Department of Energy
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March 1, 2019

CERTIFIED MAIL

Ms. Debra Cherry
University of Washington
[redacted]

Dear Ms. Cherry:

FREEDOM OF INFORMATION ACT REQUEST (FOI 2019-00537)

This letter is in response to the electronic Freedom of Information Act (FOIA) request you submitted to the U.S. Department of Energy (DOE), Headquarters FOIA Office. Your request was transferred to this office for a response and was received on March 1, 2019. In your request you asked for a copy of a document titled, "Health Effects Panel Evaluation of Pulmonary Function and Liver Enzyme Levels Among Hanford Tank Farm Workers" numbered RPP-30560.

Your request is granted and a copy of the document is enclosed. You may contact the DOE Richland Operations Office (RL) FOIA Public Liaison, Richard Buel, at (509) 376-3375, or by mail at P.O. Box 550, Richland, Washington, 99352 for any further assistance and to discuss any aspect of your request. Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire about the FOIA mediation services they offer. The contact information for OGIS is as follows: Office of Government Information Services, National Archives and Records Administration, 8601 Adelphi Road-OGIS, College Park, Maryland 20740-6001, email at ogis@nara.gov; telephone at (202) 741-5770; toll free at 1-877-684-6448; or facsimile at (202) 741-5769.

If you have any questions regarding your request, please contact me at our address or at (509) 376-6288.

Sincerely,

Original signed by

Dorothy Riehle
Freedom of Information Act Officer
Office of Communications
and External Affairs

OCE:DCR

Enclosure

HEALTH EFFECTS PANEL EVALUATION OF PULMONARY FUNCTION AND LIVER ENZYME LEVELS AMONG HANFORD TANK FARM WORKERS

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CH2M HILL Hanford Group, Inc
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

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Abstract:
Existing medical surveillance data for more than 5,000 Hanford Site tank farm workers employed between 1990 and 2004 were evaluated to determine if there is a potential health impact on two organ systems deemed most likely to be affected by historical or ongoing exposure to tank vapors.

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HEALTH EFFECTS PANEL EVALUATION OF PULMONARY FUNCTION AND LIVER ENZYME LEVELS AMONG HANFORD TANK FARM WORKERS

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July 2006

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EXECUTIVE SUMMARY

Existing medical surveillance data for more than 5,000 Hanford Site tank farm workers employed between 1990 and 2004 were evaluated to determine if there is a potential health impact on two organ systems deemed most likely to be affected by historical or ongoing exposure to tank vapors. Pulmonary function test results and liver enzyme test results were used to identify "cases" of potential organ system effect within the worker population. Cases were matched to controls within the same population based on age and gender. Multiple estimators of potential exposure were used to compare cases and controls.

The evaluation did not identify any pervasive or systematic health effect associated with potential exposure. The evaluation did not find evidence of chronic obstructive pulmonary disease associated with any estimator of potential exposure. Due to the study design, asthma could neither be confirmed nor ruled out. The liver enzyme evaluation results were mixed. There were statistically significant correlations between elevated liver enzyme levels and some categories of potential exposure. However, the correlations did not directly increase in those groups believed to have the greatest potential exposure opportunity.

The body of data compiled for this evaluation could support additional studies.

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LIST OF TERMS

Abbreviations, Acronyms, and Initialisms

ACES	Access Control/Entry System
ALT	serum alanine aminotransferase
AMH	Advance Med Hanford
AST	serum aspartate aminotransferase
BMI	body mass index
CAO	chronic airflow obstruction
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPD	chronic obstructive pulmonary disease
DOE	U.S. Department of Energy
DST	double-shell tank
FEV1	forced expiratory volume - one second
FH	Fluor Hanford
FVC	forced vital capacity
GOLD	Global Initiative on Obstructive Lung Disease
HAMTC	Hanford Atomic Metal Trades Council
HEP	Health Effects Panel
NHANES	National Health and Nutrition Examination Surveys
NIOSH	National Institute of Occupational Safety and Health
OHS	occupational health and safety
OR	odds ratio
OSHA	Occupational Safety and Health Administration
PFT	pulmonary function test
RADS	Reactive Airway Dysfunction Syndrome
RTI	Research Triangle Institute
SGOT	serum glutamic oxaloacetic transaminase
SGPT	serum glutamic pyruvic transaminase
SST	single-shell tank
WRAM	Westinghouse Radiation Area Management

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

Workers have raised concerns that exposure to chemical vapors from the Hanford Site underground waste storage tanks may have caused health effects, or may lead to future health effects. The tank farm contractor, CH2M HILL Hanford Group, Inc. (CH2M HILL) asked an expert team of scientists (designated the Health Effects Panel, and hereafter referred to as the HEP) to consider appropriate studies that might address the workers' concern. Among the considerations was a study to analyze existing data to determine if any conclusions could be drawn about health effects from past possible exposures.

1.2 DESCRIPTION OF HANFORD SITE UNDERGROUND TANKS AND WASTE

Solid and liquid radioactive wastes are stored in 177 underground tanks at the Hanford Site with capacities ranging from 50,000 to approximately 1 million gallons. There are 149 single-shell tanks (SST) and 28 double-shell tanks (DST). A typical SST is 75 feet in diameter and 30 feet tall, consisting of a reinforced concrete shell and dome with mild carbon steel lining the bottom and walls. The SSTs were constructed between 1943 and 1964, and are grouped into "farms" of 4 to 18 tanks. Double-shell tanks provide an added degree of environmental protection with a second steel shell, and were constructed from 1968 through 1986. In the 1980s, the U.S. Department of Energy (DOE) began a program to transfer pumpable liquids from the SSTs to the DSTs.

The solid and liquid constituents of tank wastes and associated headspace vapors are different for each tank. The radioactive components in the waste include long-lived fission product radionuclides and actinide elements that decay over long periods of time. Mixed tank wastes may contain metals such as lead, mercury, chromium, zirconium, potassium, and cadmium. Some tanks also contain organic compounds from spent nuclear fuel and plutonium processes. To prevent tank corrosion, caustics were added to the tanks to increase pH, which resulted in increased generation of ammonia and hydrogen in the tank headspace (i.e., the area inside the tank above the liquid/solid waste surface).

Both the SSTs and DSTs release headspace vapors to the atmosphere. The SSTs are passively ventilated through breather filters while the DSTs are actively vented through forced air ventilation systems with elevated stacks. Vapor release from SSTs with passive ventilation is affected by atmospheric variables including temperature, pressure, and wind speed. Tank vapors can also accumulate in valve pits and instrument panels located on the surface by way of conduit or piping that penetrates the tank headspace.

1.3 POTENTIAL TANK VAPOR HAZARDS

Filtered exhaust systems prevent particulate radioactive material from exiting the underground tanks into the environment. However, chemical vapors in the tank headspaces can exit through the filters. Extensive characterization of the tank headspace vapors and work areas has been performed (RPP-22491, *Industrial Hygiene Chemical Vapor Technical Basis*).

