The History of Managing Technical Information at DuPont

Florence H. Kvalnes

Abstract

In the 1960s, DuPont developed computer databases to manage its collection of technical information, and many of the individual departments had their own information centers.

During this time the duplication of efforts between departments, especially in the area of patent services, was studied. These studies had an impact on the handling of proprietary technical information. DuPont then developed, built, and implemented an integrated system for the storage, retrieval, and distribution of its in-house scientific and technical information. In addition to changes in the mechanical handling of information, changes were made in the way the content was described, for example, from classification systems to concept coordination. Many of the fundamental principles for storage and retrieval of technical information developed in the 1960s, including representations of atom-bond-atom structure and a thesaurus, were adopted and are still in use. These innovations resulted in the Scientific Corporate Information Online (SCION) database created in the early 1990s, which provides online access for DuPont's scientific community to proprietary technical information. The next generation of the SCION database is under development and will take advantage of new computer and information science technologies. An intranet was developed and continues to grow and gain importance in managing DuPont's information.

Introduction

Technical information services, although they are mostly decentralized, have been a tradition at DuPont for nearly a century. The first formal libraries were established in 1917–18 (Duncan, 1951), and groups staffed with scientists and engineers were gradually formed within libraries to index patent and proprietary information in the form of formal research reports. These groups evolved into information centers that provide a variety of information services, depending on the needs of the organization.

This article focuses on the tools and techniques for describing proprietary technical information and the development of computer databases for managing this information. For purposes of this discussion, proprietary technical information is defined as that which is documented in formal reports. It is not a comprehensive history of managing all technical information at DuPont.

Corporate Culture

DuPont company policy and corporate culture have contributed to the decentralization of information services. The company is divided essentially into autonomous segments or business units and a few staff functions, such as corporate information science, legal, financial, and so forth. The business units are not obligated to employ the services of a centralized information service organization. Thus, there has been no unified approach to handling information at DuPont (Conrad, 1955). Information technology infrastructure has a similar organizational history. Many business units or departments had their own computers and computer groups. For a long time the only centralized computer group served corporate financial, accounting, and human resource requirements.

The business units are built around a very diverse group of products, such as fibers, specialty chemicals, and agrochemicals, among others. These diverse scientific and business interests have contributed to the various challenges for managing information (Figure 1).

New directions in technology mean that information scientists need to keep up to date with current technologies as well as learn new ones as the company diversifies into new areas. Information scientists must also learn to use a variety of tools for managing information.

Figure 1.
Diversity of Information

- Scientific—chemistry, physics, math, life sciences
- Engineering
- Manufacturing
- Technical marketing services
- Market research
- Environmental science

Transition to a global company has meant networking information services overseas and adjusting to different languages and attitudes about how to manage information.

The 1960s marked a departure from the policy of little direct intervention in the management and use of information services by corporate level management. The company's executive committee requested a study of the duplication of effort in ordering and indexing patents and in indexing and searching technical information recorded in formal research reports. In 1964 this study resulted in the consolidation of nine separate information groups to form two groups called the Central Report Index and Central Patent Index (Rasmussen & Van Oot, 1969). Further consolidation occurred in 1985, when there was some centralization of library administration and services with the creation of the Technical Library Network. Also in 1985, the Technical Library Network was combined with the Central Report Index, Central Patent Index, and Language Services (Nichols, Sikes, Isselman, & Ayers, 1995–1996) to create the Corporate Information Science organization.

As a rule, the staffs of DuPont's information centers have been and continue to be educated in science or engineering. Many information professionals also have degrees in library or information science. Their responsibilities include conceptual analysis, searching, library services, patent searching, and investigating new ways to manage information or knowledge. These are recognized as the core competencies of the organization (Ayers, 1994–1995; Nichols et al., 1995–1996).

