCA LPM-1238	[C26]
Rodgers, Jimmie—Best of the Legendary Jimmie Rodgers	RCA **LSP-3315**	[C26]
Jimmie the Kid	RCA LPM-2213	[C26]
My Rough & Rowdy Ways	RCA LPM-2112	[C27]
Never No Mo' Blues	RCA LPM-1232	[C27]
Train Whistle Blues	RCA LPM-1640	[C27]
Rogers, Roy, & Dale Evans—The Bible Tells Me So	Cap. **ST-1745**	[C27]
Rush, Tom—Circle Game	Elek. **74018**	[C27]
Rusty & Doug—Sing Louisiana Man	Hick. LPM-103	[C27]
Sainte-Marie, Buffy—Illuminations	Van. **79300**	[C27]
Sandburg, Carl—American Songbag	2-Caed. 2025	[C27]
Seeger, Mike—Tipple, Loom & Rail	Folk. 5273	[C27]
Seeger, Pete—Waist Deep in the Big Muddy & Other Love Songs	Col. **CS-9505**	[C28]
Where Have All The Flowers Gone	Folk. **31026**	[C28]
Seely, Jeannie—Little Things	Monu. **18104**	[C28]
Thanks Hank	Monu. **18073**	[C28]
Sellers, Brother John—Big Boat Up the River	Mon. **S-505**	[C28]
Smith, Carl—Greatest Hits	Col. **CS-8737**	[C28]

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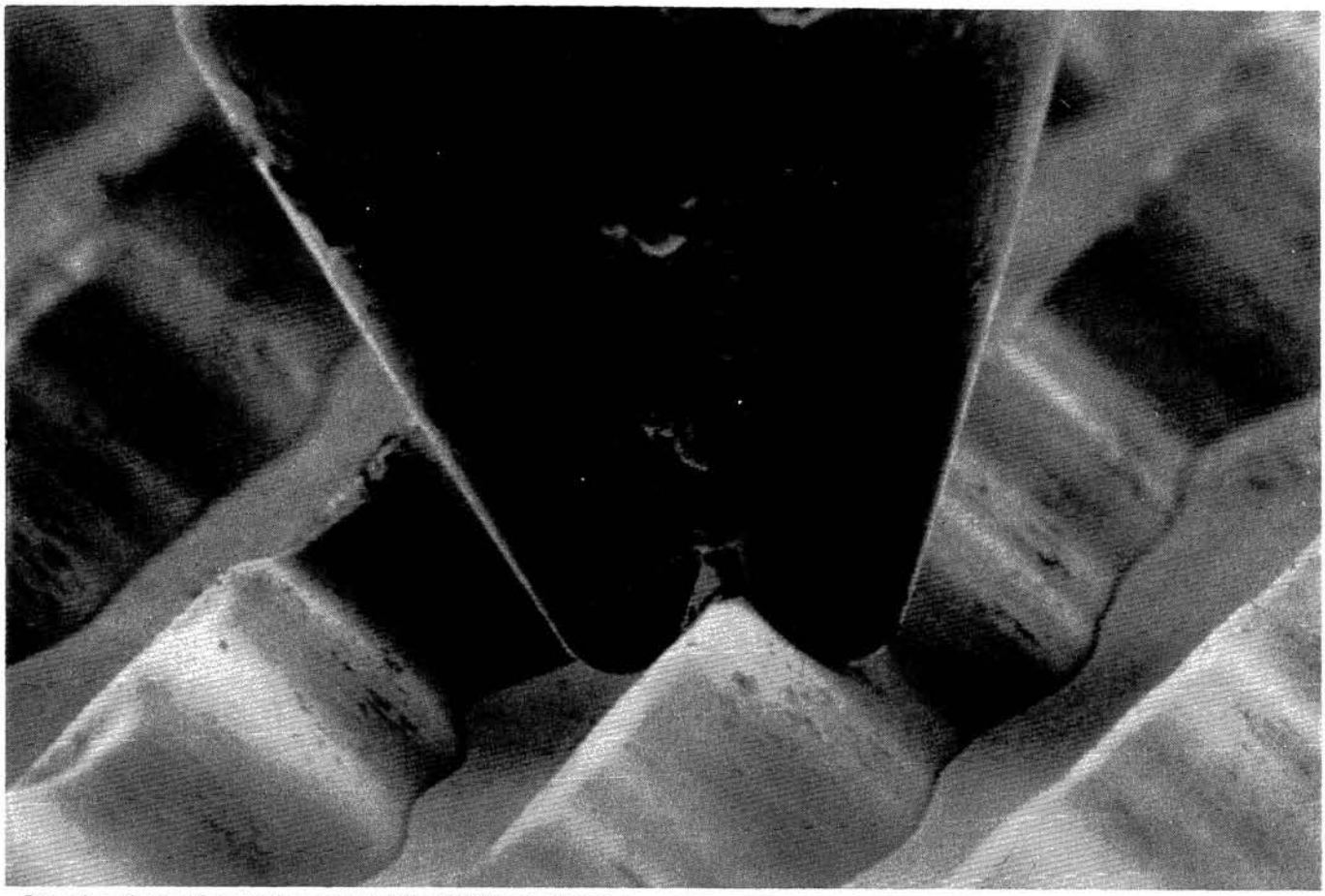

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Rubinstein, Wallenstein, Symphony of the Air
RCA **LSC-2234** **[A21]**

Danse macabre, Op. 40
Toscanini, NBC Symphony RCA VIC-1244 **[A9]**

Introduction and Rondo Capriccioso
Heifetz, Steinberg, RCA Victor Symphony
RCA LM-2069 **[A15]**

Samson et Dalila (excerpts)
Gorr, Vickers, Prêtre Ang. **S-36210** **[A42]**

Symphony No. 3 in c, Op. 78, "Organ"
Zamkochian, Munch, Boston Symphony
RCA **LSC-2341** **[A43]**

SARASATE, PABLO DE (1844–1908)

Zigeunerweisen, Op. 20, No. 1
Heifetz, Steinberg, RCA Victor Symphony
RCA LM-2069 **[A15]**

SATIE, ERIK (1866–1925)

Gnossiennes; Piano Music
Camarata, Contemporary Ensemble Deram **18036** **[A43]**

Masselos Plays Satie
Masselos RCA **LSC-3127** **[A43]**

SCARLATTI, DOMENICO (1685–1757)

Sonatas
Bream, guitar RCA **LSC-2448** **[A43]**

SCHOENBERG, ARNOLD (1874–1951)

Chamber Symphony in E♭, Op. 9
Mehta, Los Angeles Philharmonic Lon. **6612** **[A43]**

Pierrot Lunaire, Op. 21
Pilarczyk, Boulez, Domaine Musicale Ev. **3171** **[A43]**

Quartet No. 1 in d, Op. 7
Juilliard Quartet CSP CML-4735 **[A43]**

Variations for Orchestra, Op. 31
Mehta, Los Angeles Philharmonic Lon. **6612** **[A43]**

Verklärte Nacht, Op. 4
Mehta, Los Angeles Philharmonic Lon. **6552** **[A43]**

SCHUBERT, FRANZ (1797–1828)

Der Hirt auf dem Felsen, D. 965
Ameling, Deinzer, Demus RCA **VICS-1405** **[A44]**

Impromptus Op. 90, 142 (D. 899, 935)
Kraus Van. **C-10031** **[A44]**

Octet in F for Strings & Winds, Op. 166, D. 803
Vienna Octet Lon. **6051** **[A44]**

Overtures (Alfonso and Estrella, In the Italian Style, in C and D)
Menuhin, Festival Orch. Ang. **S-36609** **[A44]**

Quartet No. 12 in c, "Quartettsatz", D. 703
Amadeus Quartet DG **138048** **[A44]**

Quartet No. 14 in d, "Death and the Maiden", D. 810
Amadeus Quartet DG **138048** **[A44]**

Quintet in A (piano), Op. 114, "Trout", D. 667
Hephzibah Menuhin, Amadeus Quartet Ang. **S-35777** **[A44]**

Quintet in C, Op. 163, D.956
Heifetz, Baker, Primrose, Piatigorsky, Rejto
RCA **LSC-2737** **[A45]**

Rosamunde: Incidental Music, Op. 26, D. 797
Popp, Vaughan, Naples Orch. RCA **VICS-1638** **[A45]**

Schwanengesang, D. 957
Fischer-Dieskau, Moore Ang. **S-36127** **[A45]**

Songs
Ludwig Ang. **S-36462** **[A45]**

Symphony No. 8 in b, "Unfinished", D. 759
Menuhin, Festival Orch. Ang. **S-36609** **[A44]**

Symphony No. 9 in C, "The Great", D. 944
Steinberg, Boston Symphony RCA **LSC-3115** **[A45]**

Trio No. 1 in B♭ (piano), Op. 99, D. 898
Stern, Rose, Istomin Col. **MS-6716** **[A45]**

Die Winterreise, Op. 89, D. 911
Pears, Britten 2-Lon. **1261** **[A44]**

Zauberharfe (Stage Music)
Popp, Vaughan, Naples Orch. & Chorus
RCA **VICS-1638** **[A45]**

SCHULLER, GUNTHER (1925–

Seven Studies on Themes of Paul Klee (1959)
Leinsdorf, Boston Symphony RCA **LSC-2879** **[A45]**

SCHUMAN, WILLIAM (1910–

New England Triptych, Three Pieces for Orchestra (1956)
Rudolf, Cincinnati Symphony Dec. **710168** **[A18]**

A Song of Orpheus (Fantasy) (1961)
Rose, Szell, Cleveland Orch. Col. **MS-6638** **[A3]**

Symphony No. 3 (1941)
Bernstein, New York Philharmonic CSP **CMS-6245** **[A45]**

Symphony No. 6 (1948)
Ormandy, Philadelphia Orch. CSP CML 4992 **[A38]**

SCHUMANN, ROBERT (1810–1856)

Carnaval, Op. 9
Rubinstein RCA **LSC-2669** **[A45]**

Concerto in a for Cello & Orchestra, Op. 129
Rose, Bernstein, New York Philharmonic
Col. **MS-6253** **[A10]**

Concerto in a for Piano & Orchestra, Op. 54
Lipatti, Karajan, Philharmonia Orch. Odys. 32160141 **[A24]**

Dichterliebe, Op. 48
Pears, Britten 2-Lon. **1261** **[A44]**

Fantasiestücke, Op. 12
Rubinstein RCA **LSC-2669** **[A45]**

Manfred Overture, Op. 115
Klemperer, New Philharmonia Ang. **S-36353** **[A46]**

Piano Music: Kinderscenen, Op. 15, Intermezzi, Op. 4, Waldscenen, Op. 82, Variations on A-B-E-G-G, Op. 1
Eschenbach DG **139183** **[A46]**

Quintet in E♭ for Piano & Strings, Op. 44
Serkin, Budapest Quartet Col. **MS-7266** **[A13]**

Songs (22)
Fischer-Dieskau, Demus DG **139326** **[A46]**

Symphonic Etudes, Op. 13; Fantasia in C, Op. 17
Ashkenazy Lon. **6471** **[A46]**

Symphony No. 1 in B♭, Op. 38, "Spring"
Klemperer, New Philharmonia Orch. Ang. **S-36353** **[A46]**

Symphony No. 3 in E♭, Op. 97, "Rhenish"
Solti, Vienna Philharmonic Lon. **6582** **[A46]**

Symphony No. 4 in d, Op. 120
Solti, Vienna Philharmonic Lon. **6582** **[A46]**

SCRIABIN, ALEXANDER (1872–1915)

Sonata No. 3 in f♯ for Piano, Op. 23; Preludes (16), Op. 11
Horowitz RCA LM 2005 **[A46]**

Symphony No. 4 (Poem of Ecstasy), Op. 54
Mehta, Los Angeles Philharmonic Lon. **6552** **[A43]**

SESSIONS, ROGER (1896–

Concerto for Violin (1935)
Zukofsky, Schuller, French Radio Orch. CRI **S-220** **[A46]**

Symphony No. 3 (1957)
Buketoff, Royal Philharmonic RCA **LSC-3095** **[A28]**

SHOSTAKOVICH, DMITRI (1906–

Age of Gold (ballet suite), Op. 22; The Bolt (ballet suite), Op. 27
M. Shostakovich, Bolshoi Theater Orch.
Mel./Ang. **S-40062** **[A46]**

Concerto in E♭ for Cello, Op. 107
Rostropovich, Ormandy, Philadelphia Orch.
Col. **MS-6124** **[A46]**

Symphony No. 1 in F, Op. 10
Ormandy, Philadelphia Orch. Col. **MS-6124** **[A46]**

Symphony No. 5, Op. 47
Bernstein, New York Philharmonic Col. **MS-6115** **[A46]**

Symphony No. 7, Op. 60, "Leningrad"
Bernstein, New York Philharmonic 2-Col. **M2S-722** **[A47]**

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Sonata for Piano, four hands
Eden & Tamir — Lon. **6434** **[A29]**

PROKOFIEV, SERGE (1891–1953)
Alexander Nevsky, Op. 78
Elias, Reiner, Chicago Sym. — RCA **LSC-2395** **[A38]**
Concerto No. 3 in C for Piano, Op. 26
Cliburn, Hendl, Chicago Symphony — RCA **LSC-2507** **[A29]**
Concerti for Violin No. 1 in D, Op. 19; No. 2 in g, Op. 63
Milstein, Giulini, Philharmonia — Ang. **S-36009** **[A38]**
Lieutenant Kijé Suite, Op. 60
Reiner, Chicago Symphony — RCA **LSC-2150** **[A38]**
Peter and The Wolf, Op. 67
Connery (narrator), Dorati, Royal Philharmonic — Lon. **21007** **[A14]**
Ustinov (narrator), Karajan, Philharmonia — Ang. **S-35638** **[A26]**
Sonatas for Piano, No. 7 in B♭, Op. 83; No. 8 in B♭, Op. 84
Ashkenazy — Lon. **6573** **[A39]**
Symphony in D, Op. 25 (Classical)
Bernstein, New York Philharmonic — Col. **MS-7159** **[A10]**
Symphony No. 5, Op. 100
Bernstein, New York Philharmonic — Col. **MS-7005** **[A39]**

