Editors and their journals will change but slowly, and like phlogiston they will stay with us until something obviously better is proven.

Let me close with a figure which ties the whole thing together (Figure 3). Here Sam Dubin of Penn State correlates year of graduation on the horizontal axis, with, on the vertical axis, the time it takes for half the undergraduate engineering courses in that year's college catalogs to be replaced by other courses. He calls this period the half-life of a college education. As you can see, the undergraduate education of an engineer class of '45 was 14 years. The class of '65 became obsolescent faster, half-life 2 years. And in the '70's we see an apparent negative half-life. That means that this year's frosh have courses that last year's couldn't take. If you had any doubt about what people will be doing with their leisure when the 30-hour work week arrives, your answer is here. And where are they going to do it? In your libraries? With what? I think with something different from the traditional journal. Dubin estimates that today's engineer must spend 20% of his time reading just to stay even. How much time will future technologists need if the journal doesn't change or at least get supplemented by Butler-style periodicals?

Now, I promised you a demonstration of the value of an apparently irrelevant article torn from CHEMTECH and sent to a colleague. What we'll be doing is looking at the familiar in an unfamiliar way as recommended by de Bono's "Zig-Zag Thinking",[6] Gordon's "Synectics"[7] and Prince's "Mindspring".[8] My purpose is to demonstrate the value of *reading* and doing so over a wide subject range.

Please conjure up a picture of your most vexing problem. Got it? Now, open your dictionary *at random* and read the fourth word in the leftmost column. I don't know what the word will be anymore than you do, but I'll bet that you'll find that it has relevance to the solution of your problem, *if you think about it.*

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Status of Indexing and Classification Systems and Potential Future Trends†

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Expansion of industry and government research programs beginning in 1920 constitutes the basis for the growth of proprietary research activities. Practical economies dictate that technical information from such research be readily accessible to its owners. Many new indexing methods have been developed during the past 30 years to attain effective storage and retrieval of these research results. This review cites five significant developments that appear to have had the greatest impact on the handling of technical information during this period. Contributions are assessed for both indexing and classification together with speculations on possible future trends.

The author of our keynote paper has set the stage by calling the period from 1943 to the present the Golden Age of chemical information science.[7] I cannot disagree that this recent 30 years or so has been a remarkable period, and one of high activity and much significance. For the purpose of my topic, which deals with the status of indexing and classification systems as applied to chemical information science, I will be turning back a little further—back to the end of World War I. I turn to this period because it was the time when a large-scale chemical industry began to emerge and grow. Concurrent with this industrial growth more and more money, energy, and scientific guidance began to be employed in keeping this industry moving steadily forward. Also, new commercial products had to be created, developed, manufactured, and marketed. This entire program demanded more research and development. Thus, for the first time great quantities of industrial chemical information began to be created: more information, more subjects, more chemicals, more people, more people changing assignments, a growing public literature in journals and books, and a growing internal proprietary literature. During this period of growth, the 20–30 years following World War I, a new information item began to unfold across the entire chemical industry. This new item was the industrial research report.

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THE CHALLENGE OF NEW DOCUMENTS

The early industrial research reports presented no particular retrieval problems. They were normally treated as a conventional book, pamphlet, thesis, memorandum, or letter would be handled. The organization that produced them kept them, stored them, and hopefully indexed them and could retrieve them. This latter capability was important because each one of these reports had cost a great deal of time and money to produce. For these reasons, they were valuable documents. To recreate them would cost much money. To repeat the research that they summarized would be a large unnecessary expense, and consequently, most organizations were sooner or later faced with the need to develop efficient proprietary methods for handling access to this growing body of information.

In addition to the proprietary nature of this body of industrial research information, which meant there were no public or published indexes to its contents, this literature was being produced in continuing and ever-increasing amounts. With the passage of time and a growing diversity of subjects, as products increased or changed, the lack of availability of prior records, as well as the fading recollections of individuals associated with the initial work, meant that detailed and perhaps sophisticated methods were increasingly desirable to retrieve information efficiently from these growing collections. Conditions such as these were being experienced from one research organization to another throughout the chemical industry in the period of the mid- and late 1940's, the era that initiated the Golden Age of chemical information science.

