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ABSTRACT

The purpose of this study was to develop and implement a hypertext documentation system in an industrial laboratory and to evaluate its usefulness by participative observation and a questionnaire. Existing word-processing test method documentation was converted directly into a hypertext format or "hyperdocument." The hyperdocument was designed and structured according to principals found in the literature of hypertext. It was evaluated for three months in a chemical plant quality assurance laboratory where 16 people were employed who used the hyperdocument. The hyperdocument was made available for use, but the laboratory's paper documentation was still available. Observations, discussions, and a questionnaire were used to collect the data. Participants tended to like the hyperdocument, they found it easy to learn how to operate, easy to use, and most said it was useful. They tended, however, to use it infrequently. Hyperdocument maintenance was found to be somewhat time consuming, but not unreasonably difficult. It was concluded, therefore, that: (1) the design and structuring principals given in hypertext literature led to an easy-to-use product; (2) maintenance was not too difficult; and (3) the hyperdocument was a useful and effective tool for documenting test methods in a laboratory. A copy of the evaluation questionnaire is included. (Contains 26 references.) (Author/TMK)

CREATING AND EVALUATING A HYPERTEXT SYSTEM OF DOCUMENTING ANALYTICAL TEST METHODS IN A CHEMICAL PLANT QUALITY ASSURANCE LABORATORY

THESIS

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CHAPTER 1

INTRODUCTION

As technical devices and procedures grow increasingly complex, so does their requirement for documentation. This documentation, to be useful, must be readily accessible. *Accessibility* means more than simple availability. There may be ample documentation for an instrument or a procedure; but if users cannot quickly find exactly what they require to complete a given task, then the documentation has fallen short of users' needs.

Written manuals and procedures have traditionally been the chosen method of documentation for everything from toasters to submarines. Undoubtedly, a thoroughly indexed manual is useful in that it provides accessibility to required information. However, as the physical size of a document increases, it becomes increasingly difficult and time-consuming for users to locate required information. This is precisely the problem with many highly technical (and lengthy) procedures. Another concern is the actual updating and printing of the documentation. According to Rubens and Krull (1988), "most corporations need desperately to reduce their page counts -- literally the number of times they pass a piece of paper through a printing press. They need to save both the money and the time needed to produce paper documentation" (p. 292).

Modern industry, with its increasing use of highly complex machinery and instrumentation, requires a great deal of documentation. Written manuals and procedures are required not only for the operation and maintenance of machines, but also for the procedures to test the quality of manufactured goods. A modern chemical plant's quality assurance laboratory (QA lab) is no longer a corner of the factory building with a few simple instruments where plant operators quickly check products before shipment. It is a separate entity of the plant with highly skilled laboratory technicians who are required to perform detailed, complex analyses in as short a time as possible.

The analyses performed in a QA lab fall into two categories: 1) *release* procedures that ensure products meet specification before shipment, and 2) *in-process* analyses that determine if intermediate chemicals are ready to be processed to the next step. As global competition in the chemical industry increases, these in-process analyses become increasingly important to monitor the entire process and ensure that products are made in the most safe and efficient manner possible. These analyses are an integral part of the multi-step processing of chemicals and, as such, cannot be too lengthy. If they were, they could become a serious bottleneck in the total process and jeopardize cost-effectiveness and therefore competitiveness in the marketplace.

Just as the analyses themselves cannot be too lengthy, neither can the act of accessing documentation that explains exactly how to perform the tests. Much time and effort go into developing quick and effective analytical test methods, but little effort is spent in developing quick and effective documentation for these test methods. Modern microcomputer technology provides a means to deliver quick and effective test method documentation -- hypertext.

Overview of Hypertext Technology

The term hypertext was coined in 1965 by Ted Nelson (Jonassen, 1989), but the concept was proposed by Vannevar Bush 20 years earlier (Bush, 1945). Bush, President Roosevelt's Science Advisor, proposed a device called a Memex. A Memex would be a machine that stored huge amounts of information in various formats such as written text, recordings, pictures, and photographs. The unique aspect was that it would be a mechanical device that would allow quick access to any of these pieces of information (nodes) and each node would be associated with others by any relationships between them. One could access nodes in a non-linear fashion -- similar to the way a person thinks (Bush, 1945). Thus a document could be made *three-dimensional* by having very fast (hyper) links between associated (but physically distant) sections. This led to Nelson's term hypertext. A Memex was never built, however, and it was not until much later that computer technology provided the means to accomplish the same task electronically.

Large, mainframe-based hypertext systems have been in existence since the 1960's and are still being developed, but hypertext applications for microcomputers were not available until the mid 1980's. The first of these was Owl International's *Guide*, but Apple Computer's *Hypercard* is probably the most popular. Hypertext development systems can be extensive systems that display graphics and play back recorded audio and video sequences. These are often referred to as *hypermedia* or *multimedia* systems. Alternatively, a hypertext system may be less complex and deal primarily with computer-based text files. Of course, the more complex systems require extensive hardware and software to perform efficiently (Seyer, 1991). There are a few key features that are common to all hypertext systems.

All hyperdocuments consist of a series of nodes or information "chunks". In some development systems these are called *cards* and the entire document is referred to as a *deck*. Nodes may be any length. They may be displayable on one computer screen or may be longer than one screen. There are advantages and disadvantages to screen-sized as opposed to larger nodes. Screen sized nodes may be easier for a user to assimilate, but these may require extensive linking between many nodes, which can give the user a feeling of being lost or overwhelmed by the complex structure. Longer nodes, on the other hand, may require the user to scroll through many screens which can be rather awkward (Jonassen, 1989).

All hypertext systems use links. A link is simply an instruction for the computer to "jump" to another part of the document. It may also be a link to another document, another file, another program, or to a graphic screen display or an audio or video sequence if the software supports any of these. The user may choose to select links or to ignore them and continue reading the document. Links are selected by various means -- the most common being a pointing device such as a mouse. A link can appear as highlighted text or as a graphic *button* on the screen.

Some Examples of Hypertext Applications

One of the earliest and most extensive hypertext projects was undertaken by the U.S. Navy aboard the aircraft carrier USS Carl Vinson in the early 1980's. The Ship Organization and Regulation Manual was made into a hypertext system that was not only accessible by crew members, but by shipboard system control computers as well. Another part of this shipboard hyperdocument was technical manuals for aircraft and weapons elevators (McCracken, 1984).

A popular example of the application of hypertext technology is the U.S. Environmental Protection Agency's Reg-in-a-Box package. This is a hyperdocument that contains the federal regulations for managing underground storage tanks. There is extensive cross referencing which is facilitated by hyperlinks and the EPA has found that the document is relatively easy to update and distribute as regulations change (Seyer, 1991).

Overview of this Study

This research was a study of the creation, implementation, and evaluation of an analytical test method hyperdocument. The implementation and evaluation took place in a chemical plant quality assurance laboratory (GE Specialty Chemicals' Morgantown West Virginia Plant) in which the researcher was employed as a Chemical Assistant. The researcher created the hyperdocument using a commercially available hypertext development system (HyperHelper, Azarona Software). The test methods themselves were downloaded in *American Standard Code for Information Interchange* (ASCII) format from the laboratory's VAX-based word processor and converted to hypertext format on a personal computer (PC).

The laboratory employed 16 individuals who regularly needed to access test method documentation (consisting of some 150 separate test methods -- about 400 typewritten pages), which was composed of two loose-leaf notebooks. There were five technicians (the QC Team) who worked almost exclusively in the laboratory itself rather than in an office with their own

PC. These five had the most need to access test method documentation and were potentially the heaviest users of the hyperdocument. The laboratory personnel had access (through 11 PC's) to a local area network (LAN) on which the hyperdocument was installed. There was also a non-networked PC in the laboratory on which the hyperdocument was installed. At the time the study took place the laboratory, as well as the entire production facility, was undergoing ISO-9000 registration. ISO-9000 is an internationally recognized system of standard documentation and operation that will soon be required to do business in Europe (Kelley & Larson, 1992). This environment offered a manageable setting in which to implement and evaluate a hypertext system of documentation and thereby determine its usefulness.

Problem Statement

The problem of this study was to develop and implement a hypertext documentation system for an industrial laboratory and to evaluate its usefulness by participative observation and a questionnaire.

Purposes of this Study

The purposes of this study were:

1. To identify problems (and possible solutions) encountered in creating and implementing the hyperdocument.
2. To determine if a hyperdocument was a valuable reference tool in an industrial laboratory.

Study questions

The study attempted to answer the following questions:

1. What problems were encountered in creating the hyperdocument and how were they solved?
2. What problems were encountered in implementing the hyperdocument and how were they solved?
3. Was the hyperdocument readily accessible to those who needed it?
4. Was the hyperdocument readily maintainable/updatable?
5. Was the hyperdocument secure?
6. Did laboratory personnel find the hyperdocument an appropriate way to document test methods at GE Specialty Chemicals?
7. Did the hyperdocument meet requirements for international documentation standards (specifically -- ISO-9000)?

Assumptions

The following assumptions were made in this study:

1. The hyperdocument users had an acceptable level of computer expertise.
2. The hyperdocument content was valid and useful.

Limitations of this Study

The limitations of this study were:

1. There was a relatively small number of participants -- 19.
2. All participants were employed in the same industry by the same company.

Definition of Terms

1. Document security -- Document security is the ability to control who has access to read and copy a document and who has access to modify the document.
2. ISO-9000 -- ISO-9000 is an international standard developed in Europe. It is a system of documentation that is used as an external quality assurance tool. In other words, a supplier with ISO-9000 certification has extensively documented systems. This assures customers that the supplier has the capability to supply consistent products (International Organization for Standardization, 1987). This standard can apply to any industry but has been particularly embraced by the chemical industry.

CHAPTER 2

LITERATURE REVIEW

The literature review was divided into two areas of investigation: 1) Design and Structure of a Hyperdocument and 2) Review of Similar Research. There has been a large amount of research on the best way to design and structure a hypertext user interface. This study was not intended to further investigate this aspect of hypertext. The intent was to investigate the actual application of hypertext technology to a specific, real world situation.

Design and Structure

Design

Keyes, Sykes, and Lewis (1988) presented a useful model for what they called "Information Design" (p. 252). This was a process that they used to develop documentation (either paper or electronic) and it was decided to apply this process to the hyperdocument development for this study. Figure 1 summarizes this process. It was a six-step procedure that served as a guideline for the development of online technical documentation.

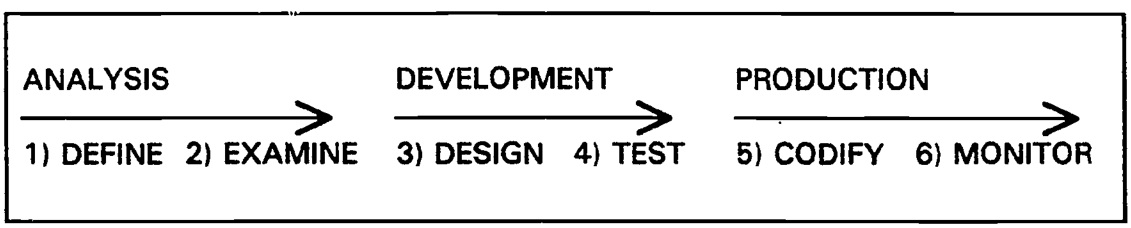

Figure 1. A Model for Information Design (from Keyes, et al., 1988).

According to this model, the first step is to define the business problem, purpose of the project, technologies to be used, budget and staffing constraints, and degree of control. The second step is to examine the users -- their background, abilities, and educational level, and how they are to use the information in the documentation. The third step is to design a "pilot" system which is then tested in the fourth step (Keyes et al., 1988). This study included only the first four steps of this information design model.

As with any technical documentation project, users' needs were paramount. A number of authors gave useful advice on analyzing user needs. Grice (1989) advised to

> Learn about them [the users], the tasks that they will do using the information you provide, and how your information will support those tasks. . . . visit customers [users] at their place of work, see their working environment and how they work in it, and talk to them about their work and their information needs (p. 30).

Similarly, Herrstrom (1989) said to profile user groups and to analyze their tasks and abilities. Herrstrom further cautioned that "hypertext seems to be a solution searching for a problem; consequently, many hypertext designs appear to be driven by technology rather than by the needs of users" (p. 45).

