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CONCEPTUAL DESIGN OF AN EXPERT SYSTEM FOR PLANNING AFLOAT INDUSTRIAL HYGIENE SURVEYS

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**Conceptual Design of an Expert System
for Planning Afloat Industrial Hygiene Surveys**

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Summary

Industrial hygienists need to have access to up-to-date information from numerous and varied sources to perform thorough shipboard industrial hygiene surveys. This paper describes an expert system designed to provide U.S. Navy industrial hygienists with information that can be used for planning and conducting shipboard industrial hygiene surveys. An expert system uses algorithms or rules to emulate the thinking of a human "expert" and make recommendations for solutions to specialized problems. In this case, an expert system is being designed to implement the complex expert knowledge that industrial hygienists use when preparing and conducting routine industrial hygiene surveys aboard U.S. Navy ships. The system will be developed using specific information about ship types and ships within each type. This information, combined with information about hazardous materials, processes, and industrial operations conducted aboard the ship, will be used to generate a variety of reports, schematics, and lists to guide the hygienist. These summaries will help industrial hygienists make more informed decisions when developing survey plans. Ultimately, it will allow them to efficiently perform comprehensive inspections by focusing on areas with the greatest potential for exposures to hazardous materials.

Introduction

Chief of Naval Operations Instruction (OPNAVINST) 5100.23D¹ requires the Navy to provide a safe and healthy work environment at naval activities ashore. OPNAVINST 5100.19C² provides similar requirements and guidance for Navy ships and submarines. One of the requirements specified in OPNAVINST 5100.19C is that each surface ship and submarine in the Navy shall arrange for baseline and/or periodic industrial hygiene surveys to be performed at least once every 18 months. These industrial hygiene surveys are normally conducted by the local Navy Environmental and Preventive Medicine Unit (NEPMU), the supporting tender safety office, or the local Bureau of Medicine and Surgery (BUMED) support activity. Since these local activities must conduct their surveys while the ship is in port or operating in the local area (sometimes for only a few days), it is important that a detailed industrial hygiene survey plan be prepared for each ship prior to the inspection.

Specific information is needed to formulate the survey plan. This includes detailed information about shipboard environments including locations of hazardous materials, the processes and industrial operations that require the use of those materials, the locations and frequencies of those operations, and the personnel involved. The professional judgment, or "expert knowledge," of an industrial hygienist is required to bring such data together and interpret the results. A computerized "expert system" may be able to assist industrial hygienists in accomplishing this task. Over the past several years, computer systems have been developed to facilitate the process of drawing data together and generating expert guidance.³ Expert systems, which use artificial intelligence to emulate the thinking of an "expert" in a particular field, have been used in the past for tracking and predicting workplace exposures in industrial facilities.^{4,5} They also have been used by health care professionals for providing possible diagnoses for medical problems.⁶ The expert system design discussed in this paper combines the expert knowledge of industrial hygienists and specific data files about ship types, hazardous materials, and processes to aid the hygienists in planning their surveys.

Data Definitions

The first step in designing an expert system is to decide which specific data are necessary for the system to function, then to create files containing these data. Each file must be well defined, contain all pertinent information about the subject, and be stored in a format compatible with the expert system shell being used to process the data. The design of the system for industrial hygienists will use specific data about **ship types**, **hazardous materials** and **processes**, and use these data the way an industrial hygienist would, to determine which areas or operations may have the potential for injury-causing accidents or exposures to hazardous materials. These data will be acquired from a variety of sources and then integrated into the system. Some of the required data files may already exist in a format that can be loaded directly into the system. Other files will have to be created or modified before they are loaded. The definitions of these data files are presented here to help provide a clear understanding of what they are and how they will be used in the system.