Conceptual Analysis

Between 1917–18, when the first DuPont libraries were formed, and about 1958, technical information in libraries, file rooms, and information centers was "indexed" using various classification schemes. In the mid-1950s it was becoming apparent that because of the increase in information to be classified, new ways of managing this information were needed. At that time the charter of a group of consultants in the Business Analysis group of the engineering department was to find better methods for managing engineering information. They extensively studied and evaluated the methods of E. Wall (1959), M. Taube (1953, 1962), F. W. Lancaster and J. Mills (1964), H. P. Luhn (1957), G. Salton (1961), and S. Herner, F. W. Lancaster, and W. F. Johannigsmeirer (1964). Most if not all of the techniques summarized in a recent publication by F. G. Kilgour (1997) were tried or used at one time or another (Dinwiddie & Conrad, 1954; Edge, Fisher, & Bannister, 1957) (Figure 2).

Information centers in other parts of the company learned of the efforts of the Business Analysis group of the engineering department and asked for assistance to improve the centers' methods of handling information. Concept coordination, using uniterms and a thesaurus, was first adopted about 1958 for indexing technical reports, engineering drawings, patents, and correspondence (Costello, 1961). Dual dictionaries were printed and distributed to many of the DuPont plants, laboratories, and construction sites for on-site searching by chemists and engineers.

The Business Analysis consultants looked for ways to solve the problems created by different points of view about the significance of information in a document and how these points of view would affect retrieval. They developed a word association matrix to help in identifying indexing terms, and they adopted links and roles to indicate syntax. Links were used to group sets of indexing terms together to reduce false correlation, and roles were used to designate word order and relationships between terms within a link.

Figure 2.
Conceptual Analysis

- Pre-1950s: Various classification schemes
- 1950s–1960s: Active study, investigation of developments in information storage and retrieval
- About 1958: Uniterms and pre-coordinated vocabularies adopted
- Dual dictionaries, McBee keysort cards, optical incidence cards, mechanized card sorting

Word Association Matrix

The word association matrix was a listing of lead terms and the frequency of association in documents with the terms listed under the lead term. This was an attempt to

Table 1. Word Association Matrix

Lead Term	Frequency	Association
AIR POLLUTION	50	
Contaminating (see also impurities)	50	100%
Air (see also atmospheres)	48	96%
Ashes	13	26%
Power plants—power houses	8	16%

help not only indexers but also searchers find terms to search without regard to point of view.

Using Table 1 as an example, *air pollution* is the lead term, and its frequency of use in documents is fifty. *Contamination* is used in association with *air pollution* in indexing the same fifty documents; therefore, the association is 100 percent. *Air* was used with *air pollution* to index forty-eight of the same documents; thus, the association is 96 percent, and so on.

Links. Links are used to accumulate indexing terms into a sentence-like association, which describes information about a concept. When properly applied, links result in reduction of false retrieval. However, word order is not established, since common practice is to alphabetize the terms within the link.

For example, a document discusses two subjects: the steam cleaning of autoclaves and the design of extruders. The indexing terms are divided into link A and link B, as shown in Figure 3. This reduces unwanted retrieval for searches for the design of autoclaves or for steam cleaning of extruders because the terms are separated into different units. Links are taken into consideration when Boolean logic is performed.

Figure 3.
Use of Links

Link A	*Link B*
Autoclaves	Design
Cleaning	Extruders
Steam	

Roles. Another device developed by the Business Analysis consultants in an attempt to give syntax to the selected terms within a link was roles. There were twelve roles in the original set, and they were assigned to every indexing term. An internal study showed that most were ineffective except for those that described chemical reactions (Van Oot, Schultz, McFarlane, Kvalnes, & Riester, 1966) (Figure 4).

Figure 4.
Role Definitions

Role	*Definition*
1	Using, by means of, by
2/9	Cause and effect
6	Reaction by-product, impurity
8	Major topic
10	Design, drawing of
11	Receiving a physical modification
12	Claim or disclosure of in a patent

When information groups from nine of the departments were consolidated into the Central Report Index in 1964, concept coordination continued as the method of indexing. Links and roles were implemented for all documents. The various role sets were consolidated. The above roles were dropped, that is, converted to 0 for "Other," since indexing practices required that all terms be indexed with a role. Only the ones used for indexing chemical reactions were retained (Figure 5).