Although the chemical research report in industry was well established as a proprietary document with private responsibility for analysis and retrieval, a similar document, but one frequently in the public domain and widely available, the "Government Research Report", began to make its appearance in large numbers in the late 1940's. The Government Research Report is still with us and is the outgrowth of huge sums of money spent on research by the U.S. government during the past 30 years or so. Many of these government research reports deal with chemicals or chemical subjects and have been reprinted or published in the normal journal literature or as portions or topics in books. Where not so published, however, they are only treated superficially in general by the secondary indexing and abstracting literature, and thus in many respects present a parallel situation to that described for proprietary industrial chemical research. The vast majority of U.S. government research was, and still is, carried out by private contracts. Results are most frequently summarized in project technical reports of specified format and organization of contents.

The emergence of the research or technical report as a unique document summarizing private industrial research, on the one hand, and proprietary or public U.S. government research, on the other, as the chief form for recording the major segment of research in the United States, had a pronounced influence on new developments in indexing starting in the mid-1940's and continuing to the present. This impetus came from the proprietary aspects of the information (in the industrial report and some government reports), the absence of public indexes, the growing numbers of documents, the expanding time frame, and the diversity of subjects reported.

Prior to the expansion of private and government investments in research, and the resulting production of a vast number of research report summaries, the conventional scientific journal literature had managed to accomodate fairly effectively a major portion of the research then conducted. Now, however, with the increase in research in both sectors, new methods were needed to handle the increasing volume of information being created.

SPECIFIC PROBLEMS IN RETRIEVAL

All the new developments in indexing that occurred in the Golden Age of chemical information science came about because of needs. It was the pressure to meet new requirements, to solve special problems, that brought forth slowly, and not too efficiently, the significant changes we have been and still are adopting. Most of the problems were not new. It was primarily that they were being reexamined again, in a new environment, on a different scale, and for different clients.

There were several significant features that the new indexing environment sought. Indexing should cover conventional chemical nomenclature; it should also provide for chemical substructure representation; source records should be accessible both by physical and chemical properties; and the indexing should permit correlation of physical properties by chemical structure and name as desired. Thus the driving force that led to the new developments in indexing over the past 30 years was the need to handle the growing number of technical reports in a variety of special retrieval situations. Once initiated, the new developments were useful to specialized collections in a variety of areas, although they were primarily designed for only limited and narrow fields. This is probably one reason that more new developments have taken place for indexing and relatively few for classification during this period.

As we trace the developments that took place starting with the mid-1940's, we note that three special groups of individuals were the dominant sources of the innovative developments we will be examining. These were chemists, librarians, and computer specialists. Among chemists, one includes engineers and other scientists who were assigned the task of improving access to areas of specialized chemical information. Alternatively, they may have been research workers or technicians who were motivated by their own needs to develop improved routes for indexing and locating the information for which they had responsibility. In the main, such persons were new blood, so-to-speak, entering a field where librarians had historically been dominant. This change was to prove both a strength as well as a weakness, but in the long run has led to the new designation, that of information scientist. Important contributions also were made by a second group, librarians having a strong or special technical background, particulary in chemistry. I call a third group "computer specialists". These were individuals who had been trained specifically for computer programming, and/or systems development work, or were information chemists or special librarians who became, through special study and training, competent in programming computers to manipulate specialized files for information storage and retrieval.

NONCONVENTIONAL INFORMATION SYSTEMS

Most of the new indexing developments that occurred during recent years have been associated with systems that do not use traditional library schemes of classified card catalogues, i.e., the Dewey decimal system, the Library of Congress classification, etc. These new schemes have received the label of *nonconventional systems*. During the period from 1958 through 1966, a number of studies were carried out by the National Science Foundation through its Office of Science Information Service to report on the growth of such nonconventional methods and to describe the particular details employed in them and their scope of application.