Another concern was how well the information itself was suited for a hypertext application. Shneiderman (1989) listed what he called the "Golden Rules of Hypertext." These were: "[1] there is a large body of information organized into numerous fragments, [2] the fragments relate to each other, and [3] the user needs only a small fraction at any time" (p. 115).

Several writers cautioned against the pitfalls of converting existing word-processing documents into a hyperdocument. Rubens (1991) maintained that converting poorly written and poorly organized documentation into hypertext simply created poorly written and poorly organized hypertext. Glushko (1992) cited concerns with the difficulties of text conversion -- he maintained that hypertext developers should be aware of the time and effort required to convert various electronic text formats into a hypertext format. Similarly, Seyer (1991) stressed the importance of selecting hypertext software that makes the conversion process as simple as possible.

The literature search revealed approximately thirty articles on hypertext design. These concerned how to structure the knowledge, how the screen should appear, what colors were best, how much linking was appropriate, and so on. Glushko (1992) stated that "An obsessive focus on 'how it looks' often drives out serious consideration of 'how it has to work'" (p. 227). So while appearance was found to be important, ease of use and value <u>as perceived by the user</u> were found to be a primary concern in hypertext design.

The technology employed in this study defined a large part of the screen appearance. The software (HyperHelper, Azarona Software) was a text-based development system so it was limited to the screen fonts and sizes provided on the individual PC on which it was viewed. Only ASCII character graphics were possible (that is, characters such as these: ┼ ┐ └ █ ╟ ╒).

Color was configurable using HyperHelper and color monitors were to be used so this aspect of design was investigated in the literature. Murch (1985) listed eight best and eight worst color combinations possible on 16-color computer displays like the ones to be used in this study. His recommendations were based on physiological, perceptual, and cognitive data acquired in a number of related studies. Rubens and Krull (1986) conducted a study which showed that overuse of color can be very distracting. They recommended very limited highlighting in online information displays.

<u>Structure</u>

Seyer's (1991) discussion of hypertext structuring techniques provides a good summary of what is available in the literature. He describes eight approaches: 1) table of contents approach, 2) index approach, 3) summary approach, 4) decision table approach, 5) guided tour, 6) empirical approach, 7) hierarchical approach, and 8) hypermaps.

The table of contents and index approaches are self explanatory -- the user is presented with a table of contents or index in which each entry is a link to the appropriate node. Users can select the items they desire to read. The summary approach provides users with a narrative summary of the entire hyperdocument. Key words in the summary are highlighted and are links that can take users to appropriate parts of the document. The decision table approach is a sort of "expert system" that provides users with alternative paths through the hyperdocument based on their responses to queries. The guided tour approach is more of a screen show in which users are prompted to take a certain path through the document. In the empirical approach, the developer observes users actually using a hyperdocument and then modifies the structure to enhance the following of paths they used the most. The hierarchical approach involves separating the subject matter into various levels of subtopics. Users select a subtopic from the initial screen and this takes them to one or more additional screens where the topic is progressively narrowed down to the specific article or node for which the user is searching. Hypermaps are simply graphical representations of one of the above organization schemes. These help users to visualize overall structure (Seyer, 1991). Shneiderman (1989) discussed similar structuring techniques and stressed that the intended usage should define the overall structure. Shneiderman (1989) also pointed out the importance of conveying this structure to users. The design strategy of the hyperdocument in this study employed both index and hierarchical approaches. Users were able to choose which approach they desired based on what they needed at the time. A simple hypermap was also provided that illustrated this overall organization. Another consideration was linking or hyperlinking.

The hypertext developer must decide what and how many links are necessary to enable the hyperdocument to satisfy its intended purpose. Grice, Ridgway, and See (1991) maintained that a proper balance between too many and too few links can be attained based on the intended usage of a hyperdocument. For instance, a general knowledge application might contain a relatively large number of links so that users can browse through the information at will. On the other hand, a reference application (such as the hyperdocument in this study) should contain fewer, more restrictive links. "In this environment, the strength of hypertext is to allow the user quick and easy access to the specific information required. . . . placing only a minimal burden on the reader to develop a search strategy" (Grice et al., 1991, p. 54). As Shneiderman (1989) says, "Minimize the burden on the user's short-term memory. . . . The goal is to enable users to concentrate on their tasks and the contents while the computer vanishes" (p. 126).

Review of Similar Research

There have been few published studies in which hypertext technology was applied and evaluated in a real-world situation similar to that in the present study.

Hypertext has been extensively evaluated as an educational tool. In one study for example, Apple's Hypercard was used to create a hypermedia application for use as a reference and as a teaching tool in an undergraduate biology program (Hall, Thorogood, Hutchings, & Carr, 1989). The authors created a hypertext database of instructional information that contained not only hyperlinks between the cards, but also contained buttons to activate sequences on an attached videodisk player. Extensive linking was employed and the result was a complex network of information. Users were thus encouraged to make their own way through the information. The authors felt that this would enhance the learning process. After an actual evaluation with students they decided to add an index and table of contents to aid navigation. Hall, et al. (1989) concluded that the system provided students with quick and easy access to a large database of video sequences and that this enabled them to learn about the subject of cell biology. Thus a hypertext application was shown to provide a useful way to access a large amount of information (visual information in this case).

Another application of hypertext that has been evaluated is in visitor centers or museums. A good example of this was a study by Shneiderman, Brethauer, Plaisant, and Potter (1989) in which a hypertext application was evaluated in three different museums. This was a fairly extensive study with a total of over 5000 user sessions. Their application was designed to allow museum visitors (with widely varying computer skills) to casually browse an interactive database of information concerning a museum display. Their evaluation was similar to the present study in that the hypertext application was *provided* for users, but use was not necessarily *encouraged*. Thus the researchers hoped to determine the value of the hypertext application from usage levels. They were also interested in how often users activated hyperlinks in browsing as opposed to using the provided index.

Data collection in Shneiderman's, et al. (1989) study was by observational logs and by automated logging in the software itself. The authors found that the automated log data had to be interpreted carefully as there was no way to determine if one session constituted one user or multiple users. In addition, they recommended interviewing in future hypertext evaluations as a source of valuable data.

Shneiderman, et al. (1989) observed diverse usage patterns in the museum trials. These ranged from ignoring the computer completely to spending a great deal of time with it. Some even came back more than once. Some patrons seemed to be more interested in "playing" with the machine rather than actually reading the content. Only a "fraction of the visitors" (Shneiderman, et al., p. 181) even used the system, but those who did seemed to benefit from the experience. The authors concluded that a hypertext application can enhance a museum exhibit by providing an "engaging, interactive, and personal experience" (Shneiderman, et al., p. 181).

Rubens (1991) evaluated a hypertext application that was used as technical documentation -- designed to support tasks. The hyperdocument was directly compared with paper documentation with the same purpose. The word processing files of the paper documents were directly converted to hypertext format much as in the present study.

Subjects were asked to use the documentation to find answers for four questions. The questions concerned additive tasks. That is, they forced subjects to find two or more separate pieces of information and then combine these to answer the questions. Observers recorded the time it took subjects to determine the correct answers. Rubens used bar graphs to present the results and did not provide the raw data; nor was any statistical analysis presented. He stated that "Paper searches required on the order of 88 seconds; hypertext searches took about 154 seconds" (Rubens, 1991, p. 38). He concluded that paper searches were significantly faster. While the averages did tend to support this conclusion, the within-group variability was quite large -- one of the hypertext times was very long while one of the paper times was very short. The other two times were similar for hypertext verses paper. Statistical analysis (such as a t-test) would probably have shown no significant differences in the data.

Performance (correctness of answers) was presented in another bar graph. Variability was not so great here, but the hypertext documentation actually exceeded the paper documentation for two of the questions. So while Rubens concluded that hypertext technical documentation is less effective than paper documentation, his results were not conclusive enough to discourage the researcher in the present study from trying the same thing -- that is, converting existing documentation directly into hypertext format for evaluation. Clearly, more work was required to determine the effectiveness of hypertext technical documentation.

McMurray's (1990) master's thesis was a study of the creation and evaluation of a hypertext *economic analysis office reference system*. Her study extensively described the selection of a hypertext development system and the knowledge structure design. The source documentation was directly converted either from existing electronic word processing format or from scanned documents. The evaluation consisted of asking students and faculty members at the Air Force Institute of Technology (AFIT) to use the reference system for any amount of time and then complete a questionnaire. Updating capability was also part of the study.

Seventy-nine percent of the subjects indicated that a hypertext system would be a useful office reference system. Subjects ranked possible uses in the following descending order of importance: review, general browsing, learning, reference, and research.

According to McMurray,

> The time required to find and learn information on a hypertext system compared favorably to the use of any other sources of information. Users stated that the system would help them find information more easily (83 percent), would take them less time (75 percent), and they would learn more (69 percent). If they had access to a hypertext reference system, 44 percent expected to use it at least once or twice a day (p. 63).

McMurray concluded that hypertext is "compatible with the office reference environment" and "capable of providing quick access and learning of information" (p. 67). As for updating capability, she found that any major revisions such as new or rewritten regulations would require substantial redevelopment of the hypertext. She felt that more research in real world applications was needed to determine the usefulness of hypertext.

Summary

The analytical test method documentation used in this study fit very well with Shneiderman's (1989) Golden Rules of Hypertext. It was a large body of information that consisted of numerous individual test methods, a number of these related to and referred to others, and users typically referred to only one test method procedure at any given time. In addition, Shneiderman's recommendations for organization defined how the hyperdocument was to be organized -- it should have a rather highly structured form and have relatively few, carefully chosen links.

In this study, the usability testing phase of the information design model shown in Figure 1 was the data collection process. This was discussed in detail in Chapter 3, Methodology. The remaining two steps in Figure 1 -- Codify and Monitor -- would be conducted *after* the usability testing and were not within the scope of this study.

Based on the observations in the museum study (Schneiderman, et al., 1989), it was decided that automated logging would provide little valuable information so it was not actively pursued. Informal interviews and a questionnaire were used, however, to gather the same sort of information (that is, duration of usage sessions and number of usage sessions).

No published studies were found in which hypertext was applied as it was proposed for present study -- a relatively simple reference database of technical procedures. McMurray's (1990) was the closest, but she concentrated more on development while the actual trial was limited in scope. In addition, her hyperdocument was apparently much more complex in structure than that of the present study. There have been several articles published on the use of hypertext on board ship. Examples of these were McCracken (1984), which was discussed in Chapter 1, and Kellett's (1989) master's thesis. These, however, described massive and all-encompassing documentation systems for an entire ship. Therefore, they did not compare well with the present study. There was an apparent void in the literature that the present study was intended to fill.

CHAPTER 3

METHODOLOGY

Selection of a Hypertext Development System

The first step after the preliminary literature review (a study of hypertext technology and structuring techniques) was to select a suitable hypertext development system. The following aspects were considered:

- User interface and ease of use
- Ease of development
- Versatility
- Cost

Considering the newness of hypertext technology, there was a fairly wide range of development systems. Most commercial systems met all the above requirements except cost. Commercial hypertext development systems cost from several hundred dollars to several thousand while most shareware systems cost one hundred dollars or less. It was decided to concentrate on shareware systems 1) to keep costs down and 2) because a more simple development system was well suited to the present study.

Shareware, while not free, is computer software that is available to the public on electronic bulletin boards, computer information systems, and shareware distributors. These programs are distributed on a sort of "honor system." A fully functional copy of the software can be downloaded and evaluated for a certain period of time. After the evaluation period, the user is expected to either register the software by sending the required fee to the copyright owner or to destroy the copy.

Creation of the Hyperdocument

The laboratory test methods were stored on a Digital Equipment Corporation (DEC) VAX minicomputer in WPS-PLUS (DEC's word processor) format. Like most word processors, WPS-PLUS can export a document in ASCII format or "print to disk". To create the hyperdocument, each of the some 150 individual test methods were exported in ASCII format on the VAX and then downloaded to a PC.

The next step was to create one large ASCII source file from the test method files. This involved chaining each individual document file together into one large file, removing any page formatting, and adding the appropriate commands for the hypertext compiler.