Figure 5.
Role Definitions—For Chemical Reactions

Role	*Definition*
3	Reactants in a chemical reaction
4	Special agent in reaction, e.g., catalyst
5	Reaction medium, atmosphere
7	Products of a chemical reaction
0	Other, includes properties of, uses of, etc.

Development of a Thesaurus

The various individual information centers in the old decentralized system all considered a thesaurus essential for their indexing and retrieval operations; some thesauri were synonym lists and others were hierarchical. The earliest hierarchical thesaurus at DuPont seems to have been developed by the engineering department about 1960. It was derived from their word association matrix, which was based on the statistical occurrence of terms used in the indexing of individual reports.

With the consolidation of nine different departments into the Central Report Index in 1964, a common vocabulary had to be developed. Two indexers (one a chemist, the other an engineer) experienced in term editing and hierarchical thesaurus preparation were assigned the task of consolidating the nine different vocabularies into one. About 28,000 different general terms were reviewed for selection of word form, elimination of synonyms, and significance of relationships and cross-terms. The final product consisted of 11,000 uniterms, of which 5,000 were names of equipment, techniques, devices, processes, or properties. The other 6,000 were trade names. This editing effort required eighteen person-months. The previous nine departmental indexes, that is, the indexing terms with their respective documents, were converted to the new vocabulary to produce a single index.

Between 1964 and about 1972, it became apparent that the uniterm form of a controlled vocabulary was not very effective for indexing documents covering the diverse areas of technology that were of interest to the company. A review of problem areas, notably in the area of properties, was undertaken. A decision was made to use pre-coordinated terms, such as *light stability* instead of using *light* and *stability*, and to add qualifiers to divide some terms, such as *growth* into *growth, biological* versus *growth, of markets.*

Another area of difficulty in searching resulted from practices used in indexing DuPont product lines, especially products that were all made by the same processes but that differed in certain parameters, such as use or size. For example, Dacron polyester fiber is spun from a specific polymer and is used in many kinds of apparel and bedding. The set of indexing terms used to index this product line describes a large number of polyester products. The sizable retrieval from searches for information on one of these products resulted in screening many abstracts to select those relevant to a query. From such experiences with too many retrievals or false correlations, it was decided to review the thesaurus and to create pre-coordinated terms in the technology areas where the efficiency in indexing and searching would be improved.

Chemical Structure

The studies by the Business Analysis group that led to the adoption of concept coordination showed the need for new ways to store and retrieve chemical structures and information. The nine information groups did not index chemical substances the same way. The methods included Chemical Abstracts Service nomenclature rules, International Union of Pure and Applied Chemistry (IUPAC) nomenclature rules, a system based on Beilstein classification, and fragmentation systems. These systems were error prone and costly and did not permit easy retrieval.

In 1962, two DuPont engineers, Donald Gluck and Leslie Rasmussen, developed GRAM, the Gluck Rasmussen association matrix system. GRAM was capable of handling all chemicals, including polymers, of interest to DuPont (Gluck, 1965). Two unique algorithms permitted reasonable computer costs. The input algorithm was based on uniquely positioning each atom in an ordered list according to the atoms to which it was connected. A second algorithm was used to transform the ordered compounds into a nonredundant compact list for storage and search. Another major advantage over the other systems known at the time was that input from drawn structures could be accomplished without any rules for numbering the atoms. Therefore, someone not trained in chemistry could input structures.

Between 1962 and 1964 there were discussions with Chemical Abstracts Service (CAS) about the development and use of topology for storing and searching chemical structures by atom-bond-atom via connection tables ("New system," 1963). GRAM was shared with the American Chemical Society for use by CAS in developing a chemical registration system for the entire chemical industry. Then CAS and DuPont agreed to work together on the development of a chemical registration system ("CAS and DuPont," 1964). This collaboration involved ordering of tables of atoms and bonds in the registry process, defining the compound types to be handled and the methods for handling exceptions, defining a method of file organization and screen generation, and coming up with search logic techniques and economics. H. L. Morgan, of Chemical Abstracts Service, generated a unique machine description for chemical structures using the algorithms developed by Rasmussen and Gluck (Morgan, 1965). In 1964 CAS shared the input and the atom-by-atom search programs with DuPont for testing.