1. Ship Type (source of information - Jane's Fighting Ships, 1995-1996): U.S. Navy ships are categorized into ship types. There are 29 different surface ship types in the fleet of approximately 226 ships presently active.⁷ Each type is designed for a specific type of duty or mission. For example, aircraft carriers are designed to launch and retrieve aircraft while amphibious assault ships are designed to carry and deliver troops to a beachhead. While this may be a straightforward concept, it is important because of the differences in processes or operations that take place on board and the differences in the types of equipment and hazardous materials that need to be carried by these different types of ships to successfully perform their missions. Table 1 illustrates the wide variety of ship types currently active in the fleet. Each ship in the surface ship data file will be assigned a ship type code from this list.

Table 1. Ship Types of the U.S. Navy

1. CVN Aircraft Carrier (nuclear powered)
2. CV Aircraft Carrier (conventionally powered)
3. CGN Guided Missile Cruiser (nuclear powered)
4. CG Guided Missile Cruiser (conventionally powered)
5. DDG Guided Missile Destroyer
6. DD Destroyer
7. FFG Guided Missile Frigate
8. PC Coastal Patrol Craft
9. LCC Amphibious Command Ship
10. LHA Amphibious Assault Ship (general purpose)
11. LHD Amphibious Assault Ship (multipurpose)
12. LPD Amphibious Transport Dock
13. LPH Amphibious Assault Ship (helicopter)
14. LSD Dock Landing Ship
15. LST Tank Landing Ship
16. MCM Mine Countermeasure Ship
17. MHC Minehunter (coastal)
18. AD Destroyer Tender
19. AE Ammunition Ship
20. AFS Combat Stores Ship
21. AGF Miscellaneous Command Ship
22. AO Oiler
23. AOE Fast Combat Support Ship
24. AOR Replenishment Oiler
25. ARL Repair Ship Small
26. ARS Salvage Ship
27. AS Submarine Tender
28. ATS Salvage and Rescue Ship
29. AVT Training Carrier

2. Hazardous Material Storage Inventory (source of information - Hazardous Inventory Controls System [HICS]): HICS is a part of the Navy's Consolidated Hazardous Materials Re-utilization & Inventory Management Program (CHRIMP), a philosophy developed to cut down on hazardous waste and subsequent costs through better management of the storage, use, and disposal of hazardous materials. HICS is a computer program designed to automatically track hazardous materials from the time they are received on a ship to the time they are finally disposed of or used up in a process. Knowing what hazardous materials are carried by a ship and where they are stored on board that ship is essential for a successful survey. It allows the industrial hygienist to check for proper storage methods, product expiration dates, and to make sure safety equipment, such as fire extinguishers and eyewash stations, are installed where necessary and are in good working order. Having this location information also helps to ensure that all hazardous material storage areas are checked during the survey.

3. Schematic Diagrams (source of information - Deck floor plans from Naval Sea Systems Command): This file will be used to store graphic information on the basic layouts of the deck levels of all ship types in the fleet. The purpose of these data is to provide a "map" to help the industrial hygienist locate certain storage areas or compartments. Navy industrial hygienists have suggested that deck floor plans would be very helpful to them when conducting shipboard surveys.

4. Processes/Operations (source of information - Navy PMS [Preventive Maintenance System]): The Navy PMS is used for maintenance of equipment on board a ship. The system provides guidelines and specifications for preventive maintenance procedures for all equipment on the ship. The PMS data file will be used to provide information about what specific processes are carried out and where they occur on the ship. A simple example of this would be a particular piece of machinery that needs to be serviced every 3 months. Part of the preventive maintenance program for this piece of machinery is to clean the drive-shaft roller-pin bearings in solvent. The Maintenance Requirement Card (MRC) specifies the exact type of solvent that will be used to meet Navy requirements. The expert system will use that piece of information to alert an industrial hygienist that a bearing cleaning operation requires a particular type of solvent to be used in a particular workshop or area once every 3 months. The locations and frequencies of these processes, as well as a list of any potentially hazardous materials used, is very important information for the industrial hygienist to have when doing a survey.