Data Collection and Analysis

Both qualitative and quantitative techniques were used. There were two modes of data collection in the study: 1) participative observation and 2) a questionnaire. The observations were primarily qualitative and provided the bulk of the data while the questionnaire provided supplementary quantitative data. The observations included both the creation of the hyperdocument and the observations conducted during the evaluation. The actual evaluation was conducted over a period of about three months -- from September 15, 1992 to December 17, 1992. The laboratory personnel were given an introduction to hyperdocument access techniques and capabilities and they were encouraged to use the hyperdocument in their daily work. The researcher actively supported this effort for the duration of the study. Like the museum study cited in Chapter 2 (Shneiderman et al., 1989), the hyperdocument was available, but it did not *have* to be used. The paper document was still in the laboratory. Usage or non-usage, then, gave some indication of whether or not the technicians viewed the hyperdocument as useful. Also, due to the lack of scans in the hyperdocument, technicians still had to refer to the paper documentation when they needed to see a sample scan - a chromatograph scan for example.

The researcher in this study was the author of the hyperdocument, one of the technicians who used the hyperdocument, and was the "resident expert" on usage. He was also the person responsible for maintaining the hyperdocument. He was, therefore, thoroughly immersed in the situation so a sort of ethnographic, participative data collection mode was used. In this type of data collection, as described by McMillan and Schumacher (1989), the researcher observed the other technicians' verbal and nonverbal responses while they interacted with the hyperdocument. An attempt was made to 1) determine the individual technicians' attitude toward the hyperdocument from their unique, individual perspectives that were based on their laboratory experience, computer expertise, and general mode of working and 2) to observe and describe how the hyperdocument fit into the laboratory situation as a whole. While no formal interviews were conducted, there were ample opportunities for informal discussions concerning usage of and attitude toward the hyperdocument. The researcher kept detailed notes of discussions and observations. The researcher made it clear to the other technicians that they should be absolutely candid and frank in their assessment of the hyperdocument and not be concerned with offending him if they found fault with the hyperdocument or wished to criticize it.

The questionnaire (See Appendix A) was developed specifically for this study and its design was based on principals outlined by McMillan and Schumacher (1989), Epstein and Tripodi (1977), and Slavin (1984). The primary objectives of the questionnaire were to 1) gather basic demographic data on the participants, 2) gather data concerning computer expertise and laboratory experience of the participants, and 3) to gather data that would help in answering the following study questions as given in Chapter 1:

- Was the hyperdocument readily accessible to those who needed it?
- Was the hyperdocument secure?
- Did laboratory personnel find the hyperdocument an appropriate way to document analytical test methods at GE Specialty Chemicals?
- Did the hyperdocument meet requirements for international documentation standards (specifically -- ISO-9000)?

The data from the questionnaire were tabulated to summarize and explore the distribution of responses with respect to the above study questions. Several notable relationships between variables were further analyzed using Spearman Rank Order Correlation (Statsoft, Inc., 1991).

CHAPTER 4

ANALYSIS OF DATA

Hyperdocument Creation and Implementation

This section will present the data concerned with the first two study questions:

- What problems were encountered in creating the hyperdocument and how were they solved?
- What problems were encountered in implementing the hyperdocument and how were they solved?

This was done by describing how the development system was chosen, how the hyperdocument was created and implemented, and any notable findings concerning these tasks.

Selection of the Software.

As discussed in Chapter 3, the first step in hyperdocument creation was to select hypertext development software. The following software packages were evaluated:

- Story, Alchemy Mindworks
- HyperHelper, Azarona Software
- Black Magic, Ntergaid

There were other shareware hypertext development systems, but these were not readily available to the researcher at the time the study began.

Both Story and Black Magic had a graphical user interface (GUI) while HyperHelper was a text-based application. This refers to the screen mode in which the program operates. GUI's tend to be more esthetically pleasing to the eye, but the tradeoff is speed of operation. The computer is required to perform more work to update a graphics screen than to update a text screen so a text based application runs more quickly. This was not a major concern for most newer computers; but on older models, it could make a significant difference. Therefore; HyperHelper was a better choice since the software was to be used on older, slower computers as well as newer, faster ones.

HyperHelper provided an additional user interface enhancement. It allowed the developer to include customized menus on every screen while the other two systems did not. These menus could be operated either with the keyboard or with a pointing device such as a mouse. In Black Magic the user had to press <F10> to access a menu from which to select actions such as exiting or jumping to another part of the hyperdocument. This menu had to be operated from the keyboard and it included numerous options which could be confusing to an inexperienced user. In Story the user had to click on one of the two screen buttons to get a menu. Story required a pointing device while both Black Magic and HyperHelper could be operated from the keyboard if a mouse was not attached to the computer being used. HyperHelper seemed to provide the most consistent, versatile, user-friendly interface of the three applications.

Another consideration was ease of development. All three of the applications could import ASCII files. Both Story and HyperHelper were specifically designed to do this while Black Magic had its own word processor. Importing and reformatting of the test methods would have been more labor intensive using Black Magic so Story and HyperHelper were better in this respect. With either of these applications, the researcher was able to use a familiar word processing system to reformat the test methods for the hyperdocument.

The other consideration was versatility. Both HyperHelper and Black Magic were true hypertext systems. They both allowed embedding of hypertext links anywhere in the text while Story did not. Story had only two buttons on every screen -- one to exit the application and one to jump to another page. In addition, both HyperHelper and Black Magic allowed the user to search the hyperdocument for topics of interest while Story did not. Story, as its name implies, was designed more for an online, linear presentation of a story or narrative rather than a database of information. HyperHelper and Black Magic were better in this respect as they allowed the user to quickly jump from place to place in the hyperdocument and easily return.

HyperHelper was chosen because it best served the needs of the project. HyperHelper provided the best user interface because it ran quickly on any computer, it allowed the development of customized menus that were less confusing for users, and it was equally usable with either a mouse or the keyboard. In addition, HyperHelper provided somewhat superior ease of development as it required a minimum of reformatting to convert ASCII files to an uncluttered screen presentation in the final product.

Creation of the Hyperdocument

The laboratory test methods were stored on a DEC VAX minicomputer in WPS-PLUS format. To create the hyperdocument each of the some 150 individual test methods were exported in ASCII format on the VAX and then downloaded to a PC. This relatively labor-intensive process was speeded somewhat by using WPS-PLUS's user defined processing (UDP) or macro utility. A simple macro was created that issued the appropriate commands and then typed most of the new file specification. For each test method, the researcher had to press two keys to initiate the macro and then had to manually type three more characters (the three digits of the test method number) to complete the filename and press <RETURN>. This worked out to six keystrokes per test method with a total of about 940 keystrokes. This process took approximately two hours. So what at first seems like a fairly monumental task was not unreasonably difficult.

The next step was to create one large ASCII source file from all the test method files. This involved chaining each individual document file together into one large file, removing any page formatting, and adding the appropriate commands for the hypertext compiler. To do this the researcher used WordStar International's WordStar word processor. A source file was created and then each test method file was inserted. Each file, as it was output from

WPS-PLUS, contained a printer control code for page breaks (this appeared as ^L at the beginning of each line where a new page was to begin) and page numbering. These were removed as they would have been meaningless in an online document and could confuse users. This process of concatenating and reformatting the files was, of course, the most tedious and labor intensive step of the project. It was done in several sessions over a period of two weeks and took a total of approximately 24 hours. Appendix C is an example of a part of the source file. HyperHelper included a complete online, hypertext reference manual that could be loaded as a terminate and stay resident (TSR) utility and then "popped up" while editing the source file. It was thus possible for the researcher to quickly look up commands while editing the source file. WordStar's macro utility was used to automate some of the repetitious typing of compiler commands.

Screen Appearance of the Hyperdocument

The hyperdocument was to be used primarily on color monitors so this aspect of the user interface was considered. HyperHelper's default screen colors were black text on a cyan background with links being highlighted in yellow. Although this was an option that could be altered by the researcher, it was decided to use this default color scheme. The black text on cyan appeared pleasing and easy to read and, in addition, this color combination was one of several recommended by Murch (1985) for use in online documentation.

Structure of the Hyperdocument

A typical test method was included in Appendix B to illustrate how the methods themselves were constructed on paper. Most included the following sections:

INTRODUCTION -- a brief description of the theory and chemistry involved.

SCOPE -- exactly what materials may be tested using the method.

SAFETY -- any unique hazards associated with the method.

EQUIPMENT -- the equipment used in the test, the manufacturer, and any pertinent ordering information such as model number.

REAGENTS -- the chemical reagents used in the test and any pertinent ordering information such as catalog number.

PROCEDURE -- the actual "cookbook" procedure itself.

CALCULATIONS -- detailed description of any calculations along with examples.

APPENDIX -- any supplemental information or illustrations such as scans.

The primary purpose of the hyperdocument was to provide quick and effective access to analytical test method documentation. To accomplish this the hyperdocument had to, according to Grice (1989):

- Be easy to master and use.
- Provide a consistent user interface.
- Have clear and readable screens that would not strain users' eyes.
- Provide indexing and searching capabilities that users needed.
- Adhere to standards for laboratory safety.

The hyperdocument was designed with the above requirements in mind.

Each test method was set up as one card through which the user could scroll as desired. Several methods contained hyperlinks to supplemental information or to other test methods. For example, some methods required a result or value from another test method. These two methods, then, were hyperlinked so that users could quickly jump from one to the other and back as required.

Short test methods were as few as two computer screens in length while the more complex methods were as many as sixteen screens. Many hypertext authorities recommended that a card be no more than one screen (Seyer, 1991), but this sort of structuring would have required splitting up individual test methods into numerous cards. This would have been undesirable for this application. The hyperdocument was designed to allow quick access to an *entire* test method rather than to specific sections of the test methods. This was done to help prevent users from jumping, for example, directly to the PROCEDURE section and never seeing important sections such as SCOPE or SAFETY. Even so, it was a simple matter for users to scroll very quickly to the section they were interested in at the time.

Hyperdocument card topics (or keywords) included the test method number, the instrument used, the property tested, and either the word qualitative or the word subjective. This allowed searching the hyperdocument for all the methods that used a certain instrument, tested for a certain property, or were qualitative or subjective sort of tests.

For routine situations, users knew the test method *number* for which they were looking. This information was provided by the laboratory information management system (LIMS). In that case they were able to jump to the INDEX and quickly choose the desired test method. Alternatively, in non-routine situations, the user may not have been sure which test method was applicable. In that case they could jump to the CATEGORY screen and make a judgment as to which type of analysis might be applicable. The categories were: Liquid Chromatography, Gas Chromatography, Infrared Spectroscopy, Ultraviolet Spectroscopy, Visible Spectroscopy, Titration Tests, Appearance Tests, Color Tests, Hydrolysis and Stability Tests, and Other Tests. From this CATEGORY screen they could select the desired category, which brought them to a list of the test methods in that category. From here they could select and browse test methods to determine which one might be applicable. They could quickly jump back and forth between the test methods and the category screen from which they could select another test method for browsing.

The hyperdocument did not support graphic screen mode so instrument scans could not be directly included. This could, however, have been accomplished through an add-on program to display scanned-in images. This was tried with a few infrared and chromatograph scans during development. The researcher decided not to do this for the study for two reasons: 1) scanning, configuring, and maintaining the images would have required too large an investment of time and effort; and 2) the scanned and rescaled images on the computer screen were rather difficult to directly compare with a paper copy -- it was difficult to overlay a sample scan with an actual scan to line up peaks for comparison.

When users first accessed the hyperdocument they were presented with an introductory screen with copyright information. They were prompted to press <RETURN> which brought them to the first help screen. Figure 2 is a screen capture of the first help screen and it illustrates the general structure of the hyperdocument. Experienced users could bypass the help screen by selecting from the menu items which appeared at the top of every screen.