PUCCINI, GIACOMO (1858–1924)
La Bohème
De Los Angeles, Bjoerling, Tozzi, Beecham — 2-Sera. **6000** **[A39]**
La fanciulla del West (excerpts)
Tebaldi, Del Monaco, MacNeil, Capuana — Lon. **25196** **[A40]**
Gianni Schicchi (excerpts)
De Los Angeles, Gobbi, Santini — Ang. **S-35473** **[A39]**
Madama Butterfly (excerpts)
Scotto, Bergonzi, Panerai, Barbirolli — Ang. **S-36567** **[A40]**
Tosca
Callas, Gobbi, Bergonzi, Prêtre, Paris Consv. Orch. — 2-Ang. **S-3655** **[A40]**
Turandot (excerpts)
Nilsson, Bjoerling, Tebaldi, Tozzi, Leinsdorf, Rome Opera — RCA **LSC-2539** **[A40]**

PURCELL, HENRY (c. 1659–1695)
Dido and Aeneas
Baker, Clark, Sinclair, Lewis, Chamber Orch., Chorus — Oiseau **60047** **[A40]**
Sonata in D for Trumpet and Strings
Janigro, Solisti di Zagreb — Bach **5041** **[A40]**

RACHMANINOFF, SERGEI (1873–1943)
Concerto No. 2 in c for Piano, Op. 18
Ashkenazy, Kondrashin, Moscow Philharmonic (& 3 Etudes) — Lon. **6390** **[A40]**
Concerto No. 3 in d for Piano, Op. 30
Horowitz, Reiner, RCA Victor Symphony — RCA LM-1178 **[A41]**
Cliburn, Kondrashin, Sym. of the Air — RCA **LSC-2355** **[A41]**
Piano Music
Rachmaninoff — RCA LM-2587 **[A41]**
Rhapsody on a Theme of Paganini, Op. 43
Rubinstein, Reiner, Chicago Symphony — RCA **LSC-2430** **[A20]**
Suite for 2 Pianos
Eden & Tamir — Lon. **6434** **[A29]**

RANGSTRÖM, TURE (1884–1947)
Songs
Nilsson, Bokstedt, Vienna Opera Orch. — Lon. **25942** **[A24]**

RAVEL, MAURICE (1875–1937)
Alborada del gracioso
Martinon, Chicago Symphony — RCA **LSC-3093** **[A41]**
Bolero
Munch, Boston Symphony — RCA **VICS-1323** **[A18]**
Concerto in G for Piano
Entremont, Ormandy, Philadelphia Orch. — Col. **MS-6629** **[A20]**
Daphnis et Chloé
Munch, Boston Symphony — RCA **LSC-2568** **[A41]**
Introduction and Allegro for Harp, Flute, Clarinet and String Quartet
Martinon, Chicago Symphony — RCA **LSC-3093** **[A41]**
Ma Mère l'Oye
Ansermet, Orch. Suisse Romande — Lon. **6023** **[A18]**
Martinon, Chicago Symphony — RCA **LSC-3093** **[A41]**
Munch, Boston Symphony — RCA **VICS-1060** **[A19]**
Pavane pour une infante défunte (1899)
Giulini, Philharmonia Orch. — Ang. **S-36385** **[A41]**
Quartet
Juilliard Quartet — RCA **LSC-2413** **[A18]**
Rapsodie espagnole
Giulini, Philharmonia Orch. — Ang. **S-36385** **[A41]**
Martinon, Chicago Symphony — RCA **LSC-3093** **[A41]**
Shéhérazade
Crespin, Ansermet, Orch. Suisse Romande — Lon. **25821** **[A8]**
Trio in a (piano)
Rubinstein, Heifetz, Piatigorsky — RCA LM-1119 **[A30]**
Tzigane for Violin & Orchestra
Perlman, Previn, London Symphony — RCA **LSC-3073** **[A28]**
La Valse
Munch, Boston Symphony — RCA **VICS-1323** **[A18]**
Valses nobles et sentimentales
Munch, Philadelphia Orch. — Odys. **Y-31017** **[A8]**

RESPIGHI, OTTORINO (1879–1936)
Boutique fantasque (ballet, after Rossini)
Fiedler, Boston Pops — RCA **VICS-1053** **[A27]**
Fountains of Rome; Pines of Rome
Toscanini, NBC Symphony — RCA VIC-1244 **[A9]**

RIMSKY-KORSAKOV, NIKOLAI (1844–1908)
Coq d'Or Suite; Russian Easter Overture
Ormandy, Philadelphia Orch. — Col. **MS-6092** **[A42]**
Scheherazade, Op. 35
Ansermet, Orchestre de la Suisse Romande — Lon. **6212** **[A10]**

RODGERS, RICHARD (1902–
Victory at Sea, Vol. 1
Robert Russell Bennett, RCA Symphony Orch. — RCA **LSC-2335** **[A42]**

RODRIGO, JOAQUIN (1902–
Concierto Andaluz for 4 Guitars & Orchestra; Concierto de Aranjuez for Guitar & Orchestra
Romero Family, Alessandro, San Antonio Symphony — Mer. **90488** **[A42]**
Fantasia para un gentilhombre for Guitar
Segovia, Jorda, Symphony of the Air — Dec. **710027** **[A38]**

ROREM, NED (1923–
War Scenes; 5 Whitman Songs; 4 Dialogues
Darian; Stewart; Gramm; Rorem, Cumming — Desto **7101** **[A42]**

ROSSINI, GIOACCHINO (1792–1868)
Arias
Caballé — RCA **LSC-3015** **[A42]**
Barber of Seville (excerpts)
Berganza, Corena, Ghiaurov, Varviso — Lon. **26007** **[A42]**
Overtures (William Tell, Scala di seta, Barber of Seville, Signor Bruschino, Gazza ladra, Cenerentola)
Reiner, Chicago Symphony — RCA **LSC-2318** **[A42]**
Semiramide (excerpts)
Sutherland, Horne, Malas, Bonynge, London Symphony — Lon. **26086** **[A42]**

RUGGLES, CARL (1876–1971)
Evocations; Lilacs; Portals
Kirkpatrick, Prausnitz, Juilliard String Orch. — CSP CML-4986 **[A18]**

SAINT-SAËNS, CAMILLE (1835–1921)
Concerto No. 2 in g for Piano & Orch., Op. 22

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Concertone in C for 2 Violins, K. 190
Laredo, Tree, Schneider, Marlboro Festival
Col. **MS-6848** [A30]

Divertimento in E♭ for String Trio, K. 563
Grumiaux Trio Phi. **802803** [A33]

Divertimento No. 10 in F, K. 247; Divertimento No. 11 in D, K.251
Davis, Orch. Oiseau **60029** [A33]

Divertimento No. 15 in B♭, K. 287
Karajan, Berlin Philharmonic DG **139004** [A33]

Don Giovanni, K. 527 (excerpts)
Nilsson, Arroyo, Talvela, Fischer-Dieskau, Bohm, Prague National Theater DG **136282** [A33]

Exsultate, Jubilate, K. 165
Schwarzkopf, Süsskind, Philharmonia Orch.
Sera. 60013 [A2]

The Magic Flute, K. 620 (excerpts)
Janowitz, Ludwig, Berry, Frick, Klemperer, Philharmonia Orch. Ang. **S-36315** [A33]

Marriage of Figaro, K.492 (selections)
Moffo, Schwarzkopf, Wächter, Taddei, Giulini Ang. **S-35640** [A33]

Quartets
No. 17 in B♭, "Hunting," K. 458
Amadeus Quartet DG **138886** [A26]
No. 18 in A, K. 464;No. 19 in C, "Dissonant," K. 465
Barchet Quartet Dover 5200 [A34]

Quartets (piano) in g, K. 478; E♭, K. 493
Szell, Budapest Quartet Odys. 32160139 [A34]

Quintet in A for Clarinet & Strings, K. 581
De Peyer, Melos Ensemble Ang. **S-36241** [A34]

Quintet in g, K. 516
Heifetz, Baker, Primrose, Majewski, Piatigorsky RCA **LSC-2738** [A30]

Requiem, K. 626
Leinsdorf, Boston Symphony, complete Mass celebrated by Richard Cardinal Cushing (Service for John F. Kennedy) 2-RCA **LSC-7030** [A34]

Serenade No. 10 in B♭ for 13 Wind Instruments, K. 361
London Wind Soloists Lon. **6346** [A34]

Serenade in G, K. 525, "Eine kleine Nachtmusik"
Karajan, Berlin Phil. DG **139004** [A33]

Sinfonia Concertante in E♭ for Violin & Viola, K. 364
Stern, Trampler, London Symphony Col. **MS-7251** [A11]

Sonata No. 8 in a for Piano, K.310
Lipatti Odys. **32160320** [A2]

Symphony No. 35 in D, K. 385,"Haffner"
Szell, Cleveland Orch. Col. **MS-6969** [A34]

Symphony No. 36 in C, K. 425, "Linz"
Walter, Columbia Symphony Col. **MS-6493** [A34]

Symphony No. 38 in D, K. 504, "Prague"
Walter, Columbia Symphony Col. **MS-6494** [A35]

Symphony No. 39 in E♭, K. 543
Toscanini, NBC Symphony RCA **VICS-1330E** [A35]
Walter, Columbia Symphony Col. **MS-6493** [A34]

Symphony No. 40 in g, K. 550
Toscanini, NBC Symphony RCA **VICS-1330E** [A35]
Szell, Cleveland Orch. Col. **MS-6969** [A34]
Walter, Columbia Symphony Col. **MS-6494** [A35]

Symphony No. 41 in C, K. 551, "Jupiter"
Szell, Cleveland Orch. Col. **MS-6969** [A34]

Trio in E♭ for Clarinet, Viola, Piano, K. 498
De Peyer, Melos Ensemble Ang. **S-36241** [A34]

MUSSORGSKY, MODEST (1839–1881)

Boris Godounov (excerpts)
Christoff, Lear, Cluytens, Paris Conservatory Orch. Ang. **S-36169** [A35]

Night on Bald Mountain
Ormandy, Philadelphia Orch. Col. **M-30448** [A35]

Pictures at an Exhibition
Ormandy, Philadelphia Orch. Col. **M-30448** [A35]

NIELSEN, CARL (1865–1931)

Concerto for Clarinet
Drucker, Bernstein, New York Philharmonic
Col. **MS-7028** [A35]

Concerto for Flute
Baker, Bernstein, New York Philharmonic
Col. **MS-7028** [A35]

Symphony No. 3, Op. 27, "Espansiva"
Bernstein, Royal Danish Orch. Col. **MS-6769** [A35]

OFFENBACH, JACQUES (1819–1880)

Gaité Parisienne (arr. Rosenthal)
Munch, New Philharmonia Orch. Lon. **21011** [A35]

Tales of Hoffmann (excerpts)
De Los Angeles, Schwarzkopf, Gedda, D'Angelo, Cluytens Ang. **S-36413** [A36]

La Périchole (selections)
Tourel, Abravanel, Columbia Symphony
Odys. 32160351 [A36]

La Vie Parisienne (excerpts)
Morel, Columbia Symphony Odys. 32160351 [A36]

ORFF, CARL (1895–)

Carmina Burana
Harsanyi, Petrak, Presnell, Ormandy, Philadelphia Orch., Rutgers Univ. Choir
Col. **MS-6163** [A36]

PAGANINI, NICCOLÒ (1782–1840)

Concerto No. 1 in D for Violin, Op. 6
Ashkenase, Esser, Vienna Symphony DG **139424** [A36]

Concerto No. 2 in b for Violin, Op. 7
Ashkenase, Esser, Vienna Symphony DG **139424** [A36]

PALESTRINA, GIOVANNI (1525–1594)

Missa Papae Marcelli; Motets
Schrems, Regensburg Cathedral Choir
DG **ARC-198182** [A36]

PARTCH, HARRY (1901–)

Daphne of the Dunes; Barstow—8 Hitchhiker Inscriptions from a Highway Railing at Barstow, California; Plectra & Percussion Dances;Castor & Pollux
Mitchell's Ensemble Col. **MS-7207** [A36]

PENDERECKI, KRZYSZTOF (1933–)

Passion According to St. Luke
Czyz, Cracow Philharmonic Orch. & Chorus
2 Phi. **802771/2** [A37]

PERGOLESI, GIOVANNI BATTISTA (1710–1736)

La Serva padrona
Scotto, Bruscantini, Fasano, Virtuosi di Roma
2-Ev. **S-445/1** [A37]

PISTON, WALTER (1894–)

Symphony No. 4
Ormandy, Philadelphia Orch. CSP CML 4992 [A38]

PONCE, MANUEL (1882–1948)

Concierto del Sur for Guitar & Orch.
Segovia, Jorda, Symphony of the Air Dec. **710027** [A38]

PONCHIELLI, AMILCARE (1834–1886)

La Gioconda (excerpts)
Callas, Cossotto, Votto Ang. **S-35940** [A38]

POULENC, FRANCIS (1899–1963)

Aubade, for Piano & 18 Instruments; Concerto for Piano & Orchestra (1950)
Tacchino, Prêtre Ang. **S-36426** [A38]

Concerto in g for Organ, Strings, Timpani
Duruflé, Prêtre, French National Radio-TV Orch. Ang. **S-35953** [A38]

Gloria in G (1961)
Carteri, Prêtre, French National Radio-TV Orch. Ang. **S-35953** [A38]

Mouvements perpétuels; Improvisations; Suite française, etc.
Tacchino Ang. **S-36602** [A38]

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KAY, HERSHY (1919–
Cakewalk (ballet, after Gottschalk) (selections)
Fiedler, Boston Pops RCA **VICS–1053** **[A27]**

KODÁLY, ZOLTÁN (1882–1967)
Háry János Suite; Galanta Dances
Kertesz, London Symphony Lon. **6417** **[A28]**

KREISLER, FRITZ (1875–1962)
Fritz Kreisler Souvenirs
Kreisler RCA VIC–1372 **[A28]**

LALO, ÉDOUARD (1823–1892)
Symphonie espagnole for Violin & Orchestra
Perlman, Previn, London Symphony RCA **LSC–3073** **[A28]**

LECUONA, ERNESTO (1896–1963)
Lecuona Plays Lecuona
Lecuona RCA LPM–1055 **[A28]**

