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Summary

The Hazardous Material Life-Cycle Cost Model (HMLCCM) was enhanced to include a distinction between materials and products, where each material has a unique stock number and products are the separate brands of a material. Working with Long Beach Naval Shipyard, 29 materials were identified for entering into the system and 197 products were associated with these materials. All these materials and products were added to the knowledge base and specific cost information was entered for 48 products. In addition, the model was modified so that information from the Hazardous Material Information System (HMIS) or individual Material Safety Data Sheets (MSDSs) could be entered, and so data on Permissible Exposure Limits (PELs) could be retrieved. Recommendations are made for further knowledge base development.

Database Development for the Hazardous Material Life-Cycle Cost

Recently, the Naval Health Research Center (NHRC) developed the Hazardous Material Life-Cycle Cost Model (HMLCCM) (Hermansen, *et al.*, 1992), to estimate the total life-cycle costs of using various hazardous materials in the construction, maintenance, and repair of U.S. naval systems and facilities. A computer program was developed to run the model (Mooney & Hermansen, 1992; Ly & Pearsall, 1992). It was designed with the capability to include cost factors ranging from the initial inception of a new system through its final disposition (i.e., when the system is removed from the Navy's inventory). This capability allows the model to assist decision makers at all different levels in the procurement process.

To compute the total life-cycle cost of a material, the model uses information from a three-tiered knowledge base that contains information about an array of life-cycle cost factors. The three levels range from general description (e.g., Personal Protective Equipment [PPE]) to specific items (e.g., neoprene gloves manufactured by ACME Glove Company). They are defined in the model as: (1) factors, (2) elements, and (3) items. Each factor (e.g., PPE) contains multiple elements (e.g., gloves, boots, aprons) and each element contains multiple items (e.g., ACME neoprene gloves, Vanguard rubber gloves, ABC latex gloves). The cost of all specific items per person per day are required by the model in order to calculate the total life-cycle cost of a system. Clearly, the ability of the model to generate meaningful results depends upon the completeness and accuracy of this knowledge base.

The current effort was undertaken to initiate the development of the required knowledge base. The first step was to identify one specific user and determine a current need that the model could satisfy. It was decided that the focus of this initial effort would be to use the model to assist a shipyard safety manager. The safety manager would be asked to identify a set of specific hazardous materials used at the shipyard. These materials and their associated Factors, Elements, and Items would then be entered into the system along with the cost data. The model would also be modified to include data from the Hazardous Material Information System (HMIS) and

permissible exposure limits for hazardous materials, which is listed in the Occupational Safety and Health Administration (OSHA) Z-1 table.

Methods

Long Beach Naval Shipyard (LBNS) was selected as the test site for this effort because its proximity to NHRC allowed for close interaction during the knowledge base development. Special data collection and input forms were developed and used to gather the data for entry into the enhanced HMLCCM. These forms are contained in Appendix A. A list of 29 hazardous materials of major interest to the LBNS Safety Department was compiled and forwarded to NHRC. The LBNS Hazardous Material list is presented in Appendix B. After reviewing the list with LBNS safety personnel, it was found that some of the materials are used in such small portions that even though they contain hazardous ingredients, they are a minute risk when compared to other products being used. Therefore, this project focused on degreasers because they are a high-use item at LBNS; however, for completeness, the Material Safety Data Sheet (MSDS) for every product on the list was included in the knowledge base. The cost, factor, elements, and item data were collected for the four degreasers mentioned on the LBNS hazardous materials list.

MSDSs for the 29 hazardous materials were extracted from the January 1993 Hazardous Material Control and Management (HMC&M) Hazardous Material Information System (HMIS) program distributed by the Naval Supply System Command, Code 452. A search of the HMIS database was performed on the key field National Inventory Identification Number (NIIN). Using the 29 materials listed the system retrieved 196 MSDSs. The 29 materials listed are generic materials, such as 1,1,1 Trichloromethane or PD-680 Solvent. There are many manufacturers of these materials. For example, in the HMIS database used 26 different product names are listed under PD-680 solvent. These are either different manufacturers and/or different formulations, all of which meet the PD-680 specification. For each product OSHA requires an MSDS. All of these MSDSs were retrieved and stored in an ASCII file.

A program was written in the C programming language to parse the MSDS ASCII data into the appropriate data files (Appendix C). These data files were uploaded into the appropriate HMLCCM files, which comprise the knowledge base using the FoxPro program, loadhmat.prg (Appendix D). Most of the information extracted from the HMIS was uploaded into the HMLCCM database with minimal intervention. Some of the data, however, had to be entered manually due to either a lack of defined fields in the ASCII extraction of the HMIS, or a lack of a standard nomenclature. Data such as ingredient percentages and PPE had to be manipulated and edited manually on a product-by-product basis for all 196 products.

One product, Safety Kleen, could not be extracted from the HMIS database because it is unavailable through the normal supply channels. Therefore, a hard copy of the MSDS was obtained and was manually entered into the database. As a result, the main material file, HMAT.dbf, contains a total of 197 products.