As the potential hazards of chemical exposure have become better understood over the past decades, the monitoring and protection strategy for the tank vapors has evolved. In the early 1990s, monitoring was performed for ammonia and volatile organic compounds. The use of respiratory protection with organic/ammonia cartridges was required in areas where vapors were detected above regulatory limits, or when working on activities where increased vapor levels were anticipated.

Beginning in 2004, the use of supplied air respiratory protection was instituted in a large area around all the tanks. Supplied air was required in response to concerns about nitrous oxide and to the discovery of mercury vapors in several tanks. Supplied air use has continued during the systematic detailed characterization of the tank vapors under a variety of conditions.

The current evaluation of worker health was undertaken in response to concerns about the effects of possible historical vapor exposures on worker health.

2.0 TECHNICAL APPROACH

2.1 OVERALL APPROACH

A number of studies were considered by the HEP including cohort, case-control, and cross-sectional designs. There was careful consideration given to the relative strengths and weaknesses of the different designs, and as an initial approach, a case-control study within a cohort design was recommended. The study was constructed to take advantage of the existing medical, personnel, and exposure information. This would provide a relatively quick response to the workers concerns because it would not require extensive new data collection.

In the initial case-control study, cases were paired with gender- and age-matched controls for two specific health outcomes. The study cohort was defined as all workers with at least one recorded tank farm entry between 1990 and 2004. Cases and controls were selected from this cohort. A number of estimates of potential exposure were generated from multiple data sources. Potential exposure of cases and controls was evaluated for each single exposure estimator, and for several combinations of estimators.

2.2 HEALTH OUTCOMES OF INTEREST AND AVAILABLE DATA SOURCES

2.2.1 Cohort Definition

The study cohort included all workers with at least one recorded tank farm entry between 1990 and 2004. The cohort included approximately 5,000 individuals, some of whom had worked in the tank farms for many years prior to 1990. The records used to define the cohort were from the system used to track work performed using "Radiological Work Permits." These records were also used separately as one estimate of potential exposure, and are described in more detail in Section 2.3.

2.2.2 Selection of Health Outcomes and Data Sources

Health outcomes were selected for this project based upon three considerations: 1) health effects that were considered possible consequences of exposure to chemicals of interest at the site, 2) availability of data, and 3) concerns expressed by workers. The health effects selection was conducted in a stepwise iterative fashion.

First, members of the HEP became familiar with the physical configuration and the work of the Hanford Site. They visited the Hanford Site and spoke with workers and managers about current and prior work practices. The HEP reviewed existing chemical characterization and industrial hygiene data; in addition, they reviewed additional data as it became available during the project. The HEP members also reviewed the report of a separate working group commissioned to identify chemicals of potential concern. Using the chemical characterization of the vapors in the headspaces, the panel members proposed likely organ systems that would be potential targets of the chemical vapors. Mapping the potential target organs to the hazard assessment data is a standard approach to designing surveillance programs for potentially exposed workers (Matte et al. 1990, "Guidelines for medical screening in the workplace") and this approach can be applied here to identify outcomes of interest in exposed tank farm workers. Because most of the substances identified in the exposure characterization are organic solvents or irritants, the likely organ systems at risk were determined to be the lungs (from potential irritant exposure primarily) and the liver (from potential solvent exposure primarily).

Second, the HEP obtained input from the tank farm workers about their concerns. They held open forum meetings and one-on-one confidential meetings with individual workers. Throughout the work, the HEP had periodic meetings with workers in open meetings and included worker representatives in HEP working sessions.

Third, available health outcome data were reviewed. The panel met with representatives of the occupational medical provider, AdvanceMed Hanford (AMH), including physicians, industrial hygienist, epidemiologist, medical records team lead, privacy officer, information technology staff, and AMH management. AMH personnel created a compendium of all data forms in use

since the 1970s. These forms included questionnaires completed by patients, visit logs, health status notifications, hardcopy laboratory data, and electronic format laboratory data. The forms were examined in detail by two physician members of the panel.

Fourth, preliminary data fields of possible interest were selected by the panel members. The candidate data fields were selected based upon potential relatedness to a health outcome of interest. A large number of potential data types were considered. Further evaluation indicated that some of the data forms were typically incompletely filled out, others did not use any standardized terminology, and some were used only in unusual circumstances. These forms were eliminated from further consideration. The remaining forms and the candidate data fields were explicitly delineated for further assessment.

In the fifth step, a contractor, Research Triangle Institute International (RTI), working under the direct control of AMH, was engaged to review the records of up to 100 tank farm workers who were randomly selected for review. The quality and completeness of data for each of the candidate data fields was determined. The contractor evaluated the total records for 50 of the 100 selected workers. The review of the initial 50 record sets indicated limitations in historical records for use in this evaluation, such that it was deemed unproductive to continue review of the additional 50 record sets. The information for the majority of the fields was inconsistently recorded, largely because very few of the forms were uniformly needed for all workers. Furthermore, retrieval of free text information was extremely labor-intensive since many of the older records were on microform. Based upon this information, the panel recommended that only electronically available information be employed as primary data sources.

Sixth, the availability of data in electronic format was evaluated in concert with the records manager and the privacy officer. Two data systems had been in use: the Flow Gemini system was employed from 1984 until 1998; subsequently, data were recorded in the Occupational Health and Safety System (OHS). A limited data accuracy evaluation was conducted, whereby information in the electronic format was crosschecked with the corresponding hardcopy record.

Finally, based upon considerations of health relevance of potential exposures of concern and upon feasibility, two outcomes were selected for initial analysis: spirometry and blood enzyme levels typically associated with liver disorders.

2.3 EVALUATION OF POTENTIAL EXPOSURE

2.3.1 General Considerations

Worker exposure to tank vapors is a function of time spent in the tank farms and the tasks being performed. Workers make routine entries into the tank farm to perform a variety of work activities which include: 1) waste and headspace vapor sampling; 2) waste pumping activities; 3) routine maintenance of equipment, pumps, and electrical systems; and 4) installation and modification of tank and support systems. Waste disturbing activities such as pump installation

and solid waste sampling are generally associated with a higher potential for tank vapor exposures. Workers who typically perform these tasks have specific job classifications and training requirements.

While substantial additional resources have been devoted to better characterize tank wastes, headspace vapors, and vapor exposures, historical industrial hygiene data are not sufficient for quantitative exposure assessment. However, several information sources were available for qualitative assessments of potential vapor exposures. These data sources included duration of site work, job titles and associated tasks, frequency of tank farm entry, and radiological worker training records. The primary objective of the exposure assessment was to categorize workers into groups with varying degrees of potential tank farm vapor exposures (e.g., high, medium, low) for linkage with the epidemiological analyses of health outcomes from medical surveillance data.

2.3.2 Data Sources and Potential Exposure Algorithms

Worker occupational histories, records of tank farm entries, and radiological worker training data were used to construct a number of exposure algorithms. Focus groups were used to inform and refine the exposure algorithms.

