

**Improved Systems for Worker Exposure Surveillance  
Final Report**

**Funded by**

**Grant No. R01/CCR412029-02**

**Centers for Disease Control and Prevention**

**255 East Paces Ferry Road**

**Atlanta, Georgia 30305**

**Prepared by**

**William G. Tankersley, MS, CIH**

**Principal Investigator and Project Director**

**Center for Epidemiologic Research**

**Oak Ridge Associated Universities**

**Oak Ridge, Tennessee 37830**

**December 26, 1997**

## TABLE OF CONTENTS

List of Abbreviations . . . . .	4
List of Figures . . . . .	5
List of Tables . . . . .	6
Significant Findings . . . . .	7
Usefulness of Findings . . . . .	10
Abstract . . . . .	11
Body of Report with Conclusions . . . . .	12
Introduction . . . . .	12
The Y-12 Plant as a Pilot Site . . . . .	12
Project Goals . . . . .	13
Conduct of the Project . . . . .	14
General . . . . .	14
Task 1 - Descriptive Analysis of Y-12 Monitoring Programs . . . . .	14
Data Collection . . . . .	14
Writing and Editing the Reports . . . . .	15
Description of the Reports . . . . .	15
Conclusions . . . . .	16
Task 2 - Potential Exposure Profile System (PEPS) . . . . .	16
Defining the Problem . . . . .	16
Development of Underlying Concept . . . . .	17
Description and Performance of System . . . . .	18
Software Development . . . . .	19
Development of Default List of Potential Exposures . . . . .	21
Conclusions . . . . .	22
Task 3 - The Worker Exposure Surveillance System (WESS) . . . . .	23
Defining the Problem . . . . .	23
Development of Concept for System . . . . .	24
Description of the WESS System . . . . .	25
Equipment . . . . .	25

Scanning Software .....	26
Selection of Sites for Scanner Stations .....	26
Participation - Station Managers .....	26
Participation - Workers .....	27
Data Management Software .....	27
WESS Database .....	28
Using the WESS Application .....	28
Data Security .....	30
Participant Debriefing Interview .....	30
Project Modifications/Problems .....	31
Conclusions .....	32
 Acknowledgments .....	 33
 References .....	 34
 Appendix A .....	 37
Appendix B .....	48
Appendix C .....	51
 List of Present and Possible Future Publications .....	 58
 Equipment Inventory .....	 59

## LIST OF ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
CDC	Centers for Disease Control and Prevention
CHP	Certified Health Physicist
CIH	Certified Industrial Hygienist
DOE	U.S. Department of Energy
IH	Industrial Hygiene
HP	Health Physics
LMES	Lockheed Martin Energy Systems, Inc.
NIOSH	National Institute for Occupational Safety and Health
ORAU/CER	Oak Ridge Associated Universities/Center for Epidemiologic Research
PEPS	Potential Exposure Profile System
RADCON	Radiological Control
WESS	Worker Exposure Surveillance System
Y-12	Department of Energy weapons plant in Oak Ridge, Tennessee

## LIST OF FIGURES

Figure 1	Data Collection Form for Descriptive Analysis of Y-12 Monitoring Programs . . . . .	39
Figure 2a.	Letter of Request for Input From Occupational Health Professionals On Significant Potential Exposures for U.S. Work Force . . . . .	41
Figure 2b.	Survey Form for Significant Potential Exposures for U.S. Work Force . . . . .	42
Figure 3.	Bar Code Scanner Station Participant Information Sheet . . . . .	43
Figure 4.	WESS Participant Debriefing Interview Announcement to Y-12 Management . . . . .	44
Figure 5.	WESS Participant Debriefing Interview Invitation and Consent Form . . . . .	45
Figure 6.	WESS Participant Debriefing Interview Form . . . . .	46
Figure 7.	PEPS Splash Screen . . . . .	52
Figure 8.	PEPS Main Menu Screen . . . . .	52
Figure 9.	PEPS Potential Exposure Assignment Screen . . . . .	53
Figure 10.	PEPS Occupation Description Screen . . . . .	53
Figure 11.	PEPS Query Screen . . . . .	54
Figure 12.	PEPS Designated Potential Exposures Editing Screen . . . . .	54
Figure 13.	WESS Splash Screen . . . . .	55
Figure 14.	WESS Main Menu Screen . . . . .	55
Figure 15.	WESS Surveillance Data Options Screen . . . . .	56
Figure 16.	WESS Surveillance Data Query Screen . . . . .	56
Figure 17.	WESS Query Output Screen . . . . .	57
Figure 18.	WESS Example Help Screen . . . . .	57

## LIST OF TABLES

Table 1. Potential Exposure Profile System Database Table Descriptions . . . . .	49
Table 2. Worker Exposure Surveillance System Database Table Descriptions . . . .	49

## SIGNIFICANT FINDINGS

### Descriptive Analysis of Y-12 Monitoring Programs (Task 1)

It was found that, overall, good use is being made of the results generated by the U.S. Department of Energy (DOE) Y-12 Plant monitoring programs described in the Task 1 report. Both the Radiological Control (RADCON) and Industrial Hygiene (IH) Departments report results of the personnel monitoring programs to the individuals involved and their supervisors. In addition, the RADCON Department issues departmental reports on these results so supervisors can compare employee doses for the supervised department to those of other departments. Reports are also issued, to the members of the As Low As Reasonably Achievable (ALARA) committee, presenting the year-to-date status of the radiological monitoring programs and ALARA goals for the plant.

Neither the RADCON Department nor the IH Department produce a continuing overall status report that compares current results with established standards and previous levels. It is judged by the authors that such reporting would be helpful to the Y-12 Plant in general and, in particular, to the RADCON and IH Departments in maintaining quality programs. Such reporting would likely improve communication and understanding between the employees and managers and offer an opportunity for the RADCON and IH Departments to showcase their successes and indicate actions being taken in the cases of incipient problems.

While the quality of results generated by the reviewed monitoring programs were judged overall to be excellent, the quality of the results could be improved by reporting the results as determined, i.e., zero, results not significantly different from zero (either positive or negative), and doses that are significantly different from zero in the positive direction. Instead, only significantly positive results are being reported as determined, while other results are reported as being below the minimum detectable amount, less than the lowest reported amount, or zero. This makes such results less useful for evaluating dose response for epidemiology studies or for determining averages.

The RADCON Department does a better job of personnel monitoring of all personnel with exposure potential than does the IH Department. The main reason for this appears to be that for most potential chemical exposures, the only practical method for personnel monitoring is personal air sampling which is costly and time consuming. Conversely, the meter badge and the uranium urinalysis program are relatively inexpensive methods of monitoring for the major radiation exposures of concern at this facility.

This compilation of information on, and evaluations of, the reviewed Y-12 monitoring programs is not elsewhere available. The report should be useful to the Y-12 RADCON and IH Departments in maintaining and improving the quality of their programs. The report also should be of great use to occupational health researchers conducting

studies of Y-12 Plant populations.

### **Potential Exposure Profile System (Task 2)**

It was found that binary information (Potentially exposed/Not potentially exposed) on thirty-six chemicals or physical effects can be conveniently and efficiently stored in an eleven-digit decimal number. The potential exposure information may then be used to classify groups of workers for participation in specific monitoring programs or for occupational health studies.

The Potential Exposure Profile System (PEPS) Windows 95-based computer application, developed as an integral part of the PEPS system, provides a powerful and convenient means for assigning potential exposure values (PEPS Codes) to occupations in the PEPS database and for accessing and modifying existing information in the database. The PEPS application may be customized to accommodate specific potential exposures associated with particular industries.

A general survey of Certified Industrial Hygienists (CIH) and Certified Health Physicists (CHP) throughout the U.S. to identify the most significant potential exposures for the U.S. workforce revealed a relatively small and consistent set. Thirty-seven survey respondents, when asked to identify up to 40 significant potential exposures for the U.S. work force, collectively named less than 100. A much smaller number of the named potential exposures were identified by more than one respondent. This finding suggested that the PEPS system should be more adequate for classifying workers by potential exposure than was originally conceived.

### **Worker Exposure Surveillance System (Task 3)**

It was found that commonly available bar code scanning equipment and personal computers could be easily configured to function as an automated potential exposure surveillance tool. The required equipment was relatively inexpensive and quite dependable for the intended purpose. Differences in reading error rates exist among bar code scanning technologies, therefore attention is required to match the type of scanning equipment with the bar code medium to be read. Management and retrieval of potential exposure data generated by the surveillance system required development of a relatively complex computer application with a convenient and intuitive user interface. The Worker Exposure Surveillance System (WESS) developed within this project, including such hardware and software, successfully demonstrated the functionality and practicality of such a system.

Some resistance to installation of the WESS scanner systems was found among management staff, based chiefly on concerns about possible worker resistance. Some questions, but little resistance to participation, was found among workers.

Potential exposure surveillance data collected by the WESS system provides a number of advantages and one significant disadvantage when compared to traditional industrial hygiene instrument-based monitoring data.

Advantages:

- A much larger segment of the worker population can be monitored with little interruption of work schedule
- Relatively low cost compared to instrument monitoring
- Many more data points are generated
- Data useful for other purposes (attendance verification, project accountability, etc.)

Disadvantage:

- Does not provide quantitative measurements of air concentrations.

It was found that a very small fraction of the work force at Y-12 is monitored for a very limited number of potential chemical exposures. This is not exceptional, but rather quite common in industries with large worker populations that work with a variety of materials.

## USEFULNESS OF FINDINGS

### Task 1

Over the past 20 years, much effort has been expended toward investigating procedures and data pertaining to exposure monitoring programs at DOE sites for purposes of health studies and improving health protection practices<sup>1-22</sup>. The two volumes of descriptive information, collected and published within Task 1, will serve as a basic resource for any one needing documentation for monitoring procedures and programs at the Y-12 Plant for the period of this study and until there are major changes in the monitoring programs. Recommendations included within the Task 1 volumes, based on independent review of program procedures, should be useful to Y-12 Plant management for planning monitoring program improvements.

### Task 2

The PEPS system provides a much more precise system for classifying workers according to potential exposure for purposes of health studies and establishment of monitoring groups compared to other systems based on job titles or other descriptive information. The PEPS database can be used for any purpose requiring categorization of workers by job title, work group, or potential exposure. Possible uses include rapid enumeration of workers requiring special protective equipment, identification of workers requiring particular hazards training, and as an aid with overall accountability of potential hazards among the plant work force.

### Task 3

The WESS system provides a means for surveillance of large populations for risk of exposures by continually recording worker-work location-potential exposure relationships. Monitoring of such populations by traditional methods is considered impractical due to loss of productivity and excessive analytical costs. The data generated by the WESS system can be useful for any purpose where continuous surveillance of worker activities is needed, such as for project management and personnel performance assessment. The data generated by the WESS system can be easily integrated with any available instrument monitoring data.

## ABSTRACT

In response to heightened worker awareness and concern regarding possible associations between occupational exposures and disease, it is becoming increasingly important to provide adequate worker exposure surveillance and to store and maintain results generated from such surveillance so that the results are available for review and analysis. Two practical and cost-effective informational tools were developed and tested at the Department of Energy Y-12 Plant to complement existing worker exposure assessment programs, thus providing improved surveillance for a greater percentage of the worker population.

The Potential Exposure Profile System (PEPS) is a software tool for classifying workers based on substances with which they commonly work rather than on descriptive information, such as job title, which may be uninformative or even misleading. Each occupation or individual in the PEPS database is linked to an exposure profile based on potential for exposure to a list of physical, chemical, or radiological hazards. The Worker Exposure Surveillance System (WESS) generates a chronological record of employees by task location using bar code technology. The WESS system integrates worker specific data with work area and potential exposure data for each work area in order to monitor workers for potential exposures at each location. The worker participates in the surveillance for potential exposures by scanning an identification badge when entering and leaving a monitored location. Since the system is based on bar code technology, it is both a practical and cost-effective method of increasing the degree of worker surveillance, especially for workers commonly not monitored by traditional methods. Both the PEPS and WESS systems are fully developed and functional model systems including documentation of rationale, descriptions of necessary hardware, instructions for system use, software for managing and manipulating computerized information, example databases, and documentation of system performance.