The initial report in 1958[3] described 25 systems. Similar tabulations in 1959–1960[4] listed more than 50 systems. By 1962, in a subsequent survey,[5] 87 systems were included. Report No. 4 in this series, in 1966,[6] reported on 175 unique systems then in current use throughout the United States by libraries and information and data centers contacted in the NSF survey.

An examination of the applications described in these surveys reveals that the majority of the nonconventional systems reported were in use for research and development programs and included both government and private research reports in their coverage.

Many of these specialized indexes were developed to cover specific subject areas of both published and proprietary material, for example, pharmacology, rubber, plastics, synthetic fibers, petrochemicals, etc. A large number were designed to provide access to an organization's own research and test information, including research reports, data sheets, operating manuals, trip reports, market reports, sales reports, research project descriptions, and the like.

A study of the NSF series reveals further that the 175 nonconventional systems described in the latest report[6] present a composite of the significant developments and innovations in indexing, and to some extent classification, that have been created and applied in the field of chemical information science since 1940.

MAJOR INDEXING DEVELOPMENTS

I turn now to an examination of the several tools and new methods that have had the most significant impact on the handling of technical information in our timeframe of interest.

The selection I offer, while a personal one, is based on an intimate association with this field over the past 30 years, first as a research chemist who created and used technical information, and later as an information specialist who supplied technical information to others. My choice also draws from personal contacts with literally scores of chemists and other specialists who conceived and applied the systems, tools, and methods we employ today for manipulation of technical information.

I am restricting my summary of these developments to those five I consider to have had the greatest impact for the field of chemistry, together with some aspects of their historical background and thoughts regarding possible future trends.

Punched Card Indexes. Punched cards, in spite of their basic simplicity, have had a tremendous impact on indexing. They became widely popular starting about 1940 and grew in interest among chemists through the medium of the edge-notched variety, commercially available as Keysort cards (from the McBee Co.) or Pathfinder cards (from the Charles R. Hadley Co.). Punched cards can be thought of primarily as mechanical aids to information handling. They constituted a new way to reduce the manual labor of manipulating indexes to correlate data and organize information after the intellectual work of document analysis had been completed.

Because of the novel nature of punched cards, their ready availability, and their "do-it-yourself" characteristics, they held a particular popularity among chemists. As a consequence of this deep and growing interest, the Board of Directors of the American Chemical Society established a Committee on Punched Cards in 1946 and provided its subsequent financial support. The work of this Committee led to the appearance of the book, "Punched Cards—Their Applications to Science and Industry", by Robert S. Casey and James W. Perry, in 1951. A second edition of this highly popular volume was published in 1958 with an expanded authorship including Madeline M. Berry and Allen Kent.[1] This single book had a wide and continuing influence on the use of mechanical aids in information handling. It was valuable in describing how an individual could set up and use a simple punched card file. It also offered a number of case histories by users on how they had employed punched cards in their own work. Particular emphasis was given edge-notched or hand-sorted punched cards. These cards generally have two or more rows of holes along one or more edges of the card. Meanings are assigned to individual holes or combinations of holes. Entries for a card are made by clipping open the portion of the card between the hole and the edge of the card, or between holes in some situations. This encoding enables selection of cards having particular entries by sorting with a needle to locate cards notched in the pattern specified.

Other cards, for machine sorting, have holes punched in particular rows or columns across the face of the card and can be fed automatically through machines which will select specified patterns via electrical or mechanical contacts that are made. Typically these are the IBM or Remington-Rand tabulating cards that are still familiar to most of us, but which have less popularity now than 25 years ago before the wide availability of electronic digital computers.

The great contribution of the punched card is that it brought information records out of the classical repositories and placed them directly in the hands of the ultimate users. Frankly, conditions have never been the same since this revolution started. Subsequently, many of the innovations that have resulted had their basis in the frustrations, and recognition of further needs, that were experienced by the early workers with edge-notched punched cards.