Entries into the tank farm were recorded in the Westinghouse Radiation Area Management (WRAM) system during 1990–1995 and the Access Control Entry System (ACES) system from 1995–2004. Both WRAM and ACES are radiological permit systems that provided information concerning individual dates of tank farm entry. While useful as a crude measure of tank farm work activity, both systems have a number of limitations. The most significant limitation is the allowance of multiple entries, for periods of up to one month, under one permit for some kinds of work. However, daily permits were generally required for more intense work activities with higher probability for vapor exposures. These activities often required collection of supplemental radiation dosimetry. Monthly permits were more typically used for tours and audits, but also for routine surveillance and monitoring activities not requiring supplemental dosimetry.

Given these observations, the number of tank farm entries using the combined WRAM and ACES data was judged to be a useful qualitative exposure surrogate, but not a quantitative measure of potential exposure. Several category contrasts were constructed based on the distribution of tank farms entries. In one classification, the 90th percentile of the distribution was used to designate those with the highest potential exposures (Hi_Ent) compared to all other workers (Low_Ent). Tank farm entries were further classified into tertiles (Low, Medium, and High) and used for some analyses.

Employment records for study cohort members were supplied in electronic format. These records included job titles as well as hire dates, transfer dates, and termination dates. Some records were missing hire dates; therefore, approximate hire dates were inferred based on the first date of a recorded medical surveillance examination. A limitation of this information is that

periods of absence from the site between the first and last date of employment were not captured, causing over-estimates of employment duration in some instances. Using the employment records, years of work at the site (Duration) was calculated and used as one exposure surrogate.

An additional exposure surrogate was calculated using the WRAM and ACES tank farm entries. This measure (Tank years) was calculated as the sum of the years in which there was at least one tank farm entry. A worker was considered to have worked in tank farms in any year that they had logged at least one entry in the WRAM or ACES permit systems.

Job title information was used to construct several exposure variables. The list of job titles held by members of the cohort was reviewed and ranked with regard to the probability of tank farm vapor exposures (Low_Job, Medium_Job, and High_Job) based on knowledge of typical tasks performed by the particular craft or trade. High potential for tank farm vapor exposures was assigned to jobs that required work in close proximity to potential vapor sources (e.g., health physics technicians, industrial hygiene technicians, and nuclear chemical operators) or work in close proximity to waste disturbing activities. Low potential exposure jobs included managers, engineers, scientists, and other jobs that require tank farm entry but are not associated with waste disturbing activities and/or extended periods of work in the immediate vicinity of vapor sources. Medium potential for vapor exposures was assigned to jobs judged to have some potential for tank farm vapors above the low exposure group but generally less than the highest category. Medium potential exposure jobs included most construction crafts. Experienced CH2M HILL employees, blinded as to the job status of cases and controls, assigned jobs to potential tank farm vapor exposure categories. A list of jobs by assigned potential exposure category is presented in Appendix D.14

The proposed job classification system was discussed in the employee focus groups and was modified to address comments and concerns. Focus group members generally considered the job classification system to be useful, but suggested several variations and enhancements. Saltwell pumping work during the early 1990s was considered to have a high potential for vapor exposures. To facilitate this concern, the three-category classification for jobs described above was modified to add a separate category for workers identified to been involved with this saltwell pumping work. This group was designated as the highest exposure category. The resulting exposure categories based on this classification were designated Exnew_Low, Exnew_Med, Exnew_Hi, and Exnew_Vhi, with the latter category consisting of the saltwell pumping workers.

Focus group participants suggested that the job categories that represented members of the collective bargaining unit, Hanford Atomic Metal Trades Council (HAMTC), performed work more likely to be in proximity to vapor sources than other workers. In addition, workers doing hands-on work in the tank farms are required to have a higher level of radiation protection training than workers not doing hands-on work. This training is designated "Radiological Worker 2," and these training records were used to generate other potential vapor exposure algorithms. In one classification, all HAMTC workers, regardless of Radiological Worker 2 training status, were classified as having the highest exposure potential (Expall_Hi), non-HAMTC workers with Radiological Worker 2 training were considered to have intermediate exposures (Expall_Med), and all others were classified as having low exposure potential (Expall_Low).

The final exposure algorithm used the HAMTC classification in combination with Radiological Worker 2 training records. In this classification, all HAMTC with Radiological Worker 2 were classified in the high exposure category (Expr2_Hi), HAMTC workers without Radiological Worker 2 training were classified as intermediate exposure (Expr2_Med), non-HAMTC workers with Radiological Worker 2 training were classified as intermediate exposure (Expr2_Med), and all other workers were placed in the low exposure category (Expr2_Low).

Table 1 summarizes the different exposure variables and combinations of variables used to construct the exposure algorithms. Additionally, combinations of exposure category by job classification (three classifications) and tertiles of tank farm entry from WRAM and ACES were used in some analyses, resulting in a total of nine potential exposure categories.

Table 1. Potential Vapor Exposure Variables, Variable Combinations and Exposure Variable Names.

Primary Classification Variable	Years at Site	WRAM & ACES Data Yrs	WRAM & ACES Data Totals	Exposure Categories by Job	Saltwell Pumping Work	HAMTC Workers	Radiological Worker 2 Training
Years at Site	Duration						
WRAM & ACES Data Years		Tank_years					
WRAM & ACES Data Totals			Hi_Ent (90th percentile) Low_Ent & Tertiles (Low, Med, High)				
Exposure Categories by Job				Low_Job Med_Job High_Job	Exnew_Low, Exnew_Med, Exnew_Hi, Exnew_Vhi,		
HAMTC Workers							Expall_Hi Expall_Med Expall_Low
Radiological Worker 2 Training						Expr2_Hi Expr2_Med Expr2_Low	

3.0 PULMONARY FUNCTION EVALUATION

3.1 PULMONARY FUNCTION TEST DATA

Spirometry was regularly measured on tank farm workers. Among the 5,126 workers for whom medical data existed during the covered period, 4,794 workers received one or more spirograms. A total of 39,340 spirometry tests were performed on these individuals. A limited number of outlier values that were extremely likely to represent data entry or measurement error (e.g., forced expiratory volume - one second [FEV1] = 0) were deleted from the database.

Because cigarette smoking is a major determinant of respiratory function, the availability of smoking data for the study subjects was ascertained. Smoking status was self reported by the worker at the time of the medical evaluations. Smoking information was not consistently recorded, and only the most recent information was available in electronic format. For many of the cases and controls identified from the cohort for pulmonary function evaluation, no electronic smoking information was recorded. This information had to be obtained from the individual's medical chart. Since only the most recent smoking status information was available, the smoking status at the time of each spirometry test was not known. Individuals were characterized as "ever smoker," "former smoker," or "probable never smoker." For the overall population, 19 percent did not have smoking status recorded electronically, 12 percent were current smokers, 23 percent ex-smokers, and 46 percent probable never smokers.

Three parameters were determined from the spirometry records: FEV1, forced vital capacity (FVC), and the FEV1/FVC ratio. In addition, height and age at the time of the test were recorded. Race information was also collected since race affects predicted values for lung function. Spirometry derived values were all based upon measurements made without administration of a bronchodilator. Predicted values for each individual were calculated based upon the Crapo Equations, adjusting for age, gender, height, and race.

3.2 CASE DEFINITION

The research team held extensive discussions of possible case definitions. Several of the potential definitions were dependent upon multiple measures of spirometry over time (e.g., rate of decline, step change in function); such approaches were not utilized for initial study because of greater complexity and potential difficulty applying the risk set case control matching algorithm chosen for the overall analysis.

