from any good commercial spectrophotometer, properly operated so as to give spectra with sufficient accuracy to be useful in the identification of unknown materials. Most published infrared spectra now fall in this category, but it is hoped that, with detailed specifications now available for guidance, more Class II spectra will be produced and published. The development of detailed specifications for Class I or Standard Spectra has been left to international effort through the Commission on Molecular Structure and Spectroscopy of the International Union of Pure and Applied Chemistry.

The process of collecting spectra is under way, and some 2000 contributed spectra are being organized for the evaluation process. All infrared laboratories interested in the objectives of expanding and improving published infrared spectra for qualitative analytical purposes under the sponsorship of the National Standard Reference Data Program and the American Society for Testing and Materials are invited to participate. Arrangements have been made for microfilming, at no cost to the contributing laboratory, such collections of spectra as would be helpful in the evaluation program and which might well be published also. The program contemplates publication of only such spectra that are superior in quality to any that already have been published for each given compound or of cases where the published spectrogram is relatively inaccessible to laboratories in this country. Results of the evaluation process will generally be made available to the contributing laboratories.

Finally, recognizing that there are a number of organizations interested in the process of using physical molecular data for qualitative chemical analysis, ASTM proposed the formation of a Joint Committee on Atomic and Molecular Physical Data. This has been done with charter members from the Coblentz Society, the Society for Applied Spectroscopy, the Canadian Association for Applied Spectroscopy, the Manufacturing Chemists Association, the American Petroleum Institute, and the American Society for Testing and Materials. It is the purpose of this new committee to pool talents, influence, and effort for a common objective of generating, collecting, evaluating, editing and approving for publication, and encouraging the distribution of atomic and molecular data in suitable form to serve as reference standards for pure compounds and mixtures. Initially concerned primarily with infrared spectral data, exploratory examination of programs in mass spectrometry and nuclear magnetic resonance have begun.

A corollary activity of the infrared spectral data indexing project should be of interest to those concerned with the mechanized handling of large masses of data or information where a link between such stored material and its origin in the open literature must be maintained. The publishing of lists of tens of thousands of citations to published infrared spectra prompted an investigation into the use of CODEN for concise references. CODEN are five-letter mnemonic codes for the titles of periodicals which permit the reduction of a reference to five letters plus a few digits to express volume, page, and year. Use of these codes by others has now grown until they include many industrial, institutional, and governmental organizations in many countries of the world. From some 3000 codes in 1961, when ASTM assumed custody of the project from its originator, Dr. Charles Bishop, the number has grown to 40,000 CODEN. New ones are being added by request of users at a rate of nearly 1000 per month. A new edition of *CODEN for Periodical Titles* is now available and a special service for making new code assignments has been in operation for some time. CODEN and titles are also available in computer tape and in IBM cards with a monthly updating service. An example of the use of CODEN may be found in *Chemical Titles* issued by Chemical Abstracts Service. CODEN will also be included in the next edition of the *List of Periodicals*.

Numerical Data Activities of Engineering Societies*

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Received October 7, 1966

This paper will consider only the area of physical properties of substances, further considering that mechanical properties—tensile and compressive strengths, hardness, shear strength, etc.—are physical properties. Engineers' data interests extend far beyond intrinsic properties of relatively pure materials that are well defined in composition and structure and include also those properties which are dependent upon an interaction of the material and the measuring system, as for example, hardness, breaking strength, and the like. Of course, engineers also need data on intrinsic properties of many materials too, such as the steam tables for the mechanical engineer designing high pressure power systems and the thermodynamic properties of chemicals used by the chemical engineer in designing process equipment. In general, an engineer's

* Presented before the Division of Chemical Literature, Symposium on Compilations of Data on Chemical and Physical Properties of Substances, 152nd National Meeting of the American Chemical Society, New York, N. Y., Sept. 12, 1966.