Additional data, such as cost data and data for the relationships in formulating the scenarios, were collected from LBNS and were entered into the knowledge base. Examples of input sheets from which data were input into HMLCCM knowledge base are in Appendix E. An example of code written to input this data is in Appendix F. Appendix G lists several products (seven) that make up one hazardous material (Freon). This example demonstrates that even if the products are similar (i.e., meet the same specifications), the PPE required differs. This contributes to differences in cost between products.

At the same time these data were being collected, the original version of the HMLCCM program was being revised and upgraded. These enhancements are described below and the upgraded software will be known as HMLCCM Version 1.2.

Model Enhancements

In the effort to tailor the HMLCCM system to the various activities at LBNS, a change was made in the way some of the data in the HMLCCM were defined. In Version 1.0, a

"material," such as 1,1,1 Trichloromethane, was defined as the "product" with a single listing. In Version 1.2 of the HMLCCM, however, the user must realize that for one stock number there may be multiple products made by a variety of companies for the same NIIN. One example is *PD-680 Dry Cleaning Solvent. Twenty-six different products are listed for the same NIIN* (00-274-5421). For each of these 26 products there is a separate MSDS from which the safety data are extracted. In Version 1.0, the data about the material was less precise because it was based on a variety of professional sources with knowledge about health and safety issues related to the specific materials. In Version 1.2, the MSDS is retrieved from HMIS.

This way of retrieving data enables the user to select a particular "generic" material and then compare the cost of all the different products (i.e., same generic material) made by different manufacturers. For example, a comparison could be made between all 26 products collectively known as PD-680 to find the most cost-effective product. However, even if a user finds the most cost-effective product, the procurement system may not allow purchase of a particular brand name.

In most situations, the shipyard will procure the product that is in stock, either locally or in the closest location, thus eliminating the ability to choose the most cost-effective product. Material substitution made without knowing the engineering context in which the material will be used may cause problems. In most cases, before a substitution can be made, product testing by the Quality Assurance (QA) people is required. Because all work must be done according to specification, only QA personnel can approve deviations.

After consultation with the LBNS Safety Officer, the decision was made to continue to provide the choices of products despite of the procurement restrictions. Improvements in the procurement system may be made that will allow the selection of specific products in the future. By providing the ability to choose among various products for a particular material versus the choice of materials (as in Version 1.0), HMLCCM Version 1.2, was specifically designed to accommodate this new perspective so users with the authority to choose among materials can benefit from this system. Therefore, in the remainder of this paper, the term "material" will be

used to describe the generic material (e.g., 1,1,1 Trichloromethane, or PD-680 Solvent). The term "product" is used to describe the specific company's brand name for the material (e.g., Ashland Chemical Company's Trichloromethane 111 Degreaser Cold, Octagon Process Inc.'s Dry Cleaning Solvent).

Results and Discussion

Although not one of the stated objectives of this project, a crucial by-product of this effort was combining and linking files created for other systems with new files to produce a coordinated system. Version 1.2 of HMLCCM demonstrates the interconnectivity between two systems as discussed in Appendix H. The benefits of sharing database tables or resources include: system compatibility, reduced database maintenance, and reduced needs development time for files and databases.

The HMLCCM is designed to be sufficiently flexible to accommodate different types of users. For instance, HMLCCM can be used to make comparisons of products within a material or make comparisons among different materials. Comparisons among products for a specific material is an application that may be of interest to the local user, such as a shop foreman, safety officer, or local procurement officer. Once a material is specified, these local users may query the database to find the product with the lowest life-cycle cost. Comparisons among different materials is another use of the system that may interest QA personnel, or those people involved with material substitution, either within the shipyard or Navywide. The HMLCCM would be used to compare costs for certain scenarios among several materials proven to be effective for the specified scenario.

Depending upon the construction of the knowledge base, either one or both of these uses could be supported. Currently, only comparisons among products for a specified material is supported. The knowledge base, however, does have some constraints that need further examination. There were 197 MSDS data sheets extracted and compiled from the HMIS for 29 materials. Detailed costs and PPE data are available for five of these generic materials (1,1,1

Trichloromethane, PD 680 Solvent, Freon, Safety Solvent, and Safety Kleen), and these five materials cover 48 products. These cost and scenario data were collected at only one site (LBNS) for one type of activity (shipyard) using one exposure state (no personal or environmental exposure) with one life-cycle phase (repair/maintenance). Thus, data from other activities may be different. For example, disposal costs are specified by Defense Reutilization and Marketing Office (DRMO) and these costs may vary across the country. Also, claims and compensation personnel were unable to attribute any of the costs to these five particular materials. For instance, there may be a cost of allergic dermatitis but it will not be attributed to a specific chemical because the worker used a multitude of hazardous materials.

Currently, the knowledge base does not incorporate all potential exposure states. Specifically, the current knowledge base does not contain any scenarios related to spill containment and cleanup or permit and certification requirements that may have been enacted by recent local, state, or federal legislation. Safety specialists may make decisions regarding the use of particular materials as it pertains to the health and safety of the workers under normal working conditions. Therefore, future development should extend the knowledge base to include cost of sporadically occurring events, i.e., work place mishaps, or the possibility that additional permits will be required.