A definition of "abnormal spirogram" was selected applying the Global Initiative on Obstructive Lung Disease (GOLD) criteria: FEV1/FVC Ratio <0.70 and FEV1 <80 percent of predicted. GOLD includes several classes of severity; for this study, cases defined by "abnormal spirogram" needed at least category 2 ("moderate") levels of abnormality. Our use of the GOLD definition included significant restrictive disease. The FEV1 expressed as a percentage of the predicted value was used to scale the extent of abnormality.

Individuals with an "abnormal spirogram" by the above criterion were eligible to become cases. Workers with normal spirometry (operationally defined as not having been diagnosed with mild or moderate or greater obstruction up to the date of the most recent examination) were eligible controls. Thus, individuals whose test results were abnormal but not sufficiently aberrant to meet the GOLD category 2 criteria could be neither control nor case. For each spirogra4m performed, the results were analyzed to determine if the subject could be a case or a control at that time. Thus, an individual with multiple spirograms over time was evaluated independently at each time and might be a control in one year and subsequently be a case. However, once a worker was designated as a case, he was no longer eligible to be selected as a control.

3.3 CASE AND CONTROL SELECTION

A risk set approach was employed for matching cases to controls (Breslow and Day, *Statistical Methods in Cancer Research*; Cologne and Langholz, "Selecting controls for assessing interaction in a nested case-control study"; Langholz and Goldstein, "Risk set sampling in epidemiologic cohort studies"). The study population included 4,794 individuals who received at least one spirogram and thus were eligible to become cases. An individual became a case on the date of the first spirogram meeting the criterion for abnormality; that date was employed as the case date for selecting a control. There were 499 individuals with at least one spirogram meeting the definition of a case.

A computer algorithm (Richardson 2004, "An incidence density sampling program for nested case-control analyses") was employed to identify one or more potential controls, defined by the following criteria: also working within one year of the date of the case; having had a spirometry test performed within 2 prior years; same gender as case; age within the same 5-year age bracket as the case; eligibility to be a control according to the definitions above. Smoking status was not used as a match criterion.

A single control was selected for each case. Of the 499 potential pairs of cases and controls, the 300 cases with the most severe abnormality were included in the subsequent evaluation. This selection was based on considerations of sample size and avoiding diluting the odds ratio (OR). Any effect should be more apparent by looking at the group with the worst test results. Characteristics of the cases and controls are shown in Table 2. In general, they had a similar duration of work at the site prior to the date of selection as case or control. Smoking status differed between cases and controls; more cases were classified as ever having smoked.

Table 2. Characteristics of Cases and Controls for Pulmonary Function Test Evaluation.

	Average Age	Smoker Missing Data	Smoker Never	Smoker Ever
Cases	45.2	22	197	280
Controls	44.7	44	272	183

The numbers of spirometry tests performed prior to the classification date were compared for the cases and controls. This analysis was conducted to evaluate the possibility of ascertainment bias (i.e., if cases had undergone much more frequent testing, the likelihood of being a case might be predominantly affected by test frequency). This is a particular concern because of the hypothetical possibility that individuals with jobs identified as having potentially greater exposures would be more likely to undergo regular spirometry testing. The number of prior spirograms was comparable for cases and controls, thereby making ascertainment bias unlikely.

3.4 ANALYSES

Analyses were conducted to investigate whether the likelihood of being a case was related to any of the exposure variables, taking into account potential confounders such as smoking status and age. *Cox Proportional Hazards Model* (Breslow and Day; Langholz and Goldstein) was employed for this purpose. Multiple analyses were conducted; calculated p values were not adjusted for the number of analyses conducted.

The categories of analyses conducted are summarized in Table 3. Models were developed sequentially, such that some models included only a single predictor variable (such as smoking status or one of the exposure indices), whereas others included multiple potential predictor variables. Tables 4A through 4I show the results of each pulmonary function test (PFT) evaluation. Several analyses demonstrated statistically significant relationships, and these are shown in Table 5. Complete information about all of the analyses conducted is included in the appendices.

Table 3. Summary of the Pulmonary Function Test Models.

Model No.	Exposure Variable	Confounders	Covariate	Description	No. Matched Pairs
1.0a	None	Smoking_Ever	Age		283
1.0b	None	Smoking_Current Smoking_Former	Age		283
1.1a	Med_Job High_Job (def=4a)	Smoking_Current Smoking_Former	Age	Three-level job classification potential exposure estimator	283
1.1b	Exnew_Med Exnew_Hi Exnew_Vhi (def=4d) (def=)	Smoking_Current Smoking_Former	Age	Same job classifications as model 1.1a, but one additional very high estimator added	273
1.2	Duration (def=1)	Smoking_Current Smoking_Former	Age	Number of years on the Hanford Site based on initial employment date	237
1.3	Hi_Ent (def=2)	Smoking_Current Smoking_Former	Age	Top 10 percent total number of entry records for tank farm access	197
1.4	Tank_Yrs (def= 3	Smoking_Current Smoking_Former	Age	Number of years with at least one entry record for tank farm access	197
1.5a	Expall_Med Expall_Hi (def=4b)	Smoking_Current Smoking_Former	Age	Alternate three-level job classification system	283

1.5b	Expr2_Med Expr2_Hi (def=4c)	Smoking_Current Smoking_Former	Age	Alternate three-level job classification system	283
1.6	Low_Med Low_Hi Med_Lo Med_Med Med_Hi High_Lo High_Med High_Hi (def=4e)	Smoking_Current Smoking_Former	Age	Combination of the three-level job classification used in model 1.1a (first variable) and tertiles of the total number of entry records prior to case conversion (second variable)	193

Table 4A. Pulmonary Function Analysis, Age and Smoking, Model 1.0b, 283 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Smoke + Age	Smoke_Ever	0.463	26.49	<.0001	1.588 (1.332, 1.894)
	Age (+1 yr)	0.002	0.23	0.632	1.002 (0.994, 1.011)
	Age (+5 yrs)				1.010 (0.969, 1.054)
	Age (+10 yrs)				1.021 (0.938, 1.111)
Smoke Only	Smoke_Ever	0.464	26.71	<.0001	1.591 (1.334, 1.897)
Age Only	Age (+1 yr)	0.003	0.47	0.493	1.003 (0.995, 1.011)
	Age (+5 yrs)				1.015 (0.973, 1.058)
	Age (+10 yrs)				1.030 (0.947, 1.120)
Smoke + Age	Smoke_Current	0.602	41.26	<.0001	1.826 (1.519, 2.194)
	Smoke_Former	0.298	7.22	0.007	1.347 (1.084, 1.674)
	Age (+1 yr)	0.002	0.27	0.606	1.002 (0.994, 1.011)
	Age (+5 yrs)				1.011 (0.970, 1.054)
	Age (+10 yrs)				1.022 (0.940, 1.112)
Smoke Only	Smoke_Current	0.603	41.48	<.0001	1.828 (1.522, 2.197)
	Smoke_Former	0.3	7.31	0.007	1.350 (1.086, 1.678)
Age Only	Age (+1 yr)	0.003	0.47	0.493	1.003 (0.995, 1.011)
	Age (+5 yrs)				1.015 (0.973, 1.058)
	Age (+10 yrs)				1.030 (0.947, 1.120)