Engineers draw on many sources for reliable engineering data, including commercial publishers, trade associations, and government sponsored information analysis centers. Within the engineering societies, engineers have organized continuing projects to collect, evaluate, and publish engineering data in the form of handbooks and to some extent recently, in machine-readable form. Data projects on properties of metals and chemical substances, and projects of interest in applications such as automotive engineering and pressure vessel codes are discussed. The Engineers Joint Council, through its engineering information program, is encouraging the engineering societies to increase their efforts at collecting, evaluating, and disseminating reference data within their fields of interest.

data needs are governed by the mission or project on which he is working.

For the types of engineering data that involve an interaction with a measuring system as mentioned above, the data are not meaningful unless the measuring system is completely specified and the past history of the material before performing the test is known. For this reason, standard tests such as those of ASTM and other organizations are used to establish the criteria for the measuring system. The engineer also needs to know the statistical distribution of the data for the kind of materials that he will actually be using. It should also be noted that many engineering properties, such as breaking strength, follow an extreme value distribution rather than normal distribution; this needs to be taken into account in interpreting data (*1, 2*).

DATA GATHERING PATTERNS

Data are originally determined by tests and observations in a laboratory environment, subsequently recorded with or without some evaluation. Engineering handbooks, a major source of data for use by engineers, draw on the literature and many other sources for data tables and often are simply a repackaging job of useful data tables that have appeared elsewhere.

There are also what might be called "sleeping data;" these are data that have been collected through some company or government laboratory project and simply are recorded in the files relating to that subject and not published in any form. Varying success has been achieved in collecting such data, with subsequent evaluation and dissemination for use as reference data.

Finally, when data needed for a particular project are not forthcoming from the literature or other sources, the engineer will estimate the value for his immediate purpose, perhaps with assistance from others. If it is recognized in advance of an immediate need that a certain area of data is insufficiently covered in the literature, the usual practice is for those concerned to organize research projects to generate such data.

DATA COLLECTION AND EVALUATION IN THE ENGINEERING COMMUNITY

A major source of data on properties of materials is commercial organizations. This includes publishers of handbooks, data compilations, and the like, and, in addition, materials suppliers who offer extensive technical data in company literature such as data sheets, design manuals, and the like. Several commercial organizations do an effective job of collecting technical data from a large number of commercial organizations and preparing it in compact form for quick access by the design engineer. Examples are the Thomas Microcatalog and the VSMF File of Information Handling Services, Inc. Other sources of data of interest to and used by engineers are the growing number of handbook projects and specialized data centers sponsored largely by the government but also by private industry. Examples are the Air Force-sponsored data centers such as Mechanical Properties Information Center and Electronics Properties Information Center, and the broadly sponsored Thermophysical Properties Research Center. Trade associations such as American Petroleum Institute and American Iron and Steel Institute also sponsor data projects in their fields.

In general, the engineering societies concern themselves with the collection, evaluation, and publication of data in an organized fashion only when such data are not adequately available from other sources. In a few instances, engineering societies do an effective job of collecting data from a great variety of sources and publishing it in compact and useful form in engineering handbooks. Examples are the Metals Handbook of the American Society for Metals, the ASME Handbook in four parts, the SAE Thermodynamics Manual, and the Guide and Data Book of the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Two major organizational patterns have evolved in engineering societies for the handling of data projects. One method that seems to work effectively is for the societies to organize committees of volunteers who provide guidance and, in many cases, a good deal of work in collecting and writing chapters in handbooks and data books. These committees of volunteers are then given staff support in the form of expert editorial and publishing services. Another organizational pattern that has evolved over a period of years generally has developed for those projects which require the generation of data through research projects. In this case funding is necessary and contributions from industry and government are involved. In some cases, the societies will raise funds from among the organizations represented by their members to have a research job done, say, at a university or research institute, to collect data in a certain area, and evaluate it for publication by the society. Examples of these are

psychrometric tables, developed for ASHRAE in a contract with a university, and tables of gravity and cnoidal waves developed by a university under contract with the Council on Wave Research of the Engineering Foundation and ASCE. A number of these research councils have been organized, some under the auspices of the Engineering Foundation and others under the auspices of certain engineering societies. Some of the more prolific data generating research councils will be discussed.