Finally, the current knowledge base contains information regarding only the maintenance and repair phase of the entire life-cycle cost model. Additional work must be done to incorporate additional life-cycle phases.

Recommendations and Conclusions

One of the potential uses of the HMLCCM system would be to help centralize the information needed to calculate total life-cycle costs. This will entail continuous updating and input of cost elements and items. Costs associated with the hazardous material including procurement, handling, PPE, medical surveillance, disposal, and environmental cleanup should be tracked and monitored by specific job codes that have this information. At present, no

centralized data-gathering source exists for this information. Data such as cost, safety and compensation need to be collected from a variety of sources. Some of the data collection is automated but most is unavailable in the required format. Procurement data are available on a CD-ROM in the form of the FEDLOG. It is recommended that future work include incorporating and consolidating existing electronically available databases such as those on CD-ROM (e.g., HMIS, FEDLOG). Individual agencies or private companies can maintain these databases and HMLCCM can be used to consolidate them for the managers. For HMLCCM to be most effective, all of these data should be combined and integrated in a single information system accessible to all potential users.

In the time available, it was not possible to create a direct link with the HMIS CD-ROM system. Given more time, however, direct link could be developed as well as the capability to extract HMIS MSDS data to the .dbf file that was developed.

A review of the hazardous material list with the safety personnel should be conducted to revise and update it. Appendix I shows a preliminary list provided by the Safety Office at LBNS of some possible additional hazardous materials to be added to the HMLCCM knowledge base. The cost and PPE information for the remaining and any additional materials should be entered. There may be other users at LBNS who would like to add additional hazardous materials into the knowledge base. It has been suggested that the model should be modified to allow users to choose the PPE rather than use the MSDS recommendation in the cost calculations.

The current project was only intended to initiate development of the knowledge base required for the HMLCCM. From the experience gained in this effort, it is estimated that complete development of the required knowledge base would take 3 years. Such an effort is outlined in the milestone chart provided in Appendix J. During the first year some additional system enhancements would be made and the remaining materials would be entered for one site. During the second year the knowledge base would be extended to other shipyards and work would begin on extending the capability to other types of Navy facilities. During the third year

the system would not only accommodate a wide variety of Navy facilities, but would include a generic, Navywide knowledge base.

The current version of the HMLCCM is tailored for use at the safety manager level of operation. Consequently, the system may be used to aid in the selection of particular materials for specific tasks. Using the HMLCCM will allow a safety specialist to reduce the use of potentially harmful materials by identifying less harmful replacements. The cost incurred by various selections may be analyzed and the safety officer will be able to identify the cost factors and materials to fit the needs of the end user. The result is that a well-informed selection will be made by one who is trained to make decisions regarding the protection of the health of workers who use hazardous materials.

References

Hermansen, L.A., Mooney, J.A. & Pugh, W. (1992). *Hazardous Material Life-Cycle Cost Model System Manager's Guide.* (Report No. 92-17). San Diego, CA: Naval Health Research Center.

Ly, H.L. & Pearsall, D.M. (1992). *Hazardous Material Life-Cycle Cost Model Technical Manual Version 1.0.* (Report No. 92-19). San Diego, CA: Naval Health Research Center.

Mooney, J.A. & Hermansen, L.A. (1992). *Hazardous Material Life-Cycle Cost Model System User/Operator Guide.* (Report No. 92-18). San Diego, CA: Naval Health Research Center.

Appendix A - Survey Instrument Example

PRELIMINARY Hazardous Material Life-Cycle Cost Worksheet (5/93)

Material:

Phase:

Process:

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
Purchase Cost							
Transportation							
	Drivers						
	Certification						
	Permits						
	Training						
	Vehicle						
	Maintenance						
	Fuel						
	Documentation						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
Storage/ Security							
	Containers						
	Storage Tank						
	Building						
Training							
	Workers						
	Instructors						
	Classroom						
	Documentation						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
PPE							
	Respirators						
	Gloves						
	Neoprene						
	Nitrile						
	Gauntlet						
	Butyl						
	Stanzoil						
	Boots						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
	Coveralls						
Engineering Controls							
	Vents Hoods						
	Spray Hoods						
Medical Surveillance							
	Workers						
	Doctors						
	Nurses						
	Technicians						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
	Physical Exam						
	Blood Chemistry						
	CBC						
	Chest X-ray						
	EKG						
	Urinalysis						
	Documentation						
Work place Monitoring							
	Monitors (IH)						
	Monitoring Equipment						
	Laboratory						
	Documentation						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
Disposal							
	HW Crew						
	Quantity of Material						
	Permit						
	Documentation						
Spill Containment							
	HAZMAT Team						
	Absorbent Pads						
	Documentation						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		
Medical Treatment							
	Workers						
	Doctors						
	Nurses						
	Technicians						
	Documentation						
Claims and Compensation							
	Documentation						
	Monetary Awards						
Documentation							
	Personnel						
	Paper						
	Computer Time						