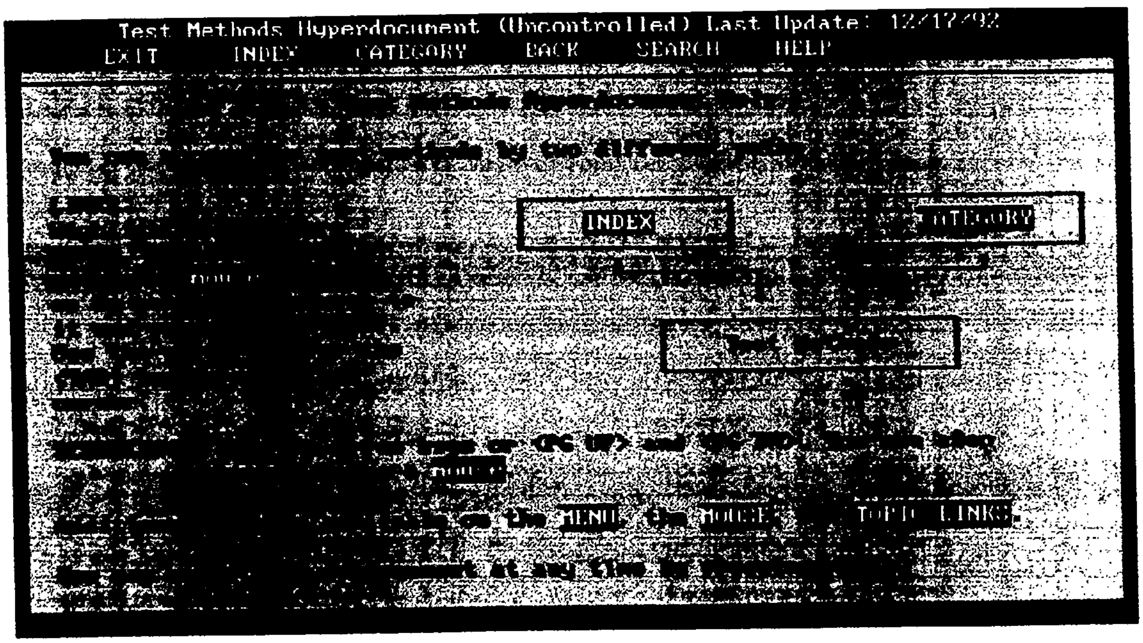

Figure 2. Screen Capture of a Sample Screen from the Hyperdocument.

This screen (Figure 2) was the root card for a short tutorial on hyperdocument usage. Users needed only to read this screen and activate its embedded hyperlinks to become familiar with searching, scrolling, operating a mouse, and navigating the hyperdocument.

Users could access specific test methods by either of two paths -- through the INDEX or through the CATEGORY selection. This simple structure was illustrated graphically on the screen shown in Figure 2.

Field Data

The researcher recorded observations and occurrences in a notebook during field implementation of the hyperdocument. A summary of the notebook entries was included in Appendix D. The entries were categorized by subject and include a date where appropriate.

The hyperdocument was officially put into service on September 15, 1992, and usage was closely monitored through December 17, 1992. Observations indicated that usage levels reached a plateau a few weeks into the implementation so it was decided that three months was sufficient time for the evaluation. The hyperdocument was installed on the plant LAN so that anyone could access it. In addition, a copy on a floppy disk was sent to the laboratory at GE Specialty Chemicals' (GESC's) Application Development Center (ADC) in Parkersburg, West Virginia.

On September 17, the researcher attended the QC Team's monthly meeting and introduced the team to hyperdocument usage. On the same day the hyperdocument was installed on the PC in the lab where the QC team could use it in their daily work. This PC was not attached to the LAN so a separate copy of the hyperdocument had to be installed on its hard drive. Initial responses were either favorable or nonexistent. Some people said things like "Great" or "I'll be able to use this." Others said little or nothing about the hyperdocument.

In the first three weeks of the study, six people asked how to access the hyperdocument or asked the researcher to set up their PC to access it. A chemist visiting from the GESC lab in Bergen-Op-Zoom (BOZ), The Netherlands, saw the hyperdocument in use and asked that a copy be sent to that European facility.

Initial Reactions to the Hyperdocument

In the first week of implementation, three individuals who had their own PC asked how to set up their machine to access the hyperdocument. When they were shown how it could be used, they expressed a positive attitude toward the hyperdocument. One technician made comments such as "Far out" and "Great." Another said, "I'll be able to use this." The third individual was not present when the hyperdocument was set up on his PC. He said later that he found the hyperdocument impressive, but did not have much need to use it in his daily work. Within the next two weeks, three more people asked how to set up their office PC to access the hyperdocument. They were told how to do it and they did it themselves so the researcher was not present to record their initial reactions.

Apparently, all six of these people initially felt that the hyperdocument had some value to them. At least one of them, however, found that he did not routinely need to use the hyperdocument. The most likely reason was that his daily activities did not often require him to look up a test method. That person was one of the management people in the lab so he did not perform lab work (or look up test methods) as often as would a technician.

During the demonstration for the QC team, responses were either favorable or nonexistent. Two of the five technicians expressed positive attitudes toward the hyperdocument. One said, "That's great." The other said, "Pretty nice." The other three technicians made no comments one way or the other.

Usage Logging

Automated logging of usage was tried early in the study. This would have provided some hard data on time of usage, length of sessions, and number of keystrokes per minute. To do this on the networked version of the hyperdocument, everyone would have required *write access* to the hyperdocument file service. Since this would have allowed anyone to accidentally delete the hyperdocument file, it was not done. Automated logging was set up on the non-networked lab PC, but was later deinstalled as it gave spurious results. Even if it had functioned properly, it would not have provided much information that was not collected by other means such as observations and interviews. This was also the conclusion of Shneiderman, et al. (1989) in the museum trials. The automated logging trial, however, did tend to confirm the observation that the hyperdocument was not heavily used. There were times when no one accessed it for several days.

Maintenance

The researcher gained considerable experience in what was necessary to maintain the hyperdocument. During the study, some forty test methods were altered to conform to ISO-9000 standards. Updating was usually accomplished by deleting the entire test method in the source file and then inserting the new ASCII source file that had been previously downloaded from the VAX. Updating was occasionally done section by section for a particularly long method or one that had changed very little -- when doing this, however, the researcher had to read very carefully through the entire method to ensure that no updated items were missed and that technical information was accurate. An important consideration here was extended characters.

When the word processing document was converted to ASCII format, extended characters such as the degree sign (°) or plus-or-minus (±) were not translated correctly. The degree sign, for instance, translated as zero (0). This made 30°C into 300C -- a very significant difference that could be a safety concern. WordStar's search function was used to find and correct these, but it was still a tedious and time-consuming process.

Updating took an average of about fifteen minutes per test method. This included downloading, editing the source file, compiling, checking for errors, and recompiling. With forty-one methods updated over a course of twelve weeks, slightly less than one person/hour per week was spent in maintaining the hyperdocument. This would usually be less as there was an abnormally large number of ISO-9000 updates during the study.

Observations and Discussions

There were no structured observations of usage. During the study the researcher casually observed hyperdocument usage and occasionally initiated discussions of the hyperdocument. The hyperdocument was simply *made available* to technicians. In this way, their usage or non-usage indicated how appropriate they felt the hyperdocument was for documenting test methods.

The participants at the ADC in Parkersburg and at BOZ in the Netherlands could not be observed while using the hyperdocument. Their questions and comments, however, indicated that they were more interested in printing hardcopies than in using the hyperdocument as online documentation. Users at both of these sites asked how to print methods from the hyperdocument. A user at BOZ commented that they had determined how to import test methods from the hyperdocument into Wordperfect.

Eight of the seventeen participants in the Morgantown lab (47%) said that they liked the hyperdocument. One technician went so far as to say, "I like the hyperdocument better than the methods book." Another said, "It's very easy to use." Many *comments* were favorable; but *usage* was minimal. People said they liked using the hyperdocument -- they just did not use it very often. The discussions conducted throughout the study (see Appendix D) revealed 11 clearly positive comments and 10 clearly negative comments.

Six (60%) of the negative comments were essentially security concerns. These were not concerns about release of proprietary information, but dealt with procedures for updating. Three of the participants felt that there was too much potential for someone to inadvertently use an out-of-date method. Unfortunately this did happen. During the study, the hyperdocument was maintained "outside" the usual test updating procedure. There was a written ISO-9000 procedure for updating hardcopy test methods, but the hyperdocument was maintained solely by the researcher on a trial basis. In the first four weeks of the evaluation, 18 test methods were found to be out-of-date in the hyperdocument due to the researcher not having been notified of the changes. This probably led to the security concerns of the three individuals. However, if the hyperdocument had been accepted and made a permanent part of the written updating procedure, this occurrence would be very unlikely (there were no occurrences of out-of-date methods in the final eight weeks of the study).

The other negative comments concerned 1) resistance to change, 2) not enough time, 3) inconvenient location (of the lab PC), and 4) absence of graphics. One technician stated that, "Old habits die hard -- I probably would not use the hyperdocument unless the methods book was taken out of the laboratory." Another said he did not "have time" to use the hyperdocument and that he did not "have to look up many methods anymore anyway." On one occasion, the researcher observed that a technician had carried the entire methods book over to an instrument that was about two steps from the lab PC on which the hyperdocument was available. This indicated that at least one technician was unable to visualize how the hyperdocument could make a task easier. This observation and the comment about not having time to use the hyperdocument indicate that these two participants saw the hyperdocument as something *extra to have to do* rather than as a tool to better accomplish tasks. Out of the five technicians who work shift work in the lab, only one used the hyperdocument regularly. The other four used it very little if at all.

Almost everyone found the hyperdocument very easy to understand and learn how to use. The questionnaire responses supported this observation. Since there were so few problems with learning and understanding the hyperdocument, the ease-of-use principals employed in its structure and design apparently worked. Except for printing from the hyperdocument (which was not an intended purpose), everyone who used it was able to quickly grasp its operation.

There were four requests concerning how to print from the hyperdocument. While it was possible to print a test method using the hyperdocument, this capability was not stressed. Pressing <P> while a method was displayed would do this, but this capability was not included on the menu nor was it included in the help screens. It probably should have been as this was what some users needed (particularly those at the ADC and BOZ where, before the hyperdocument, there was no comprehensive documentation of these test methods). As one technician commented, "It is sometimes necessary to have a hardcopy of all or part of a test method to carry over to an instrument for typing in parameters or for verifying complex procedures." On the other hand, another technician felt that ISO-9000 would not allow numerous hardcopies to be lying around and possibly be out of date. These requests to print, again, demonstrated the apparent inability of some of the subjects to visualize the hyperdocument's unique capabilities (such as searching and quick lookup). The participants at the ADC and BOZ seemed to view the computer as a tool for creating paper documentation rather than as a tool for storing information for online viewing.

Analysis of Questionnaire Responses

Twenty questionnaires were distributed: sixteen to personnel in the Morgantown lab, two to the ADC lab in Parkersburg, and two to the lab at BOZ in Europe. Names were not requested, but four of the respondents signed their questionnaires. Fifteen (75%) were returned. Unanswered questions were included in the tabulations as "Missing", but these were ignored for the analyses. The responses from the questionnaire were tabulated using CSS:Statistica (a statistical analysis software package) and were listed in Appendix E.

Demographics

Questions 1 through 5 dealt with demographics.

Question 1 -- What is your highest level of education? Only 2 participants (13%) indicated that high school was their highest level of education. Four (27%) had taken some college courses. Three (20%) had a bachelor's degree, 3 (20%) had done some graduate work, and 3 (20%) had a graduate degree. Therefore, the participants had a fairly high level of education with 9 (60%) having a bachelor's degree or higher and with another 4 (27%) having had at least some college.

Question 2 -- How long have you worked in a laboratory? No one indicated that they had less than one year's lab experience. Three participants (20%) indicated that they had 3 to 6 years lab experience, 1 (7%) indicated 6 to 10 years, and the remaining 11 (73%) had worked over 10 years in a lab. The participants clearly represented a group who had a fairly large amount of laboratory experience.

Question 3 -- How would you rate your ability with computers? Four participants (27%) rated themselves as beginners. Another 4 (27%) indicated that they were somewhat experienced. Six (40%) rated themselves as experienced while 1 (7%) rated him or herself as very experienced. No one rated themselves as expert. Although there was a fairly wide range of computer experience among the participants, most (73%) tended to view themselves as having more than a beginner's level of experience.

Question 4 -- How well do you like computers? One participant (7%) indicated that he or she hated computers and one other (7%) chose dislike computers. Two (13%) were indifferent toward computers. Nine (60%) said they liked computers and 2 (13%) said they liked computers very much. Again there was a wide range of responses, but most (73%) had a definite positive attitude toward computers -- they either liked them or liked them very much.