As a companion to the development of the PEPS and WESS systems, exposure monitoring programs and databases at the Y-12 Plant were evaluated and described in a formal document. This document includes all currently implemented programs at Y-12 that generate data useful for assessment of worker exposure, including an analysis of each program's intended purpose(s) and actual utility.

The resulting products of this research are believed to enable significantly improved surveillance of industrial populations for potential exposures. Their use should increase the precision of selecting workers for special exposure specific health monitoring programs and help to facilitate the integration of exposure-related information within and among facilities.

## **BODY OF REPORT WITH CONCLUSIONS**

### **Introduction**

The research conducted by Oak Ridge Associated Universities Center for Epidemiologic Research (ORAU/CER) within Grant R01/CCR412029-02 consisted of three distinct projects, designated as Tasks 1, 2, and 3 for convenience. The three projects were quite different in concept and implementation, but were linked by the common factor of being directed at developing tools for improving the overall health care of the U.S. work force. Task 1 sought to produce a much needed, well documented, single resource for information about monitoring programs and procedures at a representative heavy industrial and nuclear facility, the DOE Y-12 Plant in Oak Ridge, Tennessee. The Y-12 Plant served as a pilot site for this task, providing a fully-operational, industrial setting for demonstrating how accessibility and data collection problems would be addressed and overcome. Tasks 2 and 3 were more closely linked, since both were aimed at developing computer-based tools for supporting, enhancing, and improving currently accepted exposure evaluation procedures. These procedures usually are well designed and quite costly in time and effort, but still result in many shortcomings compared to the preferred and ideal procedure of monitoring all employees for all potential exposures. The Y-12 Plant also served as the pilot site for testing of the bar code scanner-based worker surveillance system developed within Task 3.

The three tasks within R01/CCR412029-02 were performed by a team of nine researchers, eight of which were employees of ORAU/CER and one a consultant with over 40 years employment at the Y-12 Plant. The three research tasks were conducted simultaneously, and although each team member had designated responsibilities, many of the team members participated in all three tasks as needed. All of the research team members held other project responsibilities during the conduct of this project. The total personnel effort dedicated to all three tasks was approximately 2.4 person-years.

### **The Y-12 Plant as a Pilot Site**

The Y-12 facility, managed by Lockheed Martin Energy Systems, Inc. (LMES), was a chemical and metallurgical processing and weapons components production plant and is presently a uranium storage, waste management, and weapons production standby facility. As such, a wide range of industrial activities have been, and are presently performed at the facility. This wide range of activities results in potential exposure to many hazardous materials and physical effects.

The basic concepts of the proposed research were presented to Dr. Ron Keyser, Y-12 Plant Manager of Health, Safety, Environment, and Accountability Division, prior to submission of the proposal to the Centers for Disease Control and Prevention (CDC). Performance of the proposed work would require frequent access to several operations

areas within the plant and cooperation of a number of plant personnel in collection of information, and installation and maintenance of computer equipment. Dr. Keyser expressed appreciation of the intended research and presented the proposal to Dr. Todd Butz, Y-12 Plant Manager, for approval. After a short time, during which several plant legal issues were addressed, a formal letter of agreement was delivered to ORAU/CER, granting access to the facility as needed and assuring cooperation from facility staff. Shortly after grant R01/CCR412029-02 was awarded to ORAU/CER, a strategy meeting was held at Y-12 to work out specific arrangements for conduction of the study.

## **Project Goals**

The project reported herein was aimed at developing and testing practical and affordable occupational health tools to complement and augment traditional worker exposure assessment programs. Since the Y-12 Plant management had formally agreed for the plant to serve as a pilot site for the study, all information and data utilized in the study were specific to the Y-12 Plant.

The specific objective of Task 1 was to describe the current programs at the Y-12 Plant that generate or derive data useful for assessment of workers' exposure to radiation or chemical hazards. Programs directly or indirectly applicable to assessment of radiation or chemical exposures were reviewed, documented, and analyzed. Information provided in these analyses included (1) intended utility of each program and the present utilization of results generated by each program, (2) populations participating in or associated with each program and the algorithm or logic used for selection of monitored participants or areas, (3) relative costs of each program, and (4) major advantages and disadvantages of the utilization of data from each program for exposure evaluation. Recommendations for improvement in the use or quality of the data for exposure/dose estimates were also provided, when indicated.

The objective of Task 2 was to develop and test an innovative method for classifying workers based on potential exposures, and develop the computer application for the necessary data management. The proposed system would be useful to both occupational health researchers and plant health and safety personnel for identifying groups of workers within and across facilities, by exposure potential, for analytical and programmatic purposes. It was planned to provide a fully developed model system for classification of workers based on a selected set of potential exposures known to be of significance to the U.S. work force. Details of the system, an explanation of the underlying logic, instructions for system use, an example database, and documentation were to be included.

The objective of Task 3 was to develop and test at the Y-12 plant a practical and cost-effective system based on bar code technology for monitoring the work locations of individual workers and recording the primary substances to which they are potentially exposed at these locations. As suggested in the CDC grant announcement, the

proposed system was intended to encourage worker involvement by requiring physical interacting with the data collection system, thereby promoting a greater interest and responsibility on the part of the workers regarding worker safety. It was planned to provide a working model system for surveillance of employees by work area and primary substances to which they are likely to be exposed. A description of the hardware system, all software developed, the data base of results from the pilot study, and full documentation were to be included.

## **Conduct of the Project**

### General

In order to explicitly define the degree of access and level of collaborative effort required for the conduct of Tasks 1 and 3 at the Y-12 facility, a project strategy meeting was arranged with Y-12 Plant Manager of Health, Safety, Environment, and Accountability Division, Dr. Ron M. Keyser, and key participants from Y-12 and ORAU/CER. The meeting was held in November, 1995 at Y-12, and all major issues regarding designation of collaborating personnel and access for installation of the bar code scanner systems were discussed and assignments made for resolution. Mr. Larry Brantley, industrial hygienist, was designated to coordinate the project with the other appropriate members of the Y-12 staff. Subsequently, Mr. Jim Hendershot, also an industrial hygienist, was designated as chief liaison between Y-12 and ORAU for the duration of the study.

Following this initial meeting, additional personal visits, written communications, electronic communications, and telephone conversations were utilized to coordinate the project activities at Y-12. Throughout the project, considerable time was spent at Y-12 by four research team members for the following activities: (1) interview of monitoring program managers for collection of data for Task 1 and (2) installation and periodic maintenance of, and retrieval of data from, the bar code scanner systems for Task 3. Also, at the conclusion of the data collection, research team members spent several days interviewing participating workers to discover their ideas for improving the systems.

### Task I - Descriptive Analysis of Y-12 Monitoring Programs

#### *Data Collection*

In preparation for collection of information from the persons most knowledgeable about the Y-12 monitoring programs, an interview questionnaire (Appendix A, Figure 1) was developed and used by ORAU representatives to collect the required information in an effective and efficient manner. To minimize the time required of the Y-12 personnel to a practical limit, parts of the questionnaire were directed at identifying and locating presently available documentation for the monitoring program(s). Y-12 personnel were very helpful in identifying and retrieving such documents, and the quantity of relevant material that existed was extraordinary. It was apparent that documentation of

monitoring programs had recently been given high priority, especially in the RADCON Department. Approximately 2,000 pages of procedures, reports, manuals, etc. were collected by the research team. Pertinent parts of the documents were reviewed to gather the information necessary for evaluation of 39 monitoring programs and to prepare the 16 reports describing the programs. In addition, 260 personal interviews or telephone conversations were held with some 52 persons to request assistance in collection of information and/or verify reported information.

### *Writing and Editing the Reports*

A standard format was developed for the reports to improve readability and increase the usefulness of the reports as reference documents. Drafts of the reports were written and reviewed by the ORAU/CER research team. These primary drafts of the reports were then sent to the individual(s) at Y-12 most knowledgeable about the described programs who were asked to make editorial comments and suggestions relative to the factual content of the reports. Changes were made to the draft reports as necessary to assure that the reports were factual. Editorial comments also were given due consideration and the reports rewritten as needed. Many forms and technical instruments are used in exposure monitoring programs. Copies of these forms and photographs or illustrations of instruments were electronically scanned into the computer so they could be included as integral parts of the reports to make the monitoring programs easier to describe and understand.

### *Description of the Reports*

The major deliverable for Task 1 was a two-volume set of reports with each volume consisting of two sections. Volume I, Section I, titled General Topics and Evaluation Report, addresses topics relevant to all monitoring programs and a general discussion of the reports. Section II of Volume I contains six chapters on personnel monitoring programs for internal and external radiation and survey programs for air and surface contamination.

Volume II, Section I contains seven chapters describing industrial hygiene monitoring programs. Volume II, Section II consists of chapters on the medical surveillance programs and the retrospective dose and exposure reporting programs that pertain to both RADCON and IH considerations. Lists of references and personnel contacts are included within each volume.

The Task 1 volumes, in both hard copy and electronic forms (Corel Word Perfect 6.1 format) were physically delivered to Dr. David Pedersen (NIOSH, Cincinnati) in May, 1997. Although only a limited number of hard copies were produced for the project, electronic copies are available from ORAU/CER.

### *Conclusions*

It is believed that these volumes contain a relative comprehensive yet concise compilation of information about monitoring programs installed at the DOE Y-12 Plant

as of 1996 that is not elsewhere available from a single source. This compilation of program information will likely be of use in the continuing RADCON and IH programs at Y-12 and will certainly find use by any researchers conducting occupational health studies in the future on Y-12 worker populations.

It is proposed by the authors that the value of these volumes is significant as both a current resource and as an archive. During the past 20 years, a great amount of investigative work and resources were expended by researchers at ORAU/CER and other institutions in discovery and retrospective evaluation of exposure monitoring programs at many DOE nuclear facilities for the purpose of conducting occupational health studies. Resources were also expended by the nuclear facilities to locate resource documents and to provide qualified personnel to interpret data and answer questions posed by hazards assessment research personnel. As the number of researchers involved in prospective and retrospective health and hazard evaluation increases through NIOSH intramural and extramural funding programs in the future, nuclear facility personnel may be taxed to their limit in their ability to assemble and disseminate information. It is hoped that these volumes may serve as a starting place for discussions with new researchers and may assist the facility personnel by documenting the answers to many of the questions that will be asked routinely. If thorough documentation of past monitoring programs had been available similar to the present volumes, a very large savings in time, effort, and cost would have been realized. It is expected that the present volumes will find use as technical references and as tools in occupational health studies and will increase in value with time.

## Task 2 - Potential Exposure Profile System (PEPS)

### *Defining the Problem*

Undeniably, it is impractical if not impossible to monitor all employees for all potential exposures. The alternative, in most cases, is to estimate or assign potential for exposure based on other information that may be directly or indirectly related to actual exposures. The most common types of data used to estimate potential exposure are job title and department, work group, or work area data. Traditionally, job titles or job title/department designations have been used for exposure grouping of individuals under the assumption that employees with similar job titles have similar exposures to similar substances especially if they are in the same department<sup>2,6,7,9,11,12,14,23-29</sup>.

Unfortunately, the assumption that exposure is correlatable with job title and/or department is weak at best and frequently is fundamentally flawed. Job titles typically are established by labor organizations or industrial wage standards departments, not by health and safety professionals. Consequently, job titles classify employees by organizational or economic position rather than by exposure potential. Additionally, job titles seldom provide accurate, concise descriptions of the work performed. Rather they are often uninformative (helper, operator, supv), ambiguous (asst labor, equip operator), or misleading (lab supv = laborer supervisor). As a result, job titles, and departments are often of little benefit to researchers or operations supervisors who

need to classify employees into groups according to likelihood of exposure. When health surveillance or epidemiology studies are made, these factors can necessitate a lengthy, costly investigative effort by exposure estimate staffs to discover the actual activities, associated substances, and exposure potential for many workers before a reasonably accurate exposure classification can be assigned. Obviously, a classification system based on potential for exposures would be of great benefit in identifying groups of workers for prospective health surveillance or for retrospective health surveillance studies.

#### *Development of Underlying Concept*

The two most basic criteria for the proposed worker classification system were (1) the system should have functionality to efficiently store binary data such as "potentially exposed" or "not potentially exposed" for a reasonably large number of materials or physical effects and (2) the information should be readily and conveniently accessible. Simple database tables are easily constructed and have virtually no limit to the quantity of information stored. However, the traditional database table with separate data fields for each element of data was judged not to be an efficient format to store binary values for multiple parallel informational elements. Also, queries designed to select for particular combinations of characteristics among data stored in such logically wide, repetitive field tables are usually programmatically bulky and not very flexible because of the need to evaluate the value stored in each of the multiple parallel fields in all of the database records.