Factors	Elements/Items	Charge	Unit			Life	State
			N	D	Q		

Appendix B - List of Hazardous Material From Long Beach Naval Shipyard

Code 106.113

Data Report for

Target Chemicals

LBNS MSDS Number.	Product's Common or Trade Name	Product's Chemical or Shipping Name	FSC and National Inventory Number
	Paint, Clear	Paint, Clear	8010 00-515-2487
	Tric.	Trichloromethane	6810 00-930-6311
	Paint, Red	Paint, Red	8010 00-141-2952
	Dry Moly Lubricant		8010 00-262-9172
00000006	Blue Layout Fluid 603 Old Formula		8010 01-021-3208
00000008	Dykem Remover (138)	Denatured Alcohol	6850 00-223-3593
00000015	Nutbuster	Formula 202 PN 7002	6850 00-N00-9084
00000078	Marsh Spray Stencil Inc Black	Ink Marking Stencil	7510 00-469-7910
00000103	Degreasing Fluid	Trichlorotrifluoroethane	6850 00-033-8851
00000103	Freon 113	Trichlorotrifluoroethane	6830 00-551-0854
00000127	Anti-seize Compound	Anti-seize Compound	8030 00-597-5367
00000141	Paint Remover	Methylene Chloride Methanol	8010 00-160-5800
00000217	Multi-Purpose Adhesive	Multi-Purpose Adhesive	8040 00-033-7507
00000223	Nut Buster Aerosol	Chlorinated Solvent	8030 00-838-0888
00000223	Nut Buster	Corrosion Preventative	8030 00-838-7789
00000317	T-10 Thinner	Paint Thinner Solvent	8010 00-160-5794

00000359	Devran 201 Green Before 76013	Paint	8010 00-905-9833
00000392	Sanding Sealer	Lacquer Type Sanding Sealer	8010 00-663-2673
00000706	Solvent Cleaning	Trichlorotrifluoroethane	6850 00-105-3084
00000862	Spray Lube 70	Lubricant Aerosol	9150
00000981	Primer/Trichlor	Trichloromethane	8030 00-900-2373
00001159	#MS-190HD Heavy Duty Flux Remover	Solvent	6850 00-602-2347
00001225	Paint Remover 3248, 312-6	Trichloromethane 1,1,1, Cold, Vaporous	6810 00-551-1487
00001385	Spray Lacquer ORR-LAC #914 HTR Grn	Paint Spray Lacquer	8010 01-017-1522
00001385	Spray Paint Green #914	Paint Aerosol	8010 00-017-1522
00001434	Safety Solvent	Solvent	6850 01-061-5493
00001963	Dry Moly		6850 00-N00-9008
00002023	PD680A Type II	Solvent Dry Cleaning	6850 00-274-5421