LEES, BENJAMIN (1924–
Concerto for String Quartet and Orchestra
Buketoff, Royal Philharmonic, String Quartet RCA **LSC–3095** **[A28]**

LEONCAVALLO, RUGGERO (1858–1919)
Pagliacci (excerpts)
Tucci, Del Monaco, MacNeil, Molinari-Pradelli Lon. **25334** **[A28]**

LISZT, FRANZ (1811–1886)
Concerto No. 1 in E♭ for Piano & Orchestra
Watts, Bernstein, New York Philharmonic Col. **MS–6955** **[A16]**

Hungarian Rhapsodies (Orch. Versions): Nos. 4,5; Mazeppa; Hungarian Fantasia
Karajan, Berlin Philharmonic DG **138692** **[A28]**

Homage to Liszt
Horowitz RCA LM–2584 **[A28]**

Sonata in b for Piano
Bolet (& Mephistowaltz) Ev. **3064** **[A29]**

LOCATELLI, PIETRO (1695–1764)
Concerto Grosso, Op. 1, No. 8 in f
Karajan, Berlin Phil. DG **2530070** **[A17]**

LUTOSLAWSKI, WITOLD (1913–
Variations on a Theme of Paganini
Eden & Tamir Lon. **6434** **[A29]**

MacDOWELL, EDWARD (1861–1908)
Concerto No. 2 in d for Piano
Cliburn, Hendl, Chicago Symphony RCA **LSC–2507** **[A29]**

Suite No. 2, Op. 48 (Indian Suite)
Hanson, Eastman–Rochester Orch. Mer. **90422** **[A24]**

MAHLER, GUSTAV (1860–1911)
Kindertotenlieder
Anderson, Monteux, San Francisco Symphony RCA LM–1146 **[A11]**
Horne, Lewis, Royal Philharmonic Lon. **26147** **[A55]**

Das Lied von der Erde
Chookasian, Lewis, Ormandy, Philadelphia Orch. 3-Col. **D3S–774** **[A29]**

Symphony No. 4 in G
Raskin, Szell, Cleveland Orch. Col. **MS–6833** **[A29]**

Symphony No. 10
Ormandy, Philadelphia Orch. 3-Col. **D3S-774** **[A29]**

MANFREDINI, FRANCESCO (c. 1680–1748)
Christmas Concerto in C, Op. 3, No. 12
Karajan, Berlin Phil. DG **2530070** **[A17]**

MARTINŮ, BOHUSLAV (1890–1959)
Duo for Violin and Cello
Heifetz, Piatigorsky RCA **LSC–2867** **[A1]**

MASCAGNI, PIETRO (1863–1945)
Cavalleria Rusticana (excerpts)
Simionato, Del Monaco, MacNeil, Serafin Lon. **25334** **[A28]**

MASSENET, JULES (1842–1912)
Arias (3); Manon (excerpts)
Callas Ang. **S–36147** **[A29]**

MENDELSSOHN, FELIX (1809–1847)
Concerti for Piano: No. 1 in g, Op. 25; No. 2 in d, Op. 40
Serkin, Ormandy, Columbia Symphony Col. **MS–6128** **[A29]**

Concerto in e for Violin, Op. 64
Ricci, Gamba, London Symphony Lon. **6010** **[A14]**

Midsummer Night's Dream, Incidental Music, Op. 21 & 61
Kempe, Royal Philharmonic Sera. **S–60056** **[A27]**

Octet in E♭ for Strings, Op. 20
Heifetz, Baker, Belnick, Stepansky, Primrose, Majewski, Piatigorsky, Rejto RCA **LSC-2738** **[A30]**
Laredo, Schneider, Steinhardt, Dalley, Tree, Rhodes, Parnas, Soyer Col. **MS–6848** **[A30]**

Songs Without Words (selection)
Gieseking Ang. 35428 **[A30]**

Symphony No. 4 in A, Op. 90, "Italian"
Maazel, Berlin Phil. DG **138684** **[A30]**

Symphony No. 5 in d, Op. 107, "Reformation"
Maazel, Berlin Phil. DG **138684** **[A30]**

Trio No. 1 in d, Op. 49
Rubinstein, Heifetz, Piatigorsky RCA LM–1119 **[A30]**

MENNIN, PETER (1923–
Canto for Orchestra
Rudolf, Cincinnati Symphony Dec. **710168** **[A18]**

Concerto for Piano
Ogdon, Buketoff, Royal Phil. RCA **LSC-3243** **[A30]**

MENOTTI, GIAN CARLO (1911–
Amahl and the Night Visitors
King, Yaghjian, McCollum, Patterson, Grossman, Orch., Chorus RCA **LSC–2762** **[A30]**

The Medium; The Telephone
Original Cast 2-Col. OSL 154 **[A31]**

MESSIAEN, OLIVIER (1908–
Turangalîla-Symphonie
Ozawa, Toronto Symphony 2-RCA **LSC–7051** **[A31]**

MILHAUD, DARIUS (1892–
Création du monde; Le Boeuf sur le toit
Milhaud, Orch. None. **71122** **[A31]**

Scaramouche Suite
Eden & Tamir Lon. **6434** **[A29]**

MOORE, DOUGLAS (1893–1969)
Ballad of Baby Doe
Sills, Bible, Cassel, Buckley 3-Hel. **S–25035** **[A32]**

MOZART, WOLFGANG AMADEUS (1756–1791)
Concerto in B♭ for Bassoon, K. 191
Brooke, Beecham, Royal Philharmonic Sera. **S–60193** **[A32]**

Concerto in A for Clarinet, K. 622
Brymer, Beecham, Royal Philharmonic Sera. **S–60193** **[A32]**

Concerto in C for Flute, Harp, Strings, K. 299
Baker, Jellinek, Janigro, Solisti di Zagreb Bach **5048** **[A32]**

Concerti (4) for Horn, K. 412,417,447,495
Brain, Karajan, Philharmonia Ang. 35092 **[A32]**

Concerto No. 15 in B♭ for Piano, K. 450
Casadesus, Szell, Cleveland Orch. Col. **MS–7245** **[A33]**

Concerto No. 17 in G for Piano, K. 453
Casadesus, Szell, Cleveland Orch. Col. **MS–7245** **[A33]**

Concerto No. 19 in F for Piano, K. 459
Serkin, Szell, Cleveland Orch. Col. **MS–6534** **[A33]**

Concerto No. 20 in d for Piano, K. 466
Serkin, Szell, Cleveland Orch. Col. **MS–6534** **[A33]**

Concerto No. 21 in C for Piano, K. 467
Rubinstein, Wallenstein, RCA Victor Sym. RCA **LSC-2634** **[A33]**

Concerto No. 23 in A for Piano, K. 488
Rubinstein, Wallenstein, RCA Victor Sym. RCA **LSC-2634** **[A33]**

Concerto No. 27 in B♭ for Piano, K. 595
Serkin, Ormandy, Philadelphia Orch. Col. **MS–6839** **[A4]**

Concerto No. 3 in G for Violin, K.216
Francescatti, Walter, Col. Sym. Col. **MS-6063** **[A32]**

Concerto No. 4 in D for Violin, K.218
Francescatti, Walter, Col. Sym. Col. **MS-6063** **[A32]**

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Valse–Fantasie
Svetlanov, USSR Symphony Mel./Ang. **S–40081** **[A22]**

GLUCK, CHRISTOPH WILLIBALD (1714–1787)
Orfeo ed Euridice
Moffo, Raskin, Verrett, Fasano, Virtuosi di Roma 3–RCA **LSC–6169** **[A23]**

GOEB, ROGER (1914–
Symphony No. 3
Stokowski, Orch. CRI 120 **[A23]**

GOLDMARK, KARL (1830–1915)
Symphony, Op. 26, "Rustic Wedding"
Bernstein, New York Philharmonic Col. **MS–7261** **[A23]**

GOTTSCHALK, LOUIS MOREAU (1829-1869)
Piano Music
List Van. 485 **[A23]**

GOULD, MORTON (1913–
Fall River Legend; Latin American Symphonette; Interplay
Morton Gould Orch. RCA **LSC–2532** **[A23]**

GOUNOD, CHARLES (1818–1893)
Faust (excerpts)
De Los Angeles, Christoff, Gedda, Cluytens Ang. **S–35827** **[A23]**

Roméo et Juliette (excerpts)
Carteri, Gayraud, Gedda, Lombard, Paris Opera Orch. Ang. **S–36287** **[A24]**

GRAINGER, PERCY (1882–1961)
Salute to Percy Grainger
Pears, Shirley-Quirk, Britten, English Ch. Orch., Ambrosian Singers Lon. **6632** **[A24]**

GRANADOS, ENRIQUE (1867–1916)
Colección de Tonadillas; Colección de Canciones amatorias
Caballé, Ferrer, Orch. RCA **LSC–2910** **[A24]**

Colección de Tonadillas
De Los Angeles 2-Ang. **S-3672** **[A21]**

Goyescas
Ciccolini Sera. **S-60178** **[A24]**

Spanish Dances; Allegro di Concierto in C♯
Iturbi Ang. **S-35628** **[A1]**

GRIEG, EDVARD (1843–1907)
Concerto in a for Piano
Lipatti, Galliera, Philharmonia Orch. Odys. 32160141 **[A24]**

Peer Gynt Suite No. 1
Szell, Cleveland Orch. Col. **MS–6877** **[A10]**

Songs of Scandinavia
Nilsson, Bokstedt, Vienna Opera Orch. Lon. **25942** **[A24]**

GRIFFES, CHARLES TOMLINSON (1884–1920)
Pleasure Dome of Kubla Khan; White Peacock; Clouds; Bacchanale
Hanson, Eastman–Rochester Orch. Mer. **90422** **[A24]**

GROFÉ, FERDE (1892–1972)
Grand Canyon Suite
Fiedler, Boston Pops RCA **VICS–1423** **[A24]**

HANDEL, GEORGE FRIDERIC (1685–1759)
Alcina (excerpts)
Sutherland, Berganza, Sinclair, Bonynge, London Symphony & Chorus Lon. **25874** **[A24]**

Concerti for Organ (Op. 4:Nos. 2,5; Nos. 13,16)
Biggs, Boult, London Philharmonic Col. **MS–6439** **[A25]**

Faithful Shepherd Suite
Beecham, Royal Philharmonic CSP CML–4374 **[A25]**

Julius Caesar (excerpts)
Sills, Forrester, Treigle, Rudel, NYC Opera Co. RCA **LSC–3116** **[A25]**

Love in Bath
Hollweg, Beecham, Royal Philharmonic Sera. **S–60039** **[A25]**

Messiah
Harper, Watts, Shirley–Quirk, Davis, London Symphony & Chorus 3–Phi. **PHS–3–992** **[A25]**

Water Music (complete)
Boulez, Hague Philharmonic None. **71127** **[A25]**

HANSON, HOWARD (1896–
Merry Mount (excerpts)
Hanson, Eastman-Rochester Symphony Orch. Mer. **90524** **[A26]**

HAYDN, (FRANZ) JOSEPH (1732–1809)
Concerto in C for Cello & Orchestra
Du Pré, Barenboim, English Chamber Orch. Ang. **S–36439** **[A10]**

Concerto in E♭ for Trumpet and Orchestra
Berinbaum, Somary, English Ch. Orch. Van **C–10098** **[A26]**

Quartet in C, Op. 76, No. 3, "Emperor"
Amadeus Quartet DG **138886** **[A26]**

Symphonies Nos. 82,83,84,85,86,87, "Paris"
Bernstein, New York Philharmonic 3–Col. **D3S–769** **[A26]**

Symphony No. 94 in G, "Surprise"
Richter, Berlin Phil. DG **138782** **[A26]**

Symphony No. 101 in D, "Clock"
Richter, Berlin Phil. DG **138782** **[A26]**

Toy Symphony (Mvmts. 3,4,7 of L. Mozart: Cassatio)
Karajan, Philharmonia Ang. **S–35638** **[A26]**

HERBERT, VICTOR (1859-1924)
The Immortal Victor Herbert
Shaw Chorale RCA **LSC–2515** **[A26]**

HINDEMITH, PAUL (1895–1963)
Mathis der Maler; Symphonic Metamorphosis of Themes by Weber
Ormandy, Philadelphia Orch. Col. **MS–6562** **[A27]**

Requiem for Those We Love (When Lilacs Last in the Dooryard Bloom'd)
Parker, London, Hindemith, New York Philharmonic, Schola Cantorum CSP **CMS–6573** **[A27]**

HOLST, GUSTAV (1874–1934)
The Planets
Boult, New Philharmonia Orch. Ang. **S–36420** **[A27]**

HOVHANESS, ALAN (1911–
Mysterious Mountain
Reiner, Chicago Symphony RCA **LSC–2251** **[A27]**

HUMPERDINCK, ENGELBERT (1854–1921)
Hansel and Gretel (excerpts)
Kempe, Royal Philharmonic Sera. **S–60056** **[A27]**

IBERT, JACQUES (1890–1962)
Divertissement
Fiedler, Boston Pops RCA **VICS–1053** **[A27]**

Escales (Ports of Call)
Munch, Boston Symphony RCA **VICS–1323** **[A18]**

D'INDY, VINCENT (1851–1931)
Symphony on a French Mountain Air
Henriot–Schweitzer, Munch, Boston Symphony RCA **VICS–1060** **[A19]**

IPPOLITOV–IVANOV, MIKHAIL (1859–1935)
Caucasian Sketches, Op. 10 (1894)
Abravanel, Utah Sym. Van **C–10060** **[A27]**

IVES, CHARLES (1874–1954)
General William Booth Enters Into Heaven; Circus Band; Serenity; Harvest Home Chorales
Gregg Smith Singers Col. **MS–6921** **[A27]**

Symphony No. 4
Stokowski, American Symphony, Schola Cantorum Col. **MS–6775** **[A27]**

Symphony: Holidays
Bernstein, New York Philharmonic Col. **MS–7147** **[A27]**

Three Places in New England
Ormandy, Philadelphia Orch. Col. **MS–6684** **[A17]**

JANÁČEK, LEOŠ (1854–1928)
Slavonic Mass
Lear, Rössl-Majdan, Haefliger, Crass, Kubelik, Bavarian Radio DG **138954** **[A28]**

