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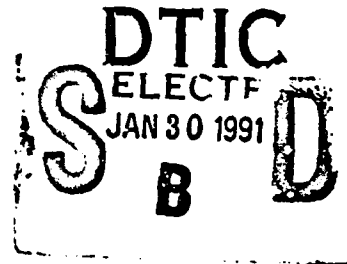
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THESIS

AN EXPERT SYSTEM FOR THE
MANAGEMENT OF HAZARDOUS MATERIALS
AT A NAVAL SUPPLY CENTER

by

David C. England

June 1990

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This thesis analyzes, designs and implements an expert system for the management of hazardous material at a Naval Supply Center (NSC). This system is part of a series of expert systems built by the Naval Postgraduate School to assist the Naval Supply Systems Command in automating its inventory management systems at NSCs. Selecting the proper storage conditions and location for newly received hazardous material requires the NSC's expert in such matters, the safety and health manager, to research the primary data base, the Hazardous Material Information System (HMIS), and any other relevant information sources, and extract the pertinent information. He determines the best storage conditions for the material and passes this information to the warehouse worker. The Hazardous Material Expert System (HAZMAT ES) will facilitate making the storage decision and will allow a warehouse worker to safely store hazardous material without the assistance of the safety and health manager.

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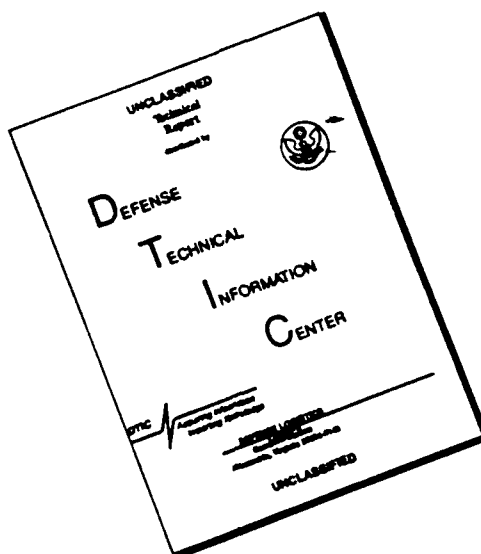| 22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
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i

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An Expert System for the
Management of Hazardous Materials
at a Naval Supply Center

by

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Submitted in partial fulfillment
of the requirements for the degree of

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ii

ABSTRACT

This thesis analyzes, designs and implements an expert system for the management of hazardous material at a Navy Supply Center (NSC). This system is part of a series of expert systems built by the Naval Postgraduate School to assist the Naval Supply Systems Command in automating its inventory management systems at NSCs. Selecting the proper storage conditions and location for newly received hazardous material requires the NSC's expert in such matters, the safety and health manager, to research the primary data base, the Hazardous Material Information System (HMIS), and any other relevant information sources, and extract the pertinent information. He determines the best storage conditions for the material and passes this information to the warehouse worker. The Hazardous Material Expert System (HAZMAT ES) will facilitate making the storage decision and will allow a warehouse worker to safely store hazardous material without the assistance of the safety and health manager. In addition, it can provide information on an item's flash point, reactivity, and disposal requirements.

iii

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

Expert systems, or knowledge based rules systems, are developed so that the knowledge and experience of an expert in a particular field may be transported, via computer, to a non-expert. Recent advances in the expert system field have made this application available at the personal computer (PC) level. A number of areas have proven to be very well adapted to expert systems. These applications cover a wide variety of topics; ranging from financial planning to medical diagnosis, from loan approvals to physical structure analysis. Several expert systems have been created as thesis projects at the Naval Postgraduate School, Monterey, Ca; they include a system to management outstanding requisitions (dues) and a system which directs causative research for missing or lost material. These systems are intended to help inventory managers at Naval Supply Centers (NSCs).

Personnel at the Navy Safety Center and the Naval Supply Systems Command (NAVSUP) felt such an expert system would be helpful to the management of ready for issue ("A" condition) hazardous material at NSCs. Such a system should be designed

1

for use by the warehouse level worker to aid in determining the proper storage conditions and location.

B. OBJECTIVE

The objective of this thesis was to develop a hazardous materials expert system if possible. Indeed, such a system was conceived, designed, programmed and tested. The product of that work has been titled the Hazardous Material Management Expert System (HAZMAT ES).

C. APPROACH AND SCOPE

The methodology used in this research consisted of reviewing available scholarly texts and journals and Departments of Defense and Navy instructions and notices. It also included research of, and interaction with, a number of existing expert systems; including those previously mentioned NSC inventory manager systems. The final step was the development of the system.

The scope of this thesis was primarily focused on developing a rule-based expert system to manage hazardous material at a Naval Supply Center (NSC). The expert system implemented in this thesis is expected to be fully operational. However, a thorough validation test should be conducted by individual NSC health and safety managers before the system is utilized. Other types of systems, such as

decision support systems or data base management systems, which might satisfactorily assist in the management of hazardous materials, were not examined.

D. PREVIEW

Chapter II looks at the actual management of hazardous material in the Department of Defense in general and specifically at NSC's. The difficulties associated with the management of hazardous materials and how this area might lend itself to an expert system application are examined. Potential problem areas to be resolved during system development are discussed.

Chapter III examines artificial intelligence, expert systems, and how expert systems are developed. Discussions are presented outlining these topics, and their relevance to the development of the HAZMAT ES. Chapter IV discusses the considerations that went into designing, developing and implementing the Hazardous Material Expert System (HA2MAT ES). Programming logic problems and how they were resolved are reviewed. The chapter also addresses user interface considerations and improvements.

The final chapter contains a summary and conclusions regarding the potential of the HAZMAT ES. Other vehicles that merit further research and consideration in this area are also addressed.

II. HAZARDOUS MATERIAL MANAGEMENT AT NAVAL SUPPLY CENTERS AND ITS ADAPTABILITY AS AN EXPERT SYSTEM

A. INTRODUCTION

This chapter addresses hazardous material (HM) from several different viewpoints: the chemical aspects, the Department of Defense's Hazardous Material Information System (HMIS), Hazardous Material as viewed by the Navy, and the management of ready for issue ("A" condition) Hazardous Material at a Naval Supply Center (NSC). The quality and usefulness of any expert system depends on how well the characteristics and problems of the application domain are understood. After these discussions establish the initial groundwork, we will look at how these combined factors and circumstances are suited to the application of an expert system.

B. CHEMICAL ASPECTS OF HAZARDOUS MATERIAL

Appendix A of the ninth edition of the Condensed Chemical Dictionary [Ref. 1:p. 429] defines hazardous material as:

Any material or substance which, if improperly handled, can be damaging to the health and well-being of man. Such materials cover a broad range of types which may be classified as follows:

(1) Poisons or toxic agents, including drugs, chemicals, and natural or synthetic products that are in any way harmful, ranging from those that cause death to skin irritants and allergens.

(2) Corrosive chemicals that burn or otherwise damage the skin and mucous membranes on external contact or inhalation.

(3) Flammable materials (q.v.) including (a) organic solvents, (b) finely divided metals or powders, (c) some classes of fibers, textiles, or plastics, and (d) chemicals that either evolve or absorb oxygen during storage, thus constituting a fire risk when in contact with organic materials.

(4) Explosives (q.v.) and strong oxidizing agents such as peroxides and nitrates.

(5) Materials in which dangerous heat build-up occurs during storage, either by oxidation or micro-biological action.

(6) Radioactive chemicals that emit ionizing radiation.

The hazard associated with certain materials is increased if the material is allowed to interact with certain other compounds. In many cases, these materials might be quite benign in their own right but, when combined, they create a deadly mixture. For example, oxidizing material stored with acids can cause fire or caustic gasses.

The hazards associated with any particular item are attributable to its physical properties. The most prevalent of these is an item's flash point when it is in its liquid state. The flash point of a liquid is the minimum temperature at which it gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid. [Ref. 2] The same source defines an ignitable mixture as one within the flammable range that is capable of the propagation of flame away from the initial source of ignition once ignited.

A second hazard associated with many items is their toxicity. Toxicity is defined as:

The ability of a substance to cause damage to living tissue, impairment of the central nervous system, severe illness or, in extreme cases, death when ingested, inhaled, or absorbed by the skin. The amounts required to produce these results vary widely with the nature of the substance and the time of exposure to it. "Acute" toxicity refers to exposure of short duration, i.e., a single brief exposure; "chronic" toxicity refers to exposure of long duration, i.e., repeated or prolonged exposures.

The toxic hazard of a material may depend on its physical state and on its solubility in water and acids. Some metals that are harmless in solid or bulk form are quite toxic as fumes, powder, or dust. Many substances that are intensely poisonous are actually beneficial when administered in micro amounts, as in prescription drugs. [Ref. 1:p. 872]

The instability of materials must also be considered when studying hazardous materials. Relatively unstable materials are referred to as reactive materials.

Reactive materials are those which can enter into a chemical reaction with other stable or unstable materials. Some materials are capable of rapid release of energy by themselves, as by self-reaction or polymerization, or can undergo violent eruptive or explosive reaction upon contact with water or other extinguishing agents or within certain other materials. [Ref. 3]

The above physical traits must be taken into account when managing potentially dangerous hazardous material at Naval Supply Centers (NSC's).

6

C. HAZARDOUS MATERIAL INFORMATION SYSTEM

Prior to discussing specific NSC operations it is important to become acquainted with the principal Department of Defense source of information concerning hazardous material. The Hazardous Material Information System (HMIS) is a computer-based information system designed to accumulate, maintain, and disseminate important characteristics of hazardous material which exist throughout the Department of Defense. The HMIS is managed by the Defense Logistics Agency (DLA).[Ref. 4]

A complete HMIS microfiche output (DoD 6050.5-LR) is produced and distributed in November of each year. Quarterly supplemental updates are published and distributed in February, May and August. The annual November HMIS microfiche output consists of approximately 200 microfiche sheets and contains information for more than 7000 line items. The main listing is by National Stock Number, but four separate cross-referenced listings are also provided. These cross-references are indexed to part number, manufacturer's code, and specification number.

The HMIS microfiche contains information on flash point, reactivity, hazard, transportation and shipping data, information on the manufacturer(s), and more. Much of the information provided is not germane to the work of on-site warehouse personnel. The HMIS is intended for use by a large

group (specifically, the entire Department of Defense logistics system) and is therefore broad in nature.

Despite the broad nature of the information, all required data to make storage management decisions is available. However, it is difficult to extract the necessary data. Microfiche is a very tedious and difficult medium to work with. A microfiche reader is necessary to display the information and the screen tends to be dark and the printing small. Because of the size of a microfiche reader the HMIS is not very mobile.