Table 4B. Pulmonary Function Analysis, Job Classification, Three-Level Definition 4a, Model 1.1a, 283 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Med_Job	0.146	1.79	0.181	1.158 (0.934, 1.435)
	High_Job	0.068	0.21	0.651	1.070 (0.798, 1.434)
	Smoke_Current	0.605	38.64	<.0001	1.830 (1.513, 2.215)
	Smoke_Former	0.303	7.12	0.008	1.354 (1.084, 1.691)
	Age (+1 yr)	0.003	0.3	0.582	1.003 (0.994, 1.012)
	Age (+5 yrs)				1.013 (0.968, 1.059)
	Age (+10 yrs)				1.025 (0.938, 1.121)
Job Risk	Med_Job	0.272	6	**0.014**	1.312 (1.056, 1.631)
	High_Job	0.17	1.29	0.256	1.185 (0.884, 1.589)
Smoke Only	Smoke_Current	0.603	41.48	<.0001	1.828 (1.522, 2.197)
	Smoke_Former	0.3	7.31	0.007	1.350 (1.086, 1.678)
Age Only	Age (+1 yr)	0.003	0.47	0.493	1.003 (0.995, 1.011)
	Age (+5 yrs)				1.015 (0.973, 1.058)
	Age (+10 yrs)				1.030 (0.947, 1.120)

Note: Odds ratio for being a case based on several sets of predictor variables. Bold= $p < 0.05$.

Table 4C. Pulmonary Function Analysis, Job Classification, Four-Level Definition 4d, Model 1.1b, 283 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Exnew_Lo	-0.117	0.63	0.427	0.889 (0.666, 1.188)
	Exnew_Med	0.027	0.05	0.821	1.027 (0.813, 1.298)
	Exnew_Vhi	-0.508	0.59	0.442	0.601 (0.165, 2.198)
	Smoke_Current	0.601	38.44	<.0001	1.824 (1.509, 2.206)
	Smoke_Former	0.291	6.55	0.011	1.338 (1.071, 1.672)
	Age (+1 yr)	0.003	0.3	0.581	1.003 (0.994, 1.011)
	Age (+5 yrs)				1.013 (0.969, 1.059)
	Age (+10 yrs)				1.025 (0.938, 1.121)
Job Risk	Exnew_Lo	-0.222	2.23	0.136	0.801 (0.599, 1.072)
	Exnew_Med	0.048	0.15	0.696	1.049 (0.826, 1.333)
	Exnew_Vhi	-0.599	0.97	0.325	0.549 (0.167, 1.808)
Smoke Only	Smoke_Current	0.603	41.48	<.0001	1.828 (1.522, 2.197)
	Smoke_Former	0.3	7.31	0.007	1.350 (1.086, 1.678)
Age Only	Age (+1 yr)	0.003	0.47	0.493	1.003 (0.995, 1.011)
	Age (+5 yrs)				1.015 (0.973, 1.058)
	Age (+10 yrs)				1.030 (0.947, 1.120)

Table 4D. Pulmonary Function Analysis, Job Classification, Three-Level, Definition 4c, Model 1.5b, 283 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Expr2_Medium	0.112	0.94	0.333	1.119 (0.892, 1.404)
	Expr2_High	0.151	1.6	0.205	1.163 (0.921, 1.469)
	Smoke_Current	0.594	39.91	<.0001	1.812 (1.507, 2.179)
	Smoke_Former	0.288	6.72	0.01	1.334 (1.073, 1.659)
	Age (+1 yr)	0.003	0.5	0.478	1.003 (0.995, 1.012)
	Age (+5 yrs)				1.016 (0.973, 1.060)
	Age (+10 yrs)				1.032 (0.947, 1.124)
Expr2 Risk	Expr2_Medium	0.107	0.78	0.376	1.113 (0.878, 1.412)
	Expr2_High	0.186	2.35	0.125	1.204 (0.950, 1.526)
Smoke Only	Smoke_Current	0.603	41.48	<.0001	1.828 (1.522, 2.197)
	Smoke_Former	0.3	7.31	0.007	1.350 (1.086, 1.678)
Age Only	Age (+1 yr)	0.003	0.47	0.493	1.003 (0.995, 1.011)
	Age (+5 yrs)				1.015 (0.973, 1.058)
	Age (+10 yrs)				1.030 (0.947, 1.120)

Table 4E. Pulmonary Function Analysis, Job Classification, Three-Level, Definition 4b, Model 1.5a, 283 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Expall_Medium	0.103	0.66	0.415	1.108 (0.866, 1.418)
	Expall_High	0.145	1.65	0.199	1.156 (0.927, 1.442)
	Smoke_Current	0.59	38.25	<.0001	1.804 (1.496, 2.174)
	Smoke_Former	0.289	6.75	0.009	1.335 (1.074, 1.659)
	Age (+1 yr)	0.003	0.4	0.527	1.003 (0.994, 1.011)
	Age (+5 yrs)				1.014 (0.972, 1.057)
	Age (+10 yrs)				1.028 (0.944, 1.118)
Expr2 Risk	Expall_Medium	0.051	0.15	0.697	1.052 (0.815, 1.358)
	Expall_High	0.2	2.96	**0.085**	1.222 (0.973, 1.535)
Smoke Only	Smoke_Current	0.603	41.48	<.0001	1.828 (1.522, 2.197)
	Smoke_Former	0.3	7.31	0.007	1.350 (1.086, 1.678)
Age Only	Age (+1 yr)	0.003	0.47	0.493	1.003 (0.995, 1.011)
	Age (+5 yrs)				1.015 (0.973, 1.058)
	Age (+10 yrs)				1.030 (0.947, 1.120)

Note: Odds ratio for being a case based on several sets of predictor variables. Bold= $p < 0.05$.

Table 4F. Pulmonary Function Analysis, Combined Job Classification, and Number of Entry Records, Definition 4e, Model 1.6, 193 Case/Control Pairs.