A better storage format would allow binary information on multiple parallel elements to be stored in a single coded value of reasonable length which could be decoded when necessary for display of stored textual information. Past experience had shown the usefulness of the mathematical principle declaring that the sum of each unique combination of integers, all of which must be powers of two and none of which can be used more than once, will also be a unique integer. Stated alternately, the principle dictates that any integer can represent only one combination of unique powers of two. The principle is illustrated by the example that the integer, 37, is equal to the sum of only one combination of powers of two, i.e.,  $(2^0 + 2^2 + 2^5)$ .

The mathematical principle that underlies this fact is actually based within the binary numbering system. In this system, each number is represented by a unique combination of bits, each bit characterized by both its position and its value which can only be either zero (off) or one (on). It should follow that each bit is also equal to either zero (if set to "off") or a unique power of two (if set to "on").

Using this principle, if each bit in a binary series is assigned to represent the value or characteristic of one member of a set of parallel data units, considerable information can be stored in a relatively compressed form. If the set of parallel data units is defined as a set of materials or physical effects to which industrial workers may have potential for exposure, the mathematical system described could be used to store potential

exposure information (yes/no) for as many items as the binary data storage number has bits. If each bit is assigned to represent a different potential exposure, with bits set to one (on) representing "potential exposure present" and bits set to zero (off) representing "potential exposure not present", a simple but powerful system for storing multiple pieces of data is possible. Further, if the information-bearing binary number is then converted to a decimal number, the stored information is even further compressed. Such a system is the basis of the PEPS worker classification system.

#### *Description and Performance of System*

The PEPS system consists of a relational database of occupational information and a fully functional Windows 95-based application for convenient management and manipulation of the database. Occupational information stored with each record includes job title, job code, job description, work group, and potential exposure profile code (PEPS Code). The PEPS application is a menu driven program providing the user with convenient access to all stored data and providing a variety of functions including assigning and modifying PEPS Codes, adding occupational records, querying the database for records with particular characteristics, and displaying and printing reports of selected records.

The potential exposure profile information, designated by the user for each record, is encoded and stored in the PEPS Code. A major function of the application is the storage and manipulation of the PEPS Code. The PEPS Code is an 11-digit decimal number equal to a 36-bit binary number in which each bit represents the presence or absence of exposure potential for 1 of 36 materials or physical effects for which exposure potential may be estimated and recorded for each occupational record in the PEPS database. During program operation, potential exposure assignments by the user are indicated by visually marking appropriate boxes associated with the list of potential exposures displayed on the computer monitor. Any combination of potential exposures may be marked and selections may be altered at any time prior to or after a record is saved to disk. Neither the actual names of the potential exposures, nor images of the marked boxes are recorded with the occupational record. The coded information is stored within the PEPS Code and is dynamically and rapidly decoded each time the user requests information to be displayed or printed. The application transparently performs all required conversions to and from the binary and decimal representations of the potential exposure profile information, and displays or prints appropriate information decoded from PEPS Codes. Table 1 (Appendix B) presents descriptions of the two database tables in which the PEPS data reside. Figures 7-12 (Appendix C) show selected screens from the PEPS application.

#### *Software Development*

The PEPS application was developed in Microsoft® Access 7.0 and published as an executable program, thereby eliminating the need for potential users to have the Access Database Management System installed on their computer. Four primary criteria for the software were established prior to beginning development. The criteria were:

- The program must be convenient and intuitive to use

It is well recognized that regardless of how powerful and useful a software application may be, the application will find little use beyond what is absolutely required if it is difficult to operate. The PEPS application includes a fully-automated installation program, common to all programs that meet the Windows 95 standard. The installation procedure provides a number of installer choices and provides for a safe uninstall. Presently, the application is available only on 3.5 inch diskettes (5), but a CD format product could be easily produced.

The PEPS application follows the Window 95 interface closely. Virtually all functions are available by pressing one or more large, labeled command buttons, most of which also present "pop-up" instructions for use when the mouse cursor is allowed to rest on the command button for more than a second or two. Large fonts were also used whenever possible to improve readability and user comfort. The default Window 95 screen colors were purposely maintained, because they are generally acceptable to most users. However, the screen colors can be changed with little programming effort.

Though very powerful, the PEPS application was designed to be very intuitive to use by a reasonably experienced operator with very little need for training. A general overview of the purpose and functionality of the PEPS application is presented immediately upon running. In addition, help files with hypertext links to other related information are provided for almost every function. A users reference manual was published and was included with the final version of the PEPS application shipped to NIOSH in Cincinnati. The reference manual covers all aspects of the application including purpose, equipment specifications, installation, operation, references, and user support. Actual prints of all major screens are included to assist the new user in becoming familiar with the application.

Much thought was given to program navigation issues, and considerable flexibility in program was incorporated. Multiple routes to almost all screens are provided, and retracing to a previous location is easily accomplished at almost any point during program operation. Provisions for cancellation of user choices is very important in the development of user confidence. In the PEPS application, almost any user choice can be canceled prior to actually writing to the database.

- The program must be powerful and flexible

The PEPS application is a powerful tool for storing, retrieving, displaying, and printing the occupational data for which it was intended. The Microsoft® Access interface is perfectly integrated with the Microsoft® Jet Database Engine which manages the stored data and performs the database functions designed in the program. There is no practical limit to the number of occupational records that can be stored in the PEPS database, other than that imposed by the physical size of the hard disk in the computer being used. All of the functions in the PEPS application was coded using Microsoft®

Visual Basic; no programming macros were used.

The PEPS application provides a number of different functions related to manipulation of data utilized for classification of workers based on known potentials for exposure as described earlier. Beginning with the basic function of assigning PEPS Codes to occupational records, the following additional functions are provided:

- Entry of additional occupational records,
  - Modification of existing occupational records
  - Searching for records with particular occupational characteristics specified by user
  - Printing of formal reports of user selected records
  - Customization of Potential Exposures Table for specific industries
- The program must be dependable and not easily disrupted

The PEPS application was designed to be as “crash-proof” as possible. Microsoft® Access and Visual Basic were specifically selected as the database management tool and programming tool because of the maturity of both of these products and their general acceptance in the database management and programming communities.

Several hundred hours were spent in quality control testing of every function programmed in the application. Every screen was reviewed for correct font, colors, text, and appropriate linkages to other screens. In addition to review by ORAU/CER project team members, the program was offered for reviewed to a number of experienced computer programmers or users outside of ORAU/CER. Few programming problems were discovered by these reviewers, and all problems were resolved before the final version of the program was shipped to NIOSH in Cincinnati.

Extreme care was taken to assure that the user would never be left in a “dead-end” position in the program. As described previously, navigation choices are always available to return to an earlier position in the application. Much attention was also given to providing the user with confirmation requests when deemed appropriate, without making unnecessary confirmation requests burdensome.

It is extremely difficult, if not impossible, to design a complex and powerful computer application that is totally immune to crashing or disruption by the user. However, every reasonable effort was expended to make the PEPS application robust under all normal usage and conditions.

- The program must be reasonably easy to modify

Regardless of the quality, performance, and applicability of a software product, it is quite likely that at some time the need or urge for modifying the program will arise. This may be due to simply personal preferences regarding the user interface or may arise from critical requirements specific to particular users. Typically, periodic upgrades with

additional features or programming repairs are made available through the software vendor or author(s). Subsequent versions are likely to address some, but not all, of the specific preferences of each user. Also, these periodic upgrades are only available as long as the software's popularity remains high enough to make the upgrading profitable.

In view of this, the PEPS application was intentionally designed to be easily modified to increase its usefulness and extend its longevity. Two factors, together, make this possible. Firstly, the programming code is well documented within the program itself. Comments are included with all but the most simple programming routines. The comments are thorough and worded clearly to make the programming logic easy to understand. Secondly, while the published software was shipped in compiled, executable form, the uncompiled program and the complete code in printed format are available from ORAU/CER. A reasonably experienced application developer should have little trouble understanding the logic and syntax used in the PEPS application and therefore should be able to modify the application to accommodate specific requirements.

#### *Development of Default List of Potential Exposures*

During the conceptualizing phase of the project, it was visualized that the proposed worker classification system should be applicable to not only the DOE facilities, but also to all U.S. industries. Consequently, it was planned to identify a set (undetermined size) of the most prominent, major, or significant potential exposures (chemical or physical effects) for the U.S. work force to be included in the PEPS application and for which PEPS Codes could be assigned. To this end, a survey questionnaire was developed and sent to a randomly selected group of over 200 CIHs and CHPs, requesting their input in identifying the potential exposures of interest (Appendix A, Figures 2a and 2b). The survey recipients were provided a basic explanation of the purpose of the project and asked to identify up to 40 potential occupational exposures that were considered to be most significant for the U.S. work force, based on professional experience. From the 37 survey responses that were returned, a listing of potential exposures was generated, ordered by frequency of occurrence. This list of potential exposures was used to select those for inclusion as defaults in the published PEPS application.

The original concept for the PEPS application specified that the potential exposures for which occupations could be classified would be hard-coded (not modifiable) within the software. During software development, it was realized that the utility of the application would be significantly increased if the program provided a function for the user to make changes to the table of potential exposures to accommodate chemicals or physical effects of most concern for workers in particular facilities or industries. This functionality was developed and included in the final version of the application shipped to NIOSH. The shipped version includes a default set of 36 potential exposures selected from the list of potential exposures identified by the CIHs and CHPs as described in the preceding paragraph. However, these default potential exposures can be easily changed by the user within the program and with no reprogramming

necessary.

### *Conclusions*

The PEPS worker classification system based on potential exposure rather than descriptive text strings (job titles, etc.) was designed and developed as proposed. The necessary software application for building and managing the occupational database was also successfully developed and is available for use. The system is relatively simple to use while also being a powerful and robust informational tool for the occupational health professional.

Based on considerable use of the PEPS application during development and quality control testing, it is believed that use of the PEPS system, or a similar system, can provide measurable improvement in a number of operational and research procedures that require identification of groups of workers characterized by similar exposures. Such procedures are frequently used by industrial hygiene and health physics personnel to select employee groups for participation in particular monitoring programs. Similar procedures also are frequently used by exposure assessment researchers to identify subpopulations of employees for analyses based on estimated potential for exposure.

Traditionally, selection of these employee groups has been based on job titles and possibly other administratively assigned designations. However, it is well recognized by occupational health professionals that such administrative descriptors can be, and often are, grossly inadequate for determining similarly exposed workers. In contrast, the occupational records residing in the PEPS database are characterized by potential exposure assignments previously applied by experts at the local facility and are not simply based on job titles, department designations, etc. Assuming the PEPS classification system had been implemented and maintained properly, selection of such homogeneous exposure groups would be very easily and quickly accomplished. This would remain true even if the total number of employees from which such groups were selected was very large, i.e., tens of thousands. Use of the PEPS system would also easily allow selection of groups characterized by complex combinations of exposures, a task that usually presents great difficulty to the occupational health professional using traditional worker group selection methods.

The same benefits are available to the occupational health researcher. In fact, because in many cases the researcher will have need to deal with large study populations, the benefits offered by the PEPS system will be even greater. Significant savings in time and costs should be realized in studies of populations where a PEPS database has been maintained.

Finally, use of the PEPS database in no way excludes use of instrument monitoring data. To the contrary, any traditional monitoring data available should certainly be used in making potential exposure assignments in the PEPS database. Similarly, PEPS data should be used to verify that appropriate populations are being monitored for

appropriate potential exposures, and actual monitoring data can be linked to the system when it is available.