For its own system, DuPont decided to develop computer-generated screens for searching based on the fragments used in several of the earlier search systems and to continue its own methods for registering polymers. The DuPont method makes certain assumptions about polymer structure to collect similar references at one point (Schultz, 1975). CAS indexes the polymer description available in the source document and does not make assumptions based on the author's description. This practice can result in the indexing of information about the same polymer under more than one reference point or registration number. Several references describe the differences between the CAS method of registering polymers and the DuPont method in more depth (Patterson, Schultz, & Wilks, 1995; Schultz & Wilks, 1997; Wilks, 1997a–d).

Computer Systems

Batch Systems

During the 1960s manual systems were converted to several small computer systems. These were searched and updated at scheduled intervals (batching), not on demand as is possible with current technology. In 1961 the management of some of the information centers explored the joint development of a computer program for information storage and retrieval. The program was written so that each department could use the same storage and retrieval functions but maintain separate databases. The Multidepartment Information Retrieval System, as this system was named, was programmed for an IBM 705 and completed in 1962. The information in the file included indexing terms and report numbers in an inverted file format. There was also a hierarchical thesaurus for indexing. Documents were posted to all upper-level terms or more generic terms in the hierarchy. This enabled searching for a family of documents without having to "or" many terms together to collect all of the documents in a given hierarchy. About 1962 nine departments were using this computer information storage and retrieval system and concept coordination. Consolidation of these nine indexes into one was facilitated by the use of the Multidepartment Information System in 1964 when the Central Report Index was formed.

With the decision to operate a central index for technical report storage and retrieval (Montague & Schirmer, 1968), work began on a system that would upgrade the computer system from the IBM 705 to the newer IBM 1410/7010 computer (Hoffman, 1968). The system on the IBM 1410/7010 computer was an interim system. The goals for developing this system were 1) to consolidate the separate databases into one database rather than maintain nine separate databases; and 2) to allow time to develop the requirements for a more comprehensive system based on the needs of the searchers. Online searching had not yet been introduced, and searching for proprietary technical information was done by the staff of the Central Report Index for company scientists and engineers. Increased efficiency and reduced costs for the newly created Central Report Index were achieved by being able to search one database rather than nine separate databases.

The database retained the inverted file structure used in the IBM 705 system. There were two inverted term-document files, one for compound registration numbers and the documents posted to them and the other for thesaurus terms and their documents. Integrated with these files was the Chemical Structure Storage and Search System (CS4) registry file (Hoffman, 1968) and a hierarchical thesaurus. CS4 stored the topology of chemical structures in the form of connection tables and served as a second-level index to the primary document system files. Registration numbers were assigned based on determinations of the uniqueness of submitted structures. These unique numbers were called CNUMBERS and were used for indexing and searching for chemical information. CNUMBERS could be retrieved by performing a substructure search or by searching explicitly for a name or molecular formula. In addition to CNUMBERS, the actual thesaurus indexing terms were used instead of the previous alphanumeric term codes. Searching was based on Boolean logic, as were the earlier computer search systems. A unique feature of the thesaurus was its interaction with the text file and with the document search system. Thus, it was the cornerstone of searching the text file by controlled terms. No term was entered into the search file unless it was in the thesaurus. A search for chemical structure in the second-level CS4 system would link by CNUMBER through the documents to other information about chemicals, such as properties, uses, processing, and so forth. Other search options included the ability to select reports by issue date, document source, or the type of report, for example, a research progress report or a market research report.

In 1966 a study was undertaken to determine the future requirements of the central report group with the goal of designing a system to handle the increasing workloads and new services more efficiently (Montague & Schirmer, 1968). Between 1966 and 1971 a detailed file organization scheme for the Information Flow System was developed for the IBM 360/65 (later replaced by an IBM 370/155) (Hoffman, 1972). Programs were written to convert the IBM 1410/7010 system to the Information Flow System. As in earlier systems the Information Flow System linked retrieval of information about chemical compounds and documents containing information about the compounds via a compound number or CNUMBER (Schultz, 1974). Other important features of the new system included the use of threaded lists in addition to inverted files to optimize searching and a file of report abstracts. Search answers were printed either as a list of accession numbers or abstracts. The printed abstract feature was a welcome replacement for the previous practice of pulling and refiling abstract cards for the screening of search results.