RESUME OF SOME DATA PROJECTS

American Society for Metals. Volume I, "Properties and Selection" of the "Metals Handbook," Eighth Edition, appeared in 1964. The handbook includes extensive data on the properties of both ferrous and nonferrous metals and alloys; a noteworthy feature of the volume is the emphasis given to statistical data on mechanical properties. About 1000 histograms of such data are included in the volume. The data tables come from many sources, including data developed by other societies, such as ASTM and ASME, as well as proprietary data obtained from materials suppliers. The "Metals Handbook" was developed by more than 1300 members of the American Society for Metals working on 83 committees. Thus, the book represents not only a data collection activity but also an extensive evaluation of the data by experts with information on design considerations.

ASTM-ASME Joint Committee on the Properties of Metals. In 1925 the two societies established this joint committee in recognition of their mutual interest in the properties of metals—ASTM's from the point of view of materials' properties, specifications, test methods, and the like, and ASME's from the point of view of code requirement for metals, especially in the field of boilers and pressure vessels. Funds for support of data collection and evaluation projects under the auspices of the committee are obtained by periodic solicitation from industry. The committee has been responsible for the publication by ASTM of a large number of reports of data on the properties of metals from cryogenic to extremely high temperatures and on a variety of metals and alloys. Many of these data tables have found their way into the ASM "Metals Handbook." They also provide necessary and valuable backup data for the assignment of code stress levels in the ASME Boiler and Pressure Vessel Code activities. The work of this joint committee led to the establishment in 1965 of the Metal Properties Council under the Engineering Foundation, discussed below.

ASHRAE Guide and Data Book. Final stages have been reached for publication early in 1967 of the ASHRAE Handbook of Fundamentals, which is one of two volumes of the "ASHRAE Guide and Data Book," the other dealing with applications. The contents of the volume are developed in a manner similar to that of the "Metals Handbook," through the operation of a number of committees having responsibilities for gathering and evaluating data and writing chapters in the book. The book includes data on fuels and combustion, refrigerants, refrigerant tables and charts, secondary coolants (brines), thermal insulation, and water vapor barriers. The data come from a variety of sources, including the open literature and proprietary data. Some of the data tables have been developed through research projects sponsored by ASHRAE. The committees responsible for the content and quality of the handbook thus serve the function of evaluating the data and information that go into the book.

ASME Handbook. The American Society of Mechanical Engineers handbook project provides engineers with a useful and comprehensive collection of data and design information. The handbook is issued in four parts which are updated at irregular intervals. The titles of the four parts, with dates of most recent issue, are:

Metals Engineering - Design	1965
Metals Engineering - Processes	1958
Engineering Tables	1956
Metals Engineering - Properties	1954

SAE Applied Thermodynamics Manual. The Society of Automotive Engineers issues the manual as a loose-leaf volume which is designed to be constantly updated by the substitution of new pages or chapters as they are revised. There are three major sections: Engineering Fundamentals, Thermophysical Properties of Materials and Fluids, and Application Engineering.

The AIChE System on Estimating Physical Properties. For more than a decade, chemical engineers have been using computers for process calculations. It soon became evident that for most new chemicals, little data existed; where it did exist, it was generally not in the form easily adaptable to use on computers. Recognizing this problem, the AIChE Computation Committee, during 1960, outlined a project to develop a generalized computer program for the estimation of physical properties of chemical compounds from various known parameters (*3, 4, 5*). Funds were sought from a number of companies interested in the project and the society was successful in raising the necessary funds to contract with Arthur D. Little, Inc. for the work, which was begun in 1963. The project has been completed and the computer programs and other data have been made available to the sponsoring companies.

According to a recent note in the Technical News Bulletin of NSRDS News, chemical engineers have also expressed considerable interest in having the data produced by various thermodynamic compilation groups stored on magnetic tape for use in process calculations. They say that the present generation of chemical engineers is being taught to use computers as freely as the previous generation used slide rules, and that therefore it is becoming increasingly important to have all data accessible from a magnetic memory bank. The Office of Standard Reference Data is exploring the feasibility of developing tapes from its associated data centers for such use.