	Variable JobClass_Records	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Low_Med	0.008	0	0.974	1.008 (0.616, 1.650)
	Low_Hi	0.01	0	0.973	1.010 (0.557, 1.833)
	Med_Lo	0.141	0.67	0.415	1.152 (0.820, 1.619)
	Med_Med	-0.011	0	0.955	0.989 (0.668, 1.463)
	Med_Hi	0.271	2.47	0.116	1.312 (0.935, 1.840)
	High_Lo	0.007	0	0.979	1.007 (0.594, 1.708)
	High_Med	0.48	4.03	**0.045**	1.615 (1.012, 2.579)
	High_Hi	0.2	0.78	0.378	1.222 (0.783, 1.907)
	Smoke_Current	0.557	25.17	<.0001	1.745 (1.404, 2.169)
	Smoke_Former	0.228	3.12	0.077	1.257 (0.975, 1.619)
	Age (+1 yr)	0.004	0.58	0.447	1.004 (0.993, 1.016)
	Age (+5 yrs)				1.022 (0.966, 1.083)
	Age (+10 yrs)				1.045 (0.932, 1.172)
Hi Entry	Low_Med	0.005	0	0.983	1.005 (0.599, 1.687)
	Low_Hi	-0.012	0	0.968	0.988 (0.541, 1.804)
	Med_Lo	0.201	1.27	0.259	1.223 (0.862, 1.735)
	Med_Med	0.038	0.03	0.855	1.038 (0.693, 1.557)
	Med_Hi	0.383	4.82	**0.028**	1.466 (1.042, 2.064)
	High_Lo	0.064	0.05	0.816	1.066 (0.620, 1.835)
	High_Med	0.534	5.08	**0.024**	1.706 (1.072, 2.715)
	High_Hi	0.258	1.33	0.249	1.294 (0.835, 2.007)
Smoke Only	Smoke_Current	0.59	28.92	<.0001	1.804 (1.455, 2.236)
	Smoke_Former	0.264	4.23	0.04	1.303 (1.013, 1.676)
Age Only	Age (+1 yr)	0.003	0.3	0.585	1.003 (0.992, 1.013)
	Age (+5 yrs)				1.015 (0.963, 1.069)
	Age (+10 yrs)				1.030 (0.927, 1.143)

Note: Odds ratio for being a case based on several sets of predictor variables. Bold= $p < 0.05$.

Table 4G. Pulmonary Function Analysis, Duration of Employment, Model 1.2, 237 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Duration (+1 yr)	-0.001	0.06	0.812	0.999 (0.987, 1.011)
	Duration (+5 yrs)				0.993 (0.935, 1.054)
	Duration (+10 yrs)				0.986 (0.875, 1.110)
	Smoke_Current	0.544	29.42	<.0001	1.723 (1.416, 2.098)
	Smoke_Former	0.249	4.54	0.033	1.283 (1.020, 1.613)
	Age (+1 yr)	0.003	0.49	0.484	1.003 (0.994, 1.013)
	Age (+5 yrs)				1.017 (0.970, 1.067)
	Age (+10 yrs)				1.035 (0.940, 1.139)
Linear Dur.	Duration (+1 yr)	-0.002	0.07	0.789	0.998 (0.987, 1.010)
	Duration (+5 yrs)				0.992 (0.936, 1.051)
	Duration (+10 yrs)				0.984 (0.876, 1.106)
Smoke Only	Smoke_Current	0.545	29.51	<.0001	1.724 (1.416, 2.098)
	Smoke_Former	0.25	4.55	0.033	1.284 (1.021, 1.615)
Age Only	Age (+1 yr)	0.003	0.37	0.545	1.003 (0.994, 1.012)
	Age (+5 yrs)				1.014 (0.968, 1.063)
	Age (+10 yrs)				1.029 (0.938, 1.129)

Table 4H. Pulmonary Function Analysis, Number of Entry Records, Model 1.3, 197 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Hi_Ent	0.155	2.35	0.126	1.167 (0.958, 1.423)
	Smoke_Current	0.537	23.42	<.0001	1.711 (1.376, 2.126)
	Smoke_Former	0.236	3.41	0.065	1.266 (0.986, 1.626)
	Age (+1 yr)	0.003	0.34	0.56	1.003 (0.993, 1.014)
	Age (+5 yrs)				1.016 (0.963, 1.072)
	Age (+10 yrs)				1.032 (0.928, 1.148)
Hi Entry	Hi_Ent	0.193	3.66	**0.056**	1.213 (0.995, 1.478)
Smoke Only	Smoke_Current	0.542	23.96	<.0001	1.720 (1.384, 2.137)
	Smoke_Former	0.25	3.82	0.051	1.284 (0.999, 1.651)
Age Only	Age (+1 yr)	0.003	0.36	0.547	1.003 (0.993, 1.014)
	Age (+5 yrs)				1.016 (0.965, 1.071)
	Age (+10 yrs)				1.033 (0.930, 1.146)

Note: Odds ratio for being a case based on several sets of predictor variables. Bold= $p < 0.05$.

Table 4I. Pulmonary Function Analysis, Number of Years with One or More Entry Record, Model 1.4, 197 Case/Control Pairs.

	Variable	Parameter Estimate	Chi-Square	P-Value	Odds Ratio (95% C.I.)
Full	Tank Exp. (+1 yr)	0.03	2.16	0.142	1.030 (0.990, 1.072)
	Tank Exp. (+5 yrs)				1.161 (0.951, 1.417)
	Tank Exp. (+10 yr)				1.348 (0.905, 2.008)
	Smoke_Current	0.547	24.37	<.0001	1.729 (1.391, 2.148)
	Smoke_Former	0.234	3.34	0.068	1.264 (0.983, 1.625)
	Age (+1 yr)	0.002	0.16	0.691	1.002 (0.991, 1.013)
	Age (+5 yrs)				1.011 (0.957, 1.068)
	Age (+10 yrs)				1.022 (0.917, 1.140)
Tank_Yrs Only	Tank Exp. (+1 yr)	0.032	2.66	**0.103**	1.033 (0.994, 1.073)
	Tank Exp. (+5 yrs)				1.174 (0.968, 1.423)
	Tank Exp. (+10 yr)				1.378 (0.938, 2.025)
Smoke Only	Smoke_Current	0.542	23.96	<.0001	1.720 (1.384, 2.137)
	Smoke_Former	0.25	3.82	0.051	1.284 (0.999, 1.651)
Age Only	Age (+1 yr)	0.003	0.36	0.547	1.003 (0.993, 1.014)
	Age (+5 yrs)				1.016 (0.965, 1.071)
	Age (+10 yrs)				1.033 (0.930, 1.146)

Note: Odds ratio for being a case based on several sets of predictor variables. Bold= $p < 0.05$.

Table 5. Model 1.6, Combined Job Classification and Number of Entry Records.

	Entries		
Job	**L**	**M**	**H**
L		1.00	0.98
M	1.22	1.03	**1.46**
H	1.06	1.7	1.29

Note: Odds ratio for being a case based on combination of Job Exposure Potential and Frequency of Entry. Bold= $p < 0.05$

The panel reviewed several categories of exposure information, including chemical identity, head space concentration levels, air level measures, work practice descriptions, and worker interviews. This led to consideration of two general exposure scenarios deemed relevant to respiratory outcomes: 1) chronic low-moderate level exposures and 2) intermittent brief excursions with high levels of irritants.

Two major respiratory health outcomes were considered: 1) chronic airflow obstruction (CAO), a group of disorders characterized by long-term unremitting reduction in FEV1; and 2) asthma, characterized by intermittent, variable FEV1 reduction. Studies of other work situations have shown that moderate levels of dusts and irritants can, on a long-term basis, lead to CAO. For example, dust exposure in mining is associated with CAO. A form of asthma known as "irritant induced asthma" or Reactive Airway Dysfunction Syndrome (RADS), develops after exposures to high levels of irritants. Given the data available for the current analysis, only CAO could be addressed.