Appendix C - Parse.C Program Listing

```
/* parse.c gp 6/15/93
 * parse file and write out file of words only
 * renamed p2.c - add info re: specific for MSDS extraction.
 * later should be called hmextract.c for Hazardous Material extraction
 * of msds info from HMIS
 * 6/22 p3 - add various files to write to
 *          works but not yet add in to append from killme.tmp file
 * 6/22 p4 - work on killme.tmp - works.  Don't know why - reversed the
 *          position at bottom of file where check for outkill != NULL
 *          else if (played with this) outmsds != NULL
 *          Also put in so outbuff will write out so not get mixed up
 *          between what's coming in and going out.  More code but easier
 *          to understand I hope.
 * 6/23 p5 - write info to variables before write out to files - done for
 *          outmat - msdsdbf.txt.
 * 6/24 p6 - work on ingredients - done w/ outing
 * 6/24 p7 - work on safety ppe stuff
 */

#include <stdio.h>
#include <dos.h>
#include <bios.h>

#define BUFFSIZE 80+1
#define ROW 12
#define COL 25

/* define debug statement */
/* #define DBG */

main() {

    /* initialize variables */
    FILE *input, *outmsds, *outmat, *outing, *outppe, *outkill;
  char msdsfilename[13];

    int haz_num = 0,
        ingredient_num = 0,
        c = 0,
        n = 0,
        i = 0,
        j = 0;
    long counter = 0;

    char *title = "DOD Hazardous Materials Information System";
    char *niin = "NIIN: ";
    char *part_name = "Part Number/Trade Name: ";
    char *mfg_name = "Manufacturer's Name: ";
```

```
   char *spec_no = "Specification Number: ";
   char *proprietary = "Proprietary: ";
char *ingred = "Ingredient: ";
char *ingred_seq_no = "Ingredient Sequence Number: ";
char *percent = "Percent: ";
char *CAS = "CAS Number: ";
char *control = "Control Measures";
char *transportation = "Transportation Data";

char buffin[BUFFSIZE], buffout[BUFFSIZE], buff[BUFFSIZE],
    buff2[BUFFSIZE], tbuff1[BUFFSIZE], buffmat[BUFFSIZE],
    buffing[BUFFSIZE], buffppe[BUFFSIZE], tbuffniin[10],
    tbuffprop[3], tbuffing[BUFFSIZE], buffname[BUFFSIZE];

  /* clrscrn(); */

  if ((input=fopen("msds.txt", "r")) == NULL) {
       puts ("Error reading msds.txt");
       return (1);
  }
  /* Material dbf */
  if ((outmat = fopen("hmatdbf.txt", "w")) == NULL) {
       puts ("Error writing hmatdbf.txt");
       return (1);
  }
  /* Material ingredients */
  if ((outing = fopen("hmingdbf.txt", "w")) == NULL) {
       puts ("Error writing hmingdbf.txt");
       return (1);
  }
  /* Safety PPE - needs to be edited when done */
  if ((outppe = fopen("hmppe.txt", "w")) == NULL) {
       puts ("Error writing hmppe.txt");
       return (1);
  }

  puts("Files are opened\n");

  while (fgets(buffin, BUFFSIZE, input) != NULL) {

       if ((n = strstr(buffin, title)) != NULL) {
            /* whenever get to title, time to write new file.  Because
             * don't know what the new file name will be, need to write
             * to a temporary file called outkill or "killme.tmp".  Once
             * get to the NIIN and get the new file name, have to close the
             * outkill file, write the contents to the outmsds and continue
             * everything to that file until get to the title again
    *
    * if msds file not opened, then write out to buffer file
    * otherwise write to appropriate msds file
    * should always write to one or the other
```

```
 */

        if (outmsds != NULL)
            fclose(outmsds);
        if ((outkill = fopen("killme.tmp", "w")) == NULL) {
            puts ("Error writing killme.tmp");
            return (1);
        }
 /* get haz mat number @ each change of title and set up buffers */
 haz_num++;
 sprintf(buffmat, "%d\t", haz_num);
 strcpy(buffing, buffmat);
 strcpy(buffppe, buffmat);
    }

/* check for match w/ niin - if match, copy to buffout so can
     * put in the order needed to write msdsdbf.txt. This line
     * should also be written to the file which contains the msds.
     */
    else if ((n = strstr(buffin, niin)) != NULL) {
        fclose(outkill);
   for (i = 0, j = strlen(niin); j <= (strlen(buffin) - 3); i++, j++)
            buff[i] = buffin[j];
        buff[i] = '\0';
        strcpy(buff2, "hm");
        for (i = 2, j = 5; i <= 6; i++, j++)
            buff2[i] = buff[j];
   sprintf(msdsfilename, "%s.%3.3d", buff2, haz_num);

   /* copy niin to buffer for use later on */
   strcpy(tbuffniin, buff);

   if ((outmsds = fopen(msdsfilename, "w")) == NULL) {
            puts ("Error writing Individual MSDS");
            return (1);
        }
        /* need to copy header from killme.tmp file */
        if ((outkill = fopen("killme.tmp", "r")) == NULL) {
            puts("Error reading killme.tmp");
            return (1);
        }
   /* copy data from killme.tmp to new msdsfile.000 */
   while (fgets (tbuff1,BUFFSIZE, outkill) != NULL) {
      strcpy(buffout, tbuff1);
      fputs(buffout, outmsds);
        }
        fclose(outkill);

 strcpy(buffout, buffin);
    }
else if ((n = strstr(buffin, part_name)) != NULL) {
```

```
    for (i = 0, j = strlen(part_name);j <= (strlen(buffin) - 3);
                i++, j++)
          buff[i] = buffin[j];
                buff[i] = '\0';
    /* to be used later on down the program at outppe */
    strcpy(buffname, buff);

    strcat(buffmat, buff);
    strcat(buffmat, "\t");

     }
else if ((n = strstr(buffin, mfg_name)) != NULL) {
    for (i = 0, j = strlen(mfg_name); j <= (strlen(buffin) - 3);
                i++, j++)
       buff[i] = buffin[j];
          buff[i] = '\0';
    strcat(buffmat, buff);
    strcat(buffmat, "\t");
    /* copy niin from above so in right order */
    strcat(buffmat, tbuffniin);
    strcat(buffmat, "\t");
     }
else if ((strstr(buffin, spec_no)) != NULL) {
    for (i = 0, j = strlen(spec_no); j <= (strlen(buffin) - 3);
                i++, j++)
       buff[i] = buffin[j];
          buff[i] = '\0';
    strcat(buffmat, buff);
    strcat(buffmat, "\t");
    /* done with buffmat; write to file */
    strcat(buffmat, "\n");
    fputs(buffmat, outmat);
}
else if ((strstr(buffin, proprietary)) != NULL) {
    for (i = 0, j = strlen(proprietary); j <= (strlen(buffin) - 3);
                i++, j++)
       buff[i] = buffin[j];
          buff[i] = '\0';
    /* put in haz_num & ingredient # then this info */
    ingredient_num++;
    sprintf(buffing, "%d\t%d\t", ingredient_num, haz_num);
    /* strip out "Y" or "N" from "Yes" or "No" */
    tbuff1[0] = buff[0];
    tbuff1[1] = '\0';
    strcpy(tbuffprop, tbuff1);
}
else if ((strstr(buffin, ingred)) != NULL) {
    for (i = 0, j = strlen(ingred); j <= (strlen(buffin) - 3);
                i++, j++)
       buff[i] = buffin[j];
          buff[i] = '\0';
```

```
    /* save for later use */
    strcpy(tbuffing, buff);
}
else if ((strstr(buffin, ingred_seq_no)) != NULL) {
    for (i = 0, j = strlen(ingred_seq_no); j <= (strlen(buffin) - 3);
                i++, j++)
        buff[i] = buffin[j];
            buff[i] = '\0';
    strcat(buffing, buff);
    strcat(buffing, "\t");
    /* now add in the proprietary & ingredient stuff */
    strcat(buffing, tbuffprop);
    strcat(buffing, "\t");
    strcat(buffing, tbuffing);
    strcat(buffing, "\t");
}
else if ((strstr(buffin, percent)) != NULL) {
    for (i = 0, j = strlen(percent); j <= (strlen(buffin) - 3);
                i++, j++)
        buff[i] = buffin[j];
            buff[i] = '\0';
    strcat(buffing, buff);
    strcat(buffing, "\t\t\t");
}
else if ((strstr(buffin, CAS)) != NULL) {
    for (i = 0, j = strlen(CAS); j <= (strlen(buffin) - 3);
                i++, j++)
        buff[i] = buffin[j];
            buff[i] = '\0';
    strcat(buffing, buff);

    /* done with buffing; write to file */
    strcat(buffing, "\n");
    fputs(buffing, outing);
}
else if ((strstr(buffin, control)) != NULL) {
    sprintf(buffout, "%d\t%s\t%s\n", haz_num, msdsfilename, buffname);
    /* 7/27/93
        not only print to ppe file but also continue output
        to outmsds file
     */
    fputs(buffout, outppe);
    /* 7/28/93 copy "Control..." to msds and leave header to ppe */
    strcpy(buffout, buffin);
    fputs(buffout, outmsds);
    while ( (fgets (buffin,BUFFSIZE, input) != NULL) &&
        ((strstr(buffin, transportation)) == NULL) ) {
            strcpy(buffout, buffin);
            /* 7/27/93 output to both files */
            fputs(buffout, outppe);
            fputs(buffout, outmsds);
```

```
        }
      }

        /*  after all the checks, write the data somewhere */
      strcpy(buffout, buffin);

        if (outmsds != NULL)
       fputs(buffout, outmsds);
        else if (outkill != NULL)
       fputs(buffout, outkill);
    }

    fclose(input);
    fclose(outmsds);
    fclose(outmat);
    fclose(outing);
    fclose(outppe);
    fclose(outkill);
    return (0);
}
```