Although the Information Flow System was state-of-the-art for its time, by the early 1980s the twenty-year-old software, though aging gracefully, was becoming unsupportable, owing to system limits, hardware obsolescence, and other factors. Interactive online searching became available in the 1970s for external literature through Chemical Abstracts Service, Dialog, Orbit, and other vendors of secondary information. DuPont scientists and the information scientists in the Central Report Index wanted an online interactive search system for their proprietary report information.

Online Systems

CRIDB. To respond to the needs of the DuPont scientists as quickly as possible, in 1985 an online free-text searchable database (CRIDB) of just abstracts and bibliographic information was implemented. The abstracts and bibliographies of documents in the Information Flow System were copied to a Basis database. (Basis is a product of Information Dimensions, Inc. [IDI].) CRIDB became available in May 1986 and was used until 1991, when it was replaced. CRIDB was searchable by command as well as by menus to accommodate those who were uncomfortable with using commands.

SCION (Scientific Corporate Information Online). In the 1980s Chemical Abstracts Service offered a private registry service. At the time when DuPont investigated this option to replace its aging Information Flow System, several organizations maintained private chemical files with CAS. Since the DuPont chemical file had been developed in conjunction with CAS in the 1970s, it was thought that an electronic conversion could be accomplished easily, although over the intervening years, differences in structure conventions had developed. After reviewing practices for handling text and chemical structures within the chemical industry, corporate information science decided that the private registry service offered the best fit for DuPont's needs. In 1986 discussions were held with CAS on system analysis, design, and development of a chemical search file, a text file for bibliographic information and abstracts, and a hierarchical thesaurus.

During 1987 and through 1988 the DuPont-CAS team designed, built, tested, and implemented the chemical file. All structures and structure-related files for the 160,000 compounds from the Information Flow System were converted to CAS hardware and software in Columbus, Ohio. New chemical input resembled standard registry format. DuPont and CAS had diverged over the years in some structure conventions for chemical classes. The first task was to convert DuPont connection tables to a format that was compatible with CAS input format. About 75 percent were converted electronically; the other 25 percent were converted by manually drawing and then keyboarding the drawn structures.

The document file was designed to parallel as closely as possible the files on STN International Network, especially File CA. Consequently, searching both in-house literature and public literature was possible with one command language and one log-in. The text file was designed to accommodate a field for the links and roles assigned during conceptual analysis. Abstract text and the fields for title, author, document numbers, issue dates, and some other information were converted to a generalized format provided by CAS. Abstracts were converted to allow sentence-level proximity searching.

The Central Report Index thesaurus was converted to the format of existing hierarchical thesauri on STN. It serves three functions: an authority or control list for conceptual analysis vocabulary; a reference for assigning indexing terms or locating terms for searching; and creator of a "generic" or "family" collection of search terms. This third feature is an improvement over the previous practice of up-posting documents to all the terms at the higher levels in the hierarchy at the time of document input. With a generic or family search a collection of search terms based on the broad term–narrow term relationships in the thesaurus is created at search by generating a Boolean logic union or using "or" logic to combine all of the narrow terms with their broad term.

Work on the document file conversion began in 1989 and was completed in 1990. Testing took place during 1990, and the necessary internal DuPont and external telecommunication links for access to the database in Columbus were determined and installed. SCION officially became available to the DuPont community in June 1991 (Marcali, Kvalnes, Patterson, & Wilks, 1993).

To accommodate searchers who did not want to learn STN command language, a DuPont team designed menu screens and the navigation routes between them for menu-assisted searching, which were sent to CAS for implementation. Menu-assisted searching became available in 1992. Work is now under way to convert SCION to an open client-server architecture, which will add additional functionality and broaden its use.