Question 5 -- How long have you been using computers? No one indicated that they had less than one year's computer experience. One respondent (7%) indicated 1 to 3 years of computer experience. Seven participants (47%) had been using computers for 3 to 6 years, 4 (27%) had used them for 6 to 10 years, and 3 (20%) had used computers for more than 10 years. The participants were clearly not strangers to computers, only 1 person (7%) had used them for less than 3 years.

Usability

Questions 7, 8, 9, 10, 13, 15, 17, and 19 dealt with usability of the hyperdocument.

Question 7 -- The process of starting the hyperdocument or "getting it on the screen" was: Seven people (50%) said that they found starting the hyperdocument to be very easy. (This is the first question for which there was a missing response so the percentages will begin to vary from previous questions because the missing responses were ignored in the tabulations.) Six (43%) found starting the hyperdocument somewhat easy. One (7%) had no opinion. No one said they found it somewhat difficult or very difficult to start the hyperdocument. A clear majority here (93%) found the hyperdocument somewhat easy to very easy to start. This strongly supports the observations that the hyperdocument was an easy-to-use tool.

Question 8 -- Finding what you were looking for in the hyperdocument was: Five participants (36%) indicated that it was very easy to find what they were looking for in the hyperdocument and the other 9 (64%) felt that it was somewhat easy. No one said they found it somewhat difficult or very difficult to find what they were looking for in the hyperdocument and no one indicated they had no opinion. All the respondents found it very easy to somewhat easy to find what they were looking for in the hyperdocument. Again, this strongly supports the observation that the hyperdocument was an easy-to-use tool.

Question 9 -- How did you find the operation of the hyperdocument the first time you used it? Eight respondents (57%) said that they found hyperdocument operation very understandable the first time they used it. Five (36%) said they found it somewhat understandable. One person (7%) indicated no opinion. No one said they found it somewhat confusing or very confusing. A large majority (93%), of the respondents found operation of the hyperdocument very understandable to somewhat understandable the first time they used it. Once again, this strongly suggests that the hyperdocument was easy to use.

Question 10 -- How did you find the operation of the hyperdocument after you became experienced with it? Eleven (79%) indicated that they found hyperdocument operation very understandable after they became experienced with it. Two (14%) said they found it somewhat understandable. One (7%) had no opinion. No one said they found it somewhat confusing or very confusing. A large majority (93%), found operation somewhat easy to very easy after some experience.

Question 17 -- How cumbersome was the hyperdocument to use? Twelve respondents (86%) indicated that they found use of the hyperdocument not cumbersome at all. Two (14%) said they found it slightly cumbersome. No one chose the last three responses: quite cumbersome, very cumbersome, or almost impossible to use.

The responses to all the above usability questions clearly indicate that the hyperdocument was easy to use. Participants found it easy to use at first and even easier after they had used it more. They had little difficulty starting the hyperdocument and finding what they were looking for in it. The on-screen instructions, screen appearance, and structuring techniques suggested in the literature were apparently valid.

Question 13 -- How much did you enjoy using the hyperdocument? Two respondents (14%) said they enjoyed using the hyperdocument very much. Six (43%) said they enjoyed it somewhat. One person (7%) said he or she did not enjoy it very much. Five (36%) had no opinion. A majority (57%) of the respondents, then, either enjoyed using the hyperdocument very much or somewhat enjoyed using it. This tended to indicate that the hyperdocument was easy to use, but may also have been a measure of the number of participants who enjoy doing anything with computers.

Question 15 -- Compared to paper documents, how easy or difficult was the hyperdocument to maintain? Two respondents (14%) indicated that it was very easy to maintain the hyperdocument. Another 2 (14%) said it was somewhat easy. Nine people (64%) said they did not know how difficult it was to maintain the hyperdocument. One person (7%) said the hyperdocument was somewhat difficult to maintain and no one said it was very difficult. The researcher performed all the maintenance so it was not surprising that the majority of participants (64%) did not know how easy or difficult it was to maintain. The purpose of this question was to get some indication of how lab personnel *perceived* hyperdocument maintenance. While most did not have an answer, those who did have one tended to think the hyperdocument was relatively easy to maintain.

Question 19 -- Which access method did you use the most? Seven respondents (54%) accessed the hyperdocument mostly on the lab PC while six (46%) used another PC -- probably the PC in their office.

Usefulness

Questions 6, 11, 12, 14, 16, and 18 concerned usefulness of the hyperdocument.

Question 6 -- How often did you use the hyperdocument? No one said they used the hyperdocument once per hour. One person (7%) responded that he or she used the hyperdocument one to several times per shift. Two (13%) said they used it one to several times per week. Ten (67%) indicated that they used the hyperdocument less than once per week and 2 people (13%) said that they never used it. This question was intended to indirectly assess usefulness. Frequent usage would have implied that participants thought the hyperdocument was useful. The five QC Team technicians were probably the only participants who had the potential to routinely use test method documentation once per hour or one to several times per shift. The other participants would probably access test method documentation no more than one to several times per week anyway. The responses to Question 6, then, tend to make hyperdocument usage levels appear low. However, for 11 (69%) of the participants, usage was probably not much less than would have been usage of paper documentation if only that had been available.

Question 11 -- How useful was the hyperdocument? Four people (29%) felt the hyperdocument was very useful. Five (36%) felt it was somewhat useful. Another 5 (36%) had no opinion. This was probably one of the most important questions on the questionnaire as a key inquiry of the entire study was to determine hyperdocument usefulness. The somewhat large number of respondents who had no opinion (36%) may be a result of the low usage levels. These five probably felt that they had just not used the hyperdocument enough to make a judgment. A majority of participants however (64%), felt that the hyperdocument was somewhat useful to very useful.

Question 12 -- Would you like to continue using the hyperdocument? Six participants (43%) said that they would like to continue using the hyperdocument and 2 people (14%) said they would if some changes were made. Four (29%) had no opinion one way or the other. No one said they felt more training was needed for usage to continue. Two (14%) said they would prefer *not* to continue using the hyperdocument. So a slight majority, eight participants (57%), said that they would like to continue using the hyperdocument.

Question 14 -- Does the hyperdocument satisfy ISO-9000 documentation requirements? None of the respondents felt that the hyperdocument (as is) would satisfy ISO-9000 documentation requirements. Five (33%) said it could with some changes. Nine (60%) did not know. No one said that the hyperdocument needed a lot of changes and no one said that it did not fit ISO requirements at all. So a majority did not know if the hyperdocument satisfied ISO-9000 documentation requirements while 33% felt that it could with some changes.

Question 16 -- How concerned are you about the security of test methods? Four participants (27%) were not concerned at all about test method security. Three (20%) were very concerned, and eight (53%) had no opinion. So a majority (80%) were not concerned or had no opinion while a few (20%) were very concerned.

Question 18 -- Would you recommend using *only* the hyperdocument for documenting test methods? Two respondents (14%) recommended using only the hyperdocument in the future while six (43%) had no opinion. Three people (21%) said they would *not* recommend using only the hyperdocument. Unfortunately, the researcher neglected to include a "both" response to Question 18 and three respondents (21%) wrote one in so these were included in the tabulations. There may, of course, have been more people choose the both response had it been available.

Spearman Rank Order Correlations

Using CSS:Statistica, the questionnaire responses were analyzed by Spearman Rank Order Correlation. Several significant correlations were discovered and are shown in Table 1.

		Valid	Spearman		
Pair of Variables		N	R	t(N-2)	p-level
QUESTION 3 &	QUESTION 4	15	.760140	4.21805	.001005
QUESTION 11 &	QUESTION 12	14	.870855	6.13729	.000050
QUESTION 11 &	QUESTION 13	14	.868183	6.06048	.000057
QUESTION 12 &	QUESTION 13	14	.820373	4.96977	.000325

Table 1: Significant Correlations of Questionnaire Responses

The correlation between Question 3 (Rate your ability with computers) and Question 4 (How well do you like computers?) indicates that the respondents who viewed themselves as having some computer expertise also tended to like computers. Question 11 (How useful was the hyperdocument?) correlated very well with Question 12 (Would you like to continue using the hyperdocument?). This correlation is illustrated in Figure 3, X-Y Plot of Correlation between Questions 11 and 12.

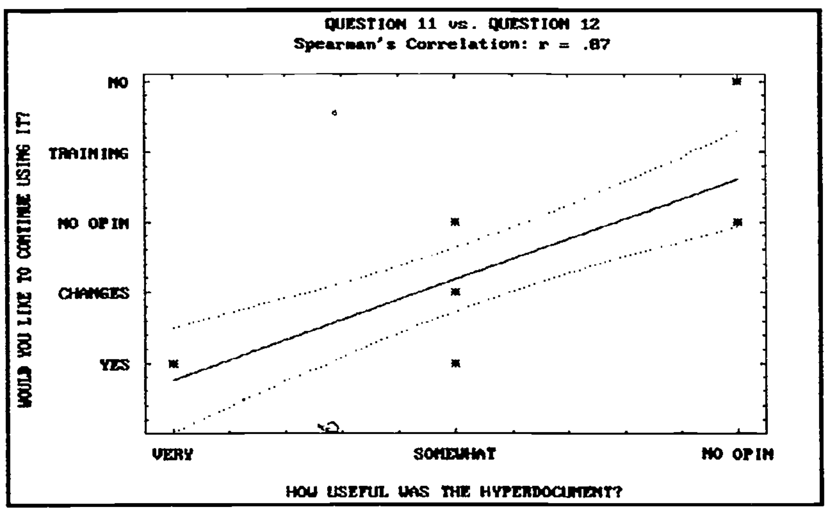

Figure 3. X-Y Plot of Correlation between Questions 11 and 12

Clearly those participants who viewed the hyperdocument as useful would have liked to continue using it. Similarly, Questions 11 and 12 also correlated well with Question 13 (How much did you enjoy using the hyperdocument?).

Comments Handwritten on Questionnaires

There were seven questionnaires with handwritten comments on them. These verbatim comments were included in Appendix E. Much of what was observed during the study was mirrored in these comments. Four of these comments were concerned with the timely and organized updating of test methods. Two comments concerned the occasional need for paper copies.

One respondent expressed concern over the use of both the <ALT and <CTRL> keys for commands, but the <CTRL> key was not used in HyperHelper and has no effect. Apparently this user did not completely understand the hyperdocument operation. This indicated that there may have been some shortcomings in the online tutorial and help screens. This happened to be one of the European users so another possibility was that the keyboard of the particular computer they were using functioned differently than most keyboards.

One respondent pointed out that he or she spent much time writing and revising methods. This person liked the search capability, but did not find much use for it. He or she also stated that flipping through paper pages was quicker than scrolling through hyperdocument screens. This person also felt that the hyperdocument would be more useful if it provided both editing/printing *and* searching/viewing capabilities.

One of the respondents outlined the discussion of the hyperdocument that occurred at a QC Team meeting. The team reached the conclusion that the cost of maintaining the hyperdocument outweighed its benefits so they recommended not to continue using it. This respondent was the one QC Technician who used the hyperdocument extensively. He also said that if the other members of the QC Team had used the hyperdocument more, they could have better realized its benefits and their decision may have been different.

CHAPTER 5

CONCLUSIONS, SUMMARY, AND RECOMMENDATIONS

Conclusions

This section will present the conclusions to the study questions listed in Chapter 1.

What problems were encountered in creating the hyperdocument and how were they solved?

The first step in creating the hyperdocument was to select a hypertext development system. Based on cost and availability considerations, three shareware systems were chosen to be evaluated. HyperHelper provided the best user interface because it ran quickly on any computer, it allowed the development of customized menus that were less confusing for users, and it was equally usable with either a mouse or the keyboard. In addition, HyperHelper provided somewhat superior ease of development as it required a minimum of reformatting to convert ASCII files to an uncluttered screen presentation. It was concluded that HyperHelper should be used because it best served the needs of the project.

The next step was creation of the hyperdocument. Some 150 test methods were downloaded from a VAX word processor to a PC and then combined into a source file using a PC based word processor. This process was aided significantly by using each word processor's macro utility. Also very helpful was loading HyperHelper's online manual as a TSR that could be accessed (to look up compiler commands) while editing the source file. Therefore, it was concluded that a thorough knowledge of the software used (both the hypertext development system and any text editor) can be of much help in the creation of a hypertext application.