5. Personnel Data (source of information - Shipboard Non-tactical ADP Program [SNAP]): Personnel data will provide the expert system with information about where crew members work (work center assignments) and the work they perform (Naval Enlisted Classification [NEC] or occupational specialty). The expert system will use this information to provide a list of potential exposures for crew members. For example, a boiler technician working in the boiler room would be much more likely to be exposed to heat and noise than would a disbursing clerk working in the payroll office. This information will allow the industrial hygienist to make sure that proper personal protective equipment is being used and that affected crew members are enrolled in the appropriate medical surveillance programs.

6. Previous Survey Data (source of information - Data collected during last survey): Information from previous industrial hygiene surveys will be used to show where problems (if any) occurred so that the hygienist can focus on those problem areas first, then move on to areas less likely to have problems.

7. Material Safety Data Sheets (source of information - Hazardous Materials Information System [HMIS]): The Occupational Safety and Health Act of 1970 sets standards of safety to prevent injury and illness among workers. This act established the Hazard Communication Rule (29 CFR 1910.1200) which requires the use of Material Safety Data Sheets (MSDS).⁸ The MSDSs are provided by the manufacturers of chemical materials and contain specific information about the toxicity, fire hazard, storage and handling precautions, and spill response equipment and procedures. An MSDS is required for all chemicals carried on the ship. This data file will serve as a reference for the industrial hygienist when information about a specific hazardous substance is required.

System Operation

The Shipboard Survey Planning System (SSPS) must be designed so it is easy to use and minimizes the need to provide training for the Navy industrial hygienists. This is very important because if the system is too complicated, it will be rejected by the very people it is designed to help. This "user-friendliness" concept is an important part of this conceptual design discussed as follows.

When operating the system, the industrial hygienist will start by selecting SSPS from a menu whereupon a prompt for the name of the ship will be displayed. The industrial hygienist will enter the hull number or the name of the ship to be surveyed. Also, if needed, an alphabetical list of all of the ships of the U.S. Navy can be displayed. The user may then scroll through the list and select a particular ship.

After a particular ship has been selected, the system will present a menu similar to the following:

- o **Hazardous Materials Storage Locations**
- o **Schematic Diagrams**
- o **Preventive Maintenance System**
- o **Personnel Data**
- o **Previous Survey Data**
- o **Material Safety Data Sheets**

The user then may select one of those options from the menu. When a particular option is selected, the system will present a screen with more choices. A detailed description of each of these main options, or "modules," and the information that the system will provide for each, follows. The logic the expert system uses to come to conclusions when queried also is briefly described here.

1. Hazardous Materials Storage Locations

If this option is selected, a new menu will be presented:

- o Hazardous Material Name**
- o Location (Compartment number)**
- o Hazard Type (e.g., solvent, explosive, acid)**

The Hazardous Materials option provides information about where hazardous materials are stored on the ship. HICS is the source of information for this module. The user can select name, location, or hazard type. The system then will provide all information about that particular item. For example, if the user wants to know the storage locations of all "acids" on board, the user first will select "Hazard Type" from the menu, then select "acid" from the list of categories the system will display. The system will search its database for all materials categorized as "acids" and then provide a list of all "acids" on board at present and their respective storage locations.

2. Schematic Diagrams

If this option is selected, a new menu will be presented:

- o First**
- o Second**
- o Third**
- o Fourth**
- o All**

The expert system's data files about ship types will determine the number of choices (decks) presented in this menu. Different ship types have different numbers of decks due to their size and design. Because each ship in the system already will have been assigned a ship type code, the system will be able to provide information about the layout and number of decks on that particular ship. When a specific deck is selected by the user, the system will provide a "floor plan" of that deck with compartment numbers and, if possible, notations about what type of work is performed in the compartment or what types of materials are stored there. If "All" is selected, diagrams will be printed sequentially until all have been printed.