Appendix D - Loadhmat.prg FoxPro Program Listing

```
* hmatload.prg gp 6.28
* load ingredient file then
* load both the .dbf and msds from text files

clear
* load hming
use hming
zap
append from hmingdbf.txt delimited with tab

* load hmat
use hmat
zap
append from hmatdbf.txt delimited with tab

* msdsload.prg gp 6/28
* use to load msds' from text file to memo fields
? " "
? " Now loading MSDS' "
? " "
use hmat
go top
append memo msds from c:\hmcm\save\p8\hm2487.001 overwrite
skip
append memo msds from c:\hmcm\save\p8\hm2487.002 overwrite
skip
append memo msds from c:\hmcm\save\p8\hm2487.003 overwrite
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```

Appendix E - Example of Input Document

PERSONAL PROTECTIVE EQUIPMENT COST LIST (7/93)		
	Each	**Per Person Per Day**
GLOVES		
Lab Safety Butyl 0.014" (bulk 144)	$ 12.50	$ 0.21
Guardian Butyl-XTR 0.014" (bulk 144)	$ 18.30	$ 0.31
North Butyl Gloves Medwt Smooth 0.017" (bulk 24)	$ 12.95	$ 0.22
Pioneer Unlined Nitrile 0.015" (bulk 72)	$ 1.65	$ 0.03
Lab Safety Latex 0.018" Yellow Flock Lined (bulk 6)	$ 1.25	$ 0.02
Lab Safety Neoprene (bulk 100)	$ 1.90	$ 0.03
Stanzoil Tri-ply Milled Neoprene (bulk 48)	$ 3.30	$ 0.06
Mediumweight Knit-lined Neoprene (bulk 144)	$ 3.40	$ 0.06
GOGGLES		
Lab Safety Fog-Free (bulk 96)	$ 2.25	$ 0.04
Sellstrom Multipurpose Fog-Free (bulk 120)	$ 4.05	$ 0.07
Econ 500 Fog-Free Clear (bulk 144)	$ 4.45	$ 0.07
Econ 160 Fog-Free Clear (bulk 144)	$ 6.40	$ 0.11
BOOTS		
Rainfair Polyurethane	$ 75.90	$ 0.84
Rainfair Neoprene Safety (bulk 3)	$ 45.80	$ 0.51
Bata Superpoly Chevron Sole (bulk 3)	$ 26.80	$ 0.30
Bata Polymax (bulk 6)	$ 37.35	$ 0.42
Bata Hazmax (bulk 6)	$ 50.85	$ 0.57
PVC Safety Plain Toe (bulk 6)	$ 13.00	$ 0.14
Bata PVC Plain Toe (bulk 6)	$ 14.15	$ 0.16
Tingley PVC/Nitrile Safety (bulk 3)	$ 25.95	$ 0.
Tingley Standard PVC Safety Plain Toe (bulk 6)	$ 16.65	$ 0.19

	Each	Per Person Per Day
Bata Polyblend Plain Toe (bulk 3)	$ 22.20	$ 0.25
Tingley Butyl Overboots (bulk 12)	$ 37.45	$ 0.42
Disposable Polyethylene Overboots (bulk 6)	$ 9.30	$ 0.10
Lab Safety Low-Cost Latex Overboots (bulk 50)	$ 5.35	$ 0.06
Rainfair Natural Rubber Overboots (bulk 4)	$ 18.50	$ 0.21
Grips Overboots (bulk 12)	$ 35.10	$ 0.39
RESPIRATORS (Silicone Half-Mask)		
North (bulk 12)	$ 22.50	
Willson 6000 Series (bulk 10)	$ 23.20	
3M Easi-Air (bulk 10)	$ 22.90	
Scott Dual Cartridge (bulk 8)	$ 27.60	
Pro-Tech (bulk 1)	$ 21.60	
Survivair (bulk 12)	$ 20.00	
AO Safety (bulk 12)	$ 20.90	
Glendale (bulk 12)	$ 20.35	
Respirator Filter and Cartridges (average)		
Willson 6000	$ 10.82	
North	$ 10.12	
3M	$ 10.93	
Scott	$ 12.41	
Survivair	$ 9.76	
AO Safety	$ 8.68	
Pro-Tech	$ 7.10	

Appendix F - FoxPro Code to Input Data Into HMTAB.dbf