### Task 3 - The Worker Exposure Surveillance System (WESS)

#### *Defining the Problem*

A major challenge to industry managers and occupational health professionals is providing surveillance of large numbers of employees for possible exposure to many potentially hazardous materials. Ideally, each employee should be personally monitored for all potentially hazardous exposures during all periods in which the employee may be exposed. To a significant degree, nuclear workers have historically been monitored in this fashion for external radiation exposures<sup>1,3,10,15,16,17</sup>. At many facilities, monitoring devices, usually photosensitive film or thermoluminescence dosimeters, have been worn continually during work hours by all workers or by workers judged to have significant risk of radiation exposure. The dosimetric product of this monitoring program is an integrated measurement of dose for each monitored individual for the total period of exposure. However, for a number of practical or economic reasons, in most other potential exposure situations, including possible internal radiation exposures and exposure to chemicals, monitoring data traditionally have been collected for only a fraction of the workers potentially exposed and/or for only a fraction of time during which exposure may occur. It is not unusual for plant records to show that many workers are monitored once a year, or not at all, for possible exposure to many materials or physical hazards with which they work. Reasons for such incomplete monitoring include (1) extraordinary costs of monitoring devices, materials, and industrial hygiene and analytical services required for routine monitoring of all employees for all potential exposures, (2) costs of employees' time required for *in vivo* or biologic monitoring, and (3) the large number of chemical and physical hazards to which workers may be potentially exposed.

In lieu of routine or even periodic monitoring of individuals under these potential exposure situations, general air or surface contamination samples may be collected in selected areas. Results from such samples provide a representative measurement of the general working environment. However, these data have a number of limitations when used as input data for assessment of exposure to individual workers. Foremost among the limitations are (1) degree of relevance of such monitoring results to specific work environments and (2) the many difficulties in accurately linking of monitored areas to individuals. In many cases when little or no instrument monitoring data are available, the assignment of workers to homogeneous risk or exposure groups has been accomplished by examination of job title/work organization classifications. While generally reliable for some workers with descriptive job titles, these methods fail to be accurate for many classes of workers such as maintenance workers, supervisors, and individuals who infrequently pass through, but are not assigned to, hazardous areas<sup>2,6,29</sup>. Also, these methods cannot accommodate workers who have differing durations of work assignments in hazardous areas. All of these factors unfortunately result in quite incomplete worker exposure surveillance data sets, in almost all industrial

situations.

*Development of Concept for System*

Since it is impractical, if not impossible, to monitor all workers for every substance and physical hazard to which they may be exposed, a practical surveillance system based on indirect or qualitative data such as work area, task, and materials available for exposure was proposed. Such a system would provide information to plant industrial hygienists, health physicists, and medical staff for making exposure control decisions. Data generated by the system also would be of great use to occupational health researchers such as epidemiologists for retrospective analyses of possible associations between occupational exposures and excess disease.

The WESS System was conceived as being technically achievable and having the following characteristics:

- Significantly beneficial for protection of workers health
- Acceptable to workers and management
- Operationally practical
- Affordable

The system would continually record work locations and potential exposures for all workers within the surveillance area. The system would significantly complement and support other monitoring programs already in place at the facility. Data generated by the surveillance system could be linked via individual, work location, substance, or time to data available from other exposure monitoring programs at the facility. In more common situations where the amount of instrument monitoring data may be very limited, or even nonexistent, having ready access to data precisely identifying each work area occupied and the major work materials present for each employee, would greatly improve the quality and completeness of data sets typically utilized for exposure assessment decisions. Such a system would provide useful qualitative data and in conjunction with any available data from area and personnel monitoring programs would provide input for quantitative exposure estimations.

#### *Description of the WESS System*

The WESS system is an integrated computer hardware and software system for monitoring potential exposures to workers. The monitoring system is comprised of (1) automatic symbolic data recognition device, (2) local or centralized hardware for data collection and storage, and (3) dedicated software for management and manipulation of surveillance data. To maximize capability of the surveillance system, as well as minimize development time and costs, it was planned to use currently existing and mature technology for the necessary equipment. No software meeting the required specifications was known to exist. The pilot system tested in this study included five such monitoring stations.

#### *Equipment*

Commonly available bar code scanners were selected for collection of surveillance data. Other devices and technologies, such as magnetic stripe readers, fingerprint readers, and retinal image readers, were available and would likely have performed equally well. Bar code scanners were chosen because of their high degree of precision and relatively low cost. Many types and configurations of scanners were available to accommodate different requirements and preferences. For this project, scanners of two configurations were used, both of which used a visible laser diode as the scanning beam. Slot scanners which required passing a semi-rigid card through a slot approximately one-eighth inch wide were used in three of the scanner stations. The other two stations used wand scanners having a pistol grip and which were non-permanently mounted in a metal stand. The wand scanner reads the bar code as it is passed at moderate speed within a prescribed "window" located 6-8 inches in front of

the scanner lens. Both types of scanners performed equally well during the study. Both types of scanners also experienced problems reading bar codes overlaid with holographic images.

Each of the bar code scanners was connected to an entry-level Intel® Pentium-based computer via an interface device called a “wedge” which was physically connected to the computer at the port normally used by a keyboard. The wedge functioned by interpreting the light images of the symbolic, bar code data and converting the optical image data via hardware-based algorithm into digital data appropriate for computer use. Interpreted data from the wedge was received by the computer as if it had been generated by keyboard input.

#### Scanning Software

Installed on each computer was a Windows-based program specifically designed for the project to facilitate collection of several elements of surveillance data including worker bar code ID, scanner location (work area), date of scanning, and time of scanning. The combination of bar code reader, wedge, and computer with scanner software was collectively referred to as a scanner station.

#### Selection of Sites for Scanner Stations

The five scanner stations were strategically placed at the entrance of five selected operations areas at the Y-12 Plant. The selected areas were:

- Radiation calibration area
- Mercury decontamination area
- Pressure vessel area
- General manufacturing area
- Beryllium processing area

#### Participation - Station Managers

Prior to installation of each scanner station, a meeting was held with the supervisor of the selected area. Purposes and goals of the study were explained and opportunity was presented to ask questions and make recommendations. In response to one such recommendation, an information sheet describing the project and scanning procedure was maintained at each station (Appendix A, Figure 3). Also at this time, a proposed location for the scanner station was selected and plans made for acquiring any necessary fixtures such as tables or electrical extension cables. Following each meeting with a scanner station manager, the scanner station equipment was installed as planned.

### Participation - Workers

The actual surveillance procedure was established as follows. All workers entering or exiting a work area monitored by a scanner station were asked to present their employment badges, bearing bar coded employee identification numbers, to the scanner. System information including scanner location, date, and time of scanning were linked to the employee identification data and stored in a FoxPro® database. Data were periodically off-loaded from the scanner stations and transferred to another computer which functioned as the central data storage and management system. At this point, employee badge numbers were encoded as prescribed by the ORAU Committee on Human Studies Internal Review Board application (CHS ID# ORAU-98). The surveillance records were then linked to potential exposure data residing in the central database that were specific for each work location. Potential exposure data were in the form of named substances or physical effects previously designated by a knowledgeable occupational health professional. A record including all personnel, system, and work location data for each entry and exit event was then created and added to the worker surveillance database.

As currently developed, the WESS database management system is flexible enough to accommodate changing definitions of exposed populations within minutes. For example, if the currently established definition of a beryllium worker was changed from

"any person who spends 15% of his/her time in beryllium processing areas"

to a more restrictive definition such as

"anyone who passes through a beryllium processing area" ,

or to a less restrictive definition such as

"anyone who spends 25% of his/her time in a beryllium processing area" ,

new lists of workers who qualify as beryllium workers can be generated rapidly. These lists could be transferred to the medical department and used to flag employment or medical records to indicate which workers need specialized blood tests to detect sensitization to beryllium during routine physical examinations.

### Data Management Software

The WESS application was developed in Microsoft® Access 7.0 as previously described for the PEPS application. While the purposes and functions of the two applications differed considerably, the development goals and criteria as well as the programming and quality control measures were the same for both. The reader is referred to the *Software Development* Section on page 19 for a thorough discussion of this topic.

The WESS data management application is a powerful tool that provides a number of different functions related to management, manipulation, and analysis of the worker

surveillance data collected by the scanner stations described earlier in this report. The major functions include the following:

- Entry of additional surveillance records;
- Editing of existing surveillance records;
- Searching for and displaying records with particular descriptive, or exposure characteristics specified by user;
- Printing of formal reports of user selected records; and
- Customization of Potential Exposures Table for specific industries.

### WESS Database

The WESS database is comprised of three types of data, surveillance data, associated data, and derived data. The surveillance data are the raw monitoring records generated by the scanner stations as workers enter and leave a monitoring area. These records include Badge, Location, Scan Date, Scan Time, and IOType (entry or exit). These records are the primary data in the WESS database upon which summary data are based. The surveillance data are logically linked to a number of other data sets, and elements from these data sets may be integrated for display or printing. Associated data refers to data elements that are directly related to the raw data, but which are not collected at the scanner stations. These include WESSID (coded identification number), Name, Employment Dates, Location Descriptions with Effective Dates, and Potential Exposures with Effective Dates. These associated data are linked to the surveillance data by logical relationships and may be manipulated in conjunction with the surveillance data. Derived data refers to summarized or calculated values based on the surveillance data. A number of different derived values may be displayed or printed; however, since these values are calculated in real time for each request, the values are not stored in the database. The advantage of this method is that derived data will always be based on current raw data, therefore any changes in the underlying surveillance or associated data will immediately be reflected in any relevant derived data.

### *Using the WESS Application*

The WESS data management application provides convenient access to all data stored in the surveillance database. Functions are provided for browsing, querying, and reporting of the WESS monitoring records as well as the underlying and supporting data tables which hold demographic, potential exposure, and other relational information. Data also may be added or modified by users with appropriate authorization.

The WESS application is event driven, meaning that it reacts or responds to input by the user. All functions are accessible by clicking on appropriate command buttons or by pressing designated pairs of keyboard keys. Help for most functions is available within the application by pressing [Help] buttons available on most screens. Table 2 (Appendix B) presents descriptions of the nine database tables in which the WESS data reside. Figures 13-18 (Appendix C) show selected screens from the WESS

application.

Records in the WESS surveillance database may be selected for viewing, editing, or reporting based on a number of different criteria including WESSID (coded identification number), Badge, Location, PExposure (Potential Exposure), Date, or Date Range. Additional criteria available for selection of records from other data sets include Employee Name and Effective Date for change in Name, Location Description, and Potential Exposure. The query tool provided in the WESS application is extremely powerful and flexible. When querying the database, the user will be prompted to enter a selection criterion value or select from a drop-down menu (pick list) of possible values. As a convenience feature, when selecting records based on Employee Name, the query engine will accept an incomplete name (search string) as the value on which to search. However, depending on how closely the search string matches the actual name sought, more than one match for the input value may be returned.

Criteria for records selection may be chosen singly or in combination. Because of this flexibility, the number of query combinations possible is almost unlimited, and it would be impractical to provide programmed queries for even a majority of the possibilities. The structure of the Microsoft® Access database is such that if other queries are needed, different from those provided, it is possible to interact with the WESS database at the Microsoft® Access program level and outside of the WESS Data Management Application.

Persons with proper authorization may edit existing records in most of the WESS database tables. Editing is performed after selection of records by querying. By design, when records are first selected they are not editable, because the file is opened in read-only mode. If editing is necessary, a specific [Edit] command must be issued. Authorized users may also add records to the WESS database, either singly or in bulk. As with editing, safe-guards were designed into the WESS application to protect the integrity of the database as much as possible. Dedicated modules are provided for adding single records and loading (importing) multiple records directly into the WESS database. Records to be loaded must comply with a prescribed file layout and may be in any of the following five commonly used formats.

- ASCII (fixed length)
- ASCII (comma-delimited)
- dBase III
- FoxPro 2.6
- Paradox 5.0

#### *Data Security*

During development of the WESS application, thought was given to the level of security necessary or desirable to maintain the integrity of the database once it was populated. It was decided that security functions would be implemented within the Microsoft® Access application. Access to the data may be enforced at the database or individual database table level. Further, access may be precisely defined according to particular

database functions. To illustrate, users may be issued privileges as follows:

- Access to entire database with all functions;
- Access to entire database but with restrictions on specific functions such as adding new records;
- Access to entire database but with read-only privileges; or
- No access to database.

Usually, database privileges are issued by the individual(s) with administrative responsibility for the database. Initially, these persons will be in a “work group” designated by Microsoft® Access as the ADMINS work group. Additional work groups can be added with various levels of access. While users privileges can be issued at the individual user level, it is highly recommended that privileges be assigned at the work group level.