3. Preventive Maintenance System

If this option is selected, a new menu will be presented:

- o Type of Maintenance Procedure (e.g., degreasing, painting)**
- o Frequency of Procedure (e.g., weekly, monthly)**
- o Type of Equipment (e.g., compressor, missile launcher)**
- o Materials Required (e.g., name)**
- o Equipment Location (e.g., compartment number or work center)**

The user first will select the category he or she wishes to search under. The system will then provide a list of subcategories. Once the subcategory (e.g., under "Type of Equipment," the user selects "compressor") is selected, the system will provide a list of all compressors on board, their locations, required preventive maintenance procedures (and frequencies), and the materials required to complete the maintenance process. This information will help the industrial hygienist by alerting him or her to maintenance processes aboard the ship that are most likely to result in hazardous materials exposures. The location of the equipment being serviced also is provided. By linking to the personnel file, the hygienist will know which crew members may be exposed and can check to see that they have proper training, equipment, and medical surveillance.

4. Personnel Data

If this option is selected, a new menu will be presented:

- o Department**
- o Division**
- o Work Center**
- o Rate (occupational specialty)**

This option provides personnel information, including each crew member's department, division, and work center assignment. It also provides each crew member's rating or occupational specialty. This information will help the hygienist to determine if crew members are enrolled in proper Navy Occupational Safety and Health (NAVOSH) training and medical surveillance programs. A crew member who is in the Engineering Department with a BT (Boiler Technician) rating would be expected to be in the Hearing Conservation and Heat Stress Reduction Programs. Or, for example, if the industrial hygienist wanted to know all of the people assigned to a particular workshop where excessive noise was present, the industrial hygienist could select the Work Center option and then query the system for a list of all crew members assigned to that work center. The industrial hygienist could then check to see if they were all enrolled in the Hearing Conservation Program. It is also useful for locating a particular crew member (for example, a division head or work center supervisor) when necessary. These data will be downloaded from the ship's SNAP program into the SSPS before the hygienist begins the survey.

5. Previous Survey Data

If Previous Survey Data is selected, a new menu will be presented:

- o Date of Last Survey (with report number)**
- o Discrepancy List**
- o Print or Display Full Survey Report**

This option provides historical information about previous industrial hygiene surveys that were completed on the ship. The suboptions allow the industrial hygienist to see when the last survey was completed. It also can provide a list of discrepancies from the previous survey so the hygienist may have a better idea where problems have been found in the past and can focus on those areas first. Finally, if necessary, the hygienist can print the full industrial hygiene survey report.

6. Material Safety Data Sheets

If this option is selected, a new menu will be presented:

- o Material Identification**
- o Ingredients and Hazards**
- o Physical Data**
- o Fire and Explosion Data**
- o Reactivity Data**
- o Health Hazard Information**
- o Spill, Leak, and Disposal Procedures**
- o Special Protection Information**
- o Special Precautions and Comments**

The MSDS for a particular product can be accessed by entering the name of the material. Once the MSDS has been found, the user may look at any section by selecting it from the above menu. Information contained in the MSDSs provides guidance for safe practices and emergency response.

File Linking and Output Reports

Files from a variety of existing systems will be integrated into SSPS where they will be used to answer queries and generate reports as shown in Figure 1.