Hyperdocument structure was also considered during creation. It was concluded that each test method should be one card so that users would not be able to jump, for example, directly to the PROCEDURE section of the test method and skip important sections such as SCOPE or SAFETY. It was concluded that the hyperdocument should provide users with both index and category methods of searching and that these features should be graphically communicated to users within the application (see Figure 2).

According to the questionnaire responses, everyone (100%) found it easy to find what they were looking for in the hyperdocument, 93% found its operation understandable the first time they used it, 86% found it not cumbersome at all, and 57% even said they enjoyed it. Therefore, it can be concluded that the structuring techniques enabled the hyperdocument to do what it was designed to do -- allow fast and easy access to test method documentation.

What problems were encountered in implementing the hyperdocument and how were they solved?

A primary consideration in implementation was to provide ready access to the hyperdocument. This was done by using the plant LAN and one non-networked PC in the laboratory. None of the participants indicated that they had difficulty in accessing the hyperdocument so it was concluded that a LAN was an excellent way to provide access to online information.

Another consideration in implementation was how to get people to use the hyperdocument. It was concluded from the observations and questionnaire responses that the hyperdocument was easy to use, but was not used extensively by many of the participants. The data indicated that, even though a tool works and is useful, its potential users must *perceive* it as such before they will accept it and use it.

Was the hyperdocument readily accessible to those who needed it?

The hyperdocument was installed on a LAN and so was fairly easy for everyone to access from their office PC's. The lab PC, on which the hyperdocument was accessed more than any other one PC, was centrally located and was usually available for use. None of the participants indicated that they had any difficulty in accessing the hyperdocument so it was concluded that it was readily accessible.

Was the hyperdocument readily maintainable/updatable?

For the documentation in this study, it took an average of about 15 minutes to update one test method in the hyperdocument. During the study, this amounted to about one person/hour per week as there was an unusually large number of methods updated. This was probably not an unreasonable amount of time and effort to be invested so it was concluded that the hyperdocument was readily maintainable and updatable.

Was the hyperdocument secure?

This question was posed to users on the questionnaire and only 20% felt that the hyperdocument was not secure. This question had two aspects. First, could someone outside the company have accessed proprietary test method information; and second, could an unauthorized person have altered a test method? The information in the hyperdocument was as secure as any of the information (much of it proprietary) that was stored on the LAN. As for unauthorized altering of test methods, this was very unlikely with the software used in this study. The hyperdocument was in binary format and one must have access to the source file and to the compiler to alter it in any way. Therefore, based on these facts and on the questionnaire responses, it was concluded that the hyperdocument was secure.

Did laboratory personnel find the hyperdocument an appropriate way to document analytical test methods at GE Specialty Chemicals?

Only 3 questionnaire respondents (20%) used the hyperdocument every week during the study. The raw data from usage levels, however, are somewhat misleading. Due to the nature of their work, 11 of the 16 Morgantown participants (69%) probably did not have the need to access test method documentation every day or even every week. In addition, hyperdocument usage was fully optional so the motivation to use it came primarily from curiosity or from the desire to try something new. Nine questionnaire respondents (64%) said the hyperdocument was useful and 8 (57%) said they would like to continue using it. Considering all the above data, it is reasonable to conclude that laboratory personnel did find the hyperdocument an appropriate way to document test methods.

Did the hyperdocument meet requirements for international documentation standards (specifically -- ISO-9000)?

Most (60%) of the questionnaire respondents did not know the answer to this question while five of them (33%) said that it could with some changes. The researcher discussed this with managers and with others who were familiar with ISO-9000 and concluded that the hyperdocument was compatible with ISO-9000 documentation standards.

Summary

The overall problem of this study was to develop and implement a hypertext documentation system for an industrial laboratory and to evaluate its usefulness by participative observation and a questionnaire. There were several important findings concerning the creation and maintenance of the hyperdocument. Overall, it was found to be a useful and effective tool.

Hyperdocument Creation

The first step in the hypertext project was to plan exactly what was to be done. Needs were assessed, and goals and objectives were set. The intended users' needs were paramount -- especially what the users *perceived* as their needs. Most of the participants liked the hyperdocument and found it useful. Many failed, however, either to see its usefulness or to accept its usefulness. It may be that the participants were not ready to accept online documentation. They saw the computer more as a tool with which to create paper documentation (a typewriter) rather than as a medium in which to store and read information.

The process of converting word processing documents into source file format was a major part of this project. One of the key aspects of this process was that the hypertext developer needed to have a thorough grasp of the technology being used. This process of editing a large file can be very tedious and time consuming, but it can be greatly enhanced by using the software's capabilities to the fullest. Most text editing software packages have macro capabilities, a search and replace function, a copy and paste function, and so on. If the developer is well-versed in using these capabilities, the hyperdocument creation process can be done much more efficiently (this is also true for maintaining and updating). Whenever the developer finds that a task seems very tedious or repetitive, it is time to open the manual, to read help screens, or to simply ask, "Is there a better way to do this?" Any time spent in learning what the software can do will be time well spent and will save much effort.

Maintenance

The data collected in this study led to the conclusion that the hyperdocument was readily maintainable/updatable. However, the effort required to maintain it was not enough to justify its continued use. People were not using it enough to make it worthwhile. One of the primary reasons the QC team recommended not to continue using the hyperdocument was the time required to maintain it. They felt that the benefits did not justify the costs. This tends to support McMurray's (1990) conclusion that maintenance of a hyperdocument can be a major task. She points out that complex hyperdocuments (that is, ones with many hyperlinks) would be significantly difficult to maintain. A hyperdocument, however, that is relatively simple (like that in the present study) may not be unreasonably difficult to maintain -- especially if a paper version of the document is widely distributed. If there are 10 widely distributed hardcopies that must be updated every time there is a change, one copy of a widely accessible hyperdocument may be easier to maintain.

Another maintenance-related consideration was the software being used. HyperHelper, like many hypertext development systems, requires a multi-step process to update a hyperdocument: 1) export from the word processor, 2) import into the source file, 3) reformat as necessary, 4) reinstall any hyperlinks, 5) compile the source file, and 6) if necessary, fix any errors and recompile. Obviously, if any of these steps is eliminated, maintenance time will be reduced. The time required to compile the source file could probably have been reduced somewhat by breaking the source file up into smaller files to be recombined when compiling. This would have reduced the time needed to write the source file to disk after each update. An even better solution might be a different system.

There are systems available that can combine the word processing function with the hypertext function. In other words, the actual word processor could be accessed in a read-only mode and utilized as a hyperdocument. In this way, there need only be one file on the computer and one software application in use. When the word processing document is updated, the hyperdocument is already updated and only needs to have hyperlinks reset.

Usefulness

Discussions indicated that accessibility could probably have been enhanced by better integration with the LIMS. One way to have done this would have been to locate the lab PC next to the LIMS terminal (the lab PC was about ten steps from the terminal). This was discussed, but would have required significant rearrangement of lab equipment to make room. For this reason, it was not done. Another way would have been to set up the lab PC as the LIMS terminal. That way, technicians could have actually "popped up" the test methods while using the LIMS. This was discussed rather late in the study, but was not done due to the time and effort required. Either of these options would have made the hyperdocument somewhat easier to access and may have increased its usage. The hyperdocument was accessible to those who needed it, but it could have been made even more accessible by better integration into the LIMS system already in place.

During this study, there were three separate computer applications used to document and access test methods: the word processor, the hyperdocument, and the LIMS. If these were integrated so that they were readily available on every terminal or PC, their combined value could exceed their separate values. For example, the test method documentation system was set up so that the QC technician entered the sample information into the LIMS. The LIMS specified what tests had to be performed on what samples by showing the test method number. The technician then had to walk to the methods book or hyperdocument PC if he or she needed to look up the test method. Why not integrate the two systems so that if the technician wants to read a method, it can be directly accessed by the LIMS? To carry this to the next step, the appropriate personnel could be given the access privileges to edit and update the methods on the same system. Anyone would be able to print methods or portions of methods as necessary. According to what was learned in this study, an integrated system such as this would serve everyone's needs in the most efficient and cost-effective manner.

Observations and the questionnaire responses indicated that the hyperdocument was not difficult to learn how to use nor was it difficult to use. The appearance, structuring, and help screens enabled the hyperdocument to do what it was designed to do -- enable users to easily search for and find test methods, but most participants used it relatively little. Observations indicated that since users could not see how the hyperdocument could help them, they chose to use paper documentation instead. Training should have been incorporated to get users to understand how their work could be made easier rather than more difficult. The training provided in this study concentrated more on how to operate the hyperdocument rather than on what it could do for users. It was left to users to visualize the possibilities for time and work savings. However, usage levels indicated that many were unable to do that. Many participants seemed to view the hyperdocument as something *extra* to do rather than as a tool to make life easier. The training should have included specific examples of how to better accomplish tasks using the hyperdocument.

To sum up; the hyperdocument was found to be a usable, useful, and effective tool for documenting test methods. From a business perspective, though, its use was not continued due to the time and effort required to maintain it. However, a LIMS-integrated system that would allow reading, viewing graphics, editing, and searching may have been found more appropriate (and worth maintaining) because it would have better served more users' needs in a cost-effective manner.

Business managers are sure to become more aware of the benefits of online documentation or hyperdocuments such as time savings, cost savings, and environmental soundness (reduced energy and paper usage). As this happens, many more online documentation systems will be put into place in business and industry. It makes sense to ensure that they are created and implemented in ways that truly benefit users and their respective businesses.

Recommendations for Further Research

There was very little published literature on studies similar to this one. More is needed -- not only to verify what was found in this study, but also to investigate hypertext's value in other similar situations (recipes in a large restaurant for example). Therefore, it is recommended that the following research be undertaken:

1. Duplicate the investigation in this study of a relatively simple reference database of procedural documentation.
2. Evaluate a laboratory documentation system that combines word processing, hypertext, graphics, and LIMS technologies into one integrated system.
3. Conduct a comparative study in which one group of hypertext users is given operational training only (as in this study) and another group is given operational as well as usefulness training.
4. Conduct a comparative study in which hypertext is directly compared with paper documentation in a situation similar to the one in this study.

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APPENDIX A

The Questionnaire for this Study

Test Method Hyperdocument Evaluation

Please mark the best answer.
Feel free to add comments.

1 . What is your highest level of education?

[ ] A. High School
[ ] B. Some College
[ ] C. Bachelor's Degree
[ ] D. Some Graduate Study
[ ] E. Graduate Degree

2 . How long have you worked in a laboratory?
(This means the total of all your lab experience.)

[ ] A. less than 1 year
[ ] B. 1 to 3 years
[ ] C. 3 to 6 years
[ ] D. 6 to 10 years
[ ] E. over 10 years

3 . How would you rate your ability with computers?
Choose one.

[ ] A. Beginner
[ ] B. Somewhat experienced
[ ] C. Experienced
[ ] D. Very experienced
[ ] E. Expert

4 . How well do you like computers?