Web-Enabled Information Management

Web-enabled technology began to have its impact about 1992. At that time a company-wide Internet-intranet

Figure 6.
The Intranet

- Corporate news
- Benefit information
- Product specifications
- Electronic commerce
- Technical publications
- Gateway to World Wide Web
- InfoNavigator catalog and contact pages for DuPont businesses
- Extranet

guidance team was established. A general-purpose server was made available to business units for setting up Web sites. There are page counters for statistics, a search engine, forms-based e-mail, password-protected areas, and software-downloading capability (Figure 6).

As Du Pont's intranet continues to grow, it will become the foundation for accessing many types of information and knowledge repositories. The library catalog is part of the intranet, and corporate information science is developing its own suite of home pages to lead DuPont scientists to the multitude of information resources available. Corporate information science also has the responsibility for cataloging sites on the intranet to allow for effective access.

Summary

The factors that have had the greatest influence on the handling of technical information at DuPont are concept coordination; development of a controlled or standard vocabulary for indexing of the large collection of scientific and technical information; atom-bond-atom connection tables, which enable the storage and retrieval of information about specific chemicals; and the computers that made implementation of the other three developments possible. The changing nature of the company's organization has led to a network of libraries and information centers around the world, which provide records management and search support for their local communities of scientists and engineers. These information centers rely on the central unit for purchasing, acquisitions, cataloging, and arranging access to externally published and online resources.

References

Ayers, R. S. (1994–1995). Turning your vision into reality. *Bulletin of the American Society of Information Science, 21(2),* 20–22.

CAS and DuPont to collaborate. (1964, July 20). *Chemical & Engineering News*.

Conrad, C. C. (1955, September). The role of centralized and decentralized information services. Presented at Division of Chemical Literature, American Chemical Society Meeting, Minneapolis, MN.

Costello, J. C. Jr. (1961). Storage and retrieval of chemical research and patent information by links and roles in Du Pont. *American Documentation 12,* 111–120.

Dinwiddie, S. M., & Conrad, C. C. (1954). Report indexing by hand-sorted punched cards. In B. H. Weil (Ed.), *The technical report* (pp. 303–316). New York: Reinhold.

Duncan, V. L. (1951). The Lavoisier library, experimental station, E. I. DuPont de Nemours & Co. *Bulletin of the Special Libraries Council of Philadelphia and Vicinity, 17*(5), 33–37.

Edge, E. B., Fisher, N. G., & Bannister, L. A. (1957). System for indexing research reports using a punched card machine. *American Documentation, 8.*

Gluck, D. J. (1965). A chemical structure storage and search system developed at DuPont. *Journal of Chemical Documentation, 5(1*), 43–51.

Herner, S., Lancaster, F. W., & Johannigsmeirer, W. F. (1964, September 3). Investigation of the effect of roles and links on the performance of a mechanized retrieval system. Presented at Division of Chemical Literature, 148th National Meeting, American Chemical Society, Chicago, IL.

Hoffman, W. S. (1968). An integrated chemical structure storage and search system operating at Du Pont. *Journal of Chemical Documentation, 8 (1),* 3–13.

Hoffman, W. S. (1972). DuPont information flow system. *Journal of Chemical Documentation, 12(2),* 116–124.

Kilgour, F. G. (1997). Origins of coordinate searching. *Journal of the American Society for Information Science, 48(4),* 340–348.

Lancaster, F. W., & Mills, J. (1964). Testing indexes and index language devices: The ASLIB Cranfield project. *American Documentation, 15,* 4.

Luhn, H. P. (1957, October). A statistical approach to mechanized encoding and searching of literary information. *IBM Journal of Research and Development*.

Marcali, J. G., Kvalnes, F. H., Patterson, J. A., & Wilks, E. S. (1993). The Du Pont global technical information system. In W. A. Warr (Ed.), *Chemical Structures 2* (pp. 145–160). Berlin: Springer-Verlag.

Montague, B. A., & Schirmer, R. F. (1968). Du Pont central report index: System design, operation, and performance. *Journal of Chemical Documentation 8*, 33–41.