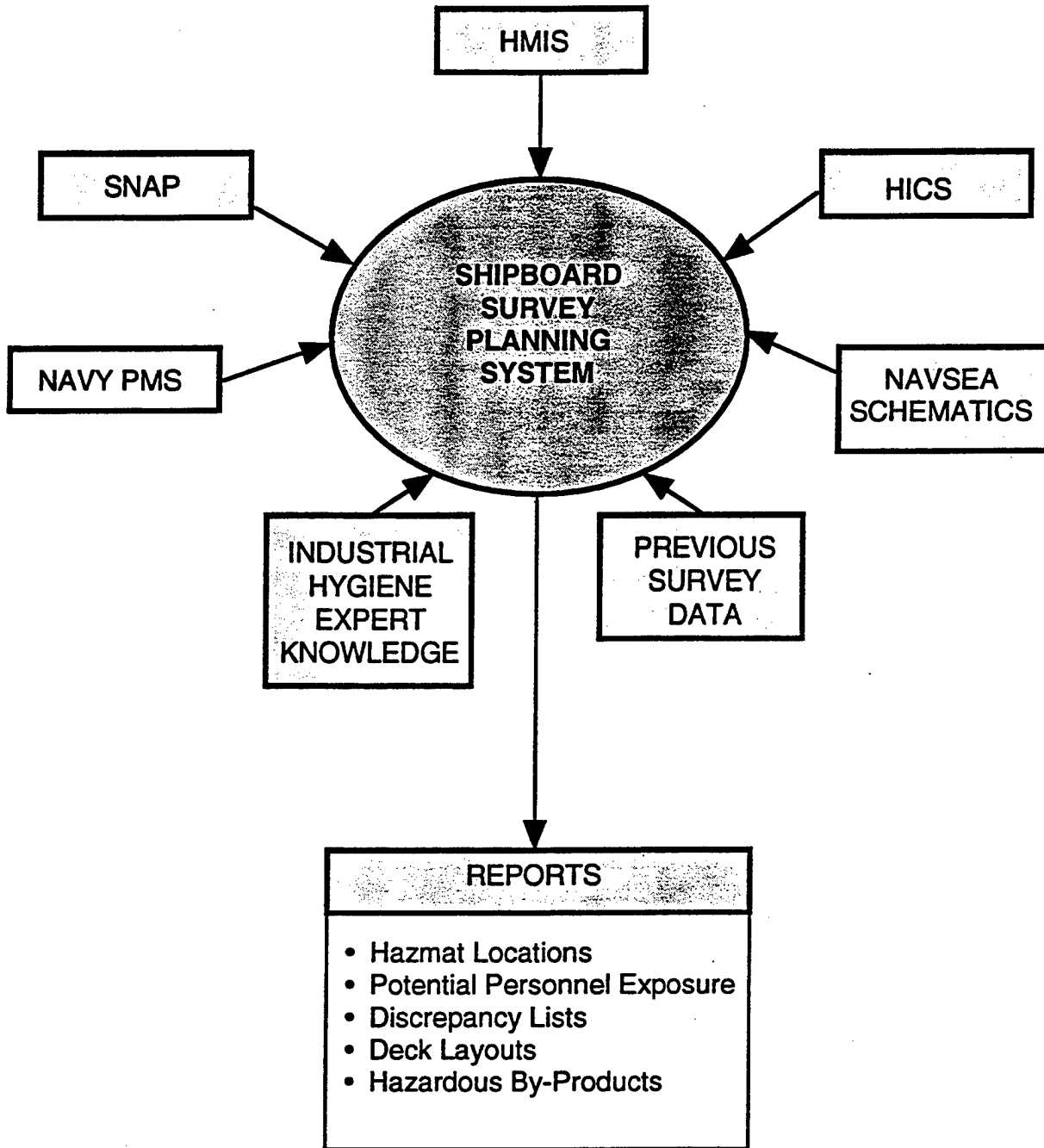


Figure 1. Integration of data from existing systems along with industrial hygiene expert knowledge to generate reports.

Table 2 lists all of the data elements SSPS will use. Each data file contains a number of different data elements. Those data elements common to more than one data file will be used to link the data files when a query is made. As previously mentioned, SSPS will provide a variety of lists, summary reports, and schematics to guide the industrial hygienist in planning the survey. Some examples of these are: a list of hazardous material storage locations, a list of locations where hazardous materials are used while performing maintenance procedures, a list of personnel who potentially may be exposed to specific hazardous materials, a list of discrepancies from previous industrial hygiene surveys, and a general "map" to help guide the industrial hygienist to areas that need to be inspected.