Additional information on security issues and implementation of security plans is available in the Microsoft® Access help files and in many independent publications on Microsoft® Access. Several of these publications are cited in Chapter VII: *Reference of the WESS Users Guide*.

#### *Participant Debriefing Interview*

At the conclusion of the WESS pilot study, a fraction (approximately three per cent) of the participating employees were asked to participate in a debriefing session including a questionnaire to be filled out by the worker prior to a short one-on-one discussion with a research team member (Appendix A, Figures 4-5). The debriefing questionnaire (Appendix A, Figure 6) and the discussion focused on gathering information and opinions about how the WESS equipment and procedures functioned, what problems were encountered, how the system could be improved, and was the system considered beneficial to the employees health and safety.

Seventeen persons participated in the debriefing procedure. Only one of the participants had experience with more than one scanning station. Most of the participants had scanned their badges more than 50 times. All participants except one thought the scanning procedure to be easy to understand and perform. Eighty-two percent thought it should be implemented in certain areas in Y-12 as a part of their health and safety program. An even greater percent (88%) rated the usefulness of the program as “having some benefit and should be developed further.”

The ideas that were expressed in the personal discussions of the programs were of similar tenor to those expressed in the printed questionnaire. The participating employees’ recognition of shortcomings of the system went beyond the recognition of system hardware problems and the difficulties of using a unit to serve as both an entrance and exit monitor. They recognized that there would be potential problems in handling areas with multiple entrances and exits. They pointed out management support as being a key factor in assuring good program participation. There was also

recognition that, beyond management support for a voluntary system, a system that would physically restrict area entrance and exit without badge scanning would be even more beneficial. The debriefings also indicated that there was an understanding that it would take a number of stations at well selected locations to establish a meaningful worker location surveillance system. The workers participating in the debriefing interviews not only convinced us that the majority of workers generally would be supportive of such a system, but also presented many additional ideas on how the system could be improved for routine use.

#### *Project Modifications/Problems*

During the course of this project it was necessary to implement three modifications to the work as originally proposed. Firstly, shortly after beginning investigation of the monitoring programs at Y-12 for Task 1, it was determined that the number of programs fitting the characteristics prescribed in the proposal was considerably larger than had been anticipated. An explanation of this discovery and a request for extension of time to complete the necessary research were included with the first year's progress report to CDC. In response to this request, the ending date of the grant award was delayed six months; no additional funds were provided.

The second modification to the proposed project related to the source of bar code badges used by the Y-12 workers for the WESS scanner stations. It was originally proposed to purchase badges especially for the research project. This was purposefully planned in order to assure compatibility of the badges with the scanners to be purchased and to insure that no wear or damage could result from any activity related to the project. However, during the initial strategy planning meeting with ORAU/CER and Y-12 staff, all interested parties concurred that there was no rational reason for purchasing bar code badges especially for project use. Indeed, the Y-12 representatives considered that use of the employees' plant identification badges offered a number of advantages, including the employees' not having to wear and handle two badges. A unforeseen benefit resulting from this change was an increase in the number of workers who were eligible for participation in the study.

The third modification to the proposed project related to the method planned for distinguishing "entry" and "exit" records generated by the WESS scanner stations. Originally, an algorithm was to be designed to designate scans as "entry" or "exit" based on chronological relationships and other factors. However, only shortly after installation of the scanner stations and operations had begun, it was discovered that a much simpler and more reliable method for generating "entry" and "exit" records was by using dual scanners connected to two I/O ports on the computer integrated with the scanner. A request for funds to purchase five additional scanners and the required software was not granted. Since the project was a pilot study, this did not hinder the development of the WESS system, nor diminish the importance of the results.

#### *Conclusions*

The proposed potential exposure surveillance system, utilizing readily available bar

code equipment, provides an economic means for surveillance of a much larger fraction of the worker population, many of whom would not ordinarily be on routine monitoring programs. Data collected by this system will lessen misclassification problems inherent in the classical methodologies and will allow rapid identification of groups of workers potentially exposed to specific substances, possibly for enrollment in special medical surveillance programs.

While the worker surveillance system was primarily intended to record basic data for monitoring of employees' working environments and potential exposures, the system lends itself to other uses. Most obvious, and perhaps most appropriate, is the ease with which the surveillance data could be linked to personnel or area monitoring data performed in the same areas. The surveillance data could also find good use in purposes related to time management of personnel or operations. As specific examples, data from the surveillance system could be used to (1) periodically verify that appropriate employees are enrolled in monitoring programs, (2) audit personnel performance on assigned tasks, and (3) quickly identify locations where particular materials are used.

## ACKNOWLEDGMENTS

The authors would like to acknowledge the many persons that made significant contributions to this project. For grant administrative support we are indebted to Roy Fleming and Georgia Jang of CDC. For project technical support as well as encouragement we offer appreciation to Ted Meinhardt (CDC) and David Pedersen (NIOSH). A great debt, as well as our thanks, is owed to Ron Keyser and Todd Butz (LMES) whose foresight and initial confidence in the project concept led to the required collaborative agreement with the Y-12 Plant. The authors and all other persons associated with the project are indebted to Jim Hendershot (LMES) who served as the Y-12 Plant liaison throughout the entire project and who was greatly responsible for day-to-day accomplishments. To all of the Y-12 Plant supervisors (Ted Arehart, Vince Brown, Rich Hamby, Scott Hawks, Ray Richardson, Don Sparkman, and Greg Gibson) and the other plant employees who participated in the pilot study, without whose cooperation the project could not have been accomplished, we dedicate the future benefits resulting from the project. Phil Bierbaum (NIOSH) provided continuing encouragement, as well as, guidance for the many reporting activities required. Sincerest appreciation is offered from the Project Director for the tenacious dedication shown by the members of the ORAU/CER research team (Donna Cragle, Elizabeth Dupree-Ellis, Nick Ingle, Jolene Jones, Lisa Larmee, Bob Rutherford, Phil Wallace, and C.M. West). Finally, personal appreciation is expressed to Donna Cragle (ORAU) for her encouragement, patience, and confidence.

## REFERENCES

1. Strom DJ, Beck WL, Stansbury PS, Tankersley WG, Watson J Jr: Standard procedures for pooling health physics data for epidemiologic studies. In: Proceedings of the Health Physics Society Sixteenth Midyear Topical Symposium, Epidemiology Applied to Health Physics, Albuquerque, New Mexico, pp. 221-230, January 9-13, 1983.
2. Tankersley WG, Checkoway H: Procedure for assignment of chemical exposure indices for use in epidemiology studies. Presented at American Industrial Hygiene Association Conference, Philadelphia, Pennsylvania, May 1983.
3. Strom DJ, Crawford-Brown DJ, Tankersley WG: Preparation of 30 years' personnel monitoring data from a uranium fabrication plant for use in epidemiologic studies. *Health Phys.* 47:123, 1984.
4. Cragle DL, Hollis DR, Qualters JR, Tankersley WG, Fry SA: A mortality study of men exposed to elemental mercury. *J. Occu. Med.* 26:817-821, 1984.
5. Checkoway H, Mathew RM, Shy CM, Watson Jr JE, Tankersley WG, Wolf SH, Smith JC, Fry SA: Radiation, work experience, and cause specific mortality among workers at an energy research laboratory. *Brit. J. Indus. Med.* 42:525-533, 1985.
6. Hickey JLS, Crawford-Brown DJ, Tankersley WG: Occupational exposures of workers to chemicals and radiation during uranium processing at the Linde Ceramics Plant. ORAU Technical Report No. 88/A-16, 1988.
7. Carpenter AV, Flanders WD, Frome EL, Tankersley WG, and Fry SA: Chemical exposures and central nervous system cancers: A case-control study among workers at two nuclear facilities. *Am. J. Indus. Med.* 13(3):351-362, 1988.
8. Cragle DL, McLain RW, Qualters JR, Hickey JL, Wilkinson GS, Tankersley WG, Lushbaugh CC: Mortality among workers at a nuclear fuels production facility. *Am. J. Indus. Med.* 14(4):379-401, 1988.
9. Tankersley WG, Cragle DL, Ziegler MF, and Watson JE: Comparison of assigned exposure indices and radiation monitoring data. Presented American Industrial Hygiene Conference, San Francisco, California, May, 1988.
10. Crawford-Brown DJ, Watson Jr JE, Strom DJ, Tankersley WG: Procedures for Assessing Occupational Radiation Monitoring Data for Use in Epidemiologic Studies. ORAU Technical Report, ORAU 89/A-127, 1989.

11. Tankersley WG, Hicks NV, Cragle DL, Robertson-Demers K, Ingle JN, Bean GL, and Googin JM: Exposure assessment for epidemiologic study of nuclear workers potentially exposed to beryllium. Presented at the AIHA National Meeting, Boston, Massachusetts, May 31-June 5, 1992.
12. Cragle DL, Wells SM, and Tankersley WG: An occupational morbidity study of a population potentially exposed to epoxy resins, hardeners, and solvents. *Appl. Occup. Environ. Hyg.* 7(12):826-834, 1992.
13. Fry SA, Cragle DL, Crawford-Brown DJ, Dupree EA, Frome EL, Gilbert ES, Petersen GR, Shy CM, Tankersley WG, Voelz GL, Wallace PW, Watkins JP, Watson Jr JE, Wiggs LD: Studies of health and mortality among contractor employees at United States Department of Energy facilities. In: *Proceedings of American Chemical Society Annual Meeting San Francisco, 1992.*
14. Wing S, Shy CM, Wood JL, Wolf S, Cragle DL, Tankersley W, and Frome EL: Job factors, radiation and cancer mortality at Oak Ridge National Laboratory: Follow-up through 1984. *Am. J. Indus. Med.* 23:265-279, 1993.
15. Wing S, West CM, Wood JL, Tankersley WG: Recording of external radiation exposures at Oak Ridge National Laboratory: implications for epidemiological studies. *J. Expos. Anal. Envir. Epid.* 4:83-93, 1994.
16. Watkins JP, Cragle DL, Frome EL, West CM, Crawford-Brown DJ, Tankersley WG: Adjusting External Doses from the ORNL and Y-12 Facilities for the Oak Ridge Nuclear Facilities Mortality Study. ORISE Technical Report 94/G-34.
17. Watson Jr JE, Wood JL, Tankersley WG, West CM: Estimation of Radiation Doses for Workers Without Monitoring Data for Retrospective Epidemiologic Studies *Health Phys.* 67(4):402-405, 1994.
18. Fry SA, Cragle DL, Crawford-Brown DJ, Dupree EA, Frome EL, Gilbert ES, Petersen GR, Shy CM, Tankersley WG, Voelz GL, Wallace PW, Watkins JP, Watson Jr JE, Wiggs LD: Health and Mortality among Contractor Employees at U.S. Department of Energy Facilities. Chapter 17 in *Radiation and Public Perception Benefits and Risks, Advances in Chemistry Series 243*, Jack P. Young and Rosalyn S. Yalow editors, 239-258, 1995.
19. West CM, Watkins J, Tankersley WG, Payne DD: Lung Dose Estimates from Air Sampling and Bioassay Data - A Comparison. *Health Physics* 69(4):481-486, 1995.

20. Dupree EA, Watkins JP, Ingle JN, Wallace PW, West CM, Tankersley WG: Uranium Dust Exposure and Lung Cancer Risk in Four Uranium Processing Operations. *Epidemiology* 6(4):370-375, 1995.
21. Tankersley WG, West CM, Watson JE, Reagan JL: Retrospective Assessment of Radiation Exposures At or Below the Minimum Detectable Level at a Federal Nuclear Reactor Facility. *Appl. Occup. Environ. Hyg.* 11(4), 330-333, 1996.
22. Watkins JP, Cragle DL, Frome EL, Reagan JL, West CM, Crawford-Brown D, Tankersley WG: Collection, Validation, and Treatment of Data for a Mortality Study of Nuclear Industry Workers. *Appl. Occup. Environ. Hyg.* 12(3), 195-205, 1997.
23. Rice C, Harris RL, Lumsden JC, Symons MJ: Reconstruction of Silica Exposure in the North Carolina Dusty Trades.. *Am. Ind. Hyg. Assoc. J.* 45:689-696, 1984.
24. Coggon D, Pannett B, Acheson ED: Use of Job-Exposure Matrix in an Occupational Analysis of Lung and Bladder Cancers on the Basis of Death Certificates. *J. Nat. Cancer Inst.* 72:61-65, 1984.
25. Kjuus H, Skjaerven R, Langard S, Lien JT, Aamodt T: A Case-Referent Study of Lung Cancer, Occupational Exposures and Smoking. Comparison of Title-Based and Exposure-Based Occupational Information. *Scand. J. Work Environ. Health* 12:193-202, 1986.
26. Marsh GM: A Strategy for Merging and Analyzing Work History Data in Industry-Wide Occupational Epidemiologic Studies. *Am. Ind. Hyg. Assoc. J.* 48:414-419, 1987.
27. Kauppinen T, Partanen T: Use of Plant- and Period-Specific Job-Exposure Matrices in Studies on Occupational Cancer. *Scand. J. Work Environ. Health* 14:161-167, 1988.
28. Coughlin SS, Chiazze Jr L: Job-Exposure Matrices in Epidemiologic Research and Medical Surveillance. *Occup. Med.* 5:633-646, 1990.
29. Stewart PA, Herrick RF: Issues in Performing Retrospective Exposure Assessment. *Appl. Occup. Environ. Hyg.* 6:421-427, 1991.