```
* gp 9/30/93 loadtab.prg
*    use to load the hmtab.dbf from a text file
*    Format is:
*          HmatId  Hmcfeiid PerP    PerD    PerQ    Prob where
*          PerP, PerD, and PerQ are 1 = Yes and 2 = No, Prob is the
*          probability for this item and the entire file is tab delimited
CLEAR
CLOSE ALL DATABASES
SELECT 1
USE hmtab
ZAP
*** ASCII file is called loadtab.txt - contains the data to be loaded ***
APPEND FROM loadtab.txt FIELDS hmatid, hmcfeiid, perp, perd, perq, prob;
    DELIMITED WITH TAB
SELECT 1
USE hmtab
SELECT 2
USE hmat
SET ORDER TO hmatid              && prep to relate to hmtab
SELECT 3
USE hmcfei
SET ORDER TO hmcfeiid        && prep to relate to hmtab
SELECT 4
USE hmcom
SET ORDER TO niin
SELECT 2
SET RELATION TO niin INTO hmcom       && relate hmcom(ch) & hmat(par)
SELECT 1
SET RELATION TO hmatid INTO hmat      && relate hmat (ch) & hmtab (par)
SET RELATION TO hmcfeiid INTO 3 ADDITIVE  && rel hmcfei (ch) & hmtab (par)