3.5 RESULTS

Tables 4A through 4I summarize regression analyses predicting case or control status. The table is organized according to the exposure index employed in the model. Both unadjusted and adjusted models are shown.

Smoking status was strongly associated with the likelihood of having an abnormal spirometry test. For example, the OR in a model including just smoking was 1.828 (P-value <0.0001) for a current smoker.

Statistically significant association between some exposure groups and abnormal spirometry was seen using the exposure index combining job category based exposure estimate and estimate of frequency of tank farm work. The study showed that cases were more likely than controls to be in the job group with high frequency of entry records and moderate job classification potential exposure levels. Table 5 summarizes the ORs for the nine combinations of job classification and entry record frequency. The relationships between ORs and exposure were not monotonic. Additionally, the job categories with greater estimated exposure potential did not show the association seen amongst the job categories with moderate potential exposure.

Overall, the results suggest that a clinically significant CAO effect of long-term exposures is unlikely to be present. Spirometry is a sensitive measure of chronic airflow obstruction. Because of the large number of case control pairs, the analysis had good statistical power to detect a difference. The average age of cases (45 years) also argues against CAO. The most common form of CAO is chronic obstructive pulmonary disease (COPD), which usually develops slowly and is rarely manifest by that age.

Furthermore, consideration of both process descriptions and air level measurements suggest that sustained levels of irritant exposures sufficient to lead to CAO are unlikely to have been present. The work situation in the tank farms differs from the prolonged dust and vapor exposures seen in jobs with CAO effects.

3.6 DISCUSSION OF PULMONARY FUNCTION EVALUATION

A single pulmonary outcome measure was selected for the analysis. Multiple exposure indices were evaluated, and a significant causal association was seen in only 1 of 39 exposure index analyses. Multiple analyses increase the likelihood of finding a spurious association, and therefore, which must be considered when interpreting the single "statistically significant" association.

The pulmonary outcome of interest was the presence of an abnormal spirometry test result. The case definition was derived from an internationally accepted standard classification scheme GOLD. Spirometry testing depends upon subject cooperation and, in addition, may be affected by many technical factors. To reduce the likelihood of misclassification, test results needed to be at least as abnormal as the GOLD class 2 (moderate abnormality) to warrant classification as a test. This criterion was chosen to avoid spurious results due to a single test with relatively minor abnormalities that may represent random short-term variation.

The case definition depends upon test values rather than upon the diagnosis of a specific pulmonary disease. Abnormal test results such as those employed in the case definition may be caused by several different conditions, including the following:

1. COPD – a pulmonary disorder leading to progressive loss of lung function often associated with emphysematous lung change. Tobacco smoking is the most common cause of COPD, but occupational and environmental exposures have also been clearly linked to this condition.

2. Asthma – a disorder characterized by variable airflow obstruction and airway inflammation. Asthma is typically characterized by significant day to day variation in spirometry test results.

3. Other airway disorders such as bronchiolitis.

4. Diseases of the pulmonary parenchyma such as asbestosis, chronic hypersensitivity pneumonitis, and idiopathic pulmonary fibrosis. Such conditions are often accompanied by restrictive abnormality patterns of spirometry; that is, reduced FVC with normal or increased FEV1/FVC ratio.

5. Nonspecific chronic airflow obstruction – this refers to the broad category of long-term obstructive pattern abnormalities.

6. Transient pulmonary disorders such as effects of a temporary infection or reversible response to irritant exposure.

7. Normal variation.

8. Inaccurate test results.

Thus, the case definition does not represent disease *per se*.

The data provide less certainty about whether there may have been transient effects or the development of asthma. The spirometry testing was carried out intermittently, and therefore, a transient effect of a brief, but high level, irritant exposure may have disappeared in the interval between two spirometry tests. Furthermore, asthma is an intermittent disease, such that individuals with asthma have some days with normal spirometry. Hence, the current study does not provide information useful in ruling out asthma as an exposure related outcome.

Several aspects of the project suggest that asthma should be further considered. The industrial hygiene data are reassuring that long term unremitting moderate or high level irritant exposures are extremely unlikely. However, the industrial hygiene measurements are less effective in demonstrating that there have not been occasional significant excursions since such brief episodes are unlikely to have been captured by the routine air level measurement. The work processes involve highly variable activity, and it is therefore possible that some individuals may have been present when there were short-term releases. The potential for a short-term, higher level exposure is consistent with the origin of irritant induced asthma, in which one or two high level exposures produce the disorder.

3.7 LIMITATIONS OF THE ANALYSIS

3.7.1 Meaning of Case Definition

The case definition, a single abnormal spirogram, depends upon a test and is not indicative of a diagnosis *per se*. However, spirometry is particularly useful for several reasons. First, it has been used for many years, and therefore, data are available for the entire study period. Second, the test has been well standardized, meaning that data are likely to be reliable. Indeed, the stability of numbers of cases detected per year and the limited validation analyses suggest such accuracy. Third, the test is affected by many diseases and therefore, is likely to be indicative of several of the possible outcomes (in particular, chronic airflow obstruction and asthma).

It is likely that the "cases" represent a mixture of medical conditions. The average age is 45 years. This is relatively young for COPD, and the effects of chronic low level occupational exposure are likely to require many years to accumulate, particularly because individuals with mild chronic airflow obstruction (GOLD class one) were excluded. It is also likely that some individuals have asthma, a disorder marked by airflow obstruction of a more intermittent nature.

4.0 LIVER FUNCTION EVALUATION

4.1 MEDICAL SURVEILLANCE DATA SOURCE

Liver enzyme data obtained from blood test results were made available from the medical clinic database. Initial review of the data revealed that liver serum transaminase enzymes were routinely measured in Hanford Site employees undergoing annual medical surveillance and analyzed by the same national laboratory vendor since 1992. Following some data "cleaning" and quality assurance steps to document the laboratory methodology and range of normal values over time, these data were accessed electronically for analysis.

4.2 LIVER ENZYME OUTCOMES OF INTEREST

Serum transaminase enzymes were evaluated as an indicator of potential liver effects that workers might experience from chronic exposure to vapors in the tank farms. Two commonly measured enzymes were used to assess liver effects: the serum glutamic pyruvic transaminase (SGPT), also often referred to as serum alanine aminotransferase (ALT); and the serum glutamic oxaloacetic transaminase (SGOT), similar to the above, also called the serum aspartate aminotransferase (AST).

4.3 CASE DEFINITION AND SELECTION

Two different case definitions were used for liver effects. Each was based on having only a <u>single</u> blood test result above a cut-off value which defined a case as described below.