Table 2. Data Files and Elements

<u>Data File</u>	<u>Data Elements</u>
Ship List	Ship names Ship types
Schematics	Ship names Ship types Number of decks Deck numbers (level) Deck "maps"
CHRIMP	Ship names HAZMAT storage locations Materials Type of materials
PMS Data	Ship names Work centers System or equipment names Maintenance procedures Frequencies of maintenance procedures Materials required

SNAP	<ul style="list-style-type: none"> Ship names Crew member names Rates/ranks Departments Divisions Work centers
MSDS	<ul style="list-style-type: none"> Materials Ingredients & hazards Physical data Fire & explosion data Reactivity data Health hazard information Spill, leak, & disposal data Special protection information Special precautions & comments
Previous Surveys	<ul style="list-style-type: none"> Ship names Survey dates Survey types (baseline or periodic) Survey report summaries Discrepancy lists

Figure 2 illustrates how files will be linked, using matching data items, to create reports. For example, to generate a list of crew members potentially exposed to hazardous materials, data from the PMS file might be combined with SNAP information. The PMS data would specify which materials are required for maintenance procedures performed on equipment in a specific **work center**. The SNAP file would indicate which crew members were assigned to that **work center**, and thus, the potential exposures of individual crew members to specific hazardous materials. In this example, **work center** is the matching data item that the system uses to link hazardous materials to individual crew members.