DLA has recently started providing the HMIS output on compact disk-read only memory (CD-ROM). This format is much easier to work with than microfiche. The information is primarily provided in plain English, and includes: manufacturer/vendor, identifying information, ingredients, physical properties, reactivity, fire danger, explosive hazard, handling information, transportation, and disposal. In total, there are eleven screens of information for each line item.

The method of presentation using CD-ROM technology is superior to the microfiche version. However, drawbacks still exist from the viewpoint of the warehouse worker. The majority of the information provided is not required by the warehouse worker trying to decide where to stow an item. In order to obtain any pertinent information he must wade through considerable unnecessary information. Even then the pertinent

8

information does not fully instruct him as to the proper storage conditions for the item under considerations.

D. HAZARDOUS MATERIAL MANAGEMENT AT NAVAL SUPPLY CENTERS

1. General Policy

In accordance with OPNAVINST 4110.2, there are a large number of organizations within the Navy who have some involvement with HM management. They include, but are not limited to, the Chief of Naval Operation's Office (Deputy Chief of Naval Operation for Logistics (OP-04)), the Office of the Naval Inspector General, the Chief of Naval Research, the Commander Naval Supply Systems Command (NAVSUP), the Navy Environmental Health Center, the Commander Naval Facilities Engineering Command, and the Navy Safety Center. Although there are a large number of interested participants involved with HM management this thesis is primarily concerned with the aspects under the control of NAVSUP.

NAVSUP is assigned responsibility as the overall manager for all supply and logistics aspects of the Navy's Hazardous Material Control and Management Program. These aspects include, but are not limited to, manual and automated warehousing and material information systems, and information pertaining to storage capability at Naval Supply Centers and distribution points.[Ref. 4]

9

This thesis effort was initially defined by the NAVSUP Hazardous Material Coordinator, Ms. Cindy Williams. General discussions were held via telephone regarding HM management at various NSCs and a west coast NSC that could provide useful information and experiences if visited was decided upon. The Naval Supply Center, Puget Sound, Wa (NSC PS), although it has a smaller operation than most NSCs, was considered a good candidate to visit and study.

2. Conditions at NSC Puget Sound

The purpose of the visit to NSC PS, conducted 11 - 12 September 1988, was to obtain an understanding of HM storage and management at the stock point level. To achieve this, an interview with the center's safety and health manager and the HM warehouse personnel was conducted. Also, HM stock identification procedures, storage facilities, and general working conditions were observed and training records reviewed.

The NSC PS hazardous material warehouse contains approximately 1500 line items of hazardous material. This is a fairly light load compared to the number of line items maintained by NSC Oakland and NSC Norfolk. Regardless, Ms. Williams was confident that the conditions to be addressed by this thesis would be the same at any NSC.

a. Personnel and Training

The safety and health manager, Mr. John Jensen, has been employed by NSC PS in that capacity since 1979. His education includes a master's degree in industrial safety and Ms. Williams considers him the best of all the NSC HM managers.

The HM warehouse is manned by three full-time personnel. All are wage grade level five (WG-5) employees with five to seven years experience at the NSC. Not all of their experiences at the NSC have been related to HM storage and management. Mr Jensen indicated their backgrounds are typical of NSC HM warehouse personnel he has seen during his tour at NSC PS. Due to the potential hazards associated with HM items the warehouse personnel tend to be more experienced and mature than the average NSC non-HM warehouse employee.

The HM warehouse personnel receive very little formal training. The extent of their formal training is a mandatory NAVSUP Competency Board Certification (CBC) program. The training they receive is from the HM module of the CBC, but the main emphasis of this training is accountability rather than the hazardous traits of the materials they are dealing with. The majority of their hazardous material training is comprised of on-the-job training from Mr. Jensen and the more experienced personnel in the HM warehouse.

b. The Storage Decision Process

The current method of arriving at storage decisions must be understood in order to evaluate a concept for an expert system to assist the warehouse personnel in their storage decisions. Hazardous material stocking decisions fall into two basic categories: (1) receipt of items already carried in stock, and (2) receipt of items not currently carried in stock.

When an item is received that is already carried in stock the new receipt is placed into storage with similar material. This rule holds true for varying units of issue and different size containers of the same material. The physical properties that create the hazard remain constant, regardless of the container's size or unit of issue.

The situation encountered when an item comes into stock for initial placement is not as simple. Providing proper storage guidance to the warehouse worker in this situation is the goal of the expert system under consideration as part of this thesis.

The warehouse is divided into various sections, such as flammable storage, an acid locker, compressed gas storeroom, etc. When an item is received into stock for the first time, warehouse personnel stow the material into the general area where they think it should go using an "educated guess."

A follow-up inquiry, describing the material received and the initial storage decision made, is forwarded to the safety

12

and health manager. Upon receipt of this form the safety and health manager researches the proper storage criteria for the item using the HMIS and other references available to him. He annotates the required information and returns the form to the warehouse. The elapsed time for the form to be initiated, forwarded to the safety and health manager, and then returned to the warehouse is usually seven to ten calendar days. Mr. Jensen indicated that in many instances the warehouse personnel's initial decisions are correct. New items that require this process to occur arrive three to four times per week.

The previously discussed problems associated with the HMIS have made it difficult for warehouse personnel to become adept at its use. Mr. Jensen has made some efforts to train them in the use of the HMIS with limited success.

Although the current situation is reasonably successful the potential for a catastrophic error is obvious. For example, a spill or leak from a package stored in close proximity to a material it is highly reactive with could prove fatal. The storerooms observed at NSC Puget Sound were extremely clean and well organized and no such occurrences were observed. However, damaged packages and spilled material are a fact of life when transporting, handling, and storing large quantities of material.

I discussed the concepts behind the proposed HM expert system with Mr. Jensen and the warehouse personnel. The

ability to use such a personal computer based expert system would require limited information and training, and could rapidly provide a correct storage decision. They received the proposal very positively.

E. HAZARDOUS MATERIAL EXPERT SYSTEM

The conditions surrounding hazardous material storage at an NSC would appear to be ideally suited for the development and application of an expert system. Some of the applicable characteristics of an ES, which will be discussed in chapter III, include: objective, scope, who/what makes the recommendation, domain, and type of problem addressed. These characteristics must be reviewed for any potential expert system application.

As conceived during initial investigation and study, the objective of the HAZMAT ES would be to replicate the knowledge of the expert (in this case, the supply center's safety and health manager) and immediately provide it at the warehouse worker's level. It is possible that then the safety and health manager could be left completely out of this decision making process.

The proposed HAZMAT ES would be directly accessed by the warehouse worker. The HAZMAT ES would pose questions to the worker in order to obtain sufficient information to provide a correct storage decision. In addition, all possible user responses would be presented along with questions.

14

The domain being addressed, hazardous material management, is very narrow and the characteristics of hazardous materials are clearly defined. The problem which would be addressed by the HAZMAT ES is very repetitive in nature, as all decision processes would be very similar to each other.

Customizing the HAZMAT ES to the local NSC will give it an additional advantage over the HMIS. It will not be difficult to tailor the HAZMAT ES's responses to a local NSC's storage conditions and configurations. For example, rather than simply making a recommendation for a type of storage condition, the HAZMAT ES can make recommendations specific to the NSC. The recommendation can name a storeroom by name, such as "store this item in storeroom #3, sector 27."

The most difficult aspect of the proposed HAZMAT ES is determining which characteristics need to be addressed and how much detail can be included (as will be discussed in chapter III, this is often a major problem in designing any expert system application). The HMIS addresses each line item as a distinct entity. To make the HAZMAT ES workable at the personal computer level it is not possible to treat items uniquely (insufficient power and memory is available in a personal computer). Rather, items would have to be grouped by hazard types, specifically: acid, flammable, toxic, explosive, combustible, alkaline, oxidizer, and poison. The items would also have to be categorized by their physical state (i.e., solid, liquid or gas). The basic characteristics

of specific items within each hazard type are homogenous enough to make this HAZMAT ES concept effective.

In addition, if all of the hazardous items were treated uniquely it would be necessary to maintain the system on a quarterly basis. This is the frequency at which the HMIS is distributed. Quarterly HMIS changes include additions, deletions, and adjustments to existing records. The HMIS contains approximately 7500 line items, an expert system with the capabilities of the HAZMAT ES would require over 30,000 rules to manage such a domain. This estimation is based on the HAZMAT ES rule base which contains four rules for each type of hazard.

As will be discussed in Chapter III, one of the primary weaknesses associated with any ES is the system's inability to identify when it is operating beyond its expertise. This should not be a factor for the proposed HAZMAT ES. All HMs carried at an NSC are included in one of the hazard types identified at the start of the chapter, ensuring all potential situations can be addressed by the HAZMAT ES.

III. ARTIFICIAL INTELLIGENCE, EXPERT SYSTEMS, AND DEVELOPING EXPERT SYSTEMS

A. INTRODUCTION

This chapter addresses artificial intelligence, expert systems, and the development of an expert system. It also discusses issues related to knowledge acquisition methods for producing a knowledge base and the steps in the development of an expert system. The discussions will include considerations regarding the development of the hazardous material expert system (HAZMAT ES).

B. ARTIFICIAL INTELLIGENCE

The general perception of artificial intelligence (AI) is an exotic one, linked with science fiction robots and vindictive computers; HAL in the movie "2001: A Space Odyssey" is a prime example. In reality, artificial intelligence is much more benign than that. One of the original definitions of AI is offered by Marvin Minsky, a founding father of the field. He defines AI as simply "the science of making machines do things that would require intelligence if done by men" [Ref. 5:p. 65]. This implies that computers can be designed to reason and make inferences based on knowledge they

17

have stored in their data bases. The ability to learn from mistakes (i.e., acquire information while accomplishing their assigned tasks) must be considered as well.

Most experts in the field agree that AI is not a science or a tangible end item in and of itself. Specific applications, such as expert systems, are the end product of artificial intelligence. Three general products currently have sprung from AI, they are: Expert Systems (ES), Natural-Language Systems, and Neural Networks.

Both ES and natural-language systems are knowledge-based systems. They attempt to replicate an expert's abilities with a data base and software that utilize the expert's knowledge and reasoning capabilities. The systems then provide these abilities to a non-expert. Natural-language software consists of powerful programs that allow users to interact with the system using plain language commands. On the other hand, an ES requires more structured commands when being queried, but is still designed to be easy to interact with (i.e., user friendly). ES will be discussed more fully later.

Neural networks are still in the research phase and have no working models. They are an attempt to duplicate the neural patterns of a living being in order to reproduce their thought processing capabilities [Ref. 6:p. 20].

C. EXPERT SYSTEMS

The literature defines "expert systems" in a variety of ways. Generally, ES are an outgrowth or product of artificial intelligence that attempts to mimic or replicate the expertise and knowledge of an acknowledged expert in a specified field. In this thesis an expert system is defined as a computer program which uses a knowledge-based reasoning process which provides the user with a correct choice for a given problem in a very narrow field. An ES is comprised of a knowledge base and an inference engine.