## APPENDIX A

## Figure 1 Data Collection Form for Descriptive Analysis of Y-12 Monitoring Programs

### **Project Identification**

Program no. \_\_\_\_\_

Program name

### **Sources of Information**

DOE orders \_\_\_\_\_

Departmental procedure nos. \_\_\_\_\_

Plant procedures \_\_\_\_\_

Documents (numbers and/or titles, dates, and authors) \_\_\_\_\_

Individuals contacted (Name, date, and how long)

Other sources

### **Personnel Monitoring Program**

Employees or areas covered by program

How decided upon?

How is the decided upon area(s) or employee(s) kept current?

How is it decided that no other areas or employees are monitored?

Major advantages of using this program for dose or exposure evaluation?

Major disadvantages of using this program for dose or exposure evaluation?

What is the size of this program, i.e., no. of people, areas or samples involved?

Number of samples processed per quarter.

Is there an ALARA objective concerning this program?

What is it?

Figure 1 Data Collection Form for Descriptive Analysis of Y-12 Monitoring Programs  
(continued)

**Sampling and Analyses**

How was the sample taken?

How is it assured that the sample is appropriately identified?

How was the sample analyzed and by whom?

Detection instrument(s) and/or method(s) used?

How is instrument calibrated?

What quality control program exists for sampling?

What laboratory procedures were used?

Is the laboratory certified to perform the procedure?

What quality controls exist for sampling analyses?

What is the lower limit of detection (LLD)?

How LLD determined?

**Limits and Action Points**

What limits are applied?

What action points are applied?

What action is taken when action point is exceeded?

What is the source or justification for these limits?

What is the source and justification for action points?

**Coverage and Participation**

Frequency of participation or monitoring

Justification of frequency of participation or monitoring - -

How decided to change?

Figure 1 Data Collection Form for Descriptive Analysis of Y-12 Monitoring Programs  
(continued)

**Records**

How is the data from analyses entered into the system?

How are the data maintained after entry?

How can these data be retrieved?

For current reporting?

For future use?

**Utilization of program results**

Intended use of program results

Actual use if different

How are results used for statistical analyses?

How are results used to highlight problem?

How are results used to follow trends?

How is exposure or dose estimated from the results?

How do you feel about the program?

Is there anything you would like to see us make specific comments or recommendations on?

**Note:** Decide upon ways the program could be better for dose estimation.

**Reporting:**

Decision on what recommendation(s) are to be made relative to this program.

Date: \_\_\_\_\_

Decisions:

Dates:

First Draft:

Final Draft:

Final Report:

Figure 2a Letter of Request for Input From Occupational Health Professionals On Significant Potential Exposures for U.S. Work Force

Subject: Request for input in development of new worker classification system

Dear Participant:

Under contract with the National Centers for Disease Control and Prevention, Oak Ridge Associated Universities' Center for Epidemiologic Research (ORAU-CER) is developing a standardized system for classification of workers based on potential exposures commonly encountered by each worker population. Qualitative information on up to 40 potential occupational exposures will be economically encoded into a worker classification code that may be appended to the traditional job title text, job title/departmental code combination, or to the individual worker. The worker classification system is proposed for use at U. S. Department of Energy facilities as well as other private industries. Due to the nature of the encoded data, computer programs will be developed to provide the health professional or researcher with convenient means to access, modify, or assign worker classification codes.

We are soliciting your input on this project by requesting that you provide a list of up to 40 potential occupational exposures (chemicals or radiation) that you regard as prominent, major, or significant hazards for the U. S. work force. You have been personally identified among 100 Industrial Hygiene, Health Physics, and Epidemiology professionals for this survey, and we are eager to include your input. We have already begun work on the project and want to begin as soon as possible working with the actual data that will ultimately be included in the classification system. Therefore we are requesting that you return your recommended list of potential exposures as soon as possible. A simple form for listing your selections is included as an attachment. Responses received after January 31, 1996 will not be included. In advance, thank you for your participation in this work.

To those who provide the requested listing, we will send a copy of our report on this project along with information on the availability of the computer programs developed for its usage.

Sincerely,

William G. Tankersley, CIH  
Hazards Assessment Section Leader

WGT:CMW:jj

Enclosures: As stated

Figure 2b Survey Form for Significant Potential Exposures for U.S. Work Force

Significant Potential Exposures for U. S. Industrial Workers

1. _____	21. _____
2. _____	22. _____
3. _____	23. _____
4. _____	24. _____
5. _____	25. _____
6. _____	26. _____
7. _____	27. _____
8. _____	28. _____
9. _____	29. _____
10. _____	30. _____
11. _____	31. _____
12. _____	32. _____
13. _____	33. _____
14. _____	34. _____
15. _____	35. _____
16. _____	36. _____
17. _____	37. _____
18. _____	38. _____
19. _____	39. _____
20. _____	40. _____

Name \_\_\_\_\_

Title \_\_\_\_\_

Employer/Company \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_

State \_\_\_\_\_ Zip \_\_\_\_\_

To promote consistency, please consider the following criteria for suggested potential exposures.

1. Risk of harm from exposure, availability for exposure, and population size potentially exposed should be considered.
2. Candidates may be single materials or groups of related materials.
3. Chemicals should be identified by proper name rather than proprietary or common name.
4. Material form should be noted if it is considered significant.
5. Radiation exposures should be identified by type of energy and whether internal or external.

You may e-mail your response to WALLACEP@ORAU.GOV or FAX your response to (423) 576-9557.

ORAU Worker Classification System  
 Oak Ridge Associated Universities  
 Center for Epidemiologic Research  
 P.O. Box 117  
 Oak Ridge, TN 37831-0117

Oak Ridge Associated Universities

File Utilities Scan

**WORKER EXPOSURE SURVEILLANCE SYSTEM 1996**

You are being asked to participate in a research project to develop and test a **system for monitoring potential exposures** to workers as they move among different work areas. The proposed monitoring system is comprised of five bar code scanning stations each of which consists of a personal computer and bar code reader. Over the next **12 months** the system will be tested in **five locations** throughout the plant. We estimate that about 700 workers will encounter the scanning stations.

**Intentional** scanning of a badge by the **badge holder** will be taken as consent to participate in the project. Participation is **voluntary**, and there is no penalty or loss of benefits if you decide not to participate. You are also free to leave the study at any time without penalty or loss of benefits. There are **no health risks** to you from participating in this research, and **no personally identifying information** will be entered into the project data base. Lockheed Martin Energy Systems, Inc. will not have access to the data collected for this project. The sponsor reserves the right to terminate the study at any time.

There is **no financial compensation** or **immediate direct benefits** to you from participation in this research. Such a system can provide plant health physicists, industrial hygienists, and medical staff with information to make better decisions about whom should be monitored or about how to control exposures. This system will also provide much needed information to health researchers for studying possible associations between work place exposures and health effects.

The protocol for this study was approved by the ORAU/ORNL Committee on Human Studies, MPA#1394, on August 29, 1996. Questions about the study will be answered by the Principal Investigator, Bill Tankersley, at (423) 576-3141 or the Chair of the ORAU/ORNL Committee on Human Studies at (423) 576-1725.

Please Scan Badge When Entering or Exiting This Area

Scan			
Badge # _____			
Location #	Badge	Date	Time
Thank you			

A development project conducted by Oak Ridge Associated Universities for the U.S. Centers for Disease Control and Prevention

## Figure 4 WESS Participant Debriefing Interview Announcement to Y-12 Management

February 5, 1997

To: Ted Arehart  
Vince Brown  
Rich Hamby  
Scott Hawks  
Ray Richardson  
Don Sparkman  
Greg Gibson

Copies to the following  
Jim Hendershot  
Kristin Baksa  
Ron Keyser  
Tom Ford

Subject: Interviews with employees participating in Worker Exposure Surveillance System Project

The Worker Exposure Surveillance System (WESS) project is nearing completion. Our plans are to remove the scanner and computer equipment within the next four weeks and close-out activities should be completed by April 30, 1997. We continue to appreciate your support and effort in this research, without which the project could not be accomplished.

As part of the wrap-up of the project, we proposed to interview a limited number of employees who participated in the project to gather their impressions of the surveillance system. We would like to interview two to four employees from each of the five scanning stations. Participation in the interview process will of course be voluntary, and no personal reference to the individuals will be made in any report. The interview will consist of two parts, (1) 15 written questions that can be answered "yes/no" or with very short responses and (2) a 15-minute one-to-one personal interview. At this time, my plans are for the interviews to be conducted by one of the ORAU research team members. I am also considering the possible benefits of having a Y-12 staff member, such as Jim Hendershot, present. Regarding scheduling, I would like to begin the interviews by April 1, 1997 and complete them within a week or two.

As planned from the beginning, scanned badge numbers from the participants were encoded before entering records into the WESS database. Therefore, we are requesting that each scanner station manager (Vince Brown, Rich Hamby, Greg Gibson, Ray Richardson, and Don Sparkman) identify to us, four workers who regularly used the scanner system. These workers should be informed that the interview is strictly voluntary and of the nature of the interview.

If there are any questions regarding the purpose of the interviews or the interview process, please contact Bill Tankersley at 576-3141 or Donna Cragle at 576-2866.

Figure 5 WESS Participant Debriefing Interview Invitation and Consent Form

**Worker Exposure Surveillance System Project  
Participant Interview**

(Date)

On behalf of the project team for the Worker Exposure Surveillance System (WESS) project conducted by Oak Ridge Associated Universities/Center for Epidemiologic Research (ORAU/CER), I want to let you know that your participation in our work is sincerely appreciated. Our goal, from the beginning, has been to develop and test a practical and affordable system that can improve the overall exposure surveillance of the industrial worker population. As the project nears completion, we are asking you to provide input about the project and system in the form of your impressions and observations. This input will be used to evaluate the performance, usefulness, and cost/benefit of the WESS system. The project evaluation survey consists of two parts, (1) a Participant Questionnaire and (2) a 15-30 minute interview with an ORAU/CER research team member. The Participant Questionnaire consists of 15 short-answer questions, and we would like for you to complete the questionnaire prior to coming to the interview. Your responses are very important to the research, but you will not be personally identified at any time after the interview.

If you are willing to help us with the project evaluation, please sign this information and consent form, and return to Jim Hendershot at Building 9106, Mailstop 8023. Again, thanks for your time and interest in the WESS project.