International Steam Tables. Since 1954, the ASME Research Committee on the Properties of Steam has been working on the preparation of new and up-to-date tables of the properties of steam (*6*). Data are needed to extend the old tables published by ASME to cover properties at higher pressures and temperatures presently applicable to steam plant design and operation. Some of the tables now being used for pressures to 5000 P.S.I. and temperatures of 1600° F. have been extrapolated from original

data obtained at lower temperatures. The new tables, expected to be available in 1967, will probably include much that is not in the first ASME tables, such as values of H, V, and S for compressed water viscosity; and heat conductivity of both water and steam, and other basic material not in the older tables. In addition, all formulas used will be given, so that the user, if he desires, can put needed information into a computer programmed for design or checking of apparatus. The new tables are being developed through the International Steam Table Conferences and a special task group—the International Formulation Committee—made up of representatives from the United States, Great Britain, West Germany, Japan, Russia, and Czechoslovakia, with Germany holding the secretariat.

ASTM Engineering Data Projects. ASTM's data activities are so extensive that an entire symposium could be devoted to them without covering them all in depth. Elsewhere in this symposium Dr. Kuentzel has described the ASTM data projects on atomic and molecular properties, particularly for identification of materials. I shall add something on the ASTM activities dealing with the properties of metals and nonmetallic materials. Practically all of ASTM's data projects have been developed as the result of a need by industry for the data for some industrial or technical application.

ASTM, through the activities of a number of committees, publishes extensive tables of data covering volume and weight corrections for a large variety of hydrocarbons and chemicals. The data on volume and weight relationships for chemicals and hydrocarbons are used extensively for measurement of the volumes and weights of containers and shipping vessels for these materials. Substances include crude petroleum, petroleum products, certain industrial aromatic hydrocarbons such as benzene, toluene, and *p*-xylene, and in addition, certain liquid chemicals including hexylene glycol; isopropyl alcohol, anhydrous; epichlorohydrin; acetone, anhydrous; and methyl isobutyl ketone. ASTM expects to augment these tables to cover something like 200 industrial chemical liquids.

Another ASTM committee activity results in the publication of extensive tables of viscosity index and conversion factors for petroleum products and lubricants. ASTM also publishes a number of physical properties of chemicals and hydrocarbons. Some of the data have been drawn from the API Project 44 on properties of hydrocarbons. The properties are selected on the basis of their usefulness in engineering.

We have already discussed the ASTM joint activity with ASME to develop data on properties of metals. In the nonmetallic materials field, ASTM has published data tables relating to wood and, to some degree, to plastics. There are, however, no continuing data collection and evaluation projects in the field of nonmetallic materials other than the chemicals and hydrocarbons.

For many years, ASTM has developed and published data on corrosion properties of metals and alloys. Such data are essentially observational rather than critically evaluated. They have been obtained from evaluation of specimens of a great many materials that have been exposed in a number of outdoor test sites. Only recently has an effort been made to analyze the atmosphere at each of the test sites in order to characterize the corrosivity of, say, the industrial environment *vs.* the marine environment *vs.* the nonindustrial rural environment.

RESEARCH SUPPORTED BY ENGINEERING FOUNDATION

Since its organization in 1914 under the United Engineering Society (now United Engineering Trustees, Inc.), the Engineering Foundation has encouraged and supported cooperative projects, especially those that are planned on national council lines, as an excellent means of interesting industry, thus drawing research and industrial personnel together for better cooperation. The Engineering Foundation has provided support for several of the operations of individual societies discussed above. In addition, there are cooperative projects, called councils, that have been started under the auspices of the Engineering Foundation but operate relatively independently so far as staff and funding are concerned. Two of these councils are worthy of special note in view of the rather extensive data activities in which they are involved. One of these is the Metal Properties Council, organized only last year in response to recommendations of the joint ASTM-ASME Committee on the Effect of Temperatures on the Properties of Metals. Another is the Welding Research Council which has been in operation for some years to conduct research and develop data on welding. Other research councils currently supported in part by the Engineering Foundation are the Column Research Council, the Research Council on Riveted and Bolted Structural Joints, and the Fasteners Research Council.