A knowledge base is composed of two sections, the knowledge data base and the domain data base. The knowledge data base contains rules about the behavior of the elements of the subject in question. For example, a knowledge data base contains such rules as: "If a bicycle has curved handle bars and more than five gears, then it is a racing bicycle." The domain data base contains facts about the subject in question. For example: "Schwinn makes racing bicycles." The distinction here is subtle but important. The rules in a knowledge data base may be thought of a definitions which are not usually altered. Facts in the domain data base are more easily changed.

The inference engine is an algorithm that extracts information from the knowledge base, applies the rules contained in the domain data base and makes a decision using reasoning criteria contained in the inference engine.

19

Inference engines use three types cf reasoning: backward chain reasoning, forward chain reasoning, or a combination ot the two. Backward chain reasoning requires less computer memory and is more prominent.

Backward reasoning, or "goal driven inferences," starts with the goal to be attained. It collects all of the rules in the knowledge base that has "then" conditional statements that match the stated goal. Each of the rules is tested wit the pertinent information extracted from the domain data base as well as information provided by the user. The inference engine uses this information to eliminate the conditional statements which are not true for the goal at hand. It retains those condicional statements which are true, or cannot be proven either true or false. The inference engine will prompt the user for additional facts which will allow it to identify all conditional statements as true or false.[Ref. 7:p. 315-317]

For example, a young man wishes to earn $20.00, this is established as the goal. He looks for "IF-THEN" rules which will satisfy this goal. He comes upon "IF the lawn is shaggy and the car is dirty, THEN Dad will pay $20.00 to have the lawn mowed and the car washed." He must then review various conditions to determine if he can indeed accomplish the tasks (e.g.: do the car and lawn need attention?). If so, does he have the necessary tools and supplies? He has established

his goal and then proceeded backwards to satisfy this goal. See Figure 2.1 for a representation of this process.

BACKWARD CHAINING

GOAL: Make $20.00

RULE: If the lawn is shaggy and
the car is dirty and you mow
the lawn and wash the car,
then Dad will give you $20.00

Does the lawn   Does the car need
need mowing?   washing?

Do you have a mower?   hose?   bucket?   rags?

gas?   electric?   push?
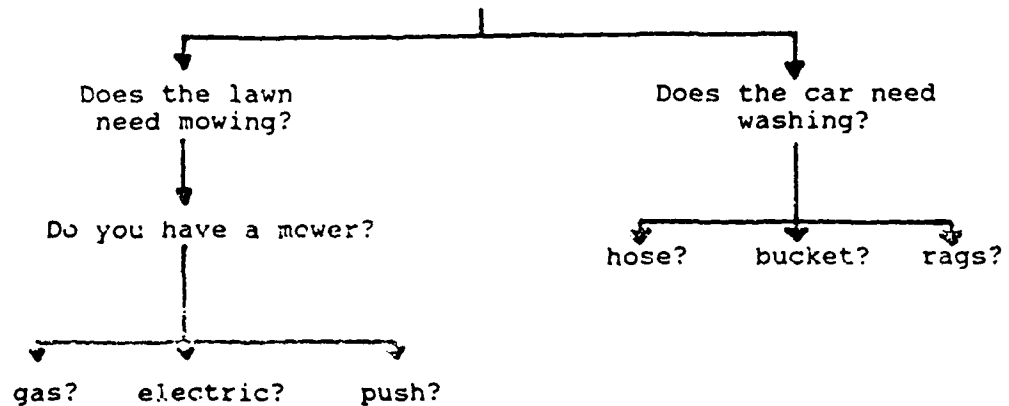
*** The inference engine will test each rule or ask the
    user for additional information.

Figure 2.1

Forward reasoning "fires" each rule from the knowledge data base that matches the given "if" facts of a problem. Firing a rule consists of asserting each of the rule's then-conclusions and of evaluating their impacts [Ref. 5:p. 65]. The reasoning strategy continues forward, determining further rules to be fired based on these conclusions. The collection of facts gathered during this chaining become the solution to

21

the problem at hand. See Figure 2.2 for a representation of this process.

FORWARD CHAINING

GIVEN: You can make $20.00
mowing lawn and washing car

If the car is dirty
and you have supplies
then the car be
washed for money
(adds statement to memory)

If the lawn is shaggy
and you have a mower
then the lawn can be
mowed for money (adds
statement to memory)

Dad says mow the lawn
and wash the car, regardless
of their condition

If the car can be washed
for money and the lawn can
be mowed for money then you
can earn money

Figure 2.2

Search patterns, defined as either breadth or depth, are techniques that allow navigation through an information base. They vary among various systems depending upon the architecture used. A breadth search pattern consists of firing all first level rules before proceeding to the second level rules. A depth pattern continues along a chain until it can go no further. This can also be conceptualized as horizontal (breadth) and vertical (depth).

22

A vertical search looks at all rules in the same level and classifies them as true or false. The process then moves on to the next level and evaluates and classifies all of them. Once all of the rules are evaluated a final solution is determined. The horizonal search process finds a true rule on the first level which will satisfy the goal and then moves horizontally to the next level, evaluating level II rules which are dependent on the level I rule that was evaluated as true. This process continues until the final solution is attained. See Figure 2.3 for a representation of this process.

SEARCH PATTERNS

DEPTH: All level I rules are searched "vertically" and
identified as True or False before going to level II

```
LEVEL       I           II          III
          R t         R t         R t
          R t         R f         R f
          R t         R t         R f
          R t         R f         R t
          R f         R t         R t
          R t         R c         R t
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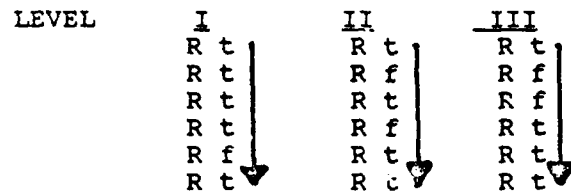
BREADTH: The search is conducted "horizontally" along a
chain of true rules, looking for the goal