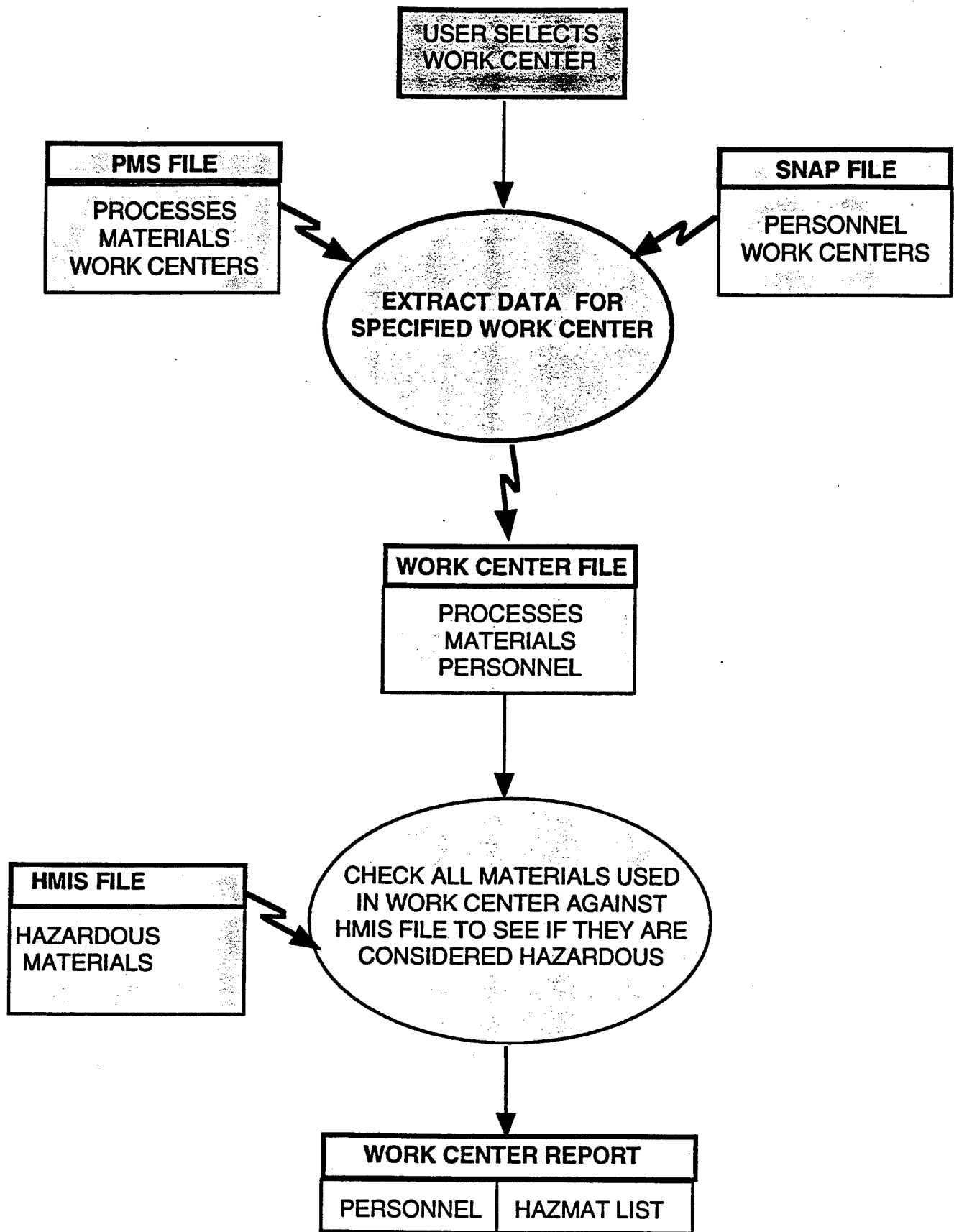


Figure 2. Linking files using "work center" as matching data item to generate hazmat potential exposure reports.

An example of a more specific query might be to find out which crew members might be exposed to benzene. The industrial hygienist would first go to the PMS data file and select "Materials Used." Then the hygienist would enter "benzene" as the material. Next, the hygienist would select "Work Center." The system would then search the PMS data file for all work centers where benzene is used in maintenance procedures. Next, the hygienist would call up the SNAP (personnel) data file and enter the work center numbers where benzene is used in maintenance procedures. Then the hygienist would select "Name" from the menu. The system will search the SNAP (personnel) data file for the names of all crew members who are assigned to those work centers where benzene is used (determined from the PMS data file search) and provide a list of those crew members. It is important to note that the system can only provide the names of those crew members **most likely** to have been exposed. Some crew members with potential benzene exposures may not appear on the list since they are not permanently assigned to those work centers. A few crew members (e.g., fire parties or damage control teams) might have been in the area for short periods and potentially might have been exposed. In the case of a particularly hazardous material, the industrial hygienist should make an effort to determine if any other crew members might have been in the area when the hazardous material was being used.

Other SSPS generated reports will require expert rules or knowledge to be supplied to make inferences from existing databases. Certain processes (e.g., welding) may generate hazardous materials as a by-product of the interaction between materials used in the process, even though the materials are not considered hazardous by themselves. A knowledge base of these processes and interactions, and the hazardous by-products produced by them, will have to be developed by industrial hygiene experts and then integrated into the system. SSPS then could alert the industrial hygienist to potential exposures by generating a special report when certain processes or material combinations are present. Figure 3 demonstrates how SSPS would use existing data files along with an "expert knowledge" file to generate this type of report.