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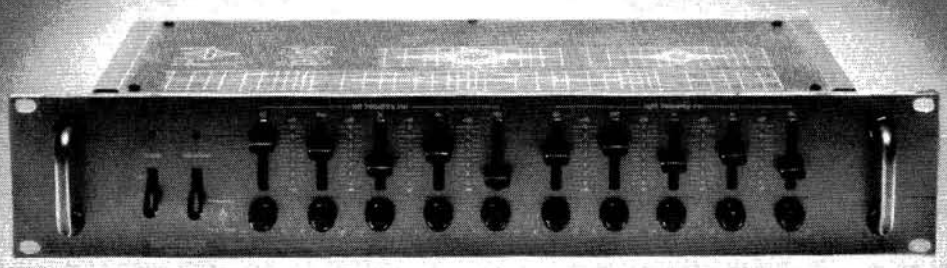

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Symphony No. 3 (1946)
Copland, London Symphony — Ev. **3018** **[A17]**

CORELLI, ARCANGELO (1653–1713)
Concerto grosso in g, Op. 6, No. 8, "Christmas"
Karajan, Berlin Phil. — DG **2530070** **[A17]**

COWELL, HENRY (1897–1965)
Hymn and Fuguing Tune, Nos. 1-8; Ballad, etc.
Mester, Louisville Orch. — Lou. **S-682** **[A17]**

Symphony No. 5
Dixon, Vienna Sym. — Desto **S-6406** **[A18]**

Toccanta for Soprano, Flute, Cello & Piano
Boatwright, Ensemble — CSP CML-4986 **[A18]**

DALLAPICCOLA, LUIGI (1904–
Variazioni per Orchestra
Rudolf, Cincinnati Symphony — Dec. **710168** **[A18]**

DEBUSSY, CLAUDE (1862–1918)
Children's Corner Suite
Gieseking — Ang. 35067 **[A18]**

Ibéria
Toscanini, NBC Symphony — RCA VIC-1246 **[A18]**

La Mer
Toscanini, NBC Symphony — RCA VIC-1246 **[A18]**

Nocturnes (Nuages, Fêtes, Sirènes)
Ansermet, Orch. Suisse Romande — Lon. **6023** **[A18]**

Prélude à l'après-midi d'un faune
Munch, Boston Symphony — RCA **VICS-1323** **[A18]**

Quartet
Juilliard Quartet — RCA **LSC-2413** **[A18]**

Suite bergamasque
Gieseking — Ang. 35067 **[A18]**

DELIBES, LEO (1836–1891)
Coppélia: Suite
Ansermet, Orchestre de la Suisse Romande — Lon. **6128** **[A18]**

DELIUS, FREDERICK (1862–1934)
On Hearing the First Cuckoo in Spring; Brigg Fair; Song Before Sunrise; Summer Night On the River; Fennimore & Gerda: Intermezzo; Marche-Caprice; Sleigh Ride
Beecham, Royal Phil. — Sera. **S-60185** **[A19]**

DELLO JOIO, NORMAN (1913–
Triumph of St. Joan Symphony
Whitney, Louisville Orch. — CSP CML-4615 **[A19]**

DOHNÁNYI, ERNST VON (1877–1960)
Concerto No. 2 in b for Piano, Op. 42
Dohnányi, Boult, Royal Philharmonic — Ang. **S-35538** **[A19]**

Variations on a Nursery Song, Op. 25
Dohnányi, Boult, Royal Philharmonic — Ang. **S-35538** **[A19]**

DONIZETTI, GAETANO (1797–1848)
Lucia di Lammermoor
Callas, di Stefano, Gobbi, Serafin — 2-Sera. 6032 **[A19]**

DUKAS, PAUL (1865–1935)
Sorcerer's Apprentice
Munch, Boston Symphony — RCA **VICS-1060** **[A19]**

DVOŘÁK, ANTONIN (1841–1904)
Concerto in b for Cello, Op. 104
Rostropovich, Karajan, Berlin Philharmonic — DG **139044** **[A19]**

Concerto in a for Violin, Op. 53
Milstein, Frühbeck de Burgos, New Philharmonia — Ang **S-36011** **[A19]**

Legends, Op. 59
Leppard, London Phil. — Phi. **6500188** **[A20]**

Quartet No. 6 in F, Op. 96, "American"
Juilliard Quartet — Col. **MS-7144** **[A20]**

Slavonic Dances
Reiner, Vienna Philharmonic — Lon. **STS-15009** **[A12]**

Symphony No. 8 in G, Op. 88
Karajan, Vienna Phil. — Lon. **6443** **[A20]**

Symphony No. 9 in e, Op. 95, "From the New World"
Kubelik, Vienna Philharmonic — Lon. **STS-15007** **[A20]**

ELGAR, EDWARD (1857–1934)
Cockaigne Overture, Op. 40
Barbirolli, Philharmonia Orch. — Ang. **S-36120** **[A20]**

Concerto in b for Violin, Op. 61
Heifetz, Sargent, London Symphony — RCA LM-2919 **[A20]**

Enigma Variations
Barbirolli, Philharmonia Orch. — Ang. **S-36120** **[A20]**

Pomp and Circumstance Marches, Op. 39; Froissart, overture
Barbirolli, Philharmonia Orch., New Philharmonia — Ang. **S-36403** **[A20]**

FALLA, MANUEL DE (1876–1946)
Nights in the Gardens of Spain
Entremont, Ormandy, Philadelphia Orch. — Col. **MS-6629** **[A20]**
Rubinstein, Jorda, San Francisco Symphony — RCA **LSC-2430** **[A20]**

Three Cornered Hat (and La Vida Breve excerpts)
Berganza, Ansermet, Orchestre de la Suisse Romande — Lon. **6224** **[A21]**

La Vida breve
De Los Angeles, Rivadeneyra, Rigueras, Cossutta, Frühbeck de Burgos, Orq. Nac'l España — 2-Ang. **S-3672** **[A21]**

FAURÉ, GABRIEL (1845–1924)
Pelléas et Mélisande, Op. 80
Munch, Philadelphia Orch. — Odys. **Y-31017** **[A8]**

FOSS, LUKAS (1922–
Baroque Variations
Foss, Buffalo Philharmonic — None. **71202** **[A15]**

Time Cycle
Addison, Foss, Bernstein, Columbia Symphony — CSP **CMS-6280** **[A21]**

FOSTER, STEPHEN (1826–1864)
Stephen Foster Favorites
Shaw Chorale — RCA **LSC-2295** **[A21]**

FRANCK, CÉSAR (1822–1890)
Sonata in A for Violin & Piano
Oistrakh, Richter — Mel./Ang. **S-40121** **[A12]**

Symphonic Variations for Piano & Orchestra
Rubinstein, Wallenstein, Symphony of the Air — RCA **LSC-2234** **[A21]**

Symphony in d
Monteux, Chicago Symphony — RCA **LSC-2514** **[A21]**

GERSHWIN, GEORGE (1898–1937)
American in Paris
Rodzinski, New York Philharmonic — Col. **CS-8641** **[A21]**

Concerto in F for Piano
Levant, Kostelanetz, New York Philharmonic — Col. **CS-8641** **[A21]**

Porgy and Bess
Winters, Matthews, Williams, Long, Engel, Orch., Chorus — 3-Odys. **32360018E** **[A22]**

Rhapsody in Blue
Levant, Ormandy, Philadelphia Orch. — Col. **CS-8641** **[A21]**

GINASTERA, ALBERTO (1916–
Concerto for Piano & Orchestra (1961)
Martins, Leinsdorf, Boston Symphony — RCA **LSC-3029** **[A22]**

Estancia; Panambí (ballet suites)
Goossens, London Symphony — Ev. **3041** **[A22]**

Variaciones Concertantes (1953)
Leinsdorf, Boston Symphony — RCA **LSC-3029** **[A22]**

GLAZOUNOV, ALEXANDER (1865–1936)
Concerto in a for Violin, Op. 82
Milstein, Frühbeck de Burgos, New Philharmonia — Ang. **S-36011** **[A19]**

GLINKA, MIKHAIL (1804–1857)
Kamarinskaya; Jota Aragonesa; Summer Night in Madrid; Russlan & Ludmila (selections);

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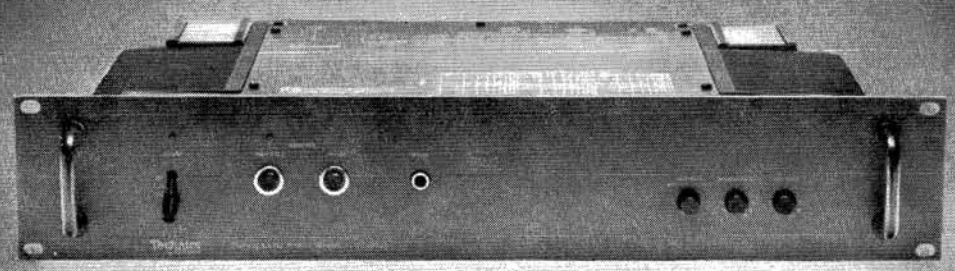

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BRAHMS, JOHANNES (1833–1897)
Academic Festival Overture, Op. 80
Szell, Cleveland Orch. Col. **MS–6965** [A11]
Alto Rhapsody, Op. 53
Anderson, Reiner, Shaw Chorale, RCA Victor Symphony RCA LM–1146 [A11]
Concerto No. 1 in d for Piano, Op. 15
Curzon, Szell, London Symphony Lon. **6329** [A11]
Concerto No. 2 in B♭ for Piano, Op. 83
Backhaus, Böhm, Vienna Philharmonic Lon. **6550** [A11]
Concerto in D for Violin, Op. 77
Heifetz, Reiner, Chicago Symphony RCA **LSC–1903** [A11]
Concerto in a for Violin & Cello, Op. 102
Stern, Rose, Ormandy, Philadelphia Orch. Col. **MS–7251** [A11]
Hungarian Dances
Reiner, Vienna Philharmonic Lon. **STS–15009** [A12]
Piano Music (from Op. 116, 118)
Rubinstein RCA **LSC–2459** [A12]
Quartets 1 and 2, Op. 51
Fine Arts Quartet Con.–Disc **226** [A12]
Quintet in b for Clarinet & Strings, Op. 115
Kell, Fine Arts Quartet Con.–Disc **202** [A12]
Quintet in f for Piano & Strings, Op. 34
Rubinstein, Guarneri Quartet RCA **LSC–2971** [A12]
Sonata No. 3 in f for Piano, Op. 5
Rubinstein RCA **LSC–2459** [A12]
Sonata No. 3 in d for Violin and Piano, Op. 108
Oistrakh, Richter Mel./Ang. **S–40121** [A12]
Songs (10)
Kipnis Sera. 60124 [A12]
Symphonies: No. 1 in c, Op. 68; No. 2 in D, Op. 73; No. 3 in F, Op. 90; No. 4 in e, Op. 98
Szell, Cleveland Orch. 3–Col. **D3S–758** [A13]
Tragic Overture, Op. 81
Szell, Cleveland Orch. Col. **MS–6965** [A11]
Trio in E♭ for Horn, Violin, Piano, Op. 40
Bloom, Tree, Serkin Col. **MS–7266** [A13]
Variations & Fugue on a Theme by Handel, Op. 24
Anievas Sera. **S–60049** [A13]
Variations on a Theme by Haydn, Op. 56a
Szell, Cleveland Orch. Col. **MS–6965** [A11]
Variations on a Theme by Paganini, Op. 35
Anievas Sera. **S–60049** [A13]
Ziegeunerlieder, Op. 103, Nos. 1-7, 11
Lotte Lehmann RCA **VICS–1320** [A13]

BRITTEN, BENJAMIN (1913–
Ceremony of Carols, Op. 28
Campbell, Canterbury Cathedral Choristers Lon. **25271** [A13]
Peter Grimes (excerpts)
Watson, Pears, Pease, Britten, Royal Opera House Lon. **26004** [A13]
War Requiem, Op. 66
Vishnevskaya, Pears, Fischer–Dieskau, Britten, London Symphony & Chorus 2–Lon. **1255** [A14]
Young Person's Guide to the Orchestra, Op. 34
Connery (narrator), Dorati, Royal Philharmonic Lon. **21007** [A14]

BRUCH, MAX (1838–1920)
Concerto No. 1 in g for Violin, Op. 26
Ricci, Gamba, London Symphony Lon. **6010** [A14]
Scottish Fantasy for Violin & Orchestra, Op. 46
Heifetz, Sargent, New Symphony, London RCA **LSC–2603** [A14]

BRUCKNER, ANTON (1824–1896)
Symphony No. 4 in E♭, "Romantic"
Klemperer, Philharmonia Orch. Ang. **S–36245** [A14]
Symphony No. 9 in d
Bernstein, NY Phil. Col. **M-30828** [A14]

CAGE, JOHN (1912–
Concerto for Prepared Piano
Takahashi, Foss, Buffalo Philharmonic None. **71202** [A15]

CANTELOUBE, JOSEPH (1879–1957)
Songs of the Auvergne
Davrath Van. **2090** [A15]

CARTER, ELLIOTT (1908–
Concerto for Piano
Lateiner, Leinsdorf, Boston Symphony RCA **LSC–3001** [A15]
Quartet No. 1 (1951)
Walden Quartet CSP CML–5104 [A15]

CASTELNUOVO–TEDESCO, MARIO (1895–1968)
Platero and I
Segovia Dec. **710054** [A15]

CHABRIER, EMMANUEL (1841–1894)
Bourrée fantasque; España; Gwendoline Overture; Habañera; Joyeuse Marche
Dervaux, Orchestre de la Société des Concerts du Conservatoire de Paris Sera. **S–60108** [A15]

CHAUSSON, ERNEST (1855–1899)
Poème for Violin & Orchestra, Op. 25
Heifetz, Solomon, RCA Victor Symphony RCA LM–2069 [A15]

CHÁVEZ, CARLOS (1899–
Sinfonía India; Sinfonía Antígona; Sinfonía Romántica
Chávez, New York Stadium Sym. Ev. **3029** [A15]