```
LEVEL       I           II          III
          R           R           R
          R           R f         R
          R t         R           R
          R           R t         R t
          R           R           R
          R           R           R
```
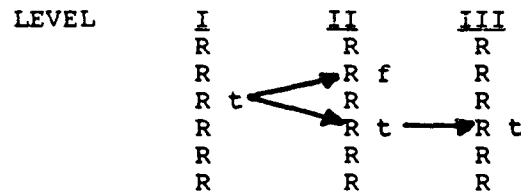
R: Rule
t: Rule has been evaluated as true
f: Rule has been evaluated as false

Figure 2.3

The characteristics attributed to successful expert

systems vary with each source consulted.   However, a few

characteristics are consistently cited by all. They are:

24

o The system can provide the user with the reasoning utilized to arrive at the solution.

o The system uses heuristic, or "rules of thumb," to arrive at a solution.

o The subjects are well-defined with narrow domains.

The shortcomings associated with expert systems are much more universally agreed upon. The most crucial weakness is an ES inability to know when it is out of its area of expertise (in other words, "it doesn't know what it doesn't know" [Ref. 8:P. 78]). In addition, an ES doesn't have the intuition and experience of a human expert, it cannot look over a situation and decide that the most appropriate action for the conditions at hand would be to break an existing rule. A human expert can make such a decision. When a human expert is being pushed beyond his normal range of expertise he still has some understanding and knowledge, albeit more shallow. He can still make a fairly well educated recommendation for an acceptable solution.

Current expert system technology is such that an ES can make no such forays beyond its data base. It has no limited experiences hiding in the recesses of its mind/memory.[Ref. 9:p. 304] However, systems are currently being developed that are intended to do this.

D. THE PROCESSING AND CREATING OF AN EXPERT SYSTEM

1. The Basic Process of an Expert System

The first expert systems ever developed were exploring unknown territories. There were no systems in existence to emulate. Each new system was custom designed and built to address only the problem being considered. In the early days of ES's, the only way to build one was from scratch, using thousands of lines of computer code. Start-up and developmental costs required millions of dollars and took several years to complete.[Ref. 5:p. 67]

Since the early 1980's, as understanding and experience with ES's has grown, several companies have emerged that provide "expert system shells" for general applications. ES shells are available at a significantly lower cost than the original expert systems. ES shells are now available for personal computer (PC) application with a total software and hardware cost that can be less than $10,000. They provide the customer with an inference engine and the structure for a knowledge base, but no knowledge base is provided. ES shells have been used to develop expert systems that provide investment advice, medical diagnosis, engineering structural analysis, and identification of organic compounds.

The system designer and/or programmer must provide the necessary information on which the knowledge base is built. Prior to system development a feasibility study must be

conducted. The primary issues to be considered at this point are: what is the system intended to provide and who will be using it? The subject to be addressed by the ES must be reducible to specific facts and a series of "if-then" rules. The level of experience and duties of the user are important. Is the user an expert also? a technician? a relatively untrained blue collar worker? The inherent weaknesses of an ES must also be considered during this study (for example, as mentioned above, the system doesn't know when it is outside of its area of expertise). Potential shortfalls in system knowledge must be considered and addressed.

The process an expert system goes through to provide its advice and decisions to the user consists of four basic steps: (1) problem identification, (2) data processing, (3) obtaining information by asking questions of the user, and (4) decision making. Step one, problem identification, is done by the developer when the goal to be attained is established. Problem identification is done by the user for a system with the option of choosing one of several goals. Steps two and three are usually repeated successively until sufficient information is available for a decision to be made. The developer must enlist the support of an expert(s) to provide the information and expertise necessary to build the knowledge base and allow the system to accomplish the second and third steps. This is done during the knowledge acquisition portion of system development. Knowledge acquisition is discussed in

27

detail in the next section. The final step is accomplished by the inference engine when it has sufficient information and provides the user with a decision.

The developer must build the knowledge base with the information provided by the expert. He must also develop the inquiries the system will present to the user. These questions are designed to gather specific information which might be necessary to reach a decision. One element to bear in mind is that the expert cannot directly interface with the system user, nor can the expert view the problem or object under consideration.

One way to visualize this situation is to imagine a telephone conversation between the expert and a completely uninformed observer who requires assistance. The expert would have to ask very specific questions of the observer in order to extract the information on which to base a decision. In many cases the expert would have to tell the observer exactly what to look for in order to provide the answer to the question. The phrasing of the questions must be carefully considered in order to obtain the necessary information.

The second step, data processing, evaluates all known data in terms of the stated goal. All applicable if-then rules are identified as either true, false, or undetermined. The rules valuated as true are checked against the goal to determine if they can satisfy the goal. If all rules fail to satisfy the goal, the undetermined rules are re-evaluated using the

28

information collected by the questions presented to the user. The questions must be designed to capture the information necessary to resolve the cause of the undetermined status of the rule.

2. Knowledge Acquisition

Knowledge acquisition is defined as the transfer and transformation of problem-solving expertise from some knowledge source to a program [Ref. 10:p. 149]. Sources of knowledge are varied and include human experts, journals, textbooks, data bases, and experimental data [Ref. 1C:p. 151, Ref. 11:p. 131]. The majority of expert systems appear to use human experts to provide most of their problem solving expertise. The knowledge engineer is the key to this process. His role is to act as a go-between helping the expert build the system [Ref. 11:p. 129].

Knowledge acquisition can be broken down into two main phases: (1) obtaining the information from the source of knowledge, and (2) coding the information so it may be of use the expert system. There are various methods of accomplishing this task and they are discussed in the following subsections.

Knowledge acquisition is often the stumbling block in the development of an ES. It is very difficult for an expert to communicate his knowledge in a sufficiently simple form for the knowledge engineer to understand and utilize.

a. Handcrafting

This method of knowledge acquisition can be both the simplest and the most difficult. In essence, the role of expert, system developer, and knowledge engineer are performed by the same person. This method of knowledge acquisition avoids the communication pitfall between the expert and the knowledge engineer.

The system developer can accumulate knowledge in the field the expert system will address, cr an expert in some domain can learn how to produce the required code for an expert system's knowledge base. While this method has few communications related problems, it may be difficult for the existing expert or developer to gain the necessary knowledge. [Ref. 10:p. 151, Ref. 12]

b. Knowledge Engineering

This technique involves the knowledge engineer interviewing and discussing the domain with an expert(s) in order to develop the knowledge base. This method is very vulnerable to communications problems. However, this can be lessened when the knowledge engineer is somewhat familiar with the topic at hand. In the course of working with the expert the knowledge engineer will himself develop a certain degree of expertise. This method is currently the most prevalent type of knowledge acquisition.

30

c. Intelligent Editing Programs

This method is essentially the same as knowledge engineering but the need for a knowledge engineer is eliminated by the use of an intelligent editing program. The expert interacts directly with an editing program capable of constructing code in the proper format for an expert system. [Ref. 11:p. 150]

d. Text Induction

Although not yet a reality, a future method of knowledge acquisition is the text induction method. With this technique a system is used that can read a textbook, extract the required information and then construct the knowledge base.

e. Knowledge Acquisition for HAZMAT ES

The ES developed in conjunction with this thesis relied less on human experts than most ESs discussed in the texts and journals reviewed. The Hazardous Material Information System (HMIS) discussed in chapter II served as the foremost source of information for the HAZMAT ES. Human expertise was only required to explain how the HMIS was utilized in arriving at a decision.

Handcrafting was the method utilized in developing most of the HAZMAT ES. The author had some previous experiences in hazardous material management; developed additional expertise through reviewing journals, texts, Department of

31

Defense regulations and instructions, and data bases; and learned to develop and write the required code.

The knowledge engineering method of knowledge acquisition was also used in developing the HAZMAT ES. During HAZMAT ES development, information was obtained from interviews with experts from NSC Fuget Sound and the Navy Safety Center. This information was then used to aid the author in developing the knowledge base.

An intelligent editing program was used to only a very slight degree in the development of the HAZMAT ES. The VP-Expert software package used to develop the HAZMAT ES has some capabilities that prompt the expert to use proper coding and format.

3. Expert System Project Life Cycle

There are six basic steps in the development of an expert system, they are: identification, conceptualization, formalization, implementation, testing, and prototype revision. Systems are typically developed and constructed through an iterative process. The initial version is quite simplistic and the final product reflects a growth in both depth and breadth. [Ref. 10]

a. Identification Stage

The identification stage requires the domain to be specified. This stage can be made more difficult by the large number of issues that may exist within a particular domain.

32

The specific problems to be addressed and their relative importance should be identified during this stage. This step also includes the identification of potential sources of expertise and information.

In the development of the HAZMAT ES the general problem was identified by NAVSUP and Navy Safety Center personnel. In essence, the problem was transforming the expertise of an NSC safety and health manager and his ability to utilize the HMIS down to the warehouse level. The author further refined their concerns and identified a manageable domain.

b. Conceptualization Stage

• The conceptualization stage requires that goals for the expert system be specifically identified. The tasks necessary to attain this goal are also identified. Consideration should be given to the following: "what types of data are available?"; "what is the flow of this information?"; "what relationship exists between the data and the goal?"; and finally, "will the available data and information allow the goal to be attained?" The HAZMAT ES development involved a review of the available data ases and how an expert used this information in arriving at a solution.

c. Formalization Stage

The formalization stage refines the problems, key concepts, and goals identified during the conceptualization stage. This refinement is based on the knowledge engineering

33

tools in use and the form the knowledge base will take.
Modeling the process used to generate the solutions is one of
the primary goals of this stage. The models can be either
mathematical or heuristic. Examination of the model used by
the expert can provide the knowledge engineer with insights
into the key data elements used by the expert in achieving a
solution. The inter-relationship of this data can also be
isolated by examining the model.

The determining characteristic of hazardous materials,
(i.e., the "hazard" category it belongs to) as defined by the
HAZMAT ES, was identified during this phase. During this
period the quality, reliability and availability of the data
is determined. The vast majority of the data used for the
HAZMAT ES was extracted from the HMIS. This data is
plentiful, reliable, and current.

d. Implementation Phase

The next step is to structure the acquired information
into the form required by the representational tools to be
utilized by the ES. The most important aspect of this phase
is testing the adequacy of the system's underlying ideas.

The knowledge base is created during this phase with
whatever knowledge acquisition methods have been chosen. This
knowledge base is the basis for the system prototype. With
the HAZMAT ES the majority of the knowledge base was
handcrafted by the author with the remainder being created

34

using the knowledge engineering style of knowledge acquisition.

e. Testing Phase

The testing phase involves running the prototype system using simplistic examples. As examples are successfully completed the testing is expanded to encompass a wider and more complicated variety of variables and conditions. A thorough testing is required so errors and weaknesses can be identified.

Once errors are identified their cause must be determined and analyzed. It may become necessary for the knowledge engineer to review the causes of these errors with the expert. Possible errors between the knowledge source and the actual coding can occur and should be checked for to ensure the code accurately reflects the knowledge base.

The input and output devices are also tested and evaluated during this stage. Errors may be the result of misunderstandings on the part of the user caused by unclear questions being presented by the ES. An inability to elicit the required information from the user can be as debilitating to the system as a basic error in logic or judgement.

More than 150 tests were conducted in the course of developing the final version of the HAZMAT ES. The author was the primary expert for the system testing its logic, while three students tested the system from a user's point of view.

35

The results of these tests are discussed in detail in chapter IV.

f. Prototype Revision

This final step of ES development is very difficult to separate from the previous steps. It is the author's opinion that this is not a unique step but rather a repetition of preceding stages. Identified problems are corrected and retested.

Regardless of the fact that this may not be a unique step it is at this point that the prototype evolves into the final version of the expert system. The changes are made and the final form of the system tested.

E. SUMMARY

Basic concepts of applied artificial intelligence and expert systems were briefly discussed in this chapter. The knowledge acquisition process in the HAZMAT ES was primarily handcrafting and knowledge engineering. The development of the HAZMAT ES followed the typical phases of an expert system software life cycle discussed in sub-section D-3.

IV. SOFTWARE AND USER INTERFACE CONSIDERATIONS IN THE DEVELOPMENT OF THE HAZARDOUS MATERIAL EXPERT SYSTEM

A. INTRODUCTION

This chapter addresses the issues and problems the system developer and knowledge engineer faced in developing the Hazardous Material Expert System (HAZMAT ES) (the author was both). The expert system shells used to produce the HAZMAT ES are also discussed, as well as considerations given to ease of use and user interface.

Two HAZMAT ES's, versions 1.0 and 2.0, were developed in the course of this thesis effort. Version 1.0 was developed for use with the M.1 expert system shell and Version 2.0 was for the VP-Expert shell. Between December 1989 and April 1990 HAZMAT ES 2.0 underwent more than 150 test consultations by the author and other students (Lieutenants David King, Brad Robinson, and Aaron Rouska) in order to confirm the system's logic, examine the presentation of information, and resolve other user interface matters. The author tested the logic of the system. The students were used to test the system from the user's point of view.