Uniterm Indexing. In picking *one* milestone that has had the greatest impact on information retrieval during the past 25 years, it has to be the Uniterm system of indexing, proposed about 1951 by Mortimer Taube.[9,11] This system in its general form was called "coordinate indexing", a name first introduced in a symposium of the Division of Chemical Literature, American Chemical Society.[12,13] The proposals articulated by Taube evolved from experiments initiated earlier for organizing subject headings in a Library of Congress project relating to the cataloging of Defense Department technical reports.[10,13]

The Uniterm system as originally applied was soon found to have serious limitations for general applications. However, a series of extensive modifications, improvements, and controls, added by subsequent practitioners, has led to the wide use and practical acceptance of this system during the intervening years.

The original application of Uniterms and coordinate indexing was for documents for the early Armed Services Technical Information Agency.[11,13] Initially they were class labels consisting of a single word for each indexing term used to characterize the documents of a collection. The words were drawn from the texts of the documents themselves or were selected from an authority list developed for the subject matter to be indexed. Term cards were created for each term employed for indexing. And, the document accession number for each term indexed was posted in numeric order on each term card used for indexing that document. Correlations, or searches for complex queries or for classification purposes, could be accomplished by comparing term cards to find common document numbers posted to each of the terms comprehended by an inquiry. The early success of this scheme stemmed in part from the relatively small numbers of terms required to index a particular subject area and the ease of manipulation of descriptors at search. However, the lack of vocabulary control, which initially had been hailed as a great economic asset, was soon to prove a serious shortcoming. Improvements and controls that came later were introduced by users who held the inherent belief that the Uniterm scheme had much to offer for flexibility and convenience.

These improvements included the binding or the precoordination of certain terms to eliminate false correlations. Another change was the binding of not only certain pairs but even strings of words representing concepts frequently met in indexing. Also, constraints on the free use of every text word were imposed to restrict each concept to a single standard expression. Thus, users began to employ only a single expression to represent synonymous terms. In time, see references were likewise introduced. Further improvements included the introduction of generic terms (another classification objective) and the use of scope notes to define specific uses of terms. Operators also found it desirable, at indexing, to bind together a group of concepts, through a device called a *link*, to minimize and control, at search, false combinations of terms within a particular document. Another device, called a *role* or role indicator, was invented to further minimize false correlations. This tool served to indicate the sense in which the term was employed. For example, in the indexing of chemical reaction information, one role was assigned to indicate the chemical substance represented by the term was the solvent or inert media, another role to indicate a chemical starting material, other roles to indicate products, special agents, and so on. Various lists of roles have been proposed and adopted for many special collections depending on the indexing and retrieval needs of systems operators.

The expression "Uniterm" was slowly replaced by the term "Concept" and by about 1957 the expression "concept coordinate indexing" began to be used to represent the practical use of Uniterms.[19] This new terminology was more restricted and specified greater sophistication. It represented an evolution from the original Uniterm. Subsequently, during the following 20 years, the concept coordinate system provided an economically feasible route for multiple access to indexed documents. It was this advance over traditional methods that started the true revolution in chemical information retrieval. This feature permitted electronical digital computers to take over more and more of the manipulative aspects of indexes and of the retrieval of citations from indexes and indexed records. Although these manipulative routes accomplished nothing intellectually that could not be done by conventional means, they did provide greater speed, flexibility, accuracy, and a better basis for cost effectiveness evaluations.

Specialized Thesauri. Another major development was the appearance of specialized thesauri which were in fact multiple-relation dictionaries. It has been said that "A *thesaurus* may be defined as a display of the terms in a retrieval language showing semantic relations between them."[18] A number of practitioners of concept coordinate indexing early realized that a thesaurus was required for effective storage and retrieval of information in order to show relationships between terms and to group related words in a meaningful way. They also found that the most authoritative thesaurus in the English language (that of Roget) was inappropriate since it covered many terms that were not of interest to chemical indexers and did not include those that were vital to assigned areas of interest.