CHOPIN, FRÉDÉRIC (1810–1849)
Ballades (4), Op. 23, 38, 47, 52
Rubinstein RCA **LSC–2370** [A16]
Concerto No. 1 in e for Piano, Op. 11
Gilels, Ormandy, Philadelphia Orch. Col. **MS–6712** [A16]
Concerto No. 2 in f for Piano, Op. 21
Watts, Schippers, New York Philharmonic Col. **MS–6955** [A16]
Études, Op. 10, 25
Browning RCA **LSC–3072** [A16]
Nocturnes
Rubinstein 2-RCA **LSC-7050** [A16]
Piano Music of Chopin
Horowitz RCA LM–1707 [A16]
Polonaises
Malcuzynski Ang. **S–35728** [A16]
Preludes
Rubinstein RCA LM–1163 [A17]
Sonatas No. 2 in b♭, Op. 35, and No. 3 in b, Op. 58
Cliburn RCA **LSC–3053** [A17]
Waltzes (14)
Lipatti Odys. **32160058E** [A17]

COLGRASS, MICHAEL (1932–
"As Quiet As"
Leinsdorf, Boston Symphony RCA **LSC–3001** [A15]

CONUS, JULIUS (1869–1942)
Concerto in c for Violin & Orchestra
Heifetz, Solomon, RCA Victor Symphony RCA LM–2069 [A15]

COPLAND, AARON (1900–
Appalachian Spring: Suite (1945)
Bernstein, NY Philharmonic Col. **MS-6355** [A17]
Fanfare for the Common Man (1944)
Ormandy, Philadelphia Orch. Col. **MS–6684** [A17]
Lincoln Portrait (1942)
Adlai Stevenson (narrator), Ormandy, Philadelphia Orch. Col. **MS–6684** [A17]
Piano Variations (1930); Piano Fantasy (1957)
Masselos Odys. **32160040** [A17]
El Salón México (1936)
Bernstein, NY Philharmonic Col. **MS-6355** [A17]

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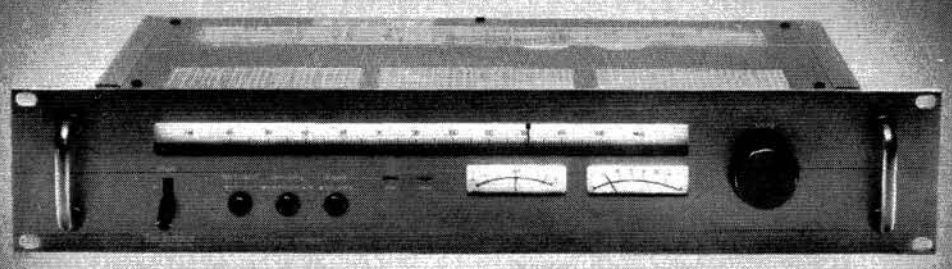

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Marshall, Merriman, Conley, Hines, Shaw
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2-RCA LM-6013 [A5]

Overtures (Coriolan, Egmont, King Stephen, Leonore No. 2)
Szell, Cleveland Orch. Col. **MS-6966** [A5]

Overtures (Coriolan, Fidelio, Leonore No. 3)
Karajan, Berlin Philharmonic DG **139015** [A5]

Quartets

No. 4 in c, Op. 18, No. 4
Bartók Quartet Dover **7280** [A5]

No. 11 in f, Op. 95
Weiner Quartet Dover **7280** [A5]

No. 12 in E♭, Op. 127
Quartetto Italiano Phi. **839745** [A5]

No. 14 in c♯, Op. 131
Juilliard Quartet RCA **LSC-2626** [A6]

No. 16 in F, Op. 135
Quartetto Italiano Phi. **839745** [A5]

Sonatas for Piano

No. 8 in c, Op. 13, "Pathétique"
Backhaus Lon. **6099** [A4]

No. 21 in C, Op. 53, "Waldstein"
Backhaus Lon. **6161** [A6]

No. 23 in f, Op. 57, "Appassionata"
Backhaus Lon. **6161** [A6]

No. 27 in e, Op. 90
Rosen 3-Col. **M3X-30938** [A6]

No. 28 in A, Op. 101
Bishop Sera. **S-60035** [A6]
Rosen 3-Col. **M3X-30938** [A6]

No. 29 in B♭, Op. 106, "Hammerklavier"
Ashkenazy Lon. **6563** [A6]
Rosen 3-Col. **M3X-30938** [A6]

No. 30 in E, Op. 109
Bishop Sera. **S-60035** [A6]
Rosen 3-Col **M3X-30938** [A6]

No. 31 in A♭, Op. 110
Rosen 3-Col. **M3X-30938** [A6]

No. 32 in c, Op. 111
Rosen 3-Col. **M3X-30938** [A6]

Sonatas for Violin & Piano

No. 5 in F, Op. 24, "Spring"
Szeryng, Rubinstein RCA **LSC-2377** [A7]

No. 9 in A, Op. 47, "Kreutzer"
Szeryng, Rubinstein RCA **LSC-2377** [A7]

Symphonies

No. 1 in C, Op. 21
Bernstein, New York Philharmonic Col. **MS-7084** [A7]

No. 2 in D, Op. 36
Bernstein, New York Philharmonic Col. **MS-7084** [A7]

No. 3 in E♭, Op. 55, "Eroica"
Munch, Boston Sym. RCA **VICS-1626** [A7]

No. 5 in c, Op. 67
Reiner, Chicago Sym. RCA **LSC-2343** [A7]

No. 6 in F, Op. 68, "Pastoral"
Reiner, Chicago Symphony RCA **LSC-2614** [A7]

No. 7 in A, Op. 92
Toscanini, New York Philharmonic RCA VIC-1502 [A7]

No. 8 in F, Op. 93
Karajan, Berlin Philharmonic DG **139015** [A7]

No. 9 in d, Op. 125, "Choral"
Furtwängler, Berlin Philharmonic Ev. **3241E** [A7]

Trio (Piano) No. 6 in B♭, Op. 97, "Archduke"
Stern, Rose, Istomin Col. **MS-6819** [A8]

Variations on a Theme by Diabelli, Op. 120
Bishop Phi. **839702** [A8]

BELLINI, VINCENZO (1801–1835)

Norma (excerpts)
Callas, Corelli, Serafin Ang. **S-35666** [A8]

La Sonnambula (excerpts)
Sutherland, Bonynge Lon. **25887** [A8]

BENNETT, ROBERT RUSSELL (1894–

Commemoration Symphony, "Stephen Foster"
Steinberg, Pittsburgh Symphony Ev. **3063** [A8]

Symphonic Story of Jerome Kern
Steinberg, Pittsburgh Symphony Ev. **3063** [A8]

BERG, ALBAN (1885–1935)

Concerto for Violin (1935)
Stern, Bernstein, New York Philharmonic
Col. **MS-6373** [A3]

BERIO, LUCIANO (1925–

Sinfonia
Swingle Singers, Berio, New York Philharmonic Col. **MS-7268** [A8]

BERLIOZ, HECTOR (1803–1869)

Damnation de Faust, Op. 24 (selections)
Munch, Philadelphia Orch. Odys. **Y-31017** [A8]

Harold in Italy, for Viola & Orchestra, Op. 16
Trampler, Prêtre, London Symphony RCA **LSC-3075** [A8]

Nuits d'été (song cycle, Op. 7)
Crespin, Ansermet, Orch. Suisse Romande Lon. **25821** [A8]

Overture (Roman Carnival)
Toscanini, NBC Symphony RCA VIC-1244 [A9]

Overtures (Corsaire, Francs-Juges, King Lear, Waverley, Roman Carnival)
Davis, London Symphony Phi. **835367** [A9]

Symphonie fantastique, Op. 14
Munch, Orchestre de Paris Ang. **S-36517** [A9]

BERNSTEIN, LEONARD (1918–

Fancy Free; On the Town (excerpts); Candide Overture; Prelude, Fugue & Riffs
Bernstein, New York Philharmonic Col. **MS-6677** [A9]

BILLINGS, WILLIAM (1746–1800)

Music of William Billings
Gregg Smith Singers Col. **MS-7277** [A9]

BIZET, GEORGES (1838–1875)

L'Arlésienne: Suite 1
Szell, Cleveland Orch. Col. **MS-6877** [A10]

Carmen
De Los Angeles, Gedda, Micheau, Beecham
3-Ang. **S-3613** [A9]

Symphony No. 1 in C
Bernstein, New York Philharmonic Col. **MS-7159** [A10]

BLITZSTEIN, MARC (1905–1964)

The Cradle Will Rock (1937)
Da Silva, Kingsley 2-CRI **S-266** [A10]

BLOCH, ERNEST (1880–1959)

Sacred Service, "Avodath Hakodesh" (1930-33)
Merrill, Bernstein, New York Philharmonic
Col. **MS-6221** [A10]

Schelomo—Rhapsody for Cello & Orchestra (1915)
Rose, Ormandy, Philadelphia Orch. Col. **MS-6253** [A10]

BOCCHERINI, LUIGI (1743–1805)

Concerto in B♭ for Cello & Orchestra
Du Pré, Barenboim, English Chamber Orch.
Ang. **S-36439** [A10]

BORODIN, ALEXANDER (1833–1887)

Prince Igor: Polovtsian Dances
Ansermet, Orchestre de la Suisse Romande Lon. **6212** [A10]

Quartet No. 2 in D
Drolc Quartet DG **139425** [A10]

CLASSICAL RECORDINGS

ADDINSELL, RICHARD (1904–
Warsaw Concerto
Litwin, Fiedler, Boston Pops — RCA **LSC–2380** **[A1]**

ALBÉNIZ, ISAAC (1860–1909)
Iberia
Ansermet, Orchestre de la Suisse Romande — Lon. **6194** **[A1]**
Suite Española
Iturbi (Nos. 3/5) (& Córdoba: Tango) — Ang. **S-35628** **[A1]**

ANDERSON, LEROY (1908–
Music of Leroy Anderson
Anderson, Orch. — Dec. **78865** **[A1]**

ARENSKY, ANTON (1861–1906)
Trio in d for Violin, Cello, Piano, Op. 32
Heifetz, Piatigorsky, Pennario — RCA **LSC–2867** **[A1]**

AUBER, DANIEL–FRANÇOIS (1782–1871)
Overtures
Bonynge, New Philharmonia — Lon. **6643** **[A1]**

BACH, CARL PHILIPP EMANUEL (1714–1788)
4 Hamburg Symphonies, Nos. 2/5, W. 182
Maier, Collegium Aureum — RCA **VICS–1453** **[A1]**

BACH, JOHANN SEBASTIAN (1685–1750)
Brandenburg Concerti (6), S. 1046/51; Suites (4) for Orchestra, S. 1066/9
Casals, Marlboro Festival Orch. — 3–Col. **D3S–816** **[A1]**
Cantata No. 51, Jauchzet Gott in allen Landen
Schwarzkopf, Gellhorn, Philharmonia Orch. — Sera. 60013 **[A2]**
Concerti (2) for Violin, S. 1041/2; Concerto in d for 2 Violins, S. 1043
D. & I. Oistrakh, Goossens, Royal Phil. — DG **138820** **[A2]**
Concerto for Solo Harpsichord, S. 972
Marlowe — Dec. **710113** **[A2]**
Fantasia & Fugue in g for Organ, S. 542; Fantasia & Fugue in c; Fantasias in c, G
Walcha — DG **ARC–198305** **[A2]**
Fantasia in c for Harpsichord; French Suite No. 5 for Harpsichord, S. 816; Italian Concerto in F for Harpsichord, S. 971; Toccata in D for Harpsichord
Marlowe — Dec. **710012** **[A2]**
Goldberg Variations, S. 938
Peter Serkin, piano — RCA **LSC–2851** **[A2]**
Jesu, Joy of Man's Desiring (from Cantata 147)
Lipatti — Odys. **32160320** **[A2]**
Mass in b, S. 232 (excerpts)
Stader, Töpper, Haefliger, Engen, Fischer–Dieskau, Richter, Munich Bach Orch. & Chorus — DG **136300** **[A2]**
Partita No. 1 in B♭ for Harpsichord, S. 825
Lipatti — Odys. **32160320** **[A2]**
Passacaglia & Fugue in c, S. 582
Ormandy, Philadelphia Orch. — Col. **MS–6180** **[A2]**
Walcha, organ — DG **ARC-198305** **[A2]**
Toccata and Fugue in d, S. 565
Ormandy, Philadelphia Orch. — Col. **MS–6180** **[A2]**
Toccata, Adagio and Fugue in C, S. 564
Ormandy, Philadelphia Orch. — Col. **MS–6180** **[A2]**
Well-tempered Clavier, Book 2, Nos. 1–8, S. 870/7
Glenn Gould, piano — Col. **MS–7099** **[A2]**

BARBER, SAMUEL (1910–
Adagio for Strings (from Quartet, Op. 11); Medea, Op. 23 (ballet suite); Overture to the School for Scandal, Op. 5; Symphony No. 1 in One Movement, Op. 9
Hanson, Eastman-Rochester Orch. — Mer. **90420** **[A3]**
Concerto for Piano and Orchestra, Op. 38
Browning, Szell, Cleveland Orch. — Col. **MS–6638** **[A3]**
Knoxville: Summer of 1915; Antony & Cleopatra (selections)
Price, Schippers, New Phil. — RCA **LSC-3062** **[A3]**

BARTÓK, BÉLA (1881–1945)
Concerto for Orchestra (1943)
Reiner, Chicago Symphony — RCA **VICS–1110** **[A3]**
Concerto for Two Pianos, Percussion & Orchestra (1940)
Gold & Fizdale, Bernstein, N.Y. Philharmonic — Col. **MS–6956** **[A3]**
Contrasts for Clarinet, Violin, Piano (1938)
Goodman, Szigeti, Bartók — Odys. **32160220** **[A3]**
Mikrokosmos (1935) (excerpts)
Béla Bartók, piano — Odys. **32160220** **[A3]**
Music for Strings, Percussion, Celesta (1936)
Bernstein, New York Philharmonic — Col. **MS–6956** **[A3]**
Quartets (6)
Juilliard Quartet — 3–Col. **D3S–717** **[A3]**
Rhapsodies (2) for Violin & Orchestra (1928)
Stern, Bernstein, New York Philharmonic — Col. **MS–6373** **[A3]**

BEESON, JACK (1921–
Lizzie Borden
Faull, Lewis, Elgar, Beattie, Coppola, New York City Opera — 3–Desto **6455/7** **[A4]**

BEETHOVEN, LUDWIG VAN (1770–1827)
Concerto No. 1 in C for Piano, Op. 15
Backhaus, Schmidt–Isserstedt, Vienna Philharmonic — Lon. **6099** **[A4]**
Concerto No. 2 in B♭ for Piano, Op. 19
Serkin, Ormandy, Philadelphia Orch. — Col. **MS–6839** **[A4]**
Concerto No. 3 in c for Piano, Op. 37
Rubinstein, Leinsdorf, Boston Symphony — RCA **LSC–2947** **[A4]**
Concerto No. 4 in G for Piano, Op. 58
Rubinstein, Leinsdorf, Boston Sym. — RCA **LSC–2848** **[A4]**
Concerto No. 5 in E♭ for Piano, Op. 73
Horowitz, Reiner, RCA Sym. — RCA **VICS–1636** **[A4]**
Concerto in D for Violin, Op. 61
Heifetz, Munch, Boston Symphony — RCA **LSC–1992** **[A4]**
Fidelio, Op. 72
Mödl, Jurinac, Windgassen, Edelmann, Frick, Schock, Furtwängler, Vienna Philharmonic & State Opera Chorus — 3–Sera. 6022 **[A5]**

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Mr. Bachman, who holds 19 U.S. patents, is a Fellow of the Institute of Electrical and Electronics Engineers and the AES. He is also the recipient of the AES Berliner award.