Morgan, H. L. (1965). The generation of a unique machine description for chemical structures technique developed at Chemical Abstracts Service. *Journal of Chemical Documentation 5,* 107–113.

New system identifies and stores formulas. (1963). *Chemical & Engineering News, 41*(49), 35–36.

Nichols, M. T., Sikes, J., Isselmann, M. M., & Ayers, R. S. (1995–1996). Survival in transition or implementing information science core competencies. *Bulletin of the American Society of Information Science 22(2),* 11–15.

Patterson, J. A., Schultz, J. L., & Wilks, E. S. (1995). Enhanced polymer structure, searching, and retrieval in an interactive database. *Journal of Chemical Information and Computer Science 35*(1), 8–20.

Rasmussen, L. E., & Van Oot, J. G. (1969). Operation of DuPont's central patent index. *Journal of Chemical Documentation, 9*(4), 201–206.

Salton, G. (1961, November). The manipulation of trees in information retrieval. *DDC (Defense Documentation Center) (in NTIS No. AD274816)*.

Schultz, J. L. (1974). Handling chemical information in the Du Pont central report index. *Journal of Chemical Documentation, 14*, 171–179.

Schultz, J. L. (1975). Polymer nomenclature, classification, and retrieval in the DuPont central report index. *Journal of Chemical Information and Computer Sciences, 15,* 94–100.

Schultz, J. L., & Wilks, E. S. (1997) Multiple-level polymer registration in the DuPont SCION database. *Journal of Chemical Information and Computer Science 37*(2), 165–170.

Taube, M., et al. (1953). *Studies of coordinate indexing, Vols. 1–1V.* Washington, DC: Documentation Inc.

Taube, M., et al. (1962, February). The state of the art of coordinate indexing. *DDC (Defense Documentation Center) (NTIS No. AD275393).*

Van Oot, J. G., Schultz, J. L., McFarlane, R. M., Kvalnes, F. H., & Riester, A. W. (1966). Links and roles in coordinate indexing and searching: An economic study of their use, and an evaluation of their effect on relevance and recall. *Journal of Chemical Documentation 6,* 95–101.

Wall, E. (1959). A practical system for documenting building research. Presented at Building Research Institute, Washington, DC.

Wilks, E. S. (1997a). Polymer nomenclature and structure: A comparison of systems used by CAS, IUPAC, MDL and DuPont. 1. Regular single-strand organic polymers. *Journal of Chemical Information and Computer Science 37*(2), 171–192.

Wilks, E. S. (1997b). Polymer nomenclature and structure: A comparison of systems used by CAS, IUPAC, MDL and DuPont. 2. Aftertreated (post-treated), alternating/periodic, and block polymers. *Journal of Chemical Information and Computer Science 37*(2), 193–208.

Wilks, E. S. (1997c). Polymer nomenclature and structure: A comparison of systems used by CAS, IUPAC, MDL and DuPont. 3. Comb/graft, cross-linked, and dendritic/hyperconnected/star polymers. *Journal of Chemical Information and Computer Science 37(2*), 209–223.

Wilks, E. S. (1997d). Polymer nomenclature and structure: A comparison of systems used by CAS, IUPAC, MDL and DuPont. 4. Stereochemistry, inorganic, coordination, double-strand, polysiloxanes, oligomers, telomers. *Journal of Chemical Information and Computer Science 37(2*), 224–235.

For Further Reading

Crow, J. E. (1967). Microforms and technical information. Presented at Division of Chemical Literature, American Chemical Society Meeting, Chicago, IL.

Grandine, J. D. 2nd, Starr, E. M., & Putscher, R. (1959, September). Report index searching on the Bendix G-15D computer. Presented at Division of Chemical Literature, American Chemical Society Meeting, Atlantic City, NJ.

Schirmer, R. F. (1967). Thesaurus analysis for updating. *Journal of Chemical Documentation 7,* 94.

Walker, J. F. (1964). The singularity sub-link—a new tool for use in the storage and retrieval of information. *Journal of Chemical Documentation 4,* 45.