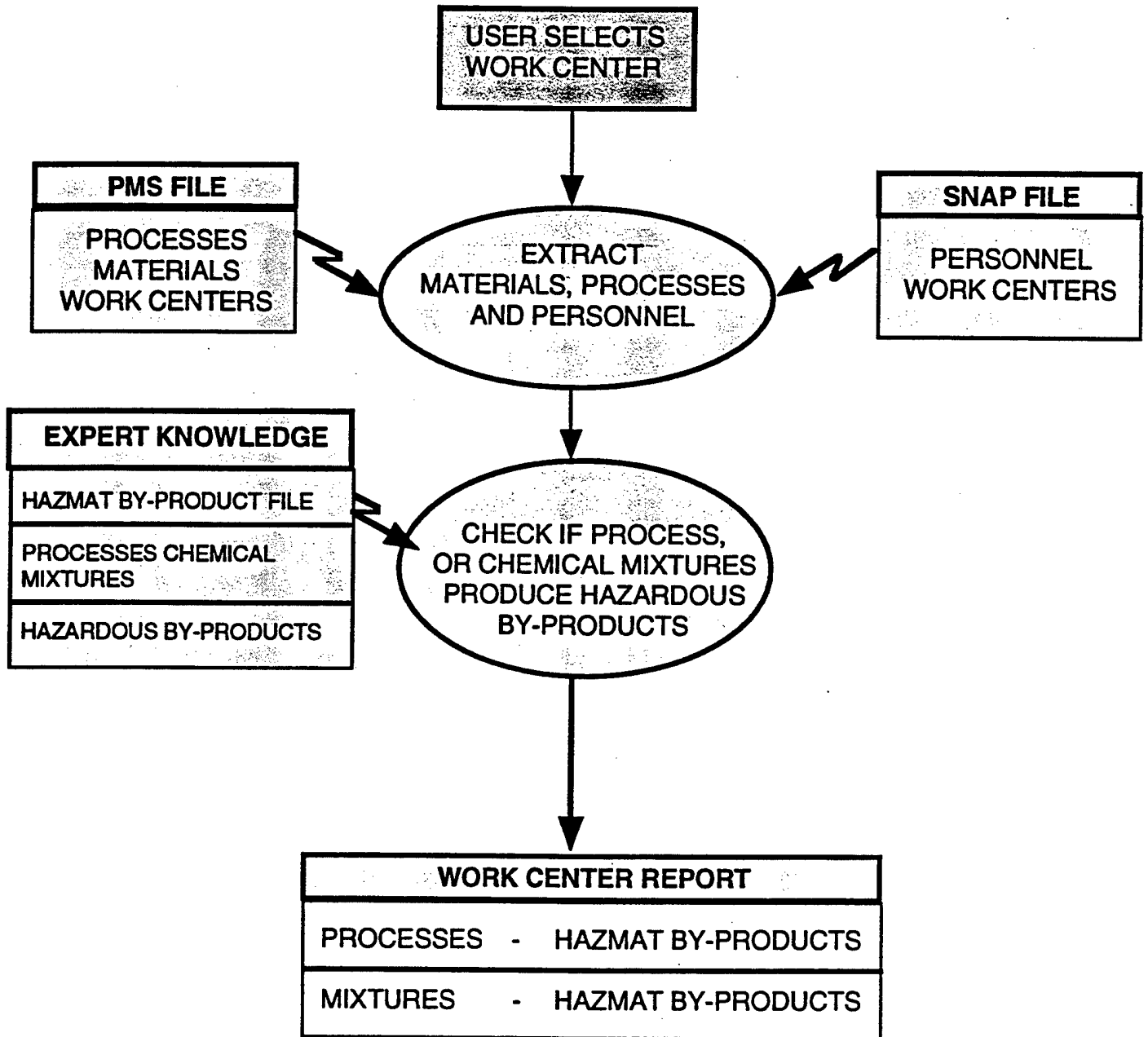


Figure 3. Generation of a hazardous by-product report.

Discussion

This paper has presented an overview of the design of a system for shipboard industrial hygiene survey planning. A detailed design is beyond the scope of the present paper and will be presented in another report. This paper illustrates how industrial hygienists need to have access to up-to-date information of different types from a variety of sources when planning a shipboard industrial hygiene survey. Professional judgment, or "expert knowledge," is needed to bring such data together so they can focus their surveys on the areas of most concern. An expert system, using the pertinent information and processes that an industrial hygienist uses, can help to accomplish this task. The conceptual design presented here is intended to provide a framework for building a shipboard survey planning system that will be easy to use and capable of quickly providing complete and accurate industrial hygiene information to the industrial hygienist. It is important that the design be flexible so it will allow for future enhancements. Also, flexibility is needed so that new "expert knowledge" about hazardous materials and processes can be incorporated into the system as it becomes available. Ultimately, a system based on this design will be evaluated to ascertain the degree it will help Navy industrial hygienists to improve their efficiency when planning and performing afloat industrial hygiene surveys.

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