B. HAZMAT ES VERSION 1.0

The M.1 rule-based expert system shell is a software tool developed by TEKNOWLEDGE, Incorporated, for use on a MS-DOS personal computer (PC). As with most ES shells it uses a knowledge system built around a knowledge base of facts and rules and an inference engine that performs the reasoning process to solve a specific task.

The M.1 system has a number of useful features:

o   Backward and, to a limited extent, forward chain reasoning

o   Menu of acceptable responses provided to the user

o   Help facility

o   Interactive debugging capability

o   Pull-down menus

o   Questions to be presented to the user can be written in plain English by the ES designer

The knowledge base for both M.1 and VP-Expert based expert systems is an ASCII text file created and edited using any ASCII text editor. In the course of developing HAZMAT ES 1.0 both Sidekick and WordPerfect editors were used. Both have their advantages and disadvantages. The Sidekick editor could be accessed while the M.1 system was on-line, allowing for easier and quicker editing. However, the Sidekick editor's memory capacity was limited and a text file could easily grow too large for the Sidekick editor. The author was more familiar with the WordPerfect editor and preferred it for

38

larger scale editing efforts such as originally building the file and making repetitive editing changes. However, in order to use the WordPerfect text editor it was necessary to exit the M.1 program and enter WordPerfect. This was too bothersome for minor changes and Sidekick was used quickly in these instances

HAZMAT ES 1.0 was initially begun as a class project for a course taught at the Naval Postgraduate School. This class project was used primarily as a feasibility study. At the end of the course the existing version of HAZMAT ES 1.0 had little work done towards improving screen presentations or user interface. The HAZMAT ES 1.0 display screen was essentially the ready made screen provided by the M.1 shell with a few minor changes made by the author. The only change made involved slight alterations to the text display screens. The alterations were required so that the text display could be made in an uninterrupted form. The delivered product would require much more attention in this area.

Due to changes in the schedule of the author, a change in thesis advisor, and the availability of an improved expert system software shell, no additional work was done with HAZMAT ES 1.0. However, HAZMAT ES 1.0 was considered a success in that it proved ES technology was a feasible and practical management alternative for hazardous material.

C. HAZMAT ES VERSION 2.0

1. VP-Expert

The VP-Expert rule-based expert system shell is a product of Paperback Software International. The initial reason for changing fror. M.1 to VP-Expert was the termination of the School's license agreement with TEKNOWLEDGE and the solicitation of a new ES shell. The change was forced upon this thesis effort but, for reasons to be discussed further, it proved to be a favorable one.

VP-Expert provides all of the same basic features as M.1 and more. VP-Expert has its own on-line ASCII text editor. If an error is detected while attempting to compile the knowledge system text file the editor automatically comes on-line, loading the text file. In addition, the editor points to the general area in which the error occurred and provides a brief error message. This made trouble shooting efforts much quicker and simpler with VP-Expert than M.1.

In addition, the VP-Expert system allows for the easy introduction of "windowed" text presentations. This feature is extensively utilized in HAZMAT ES 2.0 and will be further discussed under the user interface section of this chapter.

An expert system developed for the VP-Expert Shell normally has a multi-colored tri-window display on screen. The three windows are the rules window, the values window, and the text winaow. The rules window displays the rules as

40

they are being examined by the inference engine. The values window displays the value for any variables identified up to that point in the consultation. The text window is the principal area for communication with the user. The instructions and questions appear in this window.

These windows can be very useful during the course of system development and testing. The rule that is under consideration and the values which have been assigned are vital pieces of information when debugging logic problems in the rule base. However, to the user this extraneous information can be distracting. VP-Expert offers a feature which will eliminate the rules and values windows so that the text window will fill the entire screen. This feature was incorporated into the final version of the HAZMAT ES 2.0.

2. Program Evolution

The relationship of version 2.0 to 1.0 is very clear. The research that went into building the knowledge base was the same. The logic and organization was essentially unchanged with the exception of improvements discussed in the following sections. Some changes to the code used for HAZMAT ES 1.0 were required to satisfy VP-Expert's coding requirements.

Prior to the final version of HAZMAT ES 2.0 being produced, the program went through a number of evolutions. Six distinct versions were created, each building on its pre-

decessor. The init.al version contained all of the basic rules required to demonstrate that the logic being used would work and run on the compiler. Once the author felt comfortable with the VP-Expert systems operation this file was expanded to create a second file which covered all necessary aspects of the hazardous material environment.

The third version of the program started to address the questions that would be posed to the user by the system. The questions are needed to obtain sufficient information for the inference engine to provide a solution. An automatic question generation feature is provided with the VP-Expert system, but it is also possible to write questions tailored to the HAZMAT ES's specific user group. A third option is to use the question generator to produce basic questions and then the programmer can edit them to read exactly as desired. The questions used by the HAZMAT ES 2.0 were all designed by the author. This evolutionary process was consistent with the adaptive design approach in building expert systems as discussed in the literature.

3. User Interface: Timing Considerations

Once the programming and organization issues were re-solved the development effort was directed towards how the user viewed the system during a consultation. Prior to discussing these considerations it is necessary to review the process the inference engine uses during consultations.

As with most expert systems, the HAZMAT ES 2.0's inference engine uses backward chaining. With this type of reasoning the goal variable is immediately identified by the inference engine, the engine then moves through the "IF-THEN" rules cortained in the rule base, attempting to locate a rule with a "THEN" clause value that satisfies the goal variable. All VP-Expert systems' inference engines search through the rules in the order that the rules are listed in the text file.

The "IF" conditions which lead to the "THEN" value that satisfies the goal are identified. The engine then checks its memory, searching for solutions to these "IF" values. If all of these "IF" values are not known the system will ask the user for the values (this is where the previously discussed questions are utilized). Once all of the rule's "IF" values are determined to be true or false the engine can determine if the entire rule is true or false and can satisfy the goal variable. This is the "rule firing" process previously mentioned in Chapter II.

The first three versions of the HAZMAT ES organized the rules by hazard categories. For example, the first group of rules covered all possible situations involving combustible material. The second group contained rules covering all possible situations involving flammables, and so on.

If the rules for the hazard under consideration are located towards the end of the text file then the search time for a final solution or for the next question to be presented

43

can be one to two seconds. During system testing, waits for the next screen could seem rather long. This was particularly true when compared to the very short waits involved for consultations dealing with rules located at the beginning of the text file.

In order to correct these inconsistent waiting periods the fourth version of the HAZMAT ES featured rules grouped by the type of information being sought rather than hazard groups. The first group of rules provided final solutions for all types of hazards. The second group of rules provided flash point information for all types of hazards and so on.

The average waiting period between questions remains essentially unchanged; but the extreme waiting periods, both long and short, were eliminated. This change occurred because the responses the user gave always caused the inference engine to either: (1) provide an immediate solution; or (2) search to the next group of rules.

Depending on the speed of the PC being used a slight wait will always be experienced, but changes in version four assured the wait is relatively consistent from question to question. The average wait is now no longer than one-half second. During test consultations users quickly became accustomed to this standardized waiting period.

4. User Interface: Presentation Considerations

The changes in the fifth and sixth versions were related to user interface and presentation considerations. The questions which query the user in order to obtain the information necessary to satisfy the system's goal are designed to be clear and direct. In addition, the questions were designed so that the possible responses would be elementary and unambiguous.

The most important presentation screen is the one with the final solution. Several programming tools were used to make this screen distinctive. First, a clear screen command is given prior to the presentation of tne information. This causes all of the previously displayed questions and responses to disappear and leave the screen blank.

To reinforce the fact that the system is providing a final product and not merely asking more questions all of the screen's information is presented in capital letters. In addition, blank lines were inserted between the different

sections of the displays. Each display consists of a gener‑
ic response and then a specific (fictitious) storeroom
recommendation. For example:

"THIS POISONOUS MATERIAL MAY BE STORED IN A
GENERAL STOREROOM.

STOREROOM 9 WOULD BE AN IDEAL LOCATION."

Prior to this system actually being implemented it would
become necessary to either eliminate the fictitious store‑
rooms from the responses or edit the rules to reflect actual
storeroom locations.

To further distinguish responses VP-Expert's windowing
capabilities were utilized. Each response appears in a pop‑
up window with contrasting colors in relation to the screen
presenting the original questions.

5. System Packaging

The final step for system development was combining the
required VP-Expert files, the HAZMAT ES text file, and disk
operating system (MS-DOS) commands on to a single floppy disk.
This allows the system to be completely transportable to any
PC operating with MS-DOS and 384K of available RAM. An auto
executive file, file copy of the user's manual and greeting
message were also added. The total HAZMAT ES text file

46

contains 41 rules and 18,000 bytes. The HAZMAT ES is contained on two disks and is designed to be completely self sufficient and self starting. All the user has to do is turn on his PC and boot the first disk.

VP-Expert also contains an on-line help facility to aid the user during consultations. The features of this facility which are pertinent to the HAZMAT ES 2.0 user are discussed in the HAZMAT ES 2.0 User's Manual, Appendix B.

D. PROGRAMMING AND LOGIC CONSIDERATIONS

1. The Basic Process

As previously discussed, the HAZMAT ES views the hazardous materials under consideration as belonging to one of eight hazard categories. These categories are: acids, flammables, toxics, explosives, combustibles, alkalines, oxidizers, and poisons. Identification of the hazard group a particular material belongs to is the first variable the HAZMAT ES investigates during a consultation. This is done during a consultation by a direct question to the user asking what the material's hazard group is. The text file also contains a rule to provide the user with guidance if the material's hazard is unknown.

The goal being sought for the HAZMAT ES has been assigned the name "storage" in the rule-based text file. Two values can be achieved for the storage variable, they are "ok" and

47

"info". If the value for storage is determined to be "ok" this means the user does not require information regarding the material's flash point, disposal, or reactivity. When no information is requested the storage variable is set equal to "ok".

Once the material's hazard category has been identified and the storage variable set to "ok" the screen then displays the proper storage conditions for the material. A storeroom recommendation is also displayed on the same screen (for the purposes of examples and to show the HAZMAT ES's capabilities, fictitious storeroom locations have been created and these are what are provided on the screen display).

2. Additional Information

If required for any reason the user may obtain information on the flash point, disposal, or reactivity of the material being considered. When the user is asked if information is needed he responds with the type of information needed. The information variable is then set equal to that information (flash point, reactivity, or disposal) and the storage variable is set equal to "info". The screen display will provide the user with the requested information. The user may record this information for future use as needed. Once the information is obtained the consultation is continued on the next screen and the final storage solution may be obtained.

48

As a result of discussions with the NSC Puget Sound safety and health manager, HAZMAT ES 2.0 contains an information feature not included in version 1.0. HAZMAT ES 1.0 only offered the user information on disposal and flash point of the material under consideration. The NSC PS personnel indicated they often needed information on the reactivity of an item and having it readily available in the HAZMAT ES would make the system more useful to the warehouse workers. Incorporating this desired information into the rule base increased the number of rules by approximately twenty-five percent but did not present any major problems.

3. Testing and Potential Problems

A logic problem manifested itself during system tests. The inference engine successively asked the user if information was desired about flash point, reactivity, or disposal. The answer to each of these questions was simply "yes" or "no". However, if the user answered "yes" to more than one of these questions he was only provided with one piece of desired information. Similar testing was done to a less extensive degree with HAZMAT ES 1.0 and no such problems were discovered. It appears to be a potential problem only with VP-Expert.

A number of approaches were tried to correct this condition. One failed attempt placed rules at the beginning of each section which were designed to detect two "yes" respon-

49

ses and then instructed the user to only request one piece of information per consultation.

Another failed attempt placed all three information variables in every rule. Only one of the information variables was assigned a "yes" value in these rules and the other two variables assigned the value "no". The author was unable to determine why these approaches failed.

The solution ultimately proved to be very simple. Rather than three questions asking the user if information was desired on a specific feature (flash point, reactivity, or disposal), the user is merely asked one question with four possible answers; specifically: "What do you need information about?" The possible responses are "flash point, disposal, reactivity, or none".

E. A SAMPLE CONSULTATION

To allow the reader to understand the entire HAZMAT ES consultation process a simple example of how the system would be employed by a warehouse worker is presented. For example, a new item is received on the loading dock. The warehouse worker checks the Material Safety Data Sheet to determine the item's hazard category and finds it is a combustible, its physical state is solid. Assuming the system has been loaded to the computer as described in the user's manual (Appendix B), the greeting screens shown in figures 4.1 and 4.2 will appear in succession. Figure 4.1 is external to the VP-

50

Expert program while figure 4.2 is the customized greeting screen shown once VF-Expert has been loaded.