The research council type of organization provides a flexible means whereby industrial organizations, government agencies, and others having an interest in a particular area of research can support this research in a cooperative fashion.

The activities of two of these research councils—Metal Properties Council and Welding Research Council—will be described briefly as examples of this type of cooperative research to develop useful engineering data.

Metal Properties Council. The major purposes of the Metal Properties Council (7) as set forth in its bylaws and rules of procedure are: (a) to identify major unfulfilled needs for reliable data on the engineering properties of metals and alloys; (b) to evolve, plan, and conduct programs for collecting, generating, and evaluating such data so it may be useful; (c) to arrange for making such data available promptly by reports, publication, correspondence, or other means; (d) to keep informed of and to utilize the results of related activities, both national and international, in order to avoid duplication of effort.

The Council is supported by a solicitation of funds from industry, government, and others. Since it has only recently been organized, its present staff effort is supported by a grant from the Engineering Foundation. The Council, however, is currently developing a campaign to solicit funds from sponsors in order to carry on its planned activities. It is expected that when the work of the Council

gets under way, it will provide for most of the backup engineering data needs for the boiler and pressure vessel activities of the ASME. Indeed, its scope is conceived more broadly than this and the Council might be expected to provide an auspice for coordinated data activities in the metals field generally. The Council management has already developed a close relationship with certain of the government-supported data projects, specifically the Mechanical Properties Information Center of Belfour Engineering Company supported by the United States Air Force. At the outset, the Council may be expected to place major emphasis on the discovery of major unfulfilled needs for data and support research projects in these areas. It may be expected that the Council will provide for dissemination of the data through existing publications channels. The Council is sponsored by three major societies: ASME, ASTM, and ASM.

Welding Research Council. The Welding Research Council was established in 1936 under the auspices of the Engineering Foundation and its annual budget has grown from only a few thousand dollars in the 1930's to about $800,000 now. It has a large number of industrial and government agency sponsors and its activities involve the efforts of some 600 leading scientists and engineers.

Some 45 laboratories in the United States and four in Canada participate in its research programs. The Welding Research Council has issued a large number of bulletins relating to property and design information of welds and welded vessels. The Pressure Vessel Research Committee of the Welding Research Council works closely with the ASME Boiler Code Committee.

While the Welding Research Council is not specifically oriented to the collection and evaluation of data on properties of materials, many of its publications do contain data on the properties of welds and associated aspects. The organization of the Welding Research Council, however, represents what might be considered a typical working type of organization for the support of continuing research on problems that are broad and require the combined, cooperative support of a large segment of American industry.

Data Projects in England. For a number of years, the Royal Aeronautical Society has issued design data sheets in the aerospace field. Recently, this program has been broadened into the field of mechanical engineering in general with the joint sponsorship of a project by the Institution of Mechanical Engineers with the Royal Aeronautical Society. The data sheets are now issued under the general title of *Engineering Sciences Data*, subdivided into Aeronautical Series (initiated 1940) and Mechanical Engineering Series (initiated 1965).

COORDINATION OF DATA PROJECTS

Engineers Joint Council is currently organizing an advisory group on engineering data under the chairmanship of Victor Johnson of the Cryogenics Laboratory, Boulder, Colo. The group, which will be called the Panel on Engineering Data, will be a part of the EJC Information Systems Committee structure. The EJC information program, active since 1962, has been directed generally toward improving dissemination of information with such projects as the thesaurus development for improving the consistency of indexing and retrieval of technical information, encouragement of source indexing of technical documents by the author and the editor, and long-range planning toward the eventual development of a coordinated engineering information system. A Tripartite Committee, consisting of the presidents and vice presidents of three organizations—Engineers Joint Council, Engineering Index, and United Engineering Trustees/Engineering Societies Library—is currently developing a plan for the organizational structure and financing of a coordinated engineering information system. The Panel on Engineering Data will be concerned at first with determining what is now being done and how it is organized, and subsequently determining what the needs are and generating some long-range plans and programs to improve data collection, evaluation, and dissemination in the field of engineering. This activity will parallel the EJC program for improving the storage, retrieval, and dissemination of technical documentation.

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