•

Benjamin B. Bauer graduated from the Pratt Institute in 1932 where he studied industrial electrical engineering. In 1937 he earned the E.E. degree from the University of Cincinnati and pursued postgraduate studies in physics, mathematics, and acoustics at Chicago and Northwestern Universities. Mr. Bauer became associated with Shure Brothers Incorporated, manufacturers of acoustical devices as development engineer in 1937 and then was made director of engineering and vice president.

Since 1957 he has guided major developments at the CBS Technology Center (formerly CBS Laboratories) in the fields of acoustics and magnetics in a broad range of the communications science. He is presently vice president and general manager of the Technology Center.

Mr. Bauer's career has spanned more than 30 years in research, development, engineering, management, teaching, writing and lecturing in acoustics and communications. He has made numerous contributions in research and development including microphones for acoustical measurements, piston-phones, heart-beat measurements, hearing aids, sound ranging, military and civilian communications, public address systems, and broadcasting; headphones and artificial voice and ear devices;

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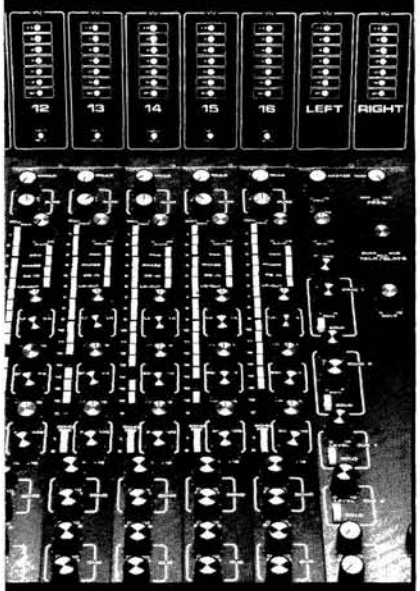

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Mr. Bauer has authored numerous papers and has contributed to textbooks on acoustical subjects. He has lectured widely on acoustics and research administration in the United States and abroad and is a visiting professor of engineering acoustics at Pennsylvania State University.

Mr. Bauer, who holds more than 50 patents, is a Fellow of the Institute of Electrical and Electronics Engineers, a Fellow of the Acoustical Society of America and associate editor of its Journal. He has been elected a Fellow of the Audio Engineering Society, its executive vice president (1967-68), president (1968-69), Honorary Member (1972), and a recipient of its Gold Medal Award. A founder, past editor-in-chief, and past national chairman of the IEEE Professional-Technical Group on Audio and Electroacoustics, he received the Group's Achievement Award in 1955. Mr. Bauer is a member of Tau Beta Pi, Sigma Xi, and Eta Kappa Nu scientific fraternities, and was recipient of the latter's honorable mention award to Outstanding Young Electrical Engineers in 1946, and its Award of Merit in 1961. In 1974 he was elected to the National Academy of Engineering of the United States.

•

Al Bodoh received a B.S. degree in electrical engineering from the University of Wisconsin. After 2 years with Underwriters Laboratories Inc. and 2 years with Northwestern University he spent 29 years with J. P. Seeburg Co. His work included electronics and telemetry combined with phonograph design and development involving electronics and mechanical projects. For 11 years he was vice president, director of engineering. He is currently working in the area of engineering administration with National Vendors in St. Louis, Missouri.

He is a Life Member of the Audio Engineering Society, a member of the Institute of Electrical and Electronics Engineers and the American National Metric Council.

•

John Borwick was born and educated in Edinburgh, Scotland, and holds a B.Sc. degree.

After 4 years as a signals officer in the RAF, Mr. Borwick joined the British Broadcasting Corporation in 1947 as program engineer. He later became responsible for training BBC

studio managers before becoming a freelance writer, broadcaster and recording engineer/producer in 1958. He is a senior lecturer (recording techniques) in the Department of Music at the University of Surrey with special responsibility for the 4-year bachelor of music (Tonmeister) course and is audio editor of the *Gramophone*.

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Peter K. Burkowitz has been executive director of Polydor International GmbH and Phonogram International B.V. since 1967. His present position in the Polygram group of

companies encompasses all audio activities, i.e. studios, recording and engineering operations at both headquarters and their international organizations, including the United States. From 1953 through 1967, he was with EMI-Electrola, first as recording manager, then from 1961 as director. There he designed the first purposely-built pop workshop-type studio in Europe and developed early multitrack mixing, routing and monitoring circuitry. From 1946 through 1953, he worked as senior balance engineer at RIAS, Berlin, where he was engaged in all kinds of sound recording, including mixing for motion picture musicals.

His first major publication, "A Scientific Approach to Mono Recording," appears in *Funk & Ton*. 1952:11, 1953:1 and 1953:5. Publications in various professional journals and periodicals include papers for Audio Engineering Society conventions in 1962, 1968 and 1969. From 1954 through 1967, he worked on the German Standardization Subcommittee "Phono," and the Technical Committee of the German Record Industry Association. He authored the rumble-measuring standard DIN 45.544. Mr. Burkowitz holds German and foreign patents and registered designs on, among other subjects, the program signal-release time-controlled compressor, the playing-time versus cutting surface computer, the crosstalk rejecting bus network, the "Breitklang" process, the branch point buffer amplifier and the design for the first mobile modular console.

Mr. Burkowitz has been a member of AES since 1960, was first Chairman of the Central Europe Section (1971-1973), a Fellow in 1972, a Governor (1973-1974), and first Vice-President, Europe Region (1973-1975). He initiated AES Europe conventions and was Convention Chairman in Cologne (1971), Munich (1972) and Rotterdam (1973). He has been instrumental in the formation of sections in Belgium, France, Denmark, the Netherlands, Austria, and South and Central Germany. Since 1973, Mr. Burkowitz has been AES Education Committee Chairman.

Leah S. Burt received a B.S. degree in chemistry in 1951 from the University of Texas at Austin. She joined the National Park Service, U.S. Department of Interior, in 1966, first at Morristown National Historical Park, and later transferred to Edison National Historic Site in 1971.

Her memberships include the Society of American Archivists, Eastern National Park and Monument Association, the American Phonograph Society, the City of London Phonograph and Gramophone Society and the As-

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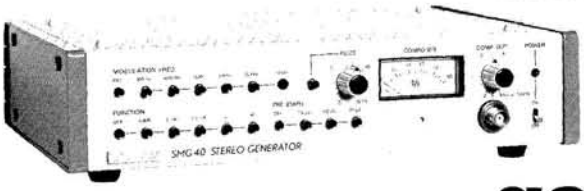

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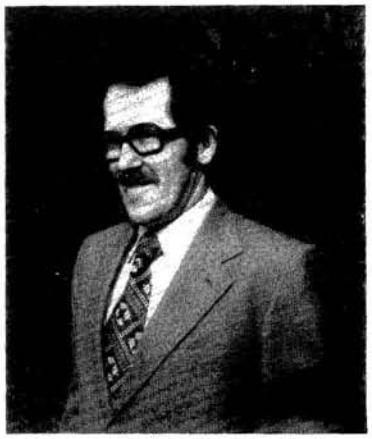
Ray Darnell was born in Sydney in 1931 and completed his education at the Sydney Technical College from which he received a Diploma in Radio



Engineering in 1954. He then apprenticed in electrical fitting at Standard Telephone & Cables Pty. Ltd. Later he worked at Amalgamated Wireless Valve Co. as an applications engineer, at Ducon Condensers Pty. Ltd. as chief applications engineer and assistant chief engineer, and then at the Electronics Division of General Electric as manager of quality control. In 1969 he joined RCA where he is now manager of manufacturing and facilities of the Australian arm of that company involved in the manufacture and distribution of recorded music products.

Mr. Darnell is a Fellow of the Institution of Radio and Electronics Engineers Australia and a founding member of the Audio Group of that organization.

•

John Eargle held a variety of positions at RCA Records from 1962 to 1969 in the areas of recording and quality control. Before developing his own consulting practice, JME Associates, in January 1974, he held the posts of chief engineer of Mercury Records in New York and director of new product development for Altec Corporation in Anaheim, California. Since January 1977 he has been a vice president with James B. Lansing Sound, Inc., Northridge, California.

Mr. Eargle is a widely published author in the field of recording technology, and holds the following

degrees: Bachelor of Music, Eastman School of Music; Master of Music, University of Michigan; Bachelor of Science and Electrical Engineering, University of Texas; Master of Engineering, Cooper Union. In 1976 he published a book, "*Sound Recording.*"

He is a senior member of the Institute of Electrical and Electronics Engineers, a member of the Acoustical Society of America and a Fellow of the Audio Engineering Society. He is active in the affairs of the AES and was president during 1974-75. Mr. Eargle is also a member of Tau Beta Pi and Eta Kappa Nu.

•

Lewis Garlick was graduated from New York University in 1940. He founded Ivy Hill Communications Inc., a supplier of packaging and collateral graphic arts materials, in 1948, later merging it with Gordon Press Inc. In 1951 he became president of Record Packaging Corporation.

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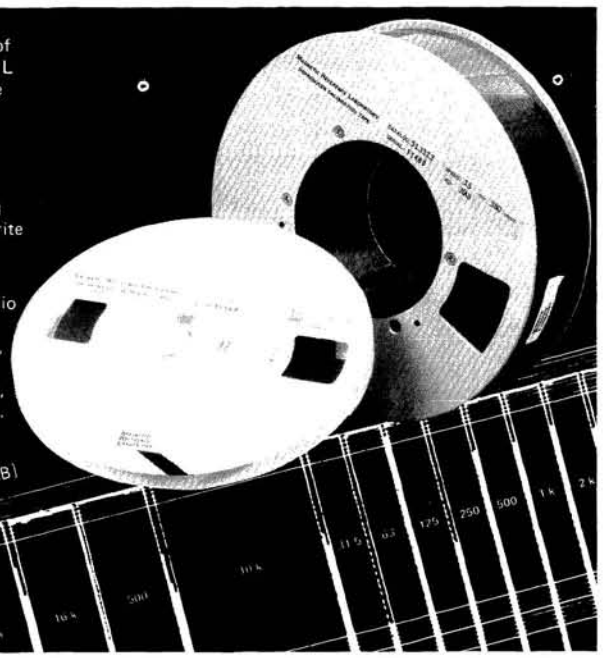

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Presently, Mr. Garlick is chairman of the board of Ivy Hill. Working with major record companies, the company was responsible for introducing full color graphics to record packaging and for innovating many new production methods and package structures which the industry has adopted. Ivy Hill is a member of Printing Industries of America, National Association of Recording Merchandisers, National Association of Printers and Lithographers and National Academy of Recording Arts and Sciences.

Mr. Garlick has served on the board of directors of two New York Stock Exchange corporations.

•

Edgar Hutto, Jr., joined RCA in Camden after graduating from Clemson University in 1947. He has worked in the fields of optics and electro-

optics. Hobby interest in record collecting and photography led him to produce a tape-slide documentary on the Victor Talking Machine Company.

He is a member of the Optical Society of America, the Association for Recorded Sound Collection, and the International Association of Jazz Record Collectors.

•

Toshiya Inoue was born in Japan in 1924 and graduated from the Tokyo Institute of Technology in 1948 with a masters degree in electrical engineering.

Since that time he has been employed by Victor Company of Japan, Ltd. (JVC) where he is engaged in developing audio and video recording systems. He developed the first cutting system for 33⅓-r/min LP and 45-r/min EP records in Japan for JVC in 1953. He introduced the first stereo 45/45 record in Japan in 1958 using his system, and then developed stereo playback equipment which has been successfully marketed ever since. Mr. Inoue then worked on the development of the video tape recorder and engineered the first VTR design with two rotating heads.

Between 1964 and 1970 Mr. Inoue served as manager of the Tape Recorder Division and was engaged in the original engineering of the Stereo-8 cartridge tape player and cassette recorder. In 1969 Mr. Inoue became manager of the Audio Engineering Research Center and the Yamato R & D Center of the Victor Company of Japan.

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Since 2131 was built, it has worked hard professionally, most of the time on the road. In and out of trucks, in and out of racks, in and out of dust, wind, rain and sun.

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In 1970 Mr. Inoue announced the development of the discrete four-channel disc system CD-4 and the CD-4 playback equipment. This system was marketed a year later and was standardized with the Recording Industry Association of America, the Electronic Industry of Japan, and the Record Industry Association of Japan.

Mr. Inoue and his research project group have made significant contributions to the acoustical engineering field and have presented numerous research papers on disc cutting technology to the *Journal of the Audio Engineering Society* and the *Journal of the Acoustical Society of Japan*.

In 1974 Mr. Inoue was made Fellow of the Audio Engineering Society and he received the 7th Montreaux International Record Award for his work in the development of the CD-4 discrete four-channel disc system from concept through commercial introduction. In the same year Mr. Inoue was elected to the board of directors of the Victor Company of Japan and concurrently serves as manager of the Research and Development Center.