```
THIS EXPERT SYSTEM CAN PROVIDE THE USER WITH
INSTRUCTIONS ON HOW OR WHERE TO STORE A NEWLY
RECEIVED HAZARDOUS MATERIAL.  IF REQUESTED THE
SYSTEM CAN PROVIDE THE USER WITH INFORMATION ON
THE HAZARDOUS MATERIAL'S FLASH POINT, REACTIVITY,
OR DISPOSAL.

AN ON-LINE HELP FACILITY IS RESIDENT IN THE EXPERT
SYSTEM AND CAN BE ACCESSED BY TYPING /H AT ANY TIME
DURING A CONSULTATION.  IN ADDITION, A TEXT FILE OF
THE USER'S MANUAL IS PROVIDED ON THIS DISK.  A COPY
MAY BE OBTAINED BY ENTERING THE DOS COMMAND  "PRINT
USER.MAN" AFTER EXITING THE CONSULTATION.
```

Strike a key when ready . . .

Figure 4.1

```
   The Hazardous Material Expert System will
provide you with advice on the proper storage for recently
received, ready-for-issue, hazardous materials.  Whenever
possible, a specific storeroom location will be
recommended.   In addition, the user may ask this expert
system to provide specific information on an item's
flash point, reactivity, or disposal. The system provide
will only one of these factors per consultation,
if more than one is desired additional consultations
should be initiated.

   Press the "go" key to begin the consultation.
```

1Help   2Go   3WhatIf   4Variable 5Rule   6Set
7Edit   8Quit

Figure 4.2

Once the user strikes the "go" key, the first screen to

appear, as represented by figure 4.3, will inquire as to the

52

primary hazard associated with the material under consideration. The response is "combustible" (The selected response is represented in the figure by ^Q, on the screen an inverted triangle is displayed).

```
What is the primary hazard associated with the
material you need storage information about? (If a second
hazard is associated with the material an additional
consultation should be run.)

  Explosive        Toxic           Combustible ^Q
  Flammable        Alkaline        Oxidizer
  Poison           Acid            Uncertain



1Help      2Go         3WhatIf    4Variable 5Rule      6Set
7Edit      8Quit
```

Figure 4.3

After the response a second question will appear on the same screen and ask the user the physical state of the material under consideration. The response, represented in figure 4.4, is "liquid." The preceding question regarding the hazard, and the response, will remain on the screen.

```
What is the primary hazard associated with the
material you need storage information about? (If a second
hazard is associated with the material an additional
consultation should be run.)
 Explosive           Toxic              Combustible ^Q
 Flammable           Alkaline           Oxidizer
 Poison              Acid               Uncertain

What is the physical state of the material
you need storage information about?
 Solid               Liquid ^Q          Gas
```

1Help   2Go   3WhatIf   4Variable 5Rule   6Set
7Edit   8Quit

Figure 4.4

The system will then inquire if information is required
regarding flash point, reactivity, or disposal. If the user
indicates that information about one of these items is needed
the response provided is shown in figure 4.5. In this example
disposal information was requested. Figure 4.6 shows the
system's response. Figure 4.7 represents a response when no
additional   information   is   needed,   only   a   storage
recommendation is desired. The response in this case is shown
in figure 4.8. Once the consultation is complete touching any
key will return the user to the main screen (figure 4.2) where
another consultation may begin or the program may be exited.

54

```
What is the primary hazard associated with the
material you need storage information about? (If a second
hazard is associated with the material an additional
consultation should be run.)
 Explosive           Toxic               Combustible ^Q
 Flammable           Alkaline            Oxidizer
 Poison              Acid                Uncertain

What is the physical state of the material
you need storage information about?
 Solid               Liquid ^Q           Gas

Do you need information about the FLASH POINT,
REACTIVITY, or DISPOSAL of the material
you are considering for storage?
 Flash Point         Reactivity          Disposal ^Q
 No
```

```
1Help      2Go        3WhatIf    4Variable 5Rule       6Set
7Edit      8Quit
```

Figure 4.5

```
IN ORDER TO DISPOSE OF THIS COMBUSTIBLE MATERIAL
MIX IT WITH SOIL RICH IN ORGANIC MATERIAL.




                        PRESS ANY KEY TC CONTINUE
```

Figure 4.6

```
What is the primary hazard associated with the
material you need storage information about? (If a second
hazard is associated with the material an additional
consultation should be run.)
 Explosive            Toxic                Combustible ^Q
 Flammable            Alkaline             Oxidizer
 Poison               Acid                 Uncertain

What is the physical state of the material
you need storage information about?
 Sclid                Liquid ^Q            Gas

Do you need information about the FLASH POINT,
REACTIVITY, or DISPOSAL of the material
you are considering for storage?
 Flash Point          Reactivity           Disposal
 No ^Q
```

1Help   2Go   3WhatIf   4Variable 5Rule   6Set
7Edit   8Quit

Figure 4.7

```
THIS COMBUSTIBLE MATERIAL MAY BE STORED IN A
GENERAL STOREROOM WITH AN AMBIENT TEMPERATURE
OF LESS THAN 125 DEGREES FAHRENHEIT.


STOREROOM NUMBER 25 IS AN IDEAL LOCATION,
STOREROOM NUMBER 27 WOULD BE AN ACCEPTABLE
LOCATION FOR SHORT-TERM STORAGE.


                          PRESS ANY KEY TO CONTINUE
```

Figure 4.8

V. SUMMARY AND CONCLUSIONS

A. The Hazardous Material Expert System

The ability to successfully develop an expert system application is largely a function of the subject being considered. The author's experience with the HAZMAT ES shows that an expert system can be developed to replace the on-site "expert" required when dealing with ready-for-issue hazardous materials at a Naval Supply Center (NSC). A warehouse worker with very little hazardous material or computer training can make the correct decision and safely store hazardous materials.

The HAZMAT ES successfully incorporates the basic guidelines contained in the principal Department of Defense source of information for hazardous material, the Hazardous Material Information System. To make the HAZMAT ES' capacity small enough to function on a personal computer it was necessary to group all of the hazardous material into eight general categories. This grouping also made it unnecessary to periodically update the HAZMAT ES when the quarterly HMIS is promulgated.

If the ES was tied to the HMIS by unique line item it would be necessary for a programmer to review and amend the

rule base on a quarterly basis. HAZMAT ES 2.0 requires no such periodic updating to remain current. Unless a significant change takes place in terms of hazardous material management technology or policy, no changes are necessary.

However, organizing the hazardous materials into groups takes away from the exactness of the expert system. The HMIS addresses each type of hazardous material as an individual item with unique characteristics. The approach taken by the HAZMAT ES uses the characteristics of the hazardous category the material belongs to. This grouping causes the system to lose its preciseness. For example, an item with a flash point of 250 degrees fahrenheit will be included in a group with a flash point characteristic of 225 degrees or higher.

Initially, because the HAZMAT ES will have to treat items as members of a hazard group and not individual items, it is recommended that storage decisions made by warehouse personnel and the HAZMAT ES be forwarded to the center's safety and health manager for validation as is done under the current procedure. Potential errors due to HAZMAT ES logic make it important that the recommended decision be verified by a human expert.

As ES technologies improve it may be possible for a personal computer-based HAZMAT ES to be developed that addresses each line item uniquely. This potentiality will be discussed further in the concluding section.

B. **Other Applications and Potential Projects For Future Study**

Other expert systems for use at Naval Supply Centers have been successfully developed by other thesis students at the Naval Postgraduate School. These systems include a dues management system and a causative research system. Other possible candidates for consideration of an expert system application are budgeting, internal auditing, and requisition filling.

The previously developed NSC expert systems, as well as the HAZMAT ES 2.0, were combined into a single application as another student's thesis effort. Lieutenant Aaron Rouska, USN, accomplished this in March 1990 during the completion of his thesis.[Ref. 12]

The HMIS was recently released on a compact disk-read only memory (CD-ROM) format. The CD-ROM HMIS, which is updated in its entirety on a quarterly basis, is designed for use with a personal computer. The VP-Expert shell may be configured for use with a data base contained on a CD-ROM. Due to the large amount of data, this would require considerable research and effort. However, such a successful application would allow each hazardous item to be uniquely identified and analyzed by an expert system. This would avoid the principal shortfall of the HAZMAT ES.

It is envisioned that the HMIS would not actually become a part of HAZMAT ES; rather, the expert system would interact with the data base and extract the necessary information.

60

Such an interaction would obviate the need for quarterly
updating of the system. As long as the format of the HMIS
remained constant the expert system would be accessing an
updated data base on a quarterly basis.

APPENDIX A: CODE FOR HAZMAT ES

The following is a listing of the ASCII text code for the
HAZMAT ES. The "!" symbol represents organizational comments
within the code that the program does not process.

HAZMAT
```
!  These first group of statements instruct the system and
!  provide the initial greeting to the user;

RUNTIME;
bkcolor = 1;
ACTIONS
WOPEN 1,3,5,16,68,6
ACTIVE 1
color = 15
     DISPLAY "     The Hazardous Material Expert System will
provide you with advice on the proper storage for recently
received, ready-for-issue, hazardous materials.  Wherever
possible, a specific storeroom location will be recommended.

     In addition, the user may ask this expert system to
provide specific information on an item's flash point,
reactivity, or disposal.  The system will can only provide
one of these factors per consultation, if more than one is
desired additional consultations should be initiated.

     Press any key to begin the consultation.`"
     CLS
WCLOSE 1
     FIND Storage;
```

```
!  These rules will provide the storage solution if no
!  information is needed for reactivity, flash point, or
!  disposal.


RULE 1
IF    Hazard = Explosive  AND
          Information = No
THEN
      Storage = OK
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
          DISPLAY "THIS EXPLOSIVE MATERIAL SHOULD BE STORED IN
A FLAMMABLE STOREROOM WITH AN INSTALLED HALON FIRE FIGHTING
SYSTEM.


STOREROOM NUMBER 27 IS AN IDEAL LOCATION.


                              PRESS ANY KEY TO CONTINUE‾";


RULE 2
IF Hazard = Acid          AND
      Information = No
THEN
      Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
```

DISPLAY "THIS ACID MATERIAL SHOULD BE STORED IN AN ACID
LOCKER THAT DOES NOT CONTAIN COMBUSTIBLES, OXIDIZERS, OR
ALKALINE MATERIALS.

STOREROOM NUMBER 16 IS AN IDEAL LOCATION.

                              PRESS ANY KEY TO CONTINUE¯";

RULE 3
IF Hazard = Toxic   AND
     Information = No
THEN
     Storage = Ok
CLS   '
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THIS TOXIC MATERIAL MAY BE STORED IN ANY AREA
THAT DOES NOT CONTAIN ACIDS, COMBUSTIBLES, OR OXIDIZING
MATERIALS.

STOREROOM NUMBER 7 IS AN IDEAL LOCATION, STOREROOM NUMBER 9
WOULD BE AN ACCEPTABLE LOCATION FOR SHORT-TERM STORAGE.

        PRESS ANY KEY TO CONTINUE¯";

RULE 4
IF Hazard = Alkaline   AND

                              64

```
        Information = No
THEN
        Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
        DISPLAY "THIS ALKALINE MATERIAL MAY BE STORED IN ANY
GENERAL STOREROOM THAT DOES NOT CONTAIN ACIDS, COMBUSTIBLES,
OR OXIDIZERS.