This problem was met by the creation of new thesauri to cover specific fields or subfields in which the indexer had responsibility for input and retrieval. One of the better known ones in use today is the "Thesaurus of Engineering and Scientific Terms" published by the U.S. Department of Defense, as a joint project of the Office of Naval Research's Project LEX and the Engineers Joint Council.[17] This compilation had as its predecessors, in the Department of Defense, the "Thesaurus of ASTIA Descriptors"[14] and, in the Engineers Joint Council, the "Thesaurus of Engineering Terms".[16] The EJC "Thesaurus of Engineering Terms" represented a tremendous consolidation of engineering terms from all branches of engineering and had its anticedents in the A.I.Ch.E. "Chemical Engineering Thesaurus".[2] The A.I.Ch.E. volume had been given impetus earlier by the release from the Du Pont Company's Engineering Information Center of a nonproprietary version of its "Thesaurus of Engineering Terms". It is interesting to note that at the time this Du Pont thesaurus was under development, Mortimer Taube was a consultant for the Du Pont Engineering Department and worked closely with the team that developed and first used a modern scientific information thesaurus—at least on an industrial basis. These thesauri were generally characterized as follows:

1. Their contents followed a standardized and readily understood format that permitted and facilitated updating and revision of contents through mechanized or computer manipulation.

2. They employed a set of standard acronyn identifiers for expressing relationships, i.e., BT = terms broader than the entry, NT = terms narrower than the entry, XT or RT = as reminders of similar concepts to indexer–searcher, USE = term to use instead of instant entry, UF = Use For = synonymous concept for which entry is to be used.

3. Scope notes and definitions were provided as aids to consistent use.

Following the appearance of the initial compilations of specialized thesauri, they became models for others to build on, borrow from, and adapt for their own specific uses. One example of such a thesaurus from another field is the "Thesaurus of ERIC Descriptors".[15] As a further example, Engineering Index, Inc. now calls their thesaurus "SHE", the acronym for Subject Headings for Engineering.[8]

The published literature records the existence of many proprietary thesauri, each designed for a specific technical collection. In such applications, the thesaurus is usually limited explicitly to the document contents covered. These thesauri, however, are open-ended and can be expanded to cover wider subject areas when required by contents of other documents that are added to the collection.

Vocabulary Control. An awareness that practical information retrieval required the use of a controlled vocabulary is another one of the significant developments that occurred during our Golden Age of chemical information science. This development was the rediscovery of a basic element necessary for efficient handling of both information input and retrieval, and became more critical in the exacting symbol-matching techniques through which computer systems function.

Through vocabulary control procedures, which are the identical ones mentioned previously in the creation and development of specialized thesauri, chemical information science has actually readopted file organization via classical classification structuring. Such classification in the guise of the specialized thesaurus of indexing terms has provided one of the essential tools required for today's specialized manipulative information storage and retrieval systems.

File Manipulations via Computers. I conclude my listing of major developments, which have had a pronounced influence on the present status of chemical information science, with the general comprehensive category of "computer manipulations". We cannot escape the fact that the evolution initiated by the use of tabulating card processors in the mid-1940's, and followed by conversion to electronic digital computers that have provided a continuum of equipment with ever-increasing capacity, manipulative ability, and speed, has had, and continues to have, a major influence on how we handle and process information. I do not need to present a detailed resume of all the applications that chemical information science has made using computers. It should be sufficient to say that chemical information in all its various forms is now being processed mechanically, both for storage and retrieval purposes as well as for correlative and predictive applications (through models and the like).

The ability to produce machine-readable listings of the words in titles, both with and without added brief lists of Uniterms or descriptors from the text, has proven of high utility in certain applications. The integration of indexes, their dictionaries or thesauri, and their statistical composition into a single composite set of records via the use of modern computers has made possible the continuous updating and revision of indexes to a degree never before feasible. Another major contribution of computer services to information handling has been the possibility of having better cost analysis of information handling operations. This is highly important for information processing. I believe it will receive more emphasis and play an even more vital role in future years.