[ ] A. Hate computers
[ ] B. Dislike computers
[ ] C. Indifferent toward computers
[ ] D. Like computers
[ ] E. Like computers very much

5. How long have you been using computers?

[ ] A. Less than 1 year
[ ] B. 1 to 3 years
[ ] C. 3 to 6 years
[ ] D. 6 to 10 years
[ ] E. More than 10 years

6. How often did you use the hyperdocument?
(please choose the answer that most *closely* describes your usage)

[ ] A. Once per hour
[ ] B. One to several times per shift
[ ] C. One to several times per week
[ ] D. Less than once per week
[ ] E. Never

7. The process of starting the hyperdocument or "getting it on the screen" was:

[ ] A. Very easy
[ ] B. Somewhat easy
[ ] C. No opinion
[ ] D. Somewhat difficult
[ ] E. Very difficult

8. Finding what you were looking for in the hyperdocument was:

[ ] A. Very easy
[ ] B. Somewhat easy
[ ] C. No opinion
[ ] D. Somewhat difficult
[ ] E. Very difficult

9. How did you find the operation of the hyperdocument the first time you used it?

[ ] A. Very understandable
[ ] B. Somewhat understandable
[ ] C. No opinion
[ ] D. Somewhat confusing
[ ] E. Very confusing

10. How did you find the operation of the hyperdocument after you became experienced with it?

[ ] A. Very understandable
[ ] B. Somewhat understandable
[ ] C. No opinion
[ ] D. Somewhat confusing
[ ] E. Very confusing

11. How useful was the hyperdocument?

[ ] A. Very useful
[ ] B. Somewhat useful
[ ] C. No opinion
[ ] D. Not very useful
[ ] E. Useless

12. Would you like to continue using the hyperdocument?

[ ] A. Yes, I would like to continue using it
[ ] B. Yes, if some changes are made
[ ] C. No opinion
[ ] D. Yes, if more training were provided
[ ] E. No, I would *not* like to continue using it

13. How much did you enjoy using the hyperdocument?

[ ] A. Enjoyed it very much
[ ] B. Enjoyed it somewhat
[ ] C. No opinion
[ ] D. Didn't enjoy it very much
[ ] E. Hated using it

14. Does the hyperdocument satisfy ISO-9000 documentation requirements?

[ ] A. Yes, very well
[ ] B. It could, with some changes
[ ] C. Don't know
[ ] D. It could, with a lot of changes
[ ] E. No, it does not fit ISO requirements at all

15. Compared to paper documents, how easy or difficult was the hyperdocument to maintain?

[ ] A. Very easy
[ ] B. Somewhat easy
[ ] C. Don't know
[ ] D. Somewhat difficult
[ ] E. Very difficult

16. How concerned are you about security of the test methods (for example, could someone easily alter a test method without going through the proper procedure)?

[ ] A. Not concerned at all, the documentation is very secure
[ ] B. No opinion
[ ] C. Very concerned, anyone can alter a test method

17. How cumbersome was the hyperdocument to use?

[ ] A. Not cumbersome at all
[ ] B. Slightly cumbersome
[ ] C. Quite cumbersome
[ ] D. Very cumbersome
[ ] E. Almost impossible to use

18. Would you recommend using *only* the hyperdocument for documenting test methods and doing away with the methods book (except for the master copy in Win's office)?

[ ] A. Yes, we should do away with the methods book and use only the hyperdocument
[ ] B. No opinion
[ ] C. No, we should keep the methods book and not use the hyperdocument

19. Which access method did you use the most?

[ ] A. The main data terminal
[ ] B. Another PC
[ ] C. The laptop

Comments:

APPENDIX B

An Example Test Method

Quality Control Method T-115
Supersedes: T-115, 05-01-1992
Issued: 05-11-1992

Acid Number Determination of Organic Compounds

Method:

The acid content of an organic compound is determined by measuring the equivalent amount of base necessary to neutralize a known amount of sample. This method as written is intended for compounds with low acid concentrations. High acid numbers may be determined by varying the sample size.

Equipment:

1 - 250 ml Erlenmeyer flask, Cat. No. 10-090B, Fisher Scientific 1981 or equivalent.
1 - 50 ml Buret, Cat. No. 03-843-1, Fisher Scientific 1981 or equivalent.
2 - Volumetric flasks 1-100 ml, 1-1 liter Cat. No. 10-210-8C Fisher Scientific 1981, Cat. No. 10-210-8G, Fisher Scientific 1981 or equivalent.
1 - Balance, Ohaus B300 or equivalent.

Reagents:

Phenolphthalein, Powder N.F., CAS # 00077-09-8 Arthur H. Thomas Co., Cat. # 2872, 1980 or equivalent.

Butanol - Anhydrous, reagent grade, CAS #71-36-3 Cat. No. A-399, Fisher Scientific, 1981 or equivalent.

Potassium Hydroxide - Cat. No. P-250, Fisher Scientific, 1981 or equivalent, CAS # 1310-58-3.

Preparation:

0.1% Phenolphthalein Indicator-Dissolve 0.1 gram Phenolphthalein indicator in Butanol and dilute to 100 ml.

0.02N KOH Solution - Dissolve 1.32 gm KOH (ACS, 85%) in methanol and dilute to 1 liter.

Standardize against standard 0.1N HCl.

Procedure:

1. Pour approx. 100 ml Butanol into a 250 ml Erlenmeyer flask and add 4-6 drops of 0.1% Phenolphthalein indicator solution.

2. Neutralize the alcohol with 0.02 N methanolic KOH to the PINK endpoint.

3. Add 8-12 grams of sample to the neutralized solution, swirl to effect solution and immediately titrate with 0.02N KOH to the same PINK endpoint.

Calculation:

$$A.N. = \frac{ml * N * 56.1}{wt.\ sample}$$

APPENDIX C

A Portion of the Hyperdocument Source File

#deck title Test Methods Hyperdocument (Uncontrolled) Last Update: 06/17/92

#default menu link 5

#menu !about_card!_! !$quit!E&XIT! !index!&INDEX! !category!&CATEGORY! !$undo!&BACK! !$srch!&SEARCH! !$help!&HELP!

#CARD !first!GE Specialty Chemicals Test Methods Hyperdocument! start begin

#cl Copyright (C) 1992, GE Specialty Chemicals

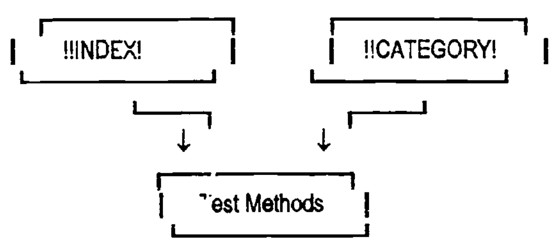
#cl Press <ENTER> to continue.

#cl !help!Continue!

#END

#CARD !@help!Test Methods Hyperdocument Help!
You can access the test methods by two different paths:

LINKS:
Highlighted words are LINKS. Select a link either by !!mouse!-clicking or by moving the cursor to it and pressing <RETURN>. Use the arrow keys or the <TAB> key to move the cursor.



SCROLLING: Use the arrow keys or <PG UP> and <PG DN>. You can also scroll using a !!mouse!.

Additional help is available on the !menuhelp!MENU!, the !!MOUSE!, and !topichlp!TOPIC LINKS!.

You may exit the hyperdocument at any time by pressing <ESC>.

#END

APPENDIX D

Summary of Notebook Entries

9/15/92 -- Officially put the hyperdocument in service. Distributed announcements to all lab personnel. Also sent a copy of the hyperdocument on a floppy disk to the lab at the Application Development Center (ADC) in Parkersburg, WV.

9/17/92 -- Made a presentation on the hyperdocument to the QC Team at their monthly meeting and gave them a demonstration. Set up the Lab PC with the hyperdocument.

Automated Logging

The networked hyperdocument. Attempted to set up automated logging on the networked hyperdocument. Would have had to allow read/write access to the hyperdocument drive for all users so that the data log could be recorded. This would have enabled anyone to accidentally delete the hyperdocument so automated logging was not set up on the networked hyperdocument.

The lab PC version of the hyperdocument. Installed a shareware automated logging system (LOGIT!) on the lab PC at 2:30 PM, 9/30/92.

10/1/92 - Ran the first LOGIT! report

10/21/92 - Ran a report. Found one instance of a huge number of keystrokes (1141 keystrokes in 0.05 minute or 22,820 per minute). Therefore, the believable data could not be trusted. Took LOGIT! off the lab PC and did not try automated logging again.

Updating

11/10/92. Added a new method -- T-362.

10/30/92. Updated 8 more methods -- about 2 hours to update.

Updated 6 test methods -- about 1 hour 45 minutes to update.

10/22/92. Updated T-85, T-89, T-94, and T-97 -- 1 hour to update.

11/13/92. Updated T-359.

11/20/92. Updated T-017, T-079, T-350, T-353.

Observations.

10/30/92. Observed that a technician had carried the entire test method book over to an instrument to run a test. There are no graphics involved in this method so the hyperdocument would have worked just as well and it was only about two steps from the instrument.

When walking through the lab and casually observing the lab PC, it appeared that there were times when the hyperdocument was not used for several days.

Problems Discovered

10/5/92. T-56 was discovered to be out-of-date - 20 minutes to update

10/6/92. Sixteen other methods were discovered to be out-of-date. Apparently these had been updated to conform to ISO-9000, but the usual notices to personnel were not sent out. These took about 3 hours 20 minutes to update.

10/13/92. T-352 was found to be out-of-date -- took about 50 minutes to update. There were two versions of this method in WPS-PLUS (a common problem with everyone having access to the methods files on the VAX. On 10/19/92 the VAX Methods account was altered so that only two people had access to it. The researcher was not one of them so the two were shown how to send a method file to the researcher's account for future updates.

Technical Concerns

For the mass (16 method) update, spent 15 minutes downloading in ASCII format. Spent a total of 3 hours 20 minutes updating the 16 methods and recompiling the hyperdocument - about 12.5 minutes per method. Range was from 4 to about 20 minutes per method. On a 386SX 16Mhz computer without disk caching, using WordStar, it took 1 minute 5 seconds to write the hyperdocument source file to disk. Saving the entire source file after each method was updated amounted to a total of about 17 minutes for the mass, 16 method update. On the same computer, it took 2 minutes 51 seconds to compile the hyperdocument source file into binary format.

When WPS-PLUS converts a document to ASCII, it changes the degree sign (°) to a zero (0). This is very important to watch for as 30°C, for example, comes out as 300C. Others are: ± is converted to + and μ comes out as u. When updating a method, it was very important to scroll through it first to visually look for extended characters (as above) that would have to be altered after the update. Wordstar's search-and-replace utility was used to facilitate this process. The researcher also had to look for hypertext links to other methods that had to be set up again after the update.

Hyperdocument Organization Concerns

The source file was about 600KB. It takes significant time to write to disk. It might have been worth the trouble to break it up into smaller files to be recombined when compiling.

10/13/92 - added a *Trademark Notice* card. Put links to it from all the trademark notices in the hyperdocument on 11/10/92..

Impromptu Discussion and Demonstration

12/3/92. The researcher demonstrated to two technicians how the hyperdocument could be set up as a TSR (terminate and stay resident program) on a PC being used as a data entry terminal for the LIMS. One of them made no comment while the other thought it was wonderful and was able to quickly grasp the implications for step-saving and time-saving.

Talked with him again on 12/29/92 - he brought up this capability in the QC technician meeting and they decided not to pursue setting up the hyperdocument in this way. In fact, they thought the hyperdocument should not be used at all. Only one of them (out of four) was using it regularly.

Verbal Comments

Positive Comments.

"Far out."

"Great."

"I'll be able to use this."

"That's great."

"Pretty nice."

Had one call from the ADC -- they'd like to set up their test methods similarly.

Sent copy of HyperHelper shareware version and explained briefly how to do it.

"I like the hyperdocument better than the methods book."

"I used it and liked it."

"It's very easy to find what you are looking for."

"It's very easy to use."

Negative Comments.

Three people expressed concerns about the ability to update copies "out of house" -- as in BOZ or ADC.

"Anyone can install it on their PC and not update regularly."

"ISO-9000 would require a written procedure updating."

"ISO-9000 would not allow unlimited hardcopies to be lying around."

"It would be nice to have scans (graphics) too."

"There were a few things I didn't understand when I first used the hyperdocument, but nothing serious."

"Old habits die hard -- I probably would not use the hyperdocument unless the methods book was taken out of the laboratory."

"I don't have time to use the hyperdocument. I don't have to look up many methods anymore anyway."

"The hyperdocument would be more convenient on the main data terminal (or adjacent to it) rather than on a PC which is about 10 steps out of the way when needing to look up a method."

General Comments

"A paper document is still necessary, for instance, so that you can carry a page over to an instrument for reference."

"How can I print a method?"

"How do I access it?"

"A hardcopy is sometimes necessary to carry to an instrument."

APPENDIX E

Questionnaire Responses

Tabulated Questionnaire Responses

1 . What is your highest level of education?

QUEST1 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	High school	2	13.33	13.33
2	B	Some college	4	40.00	26.67
3	C	Bachelor degree	3	60.00	20.00
4	D	Some graduate study	3	80.00	20.00
5	E	Graduate degree	3	100.00	20.00

2 . How long have you worked in a laboratory?
(This means the total of all your lab experience.)