STOREROOM NUMBER 6 IS AN IDEAL LOCATION, STOREROOM NUMBER 9
WOULD BE AN ACCEPTABLE LOCATION FOR SHORT-TERM STORAGE.


                            PRESS ANY KEY TO CONTINUE~";


RULE 5
IF Hazard = Combustible   AND
        State = Liquid       AND
        Information = No
THEN
        Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
        DISPLAY "THIS COMBUSTIBLE MATERIAL MAY BE STORED IN A
GENERAL STOREROOM WITH AN AMBIENT TEMPERATURE OF LESS THAN
125 DEGREES FAHRENHEIT.
```

65

STOREROOM NUMBER 25 IS AN IDEAL LOCATION, STOREROOM NUMBER
27 WOULD BE AN ACCEPTABLE LOCATION FOR SHORT-TERM STORAGE.

                              PRESS ANY KEY TO CONTINUE˜";
RULE 6
IF Hazard = Combustible AND
     State = Solid   AND
     Information = No
THEN
     Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THIS COMBUSTIBLE MATERIAL SHOULD BE STORED IN
A FLAMMABLE STOREROOM WITH AN INSTALLED HALON FIRE FIGHTING
SYSTEM.

STOREROOM NUMBER 27 IS AN IDEAL LOCATION.

                              PRESS ANY KEY TO CONTINUE˜";

RULE 7
IF Hazard = Combustible AND
     State = Gas   AND
     Information = No
THEN
     Storage = Ok
CLS
WOPEN 1,5,7,12,65,3

66

ACTIVE 1

color = 14

DISPLAY "THIS COMBUSTIBLE MATERIAL SHOULD STORED IN A COMPRESSED GAS STOREROOM WITH AN INSTALLED H. FIRE FIGHTING SYSTEM.

STOREROOM NUMBER 38 IS AN IDEAL LOCATION.

                              PRESS ANY KEY TO CONTINUE";

RULE 8
IF Hazard = Flammable   AND
        State = Liquid   AND
     Information = No
THEN
     Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THIS FLAMMABLE MATERIAL SHOULD BE STORED IN A FLAMMABLE STOREROOM WITH AN INSTALLED HALON FIRE FIGHTING SYSTEM.

STOREROOM NUMBER 27 IS AN IDEAL LOCATION.

                              PRESS ANY KEY TO CONTINUE";

RULE 9
IF Hazard = Flammable   AND

67

```
            State = Gas          AND
            Information = No
THEN
            Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
      DISPLAY "THIS FLAMMABLE MATERIAL SHOULD BE STORED IN A
COMPRESSED GAS STOREROOM.


STOREROOM NUMBER 36 IS AN IDEAL LOCATION.

                              PRESS ANY KEY TO CONTINUE¯";

RULE 10
IF Hazard = Flammable     AND
      State = Solid        AND
      Information = No
THEN
      Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
      DISPLAY "THIS FLAMMABLE MATERIAL SHOULD BE STORED IN A
FLAMMABLE STORFROOM WITH AN INSTALLED HALON FIRE FIGHTING
SYSTEM.

STOREROOM NUMBER 27 IS AN IDEAL LOCATION.


                              PRESS ANY KEY TO CONTINUE¯";
```

```
RULE 11
IF Hazard = Oxidizer      AND
     Information = No
THEN
     Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THIS OXIDIZING MATERIAL MAY BE STORED IN ANY
GENERAL STOREROOM THAT DOES NOT CONTAIN ACIDS, COMBUSTIBLES,
OR ALKALINE MATERIAL.


STOREROOM NUMBER 5 IS AN IDEAL LOCATION, STOREROOM NUMBER 9
WOULD BE AN ACCEPTABLE LOCATION FOR SHORT-TERM STORAGE.



                         PRESS ANY KEY TO CONTINUE~";


RULE 12
IF Hazard = Poison      AND
     Information = No
THEN
     Storage = Ok
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
```

69

DISPLAY "THIS POISONOUS MATERIAL MAY BE STORED IN A
GENERAL STOREROOM.

STOREROOM NUMBER 11 IS AN IDEAL LOCATION.

                              PRESS ANY KEY TO CONTINUE`";

! This rule instructs the user on how to obtain information
! on the general hazard of the item if it is not known.

RULE 13
IF Hazard = Uncertain
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "OBTAIN THE MATERIAL SAFETY DATA SHEET (MSDS)
THAT ACCOMPANIED THIS MATERIAL AND DETERMINE THE GENERAL
HAZARD ASSOCIATED WITH THIS MATERIAL. IF AN MSDS IS NOT
AVAILABLE CONTACT THE SUPPLY CENTER HEALTH AND SAFETY
MANAGER FOR ADDITIONAL ASSISTANCE.

             PRESS ANY KEY TO CONTINUE`";

! These rules provide information on the flash point of the
! various types of material.

70

```
RULE 14
IF Hazard = Toxic           AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT FOR THIS TOXIC MATERIAL IS
HIGHER THAN 200 DEGREES FAHRENHEIT.


                              PRESS ANY KEY TO CONTINUE~";


RULE 15
IF Hazard = Combustible  AND
     State = Liquid        OR
     State = Gas           AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT OF THIS COMBUSTIBLE MATERIAL
IS LESS THAN 125 DEGREES FAHRENHEIT AND APPROPRIATE CAUTION
SHOULD BE EXERCISED.

                              PRESS ANY KEY TO CONTINUE~";
```

71

```
RULE 16
IF Hazard = Combustible  AND
     State = Solid        AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT OF THIS COMBUSTIBLE MATERIAL
IS LESS THAN 200 DEGREES FAHRENHEAT.



          PRESS ANY KEY TO CONTINUE˜";


RULE 17
IF Hazard = Flammable    AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT OF THIS FLAMMABLE MATERIAL IS
LOWER THAN 100 DEGREES FAHRENHEIT, APPROPRIATE CAUTION
SHOULD BE EXERCISED.



                         PRESS ANY KEY TO CONTINUE˜";
```

```
RULE 18
IF Hazard = Explosive    AND
    Information = Flash_Point
THEN
    Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
    DISPLAY "THE FLASH POINT OF THIS EXPLOSIVE MATERIAL IS
LESS THAN 73 DEGREES FAHRENHEIT, APPROPRIATE CAUTION SHOULD
BE EXERCISED.


                    PRESS ANY KEY TO CONTINUE¯";



RULE 19
IF Hazard = Alkaline    AND
    Information = Flash_Point
THEN
    Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
    DISPLAY "THE FLASH POINT OF THIS ALKALINE MATERIAL
EXCEEDS 200 DEGREES FAHRENHEIT.



                    PRESS ANY KEY TO CONTINUE¯";
```

73

```
RULE 20
IF Hazard = Oxidizer       AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT FOR THIS OXIDIZING MATERIAL IS
LESS THAN 200 DEGREES FAHRENHEIT.


                         PRESS ANY KEY TO CONTINUE~";


RULE 21
IF Hazard = Poison         AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT OF THIS POISONOUS MATERIAL IS
IN EXCESS OF 225 DEGREES FAHRENHEIT.


                         PRESS ANY KEY TO CONTINUE~":


RULE 22
```

74

```
IF Hazard = Acid          AND
     Information = Flash_Point
THEN
     Storage = Info
CLS
WOPEN 1,5,7.12,65,3
ACTIVE 1
color = 14
     DISPLAY "THE FLASH POINT OF THIS ACIDIC MATERIAL IS
LESS THAN 200 DEGREES FAHRENHEIT.



          PRESS ANY KEY TO CONTINUE~";


!  These rules provide information for the disposal of the
!  various types of material.


RULE 23
IF   Hazard = Explosive  AND
       Information = Disposal
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THIS EXPLOSIVE MATERIAL SHOULD BE RETURNED TO
THE MANUFACTURER IF DISPOSAL IS REQUIRED.

                         PRESS ANY KEY TO CONTINUE~";
```

```
RULE 24
IF Hazard = Toxic         AND
        Information = Disposal
THEN
     Storage = info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "IN ORDER TO DISPOSE OF THIS TOXIC MATERIAL MIX
IT WITH SOIL.


                         PRESS ANY KEY TO CONTINUE`";


RULE 25
IF Hazard = Combustible  AND
     State = Solid        OR
     State = Liquid       AND
        Information = Disposal
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "IN ORDER TO DISPOSE OF THIS COMBUSTIBLE
MATERIAL MIX IT WITH SOIL RICH IN ORGANIC MATERIAL.


                         PRESS ANY KEY TO CONTINUE`";


RULE 26
```

```
IF Hazard = Combustible   AND
     State = Gas           AND
        Information = Disposal
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "IN ORDER TO DISPOSE OF THIS COMBUSTIBLE
MATERIAL CONFIRM THAT IT IS NOT TOXIC AND VENT IT TO THE
ATMOSPHERE.  IF THE GAS IS TOXIC IT MUST BE RETURNED TO THE
MANUFACTURER OR SUPPLIER FOR DISPOSAL.


                         PRESS ANY KEY TO CONTINUE";


RULE 27
IF Hazard = Flammable    AND
     State = Liquid       AND
        Information = Disposal
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "IN ORDER TO DISPOSE OF THIS FLAMMABLE MATERIAL
MIX ANY UNCOMBINED PORTIONS AND MIX THE RESULTING PRODUCT
WITH SOIL RICH IN ORGANIC MATERIALS.


                         PRESS ANY KEY TO CONTINUE";
```

```
RULE 28
IF Hazard = Flammable     AND
      State = Gas          AND
          Information = Disposal
THEN
      Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
      DISPLAY "IN ORDER TO DISPOSE OF THIS FLAMMABLE MATERIAL
CONFIRM THAT IT IS NOT TOXIC AND VENT IT TO THE ATMOSPHERE.
IF THE GAS IS TOXIC IT MUST BE RETURNED TO THE MANUFACTURER
OR SUPPLIER FOR DISPOSAL.



                        PRESS ANY KEY TO CONTINUE ";


RULE 29
IF Hazard = Flammable     AND
      State = Solid        AND
          Information = Disposal
THEN
      Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
      DISPLAY "IN ORDER TO DISPOSE OF THIS FLAMMABLE MATERIAL
SLOWLY ADD IT TO A SMALL CONTAINER OF WATER; THEN WASH THE
FILTRATE TO A SEWER DRAIN AND BURY THE REMAINING SLUDGE.
```

78

```
                                    PRESS ANY KEY TO CONTINUE`";


    RULE 30
    IF Hazard = Alkaline      AND
            Information = Disposal
    THEN
         Storage = Info
    CLS
    WOPEN 1,5,7,12,65,3
    ACTIVE 1
    color = 14
         DISPLAY "IN ORDER TO DISPOSE OF THIS ALKALINE MATERIAL
    DILUTE IT WITH EXCESSIVE WATER AND THEN DISPOSE OF THE
    RESULTING PRODUCT IN A SANITARY SEWER DRAIN.