COUNT = 1

DO WHILE .NOT. EOF("hmtab")
    REPLACE hmtab.tabid WITH count
    REPLACE hmtab.hmcomid WITH hmcom.hmcomid
    REPLACE hmtab.hmlcid WITH 4 && maint/repair
    REPLACE hmtab.hmwpid WITH 5 && degreasing
    REPLACE hmtab.hmetid WITH 3 && no exposure
    REPLACE hmtab.hmetprob WITH 1.0 && prob of no exposure
    REPLACE hmtab.hmcfid WITH hmcfei.hmcfid
    REPLACE hmtab.hmcfeid WITH hmcfei.hmcfeid
    REPLACE hmtab.hmcfeiid WITH hmcfei.hmcfeiid
    REPLACE hmtab.hmcfecost WITH hmcfei.hmcfeicost
    REPLACE hmtab.hmunit WITH hmcfei.hmcfeiunit
    REPLACE hmtab.wtaverage WITH hmtab.hmcfecost * hmtab.prob && calculation
    count = count + 1
    SKIP
ENDDO while .not. eof
```

Appendix G - Example of PPE by Material and Manufacturer

PERSONAL PROTECTIVE EQUIPMENT BY MATERIAL AND MANUFACTURER

Material: 1,1,2-Trichloro-1,1,2-Trifluoroethane
Manufacturer: Mallinckrodt, Inc.
PPE: Full-Face Respirator
Neoprene Gloves
Goggles
Work Clothing

Material: Trichlorotrifluoroethane
Manufacturer: Micro Care Corporation
PPE: Neoprene Gloves
Goggles
Work Clothing

Material: Freon 113
Manufacturer: E.I. Dupont
PPE: Impervious Gloves
Goggles

Material: Freon TF Cleaning Agent
Manufacturer: E.I. Dupont
PPE: Butyl, PVA or Neoprene Gloves
Goggles
Work Clothing

Material: 1,1,2-Trichloro-1,1,2-Trifluoroethane
Manufacturer: Fisher Scientific Co.
PPE: Impervious Gloves
Goggles

Material: Genetron 113 Trichlorotrifluoroethane
Manufacturer: Allied Chemical
PPE: PVA or Neoprene Gloves
Goggles
Work Clothing

Material: Genetron 113 Trichlorotrifluoroethane
Manufacturer: Allied Chemical
PPE: PVA Gloves
Goggles
Work Clothing: PVA or Neoprene

Appendix H - Description of System Upgrades

Inclusion of Permissible Exposure Limits

A subset of the OSHA Z-table was used to create the Permissible Exposure Limits (PEL) information. The **OSHA Z-Table** selection is right below the **Cost Analysis** selection in the **System** menu selection. When this is selected, a listing of the substance by chemical name, the Chemical Abstract Number, the PEL-TWA (Time Weighted Average), and the PEL-STEL (Short-Term Exposure Limit) appears. The TWA is the average airborne exposure in any 8-hour work shift of a 40-hour work week, which shall not be exceeded. The STEL is a 15-minute TWA exposure.

Database Modifications

Several tables were modified by adding additional fields. Existing fields and data were left intact for this version.

A new table, HMCOM.DBF, was added so common names can be associated with NIIN. Input into and/or modification of this field occurs when either entering or modifying the HMAT.DBF. This additional table allows users to associate specific stock numbers with common name. This way a user can use the common name rather than have to remember the stock numbers for the cost analyses.

Cost Analysis Modifications

In creating the report for the calculated cost a new option, PRODUCTS, was added. At this selection, the user can now choose a cost comparison for all products (selection is ALL PRODUCTS) or a single product. If the **ALL PRODUCTS** selection is made, the result will be a cost comparison between all products with the same common name. Scanning this report will give the most cost-effective product among the selected.

Appendix I - Preliminary List of Additional Hazardous Material from Long Beach Naval Shipyard's Safety Office

Product's Common or Trade Name	Product's Chemical or Shipping Name	FSC and National Inventory Number
Adhesive sealants (and similar material acetic acids)		8040-00-843-0802 8040-00-902-3871 8040-00-877-9872 8040-00-117-8510 8040-00-833-9563 8040-00-145-0020 9150-00-616-9212 6850-00-294-0860
Hydrochloric acid (descaler)		6850-00-664-6053
Sodium Nitrate		6810-00-174-1823
Sodium Nitrate		6750-00-715-0700
Hydrazine 22%		6750-00-149-2020
Grease Hi Temp	lubricant	9150-00-233-4971
Oil AG-10	lubricant	9150-00-057-8974
G-353 Grease	lubricant	9150-00-754-2595
Tribolube 10C	lubricant	9150-00-961-8975
Graphite Dry Lube	lubricant	9620-00-233-6712
0-147 Oil Instrument	lubricant	9150-00-253-4129
140 Stik-Wax	lubricant/wax blend	9150-LL-L00-3602
Graphite Dry Lube	lubricant	9620-00-233-6712
Dry Moly Spray #7260	lubricant/aerosal	9150-00-163-9036
Oil Engine	lubricant	9150-00-985-7099
4647 Corrosion	lubricant	8030-00-546-8637
Grease celvacene high	lubricant	9150-00-754-2826
Grease Silicone oil	lubricant	9150-01-080-9652
#G-354 Grease	lubricant	9150

Appendix J - Proposed Milestone for Projected Work

Action	FY 94	FY 95	FY 96
Complete entry of cost data for degreasers	**		
Enhance HMIS interface	********		
Develop FEDLOG interface	********		
Enhance HMLCCM software	****		
Enter new material suggested by LBNS	********		
Enter data for Exposure States 1 & 2	**	******	
Enter data for Production & Final Disposition Phases		********	
Enter data for other shipyards		********	
Enter data for other Navy industrial facilities		****	****
Enter data for the R & D and Procurement Phases		****	****
Develop a generic, Navywide knowledge base			********

** represents one quarter

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The Hazardous Material Life-Cycle Cost Model (HMLCCM) was enhanced to include a distinction between materials and products which are the different brand name of a material. Working with Long Beach Naval Shipyard, twenty-nine materials were identified for entering into the system and one hundred ninety-seven products were associated with these materials. All these materials and products were added to the knowledge base and specific cost information was entered for forty-eight products. In addition, the model was modified so that information from HMIS or individual Material Safety Data Sheets (MSDSs) could be entered as well as data on Permissible Exposure Limits (PELs) could be retrieved.

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