QUEST2 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
3	C	3 to 6 years	3	20.00	20.00
4	D	6 to 10 years	1	26.67	6.67
5	E	over 10 years	11	100.00	73.33

3 . How would you rate your ability with computers?
Choose one.

QUEST3 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Beginner	4	26.67	26.67
2	B	Somewhat experienced	4	53.33	26.67
3	C	Experienced	6	93.33	40.00
4	D	Very experienced	1	100.00	6.67

4 . How well do you like computers?

QUEST4 NumValue	AlphaVal	Value Label	N	valid cumm. %
1	A	Hate computers	1	6.67
2	B	Dislike computers	1	13.33
3	C	Indifferent toward computers	2	26.67
4	D	Like computers	9	86.67
5	E	Like computers very much	2	100.00

QUEST4 NumValue	AlphaVal	Value Label	valid %
1	A	Hate computers	6.67
2	B	Dislike computers	6.67
3	C	Indifferent toward computers	13.33
4	D	Like computers	60.00
5	E	Like computers very much	13.33

5. How long have you been using computers?

QUEST5 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
2	B	1 to 3 years	1	6.67	6.67
3	C	3 to 6 years	7	53.33	46.67
4	D	6 to 10 years	4	80.00	26.67
5	E	More than 10 years	3	100.00	20.00

6. How often did you use the hyperdocument?
(please choose the answer that most *closely* describes your usage).

QUEST6 NumValue	AlphaVal	Value Label	N	valid cumm. %
2	B	One to several times per shift	1	6.67
3	C	One to several times per week	2	20.00
4	D	Less than once per week	10	86.67
5	E	Never	2	100.00

QUEST6 NumValue	AlphaVal	Value Label	valid %
2	B	One to several times per shift	6.67
3	C	One to several times per week	13.33
4	D	Less than once per week	66.67
5	E	Never	13.33

7. The process of starting the hyperdocument or "getting it on the screen" was:

QUEST7 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Very easy	7	50.00	50.00
2	B	Somewhat easy	6	92.86	42.86
3	C	No opinion	1	100.00	7.14
Missing			1		

QUEST7 NumValue	AlphaVal	Value Label	total cumm. %	total %
1	A	Very easy	46.67	46.67
2	B	Somewhat easy	86.67	40.00
3	C	No opinion	93.33	6.67
Missing			100.00	6.67

8. Finding what you were looking for in the hyperdocument was:

QUEST8 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Very easy	5	35.71	35.71
2	B	Somewhat easy	9	100.00	64.29
Missing			1		

QUEST8 NumValue	AlphaVal	Value Label	total cumm. %	total %
1	A	Very easy	33.33	33.33
2	B	Somewhat easy	93.33	60.00
Missing			100.00	6.67

9. How did you find the operation of the hyperdocument the first time you used it?

QUEST9 NumValue	AlphaVal	Value Label	N	valid cumm. %
1	A	Very understandable	8	57.14
2	B	Somewhat understandable	5	92.86
3	C	No opinion	1	100.00
Missing			1	

QUEST9 NumValue	AlphaVal	Value Label	valid %	total cumm. %
1	A	Very understandable	57.14	53.33
2	B	Somewhat understandable	35.71	86.67
3	C	No opinion	7.14	93.33
Missing				100.00

QUEST9 NumValue	AlphaVal	Value Label	total %
1	A	Very understandable	53.33
2	B	Somewhat understandable	33.33
3	C	No opinion	6.67
Missing			6.67

10. How did you find the operation of the hyperdocument after you became experienced with it?

QUES10 NumValue	AlphaVal	Value Label	N	valid cumm. %
1	A	Very understandable	11	78.57
2	B	Somewhat understandable	2	92.86
3	C	No opinion	1	100.00
Missing			1	

QUES10 NumValue	AlphaVal	Value Label	valid %	total cumm. %
1	A	Very understandable	78.57	73.33
2	B	Somewhat understandable	14.29	86.67
3	C	No opinion	7.14	93.33
Missing				100.00

QUES10 NumValue	AlphaVal	Value Label	total %
1	A	Very understandable	73.33
2	B	Somewhat understandable	13.33
3	C	No opinion	6.67
Missing			6.67

11. How useful was the hyperdocument?

QUES11 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Very useful	4	28.57	28.57
2	B	Somewhat useful	5	64.29	35.71
3	C	No opinion	5	100.00	.35.71
Missing			1		

QUES11 NumValue	AlphaVal	Value Label	total cumm. %	total %
1	A	Very useful	26.67	26.67
2	B	Somewhat useful	60.00	33.33
3	C	No opinion	93.33	33.33
Missing			100.00	6.67

12. Would you like to continue using the hyperdocument?

QUES12 NumValue	AlphaVal	Value Label	N	valid cumm. %
1	A	Yes	6	42.86
2	B	Yes, if some changes are made	2	57.14
3	C	No opinion	4	85.71
5	E	No	2	100.00
Missing			1	

QUES12 NumValue	AlphaVal	Value Label	valid %	total cumm. %
1	A	Yes	42.86	40.00
2	B	Yes, if some changes are made	14.29	53.33
3	C	No opinion	28.57	80.00
5	E	No	14.29	93.33
Missing				100.00

QUES12 NumValue	AlphaVal	Value Label	total %
1	A	Yes	40.00
2	B	Yes, if some changes are made	13.33
3	C	No opinion	26.67
5	E	No	13.33
Missing			6.67

13. How much did you enjoy using the hyperdocument?

QUES13 NumValue	AlphaVal	Value Label	N	valid cumm. %
1	A	Enjoyed it very much	2	14.29
2	B	Enjoyed it somewhat	6	57.14
3	C	No opinion	5	92.86
4	D	Didn't enjoy it very much	1	100.00
Missing			1	

QUES13 NumValue	AlphaVal	Value Label	valid %	total cumm. %
1	A	Enjoyed it very much	14.29	13.33
2	B	Enjoyed it somewhat	42.86	53.33
3	C	No opinion	35.71	86.67
4	D	Didn't enjoy it very much	7.14	93.33
Missing				100.00

QUES13 NumValue	AlphaVal	Value Label	total %
1	A	Enjoyed it very much	13.33
2	B	Enjoyed it somewhat	40.00
3	C	No opinion	33.33
4	D	Didn't enjoy it very much	6.67
Missing			6.67

14. Does the hyperdocument satisfy ISO-9000 documentation requirements?

QUES14 NumValue	AlphaVal	Value Label	N	valid cumm. %
2	B	It could, with some changes	5	33.33
3	C	Don't know	9	93.33
5	E	No	1	100.00

QUES14 NumValue	AlphaVal	Value Label	valid %
2	B	It could, with some changes	33.33
3	C	Don't know	60.00
5	E	No	6.67

15. Compared to paper documents, how easy or difficult was the hyperdocument to maintain?

QUES15 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Very easy	2	14.29	14.29
2	B	Somewhat easy	2	28.57	14.29
3	C	Don't know	9	92.86	64.29
4	D	Somewhat difficult	1	100.00	7.14
Missing			1		

QUES15 NumValue	AlphaVal	Value Label	total cumm. %	total %
1	A	Very easy	13.33	13.33
2	B	Somewhat easy	26.67	13.33
3	C	Don't know	86.67	60.00
4	D	Somewhat difficult	93.33	6.67
Missing			100.00	6.67

16. How concerned are you about security of the test methods (for example, could someone alter a test method without the proper procedure)?

QUES16 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Not concerned at all	4	26.67	26.67
2	B	No opinion	8	80.00	53.33
3	C	Very concerned	3	100.00	20.00

17. How cumbersome was the hyperdocument to use?

QUES17 NumValue	AlphaVal	Value Label	N	valid cumm. %	valid %
1	A	Not cumbersome at all	12	85.71	85.71
2	B	Slightly cumbersome	2	100.00	14.29
Missing			1		

QUES17 NumValue	AlphaVal	Value Label	total cumm. %	total %
1	A	Not cumbersome at all	80.00	80.00
2	B	Slightly cumbersome	93.33	13.33
Missing			100.00	6.67

18. Would you recommend using *only* the hyperdocument for documenting test methods and doing away with the methods book (except for the master copy in Win's office)?

QUES18 NumValue	AlphaVal	Value Lab	N	valid cumm. %	valid %	total cumm. %
1	A	Yes	2	14.29	14.29	13.33
2	B	No opinion	6	57.14	42.86	53.33
3	C	No	3	78.57	21.43	73.33
4	D	Both	3	100.00	21.43	93.33
Missing			1			100.00

QUES18 NumValue	AlphaVal	Value Lab	total %
1	A	Yes	13.33
2	B	No opinion	40.00
3	C	No	20.00
4	D	Both	20.00
Missing			6.67

NOTE: Three respondents wrote in a "Both" response on their questionnaire so the researcher added this response category for the data analysis.

19. Which access me hod did you use the most?

QUES19 NumValue	AlphaVal	Value Lab	N	valid cumm. %	valid %	total cumm. %
1	A	The lab PC	7	53.85	53.85	46.67
2	B	Another PC	6	100.00	46.15	86.67
Missing			2			100.00

QUES19 NumValue	AlphaVal	Value Lab	total %
1	A	The lab PC	46.67
2	B	Another PC	40.00
Missing			13.33

<u>Comments Handwritten on Questionnaires</u>

1. Timely updating of revisions would be a top priority!
2. Certain commands require Alt or Cntrl with the letter for the command, but not all. There are not so many commands that this couldn't be set up with only one control set. We frequently import the test method into Word Perfect. This gives a nicer type face and ability to emphasize particular sections (i.e. bold, underline, etc.) in special cases.
3. I spend a lot of time either writing new methods or revising old ones. The functions I need most are 1) retrieval of a method or part of a method into an editing mode, 2) editing functions/data entry. <u>If</u> the hyperdocument could include these functions <u>and</u> be secure (like our current system of limited password access) I'm sure I would use it more. I guess what I'm saying is that I need word processing more than the ability to search. I do like the search function, however I just don't use it much. Use both [hyperdocument and methods book] -- once you have the method you need, you can scan it <u>faster</u> by flipping pages than by scrolling.
4. After bringing up the use of the hyperdocument in conjunction with the Q.C. Terminal at our team meeting, I felt that with B. Wasson's suggestion of the expense envolved [sic] as far as man hours yearly, and most technicians not quite being familiar with how simple it is to use and how it could be of an asset, they voted to not "spend the money" at this budget

conscionus [sic] time. Maybe with further indoctronation [sic] with its use, the other bench techs might feel differently. -- ? G.P.

5. I used the hyperdocument when substituting on a Saturday for a bench technician and liked it. Could the current Water Lab Test methods be added? This would give me easier access and make updates more readily made. Roger.
6. The [sic] are two issues of concern in the continued use of the hyperdocument.

   1. Time would have to be taken to make changes so that the methods in it are consistant [sic] with the current controlled methods. And it would take a little more time to control it once instituted.

   2. It is nice to have a paper copy to work from. This could be overcome by keeping the current book or by getting a printout on command. Bill.
7. We need one controlled copy be it hyperdocument or VAX. We do need paper coppies [sic] for some test methods to use while running analysis. But the hyperdocument is very easy to use.

ABSTRACT

The problem of this study was to develop and implement a hypertext documentation system in an industrial laboratory and to evaluate its usefulness by participative observation and a questionnaire. Existing word-processing test method documentation was converted directly into a hypertext format or "hyperdocument." The hyperdocument was designed and structured according to principals found in the literature of hypertext. It was evaluated for three months in a chemical plant quality assurance laboratory where 16 people were employed who used the hyperdocument. The hyperdocument was made available for use, but the laboratory's paper documentation was still available. Observations, discussions, and a questionnaire were used to collect the data. Participants tended to like the hyperdocument, they found it easy to learn how to operate, easy to use, and most said it was useful. They tended, however, to use it infrequently. Hyperdocument maintenance was found to be somewhat time consuming, but not unreasonably difficult. It was concluded, therefore, that 1) the design and structuring principals given in hypertext literature led to an easy-to-use product; 2) maintenance was not too difficult; 3) the hyperdocument was a useful and effective tool for documenting test methods in a laboratory.

APPROVAL OF EXAMINING COMMITTEE

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George R. Maughan, Ed.D.

4/27/93
Date

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