Bill Tankersley  
Project Director

Figure 6 WESS Participant Debriefing Interview Form

### Worker Exposure Surveillance System Project Survey

#### Participant Questionnaire

Name \_\_\_\_\_ Badge \_\_\_\_\_

Phone \_\_\_\_\_ Date \_\_\_\_\_

1. Location of scanning station(s) where you participated:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

2. Approximate number of times your badge was scanned:

- 1-10     11-50     51-100     100+

3. Which type(s) of scanner did you use?

- Slot Scanner     Laser Scanner     Both

4. If you used both types of scanners, which type was more convenient?

- Slot Scanner     Laser Scanner

5. Did you find the scanning procedure easy to understand and perform?

- Yes     No

6. Did you watch to see your badge displayed on the computer monitor (screen)?

- Yes     No

7. Did you consider the scanning procedure an inconvenience?

- Yes     No     No opinion

8. How much time did the scanning procedure take?

- 5 seconds or less     5-15 seconds     More than 15 seconds

9. Did you have to wait in line to scan your badge?

- Never     Rarely     Usually     Often     Always

10. Did the scanning procedure interrupt your scheduled work significantly?

- Yes     No     Don't know     No opinion

11. Did you consider the scanning procedure disruptive or bothersome?  
Yes  No  No opinion

(If you answered Yes, please explain)

---

---

---

---

12. Do you think that the Worker Exposure Surveillance System has some merit but can be improved? Yes  No  Don't know  No opinion

13. Do you understand the kind of record generated by the Worker Exposure Surveillance System? Yes  No  Somewhat

14. Do you think that a system similar to the Worker Exposure Surveillance System should be implemented as part of the Y-12 health and safety programs?  
Yes  No  Only in certain areas  Don't know  No opinion

15. How would you rate the overall usefulness and benefit of the Worker Exposure Surveillance System?

- No benefit at all
- Little benefit as is, but could be useful with many changes
- Some benefit and should be developed further
- Very beneficial

## APPENDIX B

**Table 1 Potential Exposure Profile System Database Table Descriptions**

Table Name	Name	Type	Size
Job Dictionary	JobCode	Number (Integer)	2
	JobTitle	Text	28
	WorkGroup	Text	28
	JobPEPSCode	Number (Double)	8
	JobDescription	Text	255
	YN	Text	1
PExpDictionary	ControlNum	Number (Integer)	2
	PExposure	Text	28
	PExpDetail	Text	40
	Availability	Yes/No	1

**Table 2 Worker Exposure Surveillance System Database Table Descriptions**

Table Name	Name	Type	Size
BadgeDateLocHrs	Badge	Text	7
	SDate	Date/Time	8
	Location	Text	2
	Hrs	Number (Single)	4
FieldDescription	TName	Text	20
	FName	Text	14
	FDescrip	Text	40
LocationDescription	Location	Text	2
	LocDescrip	Text	60
	DStart	Date/Time	8
	DEnd	Date/Time	8
LocationPEXposure	Location	Text	2
	PExposure	Text	60
	PExpStart	Date/Time	8
	PExpEnd	Date/Time	8
RawScannerData	Location	Text	2

Table 2 Worker Exposure Surveillance System Database Table Descriptions

Table Name	Name	Type	Size
	Badge	Text	7
	SDate	Text	10
	STime	Text	6
WESSIDBadge	WESSID	Number (Long)	4
	Badge	Text	7
	BStart	Date/Time	8
	BEnd	Date/Time	8
	RBadge	Text	7
WESSIDName	WESSID	Number (Integer)	2
	CFName	Text	20
	CMinut	Text	1
	CLName	Text	28
	CNDate	Date/Time	8
WHLsIOHs	Badge	Text	7
	Location	Text	2
	SDate	Date/Time	8
	STime	Date/Time	8
	IOType	Text	1
	Hrs	Number (Single)	4
WorkerLochHrs	Badge	Text	7
	Location	Text	2
	SDate	Date/Time	8
	STime	Date/Time	8
	IOType	Text	1

## APPENDIX C

Figure 7 PEPS Splash Screen

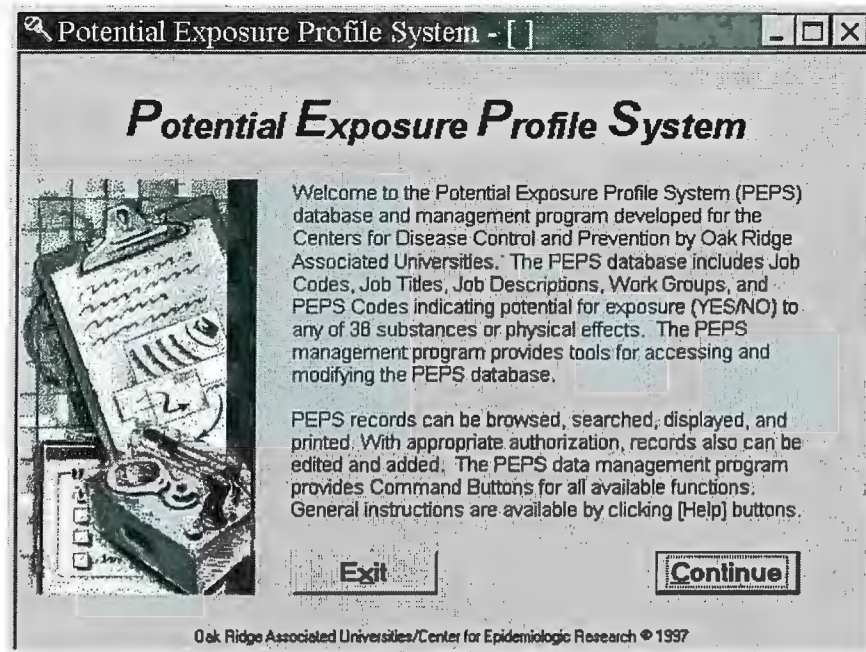


Figure 8 PEPS Main Menu Screen

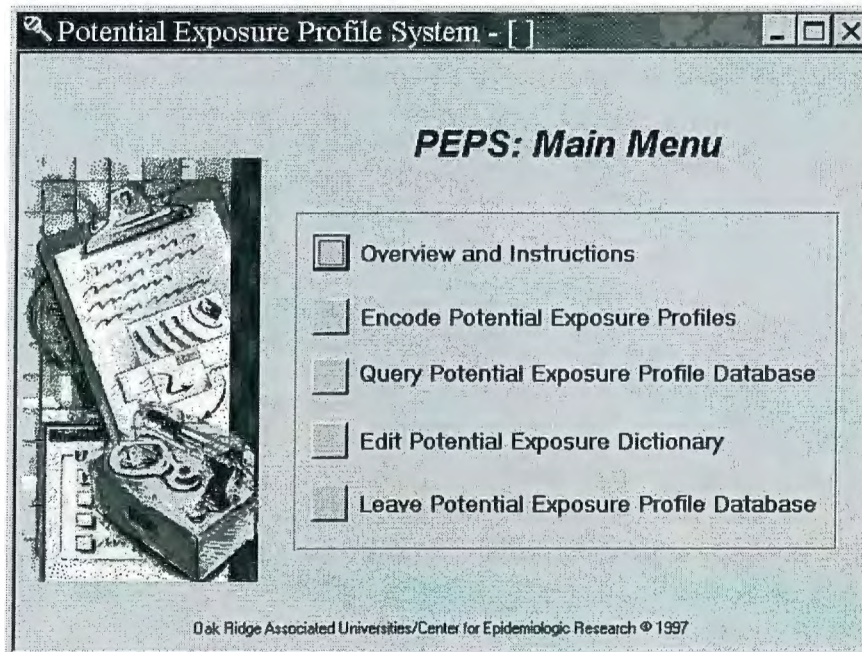


Figure 9 PEPS Potential Exposure Assignment Screen

Potential Exposure Profile System - [ ]

Job Code	Job Title	Work Group	Job Description
001020	Machine Cleaner	Machining	

<input type="checkbox"/> Lead	<input checked="" type="checkbox"/> Beryllium	<input checked="" type="checkbox"/> Excessive noise	<input type="checkbox"/> Styrene
<input type="checkbox"/> Asbestos	<input type="checkbox"/> External ionizing rad	<input type="checkbox"/> Arsenic	<input type="checkbox"/> Nickel
<input type="checkbox"/> Silica	<input type="checkbox"/> Internal ionizing radi	<input type="checkbox"/> Pesticides	<input type="checkbox"/> Electromagnetic field
<input checked="" type="checkbox"/> Toluene	<input checked="" type="checkbox"/> Cadmium	<input checked="" type="checkbox"/> Perchloroethylene	<input type="checkbox"/> Diesel exhaust
<input type="checkbox"/> Benzene	<input type="checkbox"/> Ultraviolet radiation	<input type="checkbox"/> Ozone	<input type="checkbox"/> Fiberglass
<input type="checkbox"/> Formaldehyde	<input type="checkbox"/> Welding fume	<input type="checkbox"/> Chlorine	<input type="checkbox"/> Wood dust
<input type="checkbox"/> Carbon monoxide	<input type="checkbox"/> Methylene chloride	<input type="checkbox"/> Xylene	<input checked="" type="checkbox"/> Solvents
<input type="checkbox"/> Mercury	<input type="checkbox"/> Isocyanates	<input type="checkbox"/> Coal dust	<input type="checkbox"/> Sodium hydroxide
<input type="checkbox"/> Chromium	<input type="checkbox"/> Sulfuric acid	<input type="checkbox"/> Hydrogen sulfide	<input type="checkbox"/> Methyl ethyl ketone

PEPS Code = 08592298504

Navigation: [Home] [Left] [Right] [End] [New Rec] [Clear all] [Store] [Help] [Menu]

Dak Ridge Associated Universities/Center for Epidemiologic Research © 1997

Figure 10 PEPS Occupation Description Screen

Potential Exposure Profile System - [ ]

Job Code: 001020

Job Title: Machine Cleaner

Work Group: Machining

Job PEPSCode: 08592298504

Job Description: Maintains machining tools in ready condition for immediate operation