                                    PRESS ANY KEY TO CONTINUE`";


    RULE 31
    IF Hazard = Oxidizer      AND
            Information = Disposal
    THEN
         Storage = Info
    CLS
    WOPEN 1,5,7,12,65,3
    ACTIVE 1
    color = 14
         DISPLAY "IN ORDER TO DISPOSE OF THIS OXIDIZING MATERIAL
    MIX IT WITH SOIL.

                                    PRESS ANY KEY TO CONTINUE`";
```

```
RULE 32
IF Hazard = Poison          AND
        Information = Disposal
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "THIS POISONOUS MATERIAL SHOULD BE RETURNED TO
THE MANUFACTURER OR SUPPLIER FOR DISPOSAL.


                          PRESS ANY KEY TO CONTINUE~";


RULE 33
IF Hazard = Acid            AND
        Information = Disposal
THEN
     Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
     DISPLAY "IN ORDER TO DISPOSE OF THIS ACIDIC MATERIAL
MIX IT WITH A BASE MATERIAL AND THEN WASH THE RESULTING
PRODUCT TO A SANITARY SEWER DRAIN.


                     PRESS ANY KEY TO CONTINUE~";
```

80

```
!  These rules provide information in regards to the
!  reactivity of the various types of material.


RULE 34
IF Hazard = Toxic          AND
        Information = Reactivity
THEN
      Storage = info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
      DISPLAY "THIS TOXIC MATERIAL IS STABLE.



                          PRESS ANY KEY TO CONTINUE";



RULE 35
IF Hazard = Combustible  AND
        State = Solid        OR
        State = Liquid       OR
        State = Gas          AND
            Information = Reactivity
THEN
      Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
      DISPLAY "THIS COMBUSTIBLE MATERIAL CAN BECOME UNSTABLE
IF HEATED, KEEP IT IN A COOL PLACE OUT OF THE DIRECT LIGHT
OF THE SUN.
```

RULE 36

IF Hazard = Flammable   AND
        Information = Reactivity

THEN

     Storage = Info

CLS

WOPEN 1,5,7,12,65,3

ACTIVE 1

color = 14

     DISPLAY "THIS FLAMMABLE MATERIAL MAY BECOME UNSTABLE IF
HEATED, KEEP IT IN A COOL PLACE OUT OF THE DIRECT LIGHT OF
THE SUN.

PRESS ANY KEY TO CONTINUE¯";

RULE 37

IF Hazard = Alkaline   AND
        Information = Reactivity

THEN

     Storage = Info

CLS

WOPEN 1,5,7,12,65,3

ACTIVE 1

color = 14

     DISPLAY "THIS ALKALINE MATERIAL MAY BECOME UNSTABLE IF
HEATED, KEEP IT IN A COOL PLACE OUT OF THE DIRECT LIGHT OF
THE SUN.

PRESS ANY KEY TO CONTINUE¯";


```
        RULE 38
        IF Hazard = Oxidizer      AND
                Information = Reactivity
        THEN
             Storage = Info
        CLS
        WOPEN 1,5,7,12,65,3
        ACTIVE 1
        color = 14
             DISPLAY "THIS OXIDIZING MATERIAL MAY BECOME UNSTABLE IF
        HEATED, KEEP IT IN A COOL PLACE OUT OF THE DIRECT LIGHT OF
        THE SUN.
```

PRESS ANY KEY TO CONTINUE¯";


```
        RULE 39
        IF Hazard = Poison        AND
                Information = Reactivity
        THEN
             Storage = Info
        CLS
        WOPEN 1,5,7,12,65,3
        ACTIVE 1
        color = 14
             DISPLAY "THIS POISONOUS MATERIAL IS STABLE.
```

83

PRESS ANY KEY TO CONTINUE`";

RULE 40
IF Hazard = Acid   AND
        Information = Reactivity
THEN
    Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
    DISPLAY "THIS ACIDIC MATERIAL MAY BECOME UNSTABLE IF
HEATED, KEEP IT IN A COOL PLACE OUT OF THE DIRECT LIGHT OF
THE SUN.

                        .

                        PRESS ANY KEY TO CONTINUE`";

RULE 41
IF   Hazard = Explosive AND
        Information = Reactivity
THEN
    Storage = Info
CLS
WOPEN 1,5,7,12,65,3
ACTIVE 1
color = 14
    DISPLAY "THIS EXPLOSIVE MATERIAL MAY DETONATE,
APPROPRIATE CAUTION SHOULD BE EXERCISED.

                        PRESS ANY KEY TO CONTINUE`";

```
!   The following questions and answers are used by the
!   system to will prompt the user so the system may obtain
!   the information necessary to provide the required
!   storage information.  These questions are presented in
!   standard VP-Expert format.
```

ASK Hazard: "What is the primary hazard associated with the material you need storage information about? (If a secondary hazard is associated with the material an additional consultation should be run.)";
CHOICES Hazard: Explosive, Toxic, Combustible, Flammable, Alkaline, Oxidizer, Poison, Acid, Uncertain;

ASK State: "What is the physical state of the material you need storage information about?";
CHOICES State: Solid, Liquid, Gas;

ASK Information: "Do you need information on the FLASH POINT, REACTIVITY, or DISPOSAL of the material you are considering for storage?";
CHOICES Information: Flash_Point, Reactivity, Disposal, No;

APPENDIX B: HAZMAT USER'S MANUAL

A. INTRODUCTION

The Hazardous Material Expert System will allow you to determine the proper storage conditions and location for a recently received hazardous material. In addition, it can give you information on an item's flash point, reactivity, and disposal information.

The system is keyed to the item's "hazard", specifically: is it acid, alkaline, caustic, combustible, corrosive, explosive, flammable, or poison? In order to proceed with a consultation using the HAZMAT ES you must know what this hazard is. This information is contained on the Material Safety Data Sheet (MSDS) or marked on the shipping container. It should also be labeled on the material's container.

B. GENERAL NOTES

1. These instructions assume the user is moderately familiar with MS-DOS operations. However, no PC familiarity, beyond turning on the computer, is required to actually operate the HAZMAT ES.

2. The HAZMAT ES is included on two diskettes. Diskette #1 contains all the files (MS-DOS and VP-Expert) necessary to operate the system. Diskette #2 contains user assistance files.

3. An ASCII text file copy of these instructions is included on diskette #2 under the name USER.MAN. A hard copy of the file may be produced using the MS-DOS print command or by using any word processor capable of loading an ASCII file.

4. Fixed disk users may copy both diskettes to a directory of their choosing on the C: drive. Type the command "start" to begin a consultation from the C: drive.

5. Prior to beginning a consultation it is advisable to have the appropriate MSDS at your disposal. The MSDS will provide you with the information you need to answer the system's inquiries.

C. OPERATING INSTRUCTIONS

1. Starting the HAZMAT ES: The HAZMAT ES diskette #1 contains the necessary MS-DOS files to allow you to boot your personal computer (PC) using only this disk. To do this, turn on your PC with HAZMAT ES diskette #1 in the A: drive and diskette #2 in the B: drive. You will be taken through a series of introductory and instructional screens and then the system will be on-line. Reminder: If you have copied the HAZMAT ES files to a fixed disk type the command "start" to begin a consultation.

2. HAZMAT Commands: Once the system is on-line all HAZMAT ES commands may be entered in one of three ways:

    1. Enter the number of the selection you desire.

    2. Enter the first letter of the selection you desire.

    3. Using the keypad arrows scroll the lightbar to the choice you desire and then press the "enter" key. In most cases the selection you desire will be the default selection and the lightbar will already be on that selection.

    Example: You wish to start a consultation, the command for this is "#2 Go". You may press the number "2" key, you may press the "g" (for go) key, or you may use the arrows to

87

scroll the lightbar to the "#2 Go" command and then press the "enter" key. All three options have the same effect.

3. Responding to HAZMAT questions: All HAZMAT FS questions are answered in the same manner. Scroll the lightbar to the desired response, press the "enter" key to mark the response and then press the "end" key. All possible answers are provided with the questions.

4. Starting the Consultation: At this point the knowledge base is loaded and you are ready to begin. Start the consultation by selecting the go command. You will receive a greeting screen with a quick explanation of the HAZMAT ES. Press any key to continue with the consultation.

5. The First Screen: The initial screen after the greeting will ask you the hazard associated with the material under consideration. All possible choices will be displayed, scroll the lightbar to the correct response and press the "enter" key to mark the response. To proceed to the next screen press the "end" key.

6. The State of the Hazard: Navy personnel use hazardous materials that can be in one of three physical states: solid, liquid, and gas. In order to provide accurate advice for certain materials the HAZMAT ES must know the physical state

88

of the material under consideration. Do not be concerned if this question is not asked. This means the information is not required for the material under consideration. If the question is asked, select the appropriate response and press the "end" key to proceed.

7. <u>Flash Point, Reactivity, or Disposal Information</u>: If you desire, the HAZMAT ES will provide information on the flash point, reactivity, or disposal of the material under consideration. Only one of these items may be selected per consultation. If an additional item of information is desired you have two options: run another consultation (they don't take long), or use the "#3 What If" feature. This feature is discussed in paragraph 9 below.

8. <u>The Storage Recommendation</u>: If no information is desired, select the "no" response and press the "end" key to proceed. At this point you will be provided with a recommendation for general storage conditions. In addition, a specific storeroom location(s) is/are provided. You may now start another consultation by selecting "#2 Go", or exit the program by selecting "#8 Quit" twice.

9. <u>The "Help" Feature</u>: If you desire assistance during a consultation you may enter the Help feature by selecting the back slash ("\") key and then selecting "#2 Help". (If the

HAZMAT ES has not be copied to a fixed disk then HAZMAT ES diskette #2 must be in the B: drive). The help feature will provide you with guidance on the system and its features.

10. The "What If" Feature: This feature allows you to change your responses after they have been selected and you have pressed the "end" key. This feature may also be used after a consultation is completed. Selecting this feature will give you four choices of variables to change (hazard, information, state, or storage). These choices will change the following:

- Hazard: Changes the hazard of the item, e.g.: from combustible to flammable.

- Information: Changes the requested information, e.g. from flash point to disposal. This option may be used to obtain the final storage recommendation by changing the information variable to "no".

- State: Changes the state of the material under consideration, e.g.: from solid to liquid.

- Storage: This is the ultimate goal variable being sought by the HAZMAT ES. You should not select or try to change this variable.

10. Features not available: VP-Expert, the software system that supports the HAZMAT ES, has a number of features when the program is used in its entirety. The HAZMAT ES does not provide all of these features. However, they will still appear on your menu and may be selected. If they are selected an error message will appear. These features are:

- Induce

- Edit

90

- How?

- Why?

- Slow/Fast

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2