•

Peter Jones was born in 1930 in South London and received his education at Churcher's College, Hampshire. In 1947 he began his career in journalism as a reporter with *The Evening News*, Portsmouth. He specialized in sports and show-business news and, at the outset of the rock and roll era in 1956, moved to Fleet Street, center of all British newspapers. There he covered pop-music reporting for *Weekend* magazine.

Mr. Jones then became a freelance

writer of sports and show-business/record news, and for eight years was editor of the weekly pop-music magazine *Record Mirror*. Later, he was associate editor of *Music Week*, a U.K. record-industry trade paper. While continuing to freelance, Mr. Jones is now the U.K. news director for *Billboard* magazine. He has also written several books including a biography of Tom Jones; an authorized history of the Rolling Stones; "Our Own True Story" of the Beatles; and a biography of Jim Reeves to be published in early 1978.

•

Sarwan Kumar Khanna was graduated from Punjab University in India and from Borough Polytechnic in England. He carried out postgraduate research in Polymer Rheology at Cranfield Institute of Technology in England and was rheologist with Associated Electrical Industries in the United Kingdom. Mr. Khanna was senior development engineer with Gulf Oil (Canada) Chemical Div. and is now engaged in rheological research work at RCA Engineering Laboratory at Indianapolis, Indiana.

Mr. Khanna is a coauthor of several technical papers and has been granted

a patent for the development of CD-4 compound.

•

James H. Kogen is vice president of development and design engineering, Shure Brothers Incorporated, Evanston, Illinois. He received a B.S.E.E. degree from the Illinois Institute of Technology in 1949 and an M.S.E.E. degree from Northwestern University in 1956.

Mr. Kogen is a Fellow of the Audio Engineering Society; senior member of the Institute of Electrical and Electronics Engineers; member of the Chicago Regional Chapter, Acoustical Society of America; Eta Kappa Nu; Tau Beta Pi; and Sigma Xi; past president of the National Electronics Con-

ference, the Midwest Acoustics Conference, and the Chicago Acoustical and Audio Group; past chairman of the Chicago Section, Professional Group on Audio and Electroacoustics of the IEEE; and a past central vice president and member of the board of governors of the Audio Engineering Society. He is on the board of associates of the National College of Education.

Mr. Kogen is a licensed professional engineer in the State of Illinois. He has authored technical papers in the publications of the Audio Engineering Society, the Institute of Electrical and Electronics Engineers, the Instrument Society of America, and others.

•

Oscar P. Kusisto attended the University of Michigan, Lawrence Tech and the Michigan College of Mining and Technology. His associa-

tion with Motorola dates back to 1937. He became a prime mover in the creation of the stereo 8 and 4-channel/8 track compatible sound industries.

In 1947 Mr. Kusisto worked as a sales engineer for the automotive products division, becoming general manager of the division's sales subsidiary in 1960. He was elected a corporate vice president and assistant general manager and director of marketing for the division in 1964. He was named general manager of automotive products in 1965, and was named corporate director of marketing later that year.

Before joining Motorola, Mr. Kusisto participated in development of the first microwave radar system with the Raytheon Company. His work in radar during World War II earned him a U.S. Navy commendation. Mr. Kusisto is on the board of directors of Motorola Inc., the Automotive Products Division of Motorola Ltd. in the U.K. and Alps-Motorola, Japan. He is also director and vice president of Motorola Canada Limited and vice chairman and director of Autovox in Italy.

He is active in professional organizations and was instrumental in founding the International Tape Association in 1970, becoming its first president and chairman. He has also held several offices in the Society of Automotive Engineers, and is chairman emeritus

of the International Tape Association. Mr. Kusisto is a recipient of *Billboard* magazine's Trendsetter Award.

•

Robert A. Moog received a Ph.D. in engineering physics from Cornell University, and has been actively engaged in electronic music instrument design since 1954.

At the present time Dr. Moog is president of Moog Music, Inc., manufacturer of Moog synthesizers and related audio signal generating and processing instruments. He is also director of research of the Electronic Products Group of Norlin Music.

The author of many articles on electronic music instrumentation, Dr. Moog holds a patent in the field. He is currently a Fellow of the Audio Engineering Society, and a member of the Institute of Electrical and Electronics Engineers and of the Acoustical Society of America. His recent awards include the National Academy of Recording Arts and Sciences Trustees Award (1970), the *Billboard* Trendsetter Award (1970), and the New York State Small Businessman of the Year Award (1970).

•

DeWitt F. (Bud) Morris was born in 1918 at Grand Mount, Washington and graduated from the Radio & Television Institute in 1937 with extension studies at Washington State College, the University of Southern California and University of California. In 1937 he began his career at radio station KELA, Centralia-Chehalis, Washington, where he was chief engineer until 1942. He spent from 1942-45 in San Francisco, California as engineer for Associated Broadcasters Inc. (KSFO, KWID, KWIX) specializing in disc recording and music mixing. As director of field engineering, his responsibilities included organizing and supervision of all remote recording for

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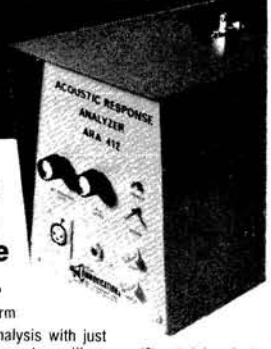

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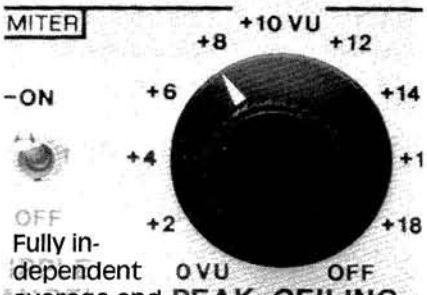

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the Office of War Information (later Voice of America). In late 1945 he was transferred to Hollywood, California, to supervise installation of facilities for Universal Recorders of California Inc. He remained there as chief engineer for 14 years, also serving as head mixer for disc, tape and film recording.

In 1959 he joined the newly-formed United Recording Corp., where he was instrumental in development of multitrack studio techniques, stereo disc recording methods, console and studio design and construction. In 1963 Mr. Morris assumed managership of URC's manufacturing subsidiaries, Universal Audio and Studio Electronics Corp., predecessors of United Recording Electronics Industries (UREI). Currently Mr. Morris is Secretary and Executive Vice President of URC and its subsidiaries, and General Manager of UREI.

He has been affiliated with the Society of Motion Picture and Television Engineers, National Academy of Recording Arts and Sciences, and throughout his 18 years with the AES has served as western vice president twice, convention chairman, on the board of governors, admissions chairman, membership chairman, and on various committees, including site selection, awards, nominations and convention policy. He is currently vice president, Western Region, and is a Fellow of the AES.

•

John T. Mullin was born in 1913 in San Francisco, California. In 1936 he graduated from the University of Santa Clara with a B.S. degree in electrical engineering, then was employed by the Pacific Telephone and Telegraph Company in the engineering department.

From 1941 to 1946 Mr. Mullin was in the U.S. Army, and as a major in the Signal Corps investigated enemy electronic developments. In 1946 he became associated with W. A. Palmer Films in San Francisco, where he worked with film, disc and tape, and was the first to introduce acceptable tape recording equipment to the broadcasting industry via the Bing Crosby Radio Show on the ABC radio network in 1947. Subsequently he became chief engineer of Bing Crosby Enterprises in Los Angeles, where he concentrated on development of in-

strumentation and video tape systems. He was responsible for the development of the original Mincom professional tape recorder after Minnesota Mining and Manufacturing Company took over the operation in 1956. With 3M he remained active in developing professional audio equipment until his retirement in 1975.

At the present time, Mr. Mullin devotes himself to the compilation of a museum of sound recording apparatus. He is a Fellow and Honorary Member of the Audio Engineering Society and a member of the Pacific Pioneer Broadcasters.

•

Harry F. Olson attended the University of Iowa, Iowa City, where he received a B.E. degree in 1924, an M.S. degree in 1925, a Ph.D. degree in 1928, and the professional degree of electrical engineer in 1932. He also received the honorary D.Sc. degree from Iowa Wesleyan College, Mount Pleasant in 1959.

In 1928 he joined the Radio Corporation of America as a member of the research department. After being placed in charge of acoustical research in 1934, he continued as head of RCA's acoustic research activities during the ensuing years, retiring as staff vice president, Acoustical and Electromechanical Research Laboratory, RCA Laboratories in 1967. At present, Dr. Olson is an advisor to RCA Laboratories.

An early and important contribution of Dr. Olson's was the development of velocity and cardioid unidirectional microphones. He has also made pioneering contributions to loudspeaker development, improvement of phonograph pickup and recording equipment, underwater sound equipment, and motion picture sound and reinforcement systems. In addition, he has guided and contributed substantially to such novel systems as the electronic music synthesizer, speech processing, and the phonetic typewriter.

A frequent contributor to professional journals, Dr. Olson has written several books and holds more than 100 U.S. patents on devices and systems in the acoustical field. He is a member of Tau Beta Pi, Sigma Xi, the American Society of Swedish Engineers, and the National Academy of Sciences, a Fellow of the American Physical Society, the Society for Motion Picture and Television Engineers, and the Acoustical Society of America, of which he is a past president, and an Honorary Member of the Audio Engineering Society, of which he is a past president and editor emeritus.

For his contributions to the field of audio engineering, Dr. Olson has received many honors, including the Modern Pioneer Award of the NAM (1940), the John H. Potts Medal of the

Audio Engineering Society (1952), the Samuel L. Warner Medal of the SMPTE (1955), the John Scott Medal of the City of Philadelphia (1956), the Achievement Award of the IRE Professional Group on Audio (1956), the John Ericsson Medal of the ASSE (1963), the Emile Berliner Award (1965), the Institute of Electrical and Electronics Engineers Mervin J. Kelly Medal (1967), Consumer Electronics Award (1969), Lamme Medal (1970), and the First Silver Medal of the Acoustical Society of America (1974).

•

John F. Pfeiffer obtained his formal musical education in Londsborg, Kansas at Bethany College, and later at the University of Arizona, where he also received his B.S. degree in electrical engineering.

Joining RCA in 1949 as an engineer in Camden and New York, Mr. Pfeiffer was assigned to the artists and repertoire department in 1950 and has

been producing Red Seal records up to the present time. He is executive producer of classical labels, RCA Records in New York City. He has been responsible for the production of recordings by Jascha Heifetz, Vladimir Horowitz, Wanda Landowska, Arturo Toscanini, Leopold Stokowski, the Philadelphia, Boston and Chicago symphony orchestras, and numerous other artists and musical groups.

Mr. Pfeiffer has published articles on musicians, music, electronic music and other technical-musical subjects in various recording industry magazines, in *The New York Times,* and in RCA's *Electronic Age* and *Engineer*. He is a composer of electronic music and a member of the Institute of Electrical and Electronics Engineers, the Audio Engineering Society, American Society of Composers, Authors and Publishers and various honorary engineering and musical fraternities.

•

H. E. Roys was born in Beaver Falls, Pennsylvania in 1902. He graduated from the University of Colorado in 1925 with a B.S. degree in electrical engineering.

From 1925 until 1930 he worked in the Radio Department of the General Electric Company, Schenectady, New York and was then transferred to the RCA Victor Company in Camden, New Jersey. He remained with that company until his retirement in 1967 at which time he was chief engineer of the RCA Victor Record Division. Through his work on disc and magnetic recording he became active on many industry standardization committees, including those of the National Association of Broadcasters, Electronic Industries Association, Institute of Radio Engineers, American Standards Institute (now USASI), and Recording Industry Association of America.

Mr. Roys is a Fellow of the Institute of Electrical and Electronics Engineers, the Acoustical Society of America and the Audio Engineering Society of which he is also a past president. He received the IRE-PGA Achievement Award in 1956, the Emile Berliner Award in 1957, the University of Colorado Distinguished Engineering Alumnus Award in 1967 and the AES Gold Medal in 1973.

•

Joseph C. Ruda received a B.S. degree in physics from the University of Scranton in 1957. He joined the record industry in 1959 and served in various engineering capacities at Capitol Records and Philips Recording Company prior to joining RCA in 1972. Since 1964, he has led engineering departments in project, process and development activities, and is

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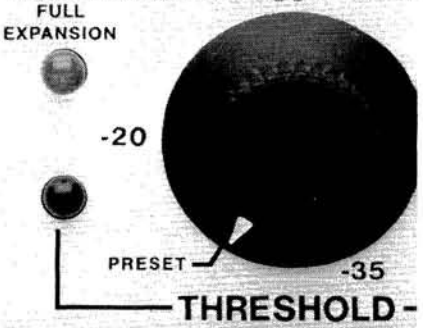

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presently manager of equipment and process development engineering for RCA Records in Indianapolis.

•

H.-W. Steinhausen was born in Berlin-Spandau in 1906. He received the Dipl. Ing. from the Technical University Berlin-Charlottenburg, where he served on the electrical engineering faculty. From 1930 to 1935 he was an assistant professor at the university and was promoted to Dr. Ing. for his dissertation on the subject of communication engineering. He then worked for Telefunken as a development engineer and, in 1950, joined Deutsche Grammophon Gesellschaft where he became technical managing director in 1958. He was also executive vice president and a member of the board of directors of Philips Phonographische Industrie when it was joined with Deutsche Grammophon to form Polygram.

Dr. Steinhausen retired in 1972. His interests include music, biology, phonography and model trains.

Thomas G. Stockham is active in the fields of electrical engineering, computer science, and audio engineering. He received his Ph.D. in electrical engineering from Massachusetts Institute of Technology and served on its faculty for ten years. Later, at the MIT Lincoln Laboratory, he developed computer techniques for simulating human auditory and visual processes. After moving to the Department of Computer Science at the University of Utah in 1968, he continued these efforts with emphasis on the development of practical methods for processing pictures and sound.

Dr. Stockham's research and that of his students has influenced the image-gathering technologies of U.S. space and defense research programs. Current Army and Air Force radar systems are based on a digital processing method developed during experiments on loudspeaker system performance. Other efforts have yielded basic theoretical and practical methods used in eliminating noise from high-quality sound tape recorders.