SIGNIFICANT DEVELOPMENTS IN CLASSIFICATION

Almost everything mentioned in the foregoing focuses on developments in indexing. I have mentioned the background of growth in research and development programs and the data and documents resulting from such efforts. I have also noted the major developments that have, in my opinion, been significant for handling this new output. These developments have to do mainly with indexing—practically nothing with classification. Most reviewers of the scene during this period of growth in information science agree there has been little classification research and no significant changes in classification. What is the reason for this?

One view holds that classification is used mainly for the shelf arrangement of books or other documents, and for that reason must hold to a well-established structure. Others see the structure, for purposes of vocabulary control, introduced by indexers into indexing authority lists and thesauri as merely applications of existing classification structures and not the creation of basically new classification schemes. Both views, however, do not alter the conclusion that the field of classification research has been relatively dormant for the past three decades.

FUTURE TRENDS

In a sense, all that has been mentioned to this point is prologue. What of the future and what trends can one envision from today's vantage point?

Broad future trends fall into two important categories, cost-effectiveness and file organization. Both relate to improvements that are necessary for modern information handling to grow and to maintain the important role it has now achieved. First, we must improve cost-effectiveness of all information handling systems, and this certainly means better cost-effectiveness for index creation, maintenance, and use. Also, we will need to improve file organization to make indexes more responsive to a wider user group and to keep in balance with expected lower file manipulative costs that should stem from larger computer storage capacities and faster and more economic computer manipulative capabilities.

Several routes are open to improve cost-effectiveness. First, I believe there will be a re-examination of the economics of present indexing work. Studies will focus on the cost of each of the manipulative steps involved. This scrutiny will separately cover both people and machine costs in order to attain the best balance of these two aspects. This balance will shift as the relative costs change for people and for computer usage. People involvement will become even more of a luxury, and efforts will have to be made to reduce the level of people participation. We will then be dealing with the basic issue of just what do information users want—or more realistically what they are willing to pay for.

My next opinion is that we are going to see a different ratio between the number of systems specialists and subject specialists associated with indexing. We have operated our nonconventional and computer-based systems, thus far, principally with subject specialists derived or borrowed from the disciplines of chemistry and of special librarianship. I see our efforts in the future dominated more by system-trained personnel and less by chemists. This transition will represent a maturing of input and retrieval techniques, and will parallel what is happening in chemical laboratory and routine engineering work today. The technicians and various specialists will have a greater hand in information storage in the future than during the development period of the recent past.

I believe two areas will become important for improving organization of indexes for greater effectiveness. The first area is that of noise reduction, by which I mean the lessening of the amount of unwanted or nonrelevant output that our current systems produce. Today this material is usually sifted out by a person who serves as an intermediary, at considerable cost and inconvenience. We still need improvements in revelance (precision) and recall, so I forecast that the studies directed to such objectives will continue as an outgrowth of the work in this area first popularized by Cyril W. Cleverdon in the early 1960's. Thus, indexes will have to be improved to attain improved recall and also to reduce the amount of screening out of unwanted information.

Another trend we should expect to see is a return of interest to the fundamentals of information organization and a revival of classification studies, both pointing to improving user costs, but still with a view to user credibility and satisfaction. Now that chemists and other scientists have access via computers to a large range of specific information collections in a highly manipulative mode, with few constraints on storage size and manipulative speeds, an area where great improvements can and should be made is that of more efficient and user-oriented file classification. Such improvements will become ever more desirable as telecommunications and network arrangements lead to more and more dependence on central processors. These changes will also be required because the systems will be used more and more by people who are not primarily subject specialist intermediaries but are simply users who need information. Furthermore, better classification will be required to provide answer output as graduated levels of abstraction in order to better supply users with information tailored to their specific needs. Thus, classification research will become highly important to help compress information into packets suited to users' tastes. This is another step in the trend of changing systems to respond to people, and thus away from purely mechanistic aspects.

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