Return

Dak Ridge Associated Universities/Center for Epidemiologic Research © 1997

Figure 11 PEPS Query Screen

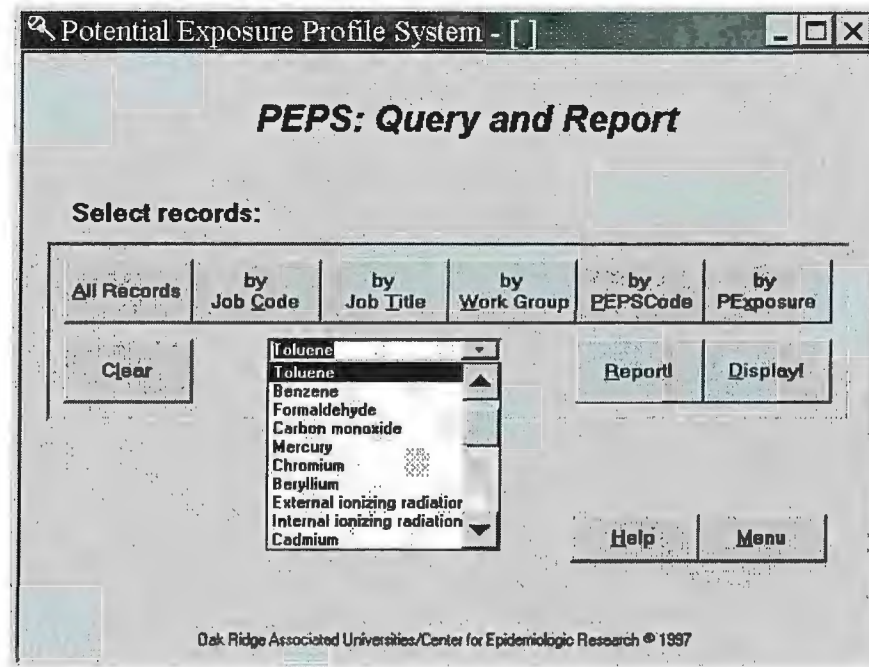


Figure 12 PEPS Designated Potential Exposures Editing Screen

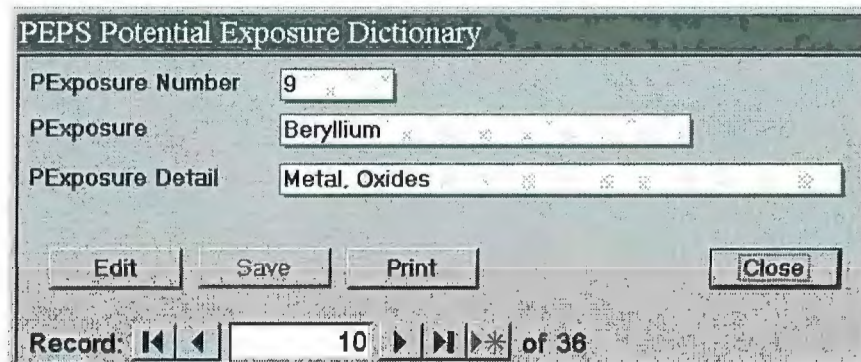


Figure 13 WESS Splash Screen

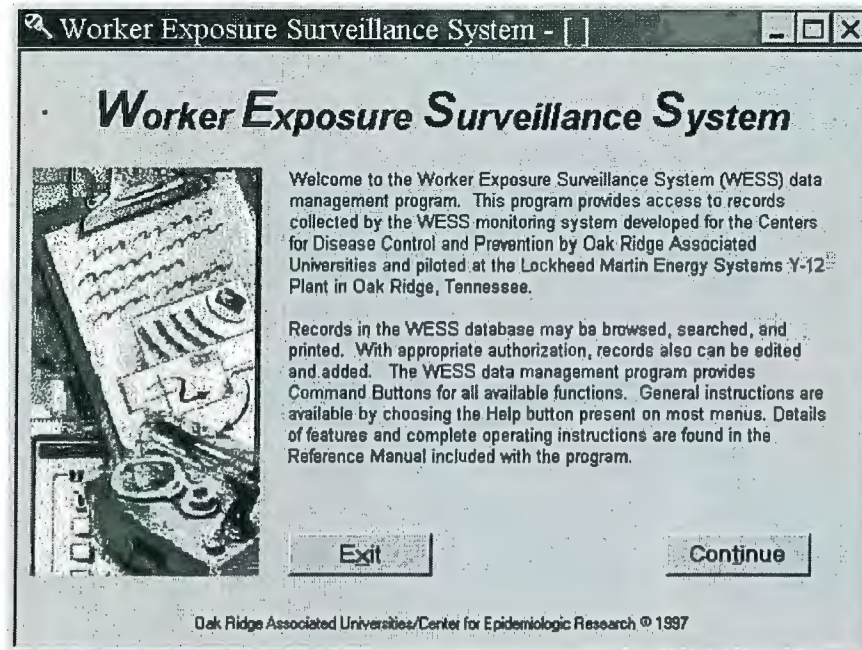


Figure 14 WESS Main Menu Screen

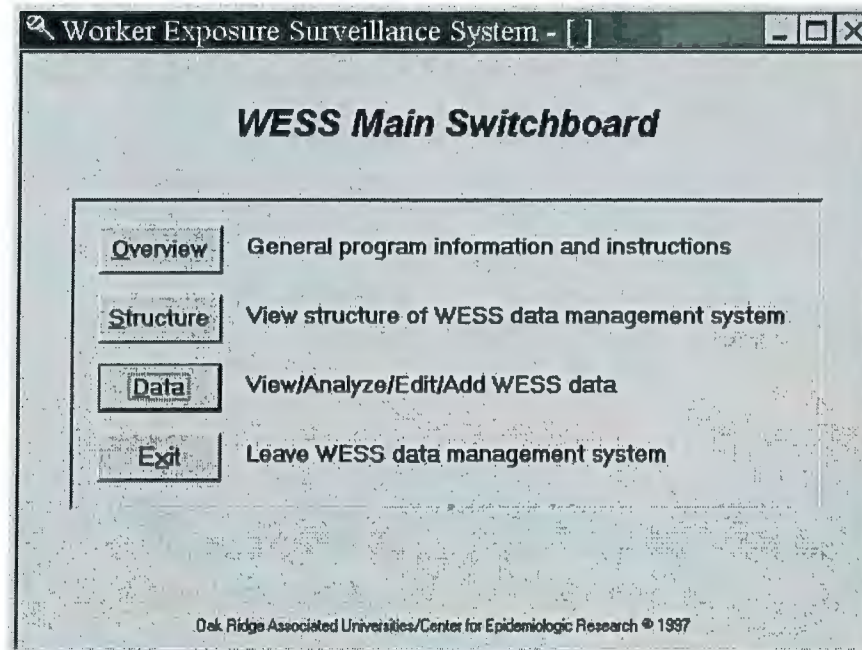


Figure 15 WESS Surveillance Data Options Screen

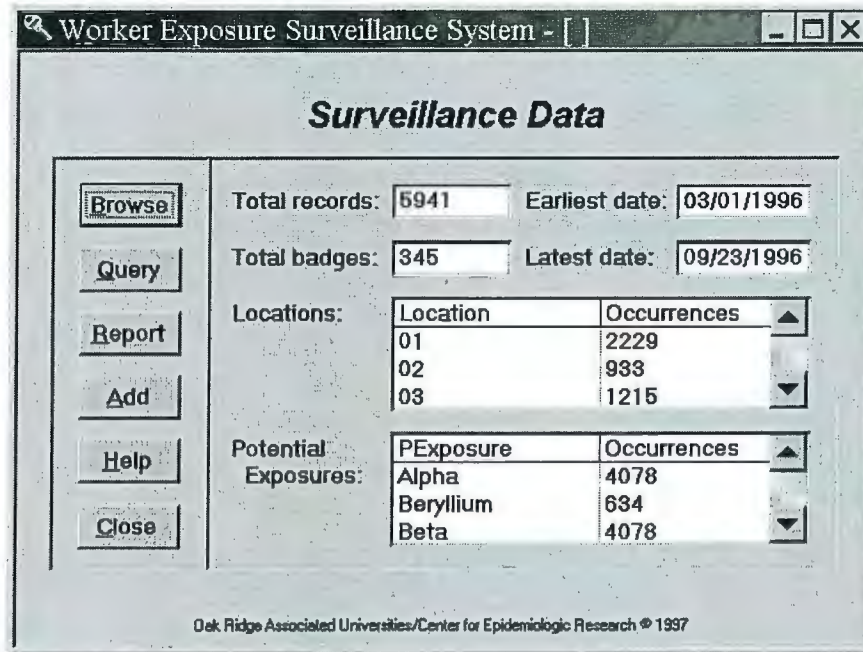


Figure 16 WESS Surveillance Data Query Screen

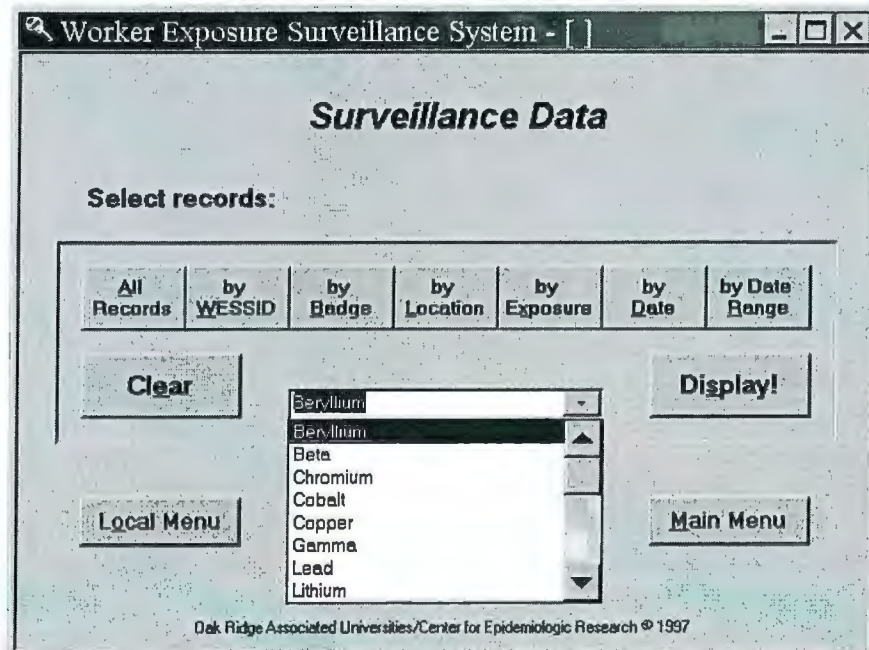


Figure 17 WESS Query Output Screen

WE	SSID	Badge	Location	Date	Time	IOType	PExposure
0001248	E001248	05	07/15/1996	13:06:42	I	Beryllium	
0001248	E001248	05	07/15/1996	13:06:57	O	Beryllium	
0001248	E001248	05	07/15/1996	13:09:22	I	Beryllium	
0001248	E001248	05	07/15/1996	14:29:24	O	Beryllium	
0001248	E001248	05	08/26/1996	09:40:24	I	Beryllium	
0001248	E001248	05	08/26/1996	09:40:36	I	Beryllium	
0001248	E001248	05	08/26/1996	09:42:52	I	Beryllium	
0001248	E001248	05	08/26/1996	11:17:54	O	Beryllium	
0001248	E001248	05	08/26/1996	11:40:37	O	Beryllium	

Buttons: Edit, Save, Close

Figure 18 WESS Example Help Screen

**Help** Surveillance Data ...

---

**Reporting records:**  
 The Reports module provides for a number of predesigned reports based on record selection criteria from the user. The criteria available for record selection are generally those available for querying for viewing. Some caution is advised when requesting reports, since the output may be much larger than expected. A message box is always provided to warn when this is likely. It may be useful to first display the selected records to ascertain if they are indeed the intended records. It is possible, of course, to interrupt the printing of a report.

Printing of reports should be possible with any printer supported by a Windows printer driver. However, higher quality output will result from using laser or LCD page printers or ink jet type printers. Note that changing the default font may produce undesirable changes in the format of the reports.

Page Up
Page Down
1st Page
Close

Oak Ridge Associated Universities/Center for Epidemiologic Research © 1997

## LIST OF PRESENT AND POSSIBLE FUTURE PUBLICATIONS

West CM, Rutherford BF, Tankersley WG: Current Programs for Estimating Radiological Dose and Chemical Exposure, Volumes I & II, Oak Ridge Associated Universities/Center for Epidemiologic Research, Oak Ridge, Tennessee, March 31, 1997.

Tankersley WG: Potential Exposure Profile System Software and User Reference, Oak Ridge Associated Universities/Center for Epidemiologic Research, Oak Ridge, Tennessee, May 1997.

Tankersley WG: Worker Exposure Surveillance System Software and User Reference, Oak Ridge Associated Universities/Center for Epidemiologic Research, Oak Ridge, Tennessee, May 1997.

Tankersley WG, Cragle DL, Ellis ED, Ingle JN, West CM, Hendershot J: A Practical and Affordable Worker Exposure Surveillance System. Presented at AIHA Conference, Dallas, Texas, May 22, 1997 (to be submitted for publication).

## EQUIPMENT INVENTORY

The following equipment was purchased and used solely for the conduct of Grant R01/CCR412029-02; the equipment presently resides at ORAU/CER.

<b>Item</b>	<b>Number</b>	<b>Unit Cost</b>	<b>Total Cost</b>
Bar code scanner (Slot)	3	\$500.00	\$1000.00
Bar code scanner (Wand)	2	\$850.00	\$1700.00



## Memorandum

Date APR 23 1999

From Roy M. Fleming, Sc.D., Director, Research Grants Program RMF  
Office of Extramural Coordination and Special Projects, NIOSH

Subject Final Report Submitted for Entry into NTIS for Grant 1 R01 CCR412029-01

To William D. Bennett  
Data Systems Team, Information Resources Branch, EID, NIOSH

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report. Any publications that are included with this report are highlighted on the attached List of Publications. Thank you.

### Attachments

List of Publications  
Final Report

## Improved Systems for Worker Exposure Surveillance

*William G. Tankersley  
Oak Ridge Associated Universities  
Oak Ridge, Tennessee 37831*

*Hazard Surveillance  
1 R01 CCR412029-01  
09/30/95 - 09/29/97  
\$138,399 (\$375,195 Cum)*

### Unpublished Articles

Final Report, William G. Tankersley, Improved Systems for Worker Exposure Surveillance, December 26, 1997

Tankersley WG, Cragle DL, Ellis ED, Ingle JN, West CM, Hendershot J: A Practical and Affordable Worker Exposure Surveillance System. Presented at AIHA Conference, Dallas, Texas, May 22, 1997 (to be submitted for publication)

1 Tankersley WG: Potential Exposure Profile System Software and User Reference, Oak Ridge Associated Universities/Center for Epidemiologic Research, Oak ridge, Tennessee, May 1997

2 Tankersley WG: Worker Exposure Surveillance System Software and User Reference, Oak Ridge Associated Universities/Center for Epidemiologic Research, Oak Ridge, Tennessee, May 1997

West CM, Rutherford BF, Tankersley WG: Current Programs for Estimating Radiological Dose and Chemical Exposure, Volumes I & II, Oak Ridge Associated Universities/Center for Epidemiologic Research, Oak ridge, Tennessee, March 31, 1997