In 1973 and 1974, Dr. Stockham served as one of a six-member panel which analyzed the Watergate tapes in behalf of Chief Judge John J. Sirica. In 1975 he founded Soundstream, Inc., Salt Lake City, which promotes the use of digital methods for recording and processing sound for the recording industry. In August 1977 Soundstream and the RCA Red Seal Division released a collection of 16 digitally restored arias by Enrico Caruso. In addition, the company has recently demonstrated a new kind of recorder which achieves a departure in sound technology by writing sound waves encoded in numerical form instead of directly as vibration patterns.

•

Jiří Struska was born in Czechoslovakia in 1925. During his studies at the Technical University in Prague, he worked as assistant lecturer at the Institute for Theoretical and Experimental Electrotechnology. Since 1950 he has been with the Research Institute of

Sound and Picture in Prague. He received a CSc degree after his thesis on the "Physical Properties of Magnetic Recording Tapes."

The course of his work had been centered around cinema techniques and then in mechanical and magnetic recording. Recently, he has concentrated on the physical properties of magnetic tapes and the history of signal recording. He is also concerned with the theory of mass media.

Mr. Struska is president of the Czechoslovak National Committee for Signal Recording, a member of the subcommittee of the Czechoslovak Academy of Sciences for Electroacoustics, and holds the office of Czechoslovak delegate at the IEC TC/60. He was awarded the highest national recognition in his country, the Czechoslovak State Prize, for outstanding achievements in magnetic recording, and received a medal of Success Worker for his work in the field of electroacoustics in the performing arts.

•

George M. Tavares graduated from Villanova University and holds a Doctorate of Jurisprudence from the New England School of Law and a Masters in International Business Management from the American Graduate School of International Management. Mr. Tavares served with the U.S. Army 8th Special Forces in the

Canal Zone for over 3 years, traveling extensively throughout Central and South America.

In 1976 he joined CBS Records International in the newly-created position of manager, Area Desk West within the assistant to the president department. In this position, Mr. Tavares is monitoring and generating a management information system that provides alternatives and solutions required as a result of the diverse political, economic, sociological and technological conditions that exist in countries where CBS Records International has, or anticipates establishing subsidiary companies. His primary areas of concern are Latin America, Canada and Japan.

•

Emil L. Torick, director of audio technology for CBS Inc., has been a member of the professional staff of the CBS Technology Center (and its predecessor, CBS Laboratories) since 1958. His technical achievements include the design of professional broadcast and recording equipment, and developments in magnetic tape duplication, noise measurement and control, medical electronics, underwater communications, psychoacoustics, telecommunications, and digital encoding and transmission. Prior to joining CBS, Mr. Torick served as an officer in the United States Air Force. He is a graduate of music (B.M.) from Duquesne University, has a B.S. degree in physics from the University of Pittsburgh, and an M.B.A. degree in business administration from the University of Connecticut. Initially a professional symphony violinist and church organist-choir director, he continues to enjoy these activities on an avocational basis.

Mr. Torick has been a member of the Audio Engineering Society since 1959. He was named a Fellow in 1968, was elected to the board of governors for the period 1972-1975, and is presently serving as president-elect. He has served as its convention technical sessions chairman, on the awards committee, the publications awards committee, and, since 1968, on the editorial review board. He is the editor of the AES publication, *Careers in Audio Engineering*.

Mr. Torick is the author of more than 30 technical publications, has published in the *Journal of the Audio Engineering Society*, and has been awarded 11 United States patents. He was a member of the U.S. delegation to the meetings of the International Consultative Committee for Radio Communication (CCIR) in Geneva in 1974 and 1976, and has served on the standards committee of the Institute of High Fidelity. He was chairman for matrix compatibility on the National Quadraphonic Radio Committee, and is presently vice-chairman for transmission standards of the National AM Stereophonic Radio Committee.

•

Stephen Traiman, Tape/Audio/Video Editor of *Billboard* Magazine, has been with the parent Billboard Publications Inc. for 18 years. He received his B.S. degree in journalism from the University of Florida in Gainesville in 1957, and subsequently worked on *The Gainesville (Florida) Daily Sun* and for United Press International in Miami, before joining *Billboard*. Prior to his current position which he has occupied since 1974, he was editor and publisher of *VidNews* (now *VideoNews*), a biweekly international video-media newsletter, and

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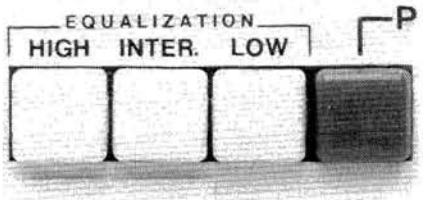

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Index of Advertisers

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Audio Designs and Manufacturing, Inc. 967
Audio-Technica U.S., Inc. 975
Audiotechniques, Inc. 931
Auditronics, Inc. 945
BGW Systems 928, 929
B & K Instruments, Inc. 957
Communications Company, Inc. 981
Community Light & Sound, Inc. .. 947, 949
Compteurs Schlumberger 913, 915
Crown International, Inc. 979
dbx, Incorporated 955
Dolby Laboratories Inc. 921
Eventide Clockworks, Inc. 939
Gallien-Krueger 970
Gotham Audio Corporation 963
Industrial Research Products 962
Inovonics Incorporated . 981, 983, 985, 987
Institute of Audio Research 972
Interface Electronics 964
James B. Lansing Sound, Inc. 933
Knowles Electronics, Inc. 953
Lexicon, Inc. 971
The London Company 977
Magnetic Reference Laboratory, Inc. . 978
Orban/Parasound 966
Panasonic Electronic Components ... 919
Quad/Eight Electronics 923
Recording Supply Co. 985
Rupert Neve Incorporated 943
Scully Recording Instruments 973
Sennheiser Electronic Corporation ... 911
Sescom, Inc. 987
Shure Brothers Inc. 959
Sound Workshop 941
Spectra Sonics 916
Standard Tape Laboratory, Inc. 960
Stanton Magnetics, Inc. 935
Studer Revox America, Inc. 927
Taber Manufacturing & Engineering Company 944
Tangent Systems, Inc. 976
TAPCO 925
TDK Electronics 965
Technics by Panasonic 901, 903, 905, 907
United Recording Electronics Industries 969, 983
Wilmot Breeden Electronics 961
Yamaha, Musical Instruments Combo 937

produced two VidExpo video expositions for that company.

He is active in a number of professional and industry associations, and a freelance contributor on audio and video.

•

Daniel R. von Recklinghausen was born in New York City in 1925. He received his B.S. degree in 1951 in electrical engineering from the Massachusetts Institute of Technology in Cambridge. Before receiving his degree, Mr. von Recklinghausen was employed at Rohde & Schwarz, Munich, Germany, and at the Research Laboratory of Electronics, and the High Voltage and Acoustics laboratories of MIT doing development work on UHF and SHF meters and generators, reverberation devices and recording and studio facilities.

He joined H. H. Scott, Inc. in 1951 as project engineer responsible for the development of sound analyzers, tuners, amplifiers, and other acoustical instruments. In 1955 he became chief research engineer at Scott and in 1969 was appointed technical director of the company. In 1973 he became staff consultant to Eastern Air Devices, now Electro Audio Dynamics and in 1975 he was appointed vice president for research and development of the KLH Corporation, subsidiary of EAD; he continues to hold both positions at the present time.

Mr. von Recklinghausen has been a member of panels 4 and 5 of the National Stereophonic Radio Committee and was chairman of Subcommittee 4.1 and 5.4 NSRC. He was chairman of panel 4 (receivers) of the National Quadraphonic Radio Committee. He has been a member of the administrative committee of the IEEE G-AE, chairman of the Boston Chapter, IEEE Group on Audio, chairman of several technical sessions of NEREM, member of the NEREM Program Committee, chairman of a lecture series on audio of the IEEE Boston Section, and a member of the executive committee of IEEE, Boston Section, and has been a governor and chairman of various committees of the Audio Engineering Society.

Mr. von Recklinghausen is a member of Tau Beta Pi, Sigma Xi, and Eta Kappa Nu. He is a Fellow of the Audio Engineering Society and the Institute of Electrical and Electronics Engineers and various IEEE professional groups. Mr. von Recklinghausen is the chairman of the IEEE Subcommittee on Frequency Modulation Receivers, a member of the Standard Committee IEEE G-AE, chairman of the Standards Committee of the Institute of High Fidelity, a member of the

editorial board of the *Journal of the Audio Engineering Society*, and governor and past president of that Society. He holds over 15 U.S. patents on circuits for high quality sound reproduction and has written numerous articles on that subject.

•

Walter L. Welch was born in Syracuse, New York, where he received his education. He began his career in the display and lighting business and at 40 years of age entered Syracuse University to study architecture, receiving his B.A. degree in 1946. After a period of service in architectural offices, Mr. Welch was offered a teaching position in the Department of Landscape Architecture of the New York State College of Forestry, where within a decade he became

an associate professor. In 1963, he requested early retirement to head the newly forming Syracuse University Audio Archives, where he has been the Curator and also Director of the Thomas Alva Edison Re-recording Laboratory.

Phonographs and records have been a lifetime hobby of Mr. Welch, and for many years he was associated with the late Melville A. Clark, musician and inventor in the building of a collection of rare recordings and phonographs.

This led to the beginning of experiments by Mr. Welch in the proper techniques for reproducing the obsolete types of cylinders and discs to suitable standards. After the introduction of magnetic tape it became obvious that this was an ideal medium for re-recording to even more exact standards. Therefore, a 3-year program was developed by which an audio archive and research laboratory would be established at Syracuse University in part supported by the Thomas Alva Edison Foundation, Inc. and the Charles and Rosanna Batchelor Memorial. In the years since, his experiments have contributed to the fields of sound preservation and education.

Mr. Welch is coauthor of the book, *From Tinfoil to Stereo*.

•

J. G. Woodward received a B.S. degree from North Central College in 1936, and an M.S. degree in physics from Ohio State University in 1942. For the past 35 years he has worked in research at the RCA Laboratories' David Sarnoff Research Center at Princeton, New Jersey, where he was elected a laboratories fellow in 1972. His research has included a wide range of projects in electroacoustics, audio, video, and digital recording.

Dr. Woodward is a Fellow of the Acoustical Society of America, the

American Association for the Advancement of Science, and the Institute of Electrical and Electronics Engineers, and a member of the IEEE Magnetics Society and the IEEE Acoustics, Speech, and Signal Processing Society. He is a past president and Honorary Member of the Audio Engineering Society.

•

Tokugen Yamamoto was born in Tokyo, Japan. He attended Shibaura Technical College, Tokyo, where he majored in civil engineering, and graduated in 1947. In 1961 he was graduated from Waseda University with a major in economics. He also attended Harvard University in 1965, majoring in English literature. His professional experience includes work for the U.S. Educational Commission,

Japan (Fulbright Commission), and RCA Engineering Laboratories Ltd., Tokyo, where he was manager of administration. From 1959 to 1961 he was purchasing agent in Japan for the RCA Corporation, then manager, Liaison for RCA. Since 1968 he has been manager of planning and holds the position of director of regional market development in Asia and the Pacific for RCA Records.

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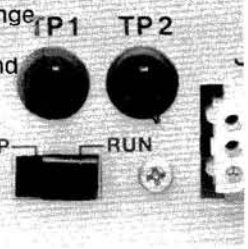

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The AES: Its Function and Development

Centennial Issue...

In 1948 when the Audio Engineering Society first started, its membership consisted of a group of 500 persons in New York. Today it is a worldwide organization with a membership approaching 9000.

The young audio industry of 1948 found the AES a vehicle for exchanging information, and within a year of its founding, the Society held a convention and exhibit of technical products. This exhibit in New York City, which covered three floors of the New Yorker Hotel, also presented a program of technical papers. In 1950 the Society conducted a series of educational programs in New York, and two years later it published vol. 1, no. 1 of its now world-respected *Journal*.

Within a year of the organization of the New York Chapter of the Society, a West Coast Section was formed, and then by 1950, a Midwest Section. This launched a

period of growth which has continued to the present time. The growth of the home entertainment industry, particularly the area of high fidelity, helped increase interest in the Society and highlight its industry value. In 1954 the concept of a convention and exhibit was established on the West Coast, and in a few years membership in this area grew rapidly.

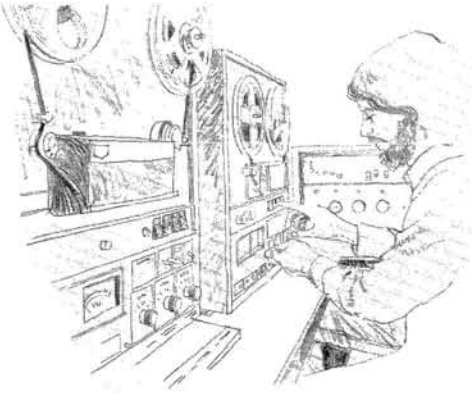
The *Journal* was an impetus to expanding interest in the AES in Europe and other parts of the world. In 1971 a small convention, held in Cologne, was organized by AES members in Europe. This also acted as a membership stimulus. The plan was formulated for a European Convention every two years, but interest was so strong that another convention was organized the following year in Munich. This was followed by one in 1973 (Rotterdam), another in 1974 (Copenhagen), and subsequent yearly meetings in London, Zurich and Paris. The 1978 convention will be held in Hamburg.

The Society serves members in five regions: Eastern, Central, Western, Europe and International, where boundaries stretch to include members in 71 countries and 33 sections. These sections hold regular meetings throughout the year where audio technology is discussed and examined.

In order to recognize contributions to the art, to recording and to the Society, an annual awards program was begun in 1948. The Society presents gold, silver and bronze medals for such contributions. In addition, it gives a publications award to encourage the dissemination of new ideas. Special emphasis and encouragement is given to those under the age of 35 for the purpose of stimulating thinking from the young audio engineer.

With the aim of fostering direction to the young, the Society maintains an active up-to-date publications library. It publishes a career guide, and is in the process of preparing an educational resource guide as a companion piece.

Through the varied activities of the AES there have been many improvements in recording and reproduction. This has been a result of "knocking down the walls of secrecy that surrounded the various facets of the art and discipline." In its 30-year history, the Audio Engineering Society has been a vital force in the field of audio—particularly in the art of recording.



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