In the **first case definition**, a significant liver enzyme result was defined as:

> A single SGPT (or ALT) value greater than 1.2 times the upper limit of the test's normal range
>
> AND SIMULTANEOUSLY
>
> The ratio of the SGPT/SGOT must be >1.0

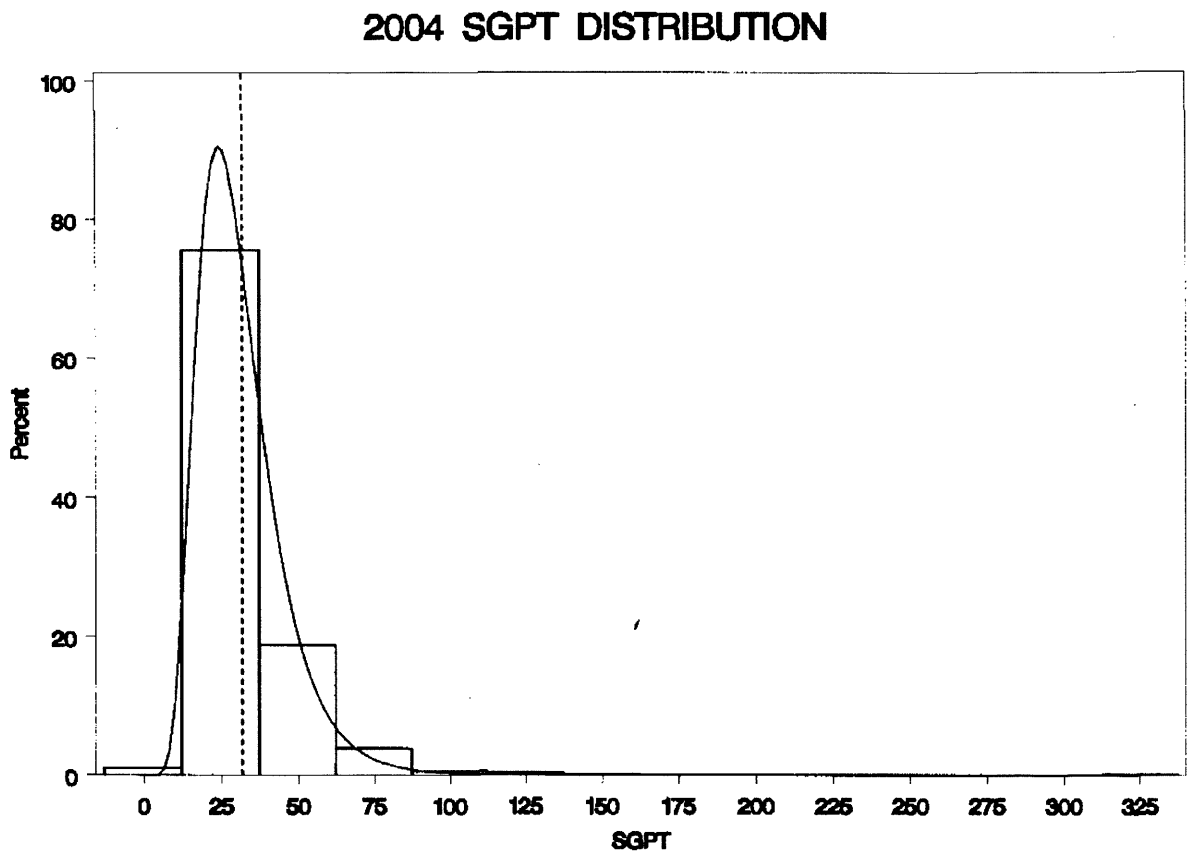
A **second case definition** comprised a subset of the first case definition above, where the SGPT values were in the upper quartile of the cohort SGPT distribution.

The well-documented effect of alcoholic beverage consumption on liver-related transaminase results was minimized by requiring the ratio of SGPT/SGOT >1.0 in the first case definition. While both of the transaminase concentrations, when expressed as "levels," may rise from drinking an alcoholic beverage or from a non-alcohol-related exposure, the differential effect of alcohol, generally enhancing SGOT, more so than SGPT results, has been observed by clinicians

and pathologists for decades and remains a reasonable tool in distinguishing an alcohol-mediated effect on transaminase levels from other causes. Another powerful affector of transaminase levels, Hepatitis C virus infection status, was not available for the population.

Liver function tests were considered useful for those members of the cohort who had at least one test taken after January 1, 1990. The population included 4,913 individuals, with a total of 40,315 tests. Figure 1 shows the distribution of SGPT values for the entire set of year 2004 test results.

Figure 1. Distribution of SGPT Values for 2004 Test Results.



In addition, the body mass index (BMI) by quartile was calculated based on available height and weight data and considered as a possible modifier in the evaluation of liver effects. BMI information was available for only approximately half the case/control population.

The potential controls were defined as those members of the cohort whose liver enzyme tests were "normal" (i.e., SGPT <1.2 X the upper limit of the test's normal range) prior to, and at the time at which a case was identified.

4.4 LIVER ENZYME ANALYSES

Analyses were conducted to determine whether the likelihood of becoming a raised liver enzyme case was related to any of the exposure variables described above, while considering potential confounders, such as elevated BMI.

4.4.1 First Case Definition – Raised SGPT Liver Enzyme Value

Models were fit to the elevated liver enzyme case-control pairs (Table 6 and Model Results Tables 7A through 7H). BMI quartiles for the cohort were determined and a 5-level BMI categorical variable (one level for each quartile plus a fifth level for individuals for whom BMI values could not be calculated) was determined. Categorical BMI variables were included as possible confounders in all the models; the lowest quartile was used as the reference category. In addition to BMI quartiles and a potential exposure factor, each model contained a covariate for age (continuous) at the time of case conversion. While cases were matched on age (within 5 years) as described previously, residual effects of age were also examined in the models. The number of matched pairs for each of the eight models tested ranged from 825 to 975. Average age of cases and controls at date of case conversion was 39 years.

4.4.2 Second Case Definition – SGPT in Top Quartile of the Distribution

A separate set of analyses was made for the subset of SGPT values which were in the upper quartile of the cohort SGPT distribution. The models for exposure variables with the sequential addition of other predictor variables such as age and BMI were fit to this subpopulation possessing high SGPT values. Model results 3.1a, 3.1b, and 3.6 (Tables 8A, 8B, and 8E) were fit to a sample of 206 risk sets; all other models were fit to a sample of 246 risk sets.

The model parameters, which include the continuous potential exposure variables (Duration and Number of Tank Years) and the age covariate, provide estimates of the change in the odds of becoming a case due to a 1-year change in number of years of prior Hanford Site employment, the number of tank farm entries, and age at the time of case conversion, respectively. Because interest will usually focus on larger increments of change, OR estimates were computed for changes of 1, 5, and 10 years for each continuous variable in each model. Exponentiation of the estimated model parameters for each categorical variable provides an estimate of the ratio of the odds of becoming a case relative to individuals in the corresponding reference category.

Table 6. Summary of the Liver Enzyme Models.

Model No.	Exposure Variable	Confounders	Covariate	Description	No. Matched Pairs All Cases	Top 25%
2.1a 3.1a	Med_Job High_Job (def=4a)	BMI Quartiles	Age	Three-level job classification potential exposure estimator	825	975
2.1b 3.1b	Exnew_Med Exnew_Hi Exnew_Vhi (def=4d)	BMI Quartiles	Age	Same job classifications as model 1.1a, but one additional very high estimator added	825	206
2.2 3.2	Duration (def=1)	BMI Quartiles	Age	Number of years on the Hanford site based on initial employment date	975	246
2.3 3.3	Hi_Ent (def=2)	BMI Quartiles	Age	Top 10 percent total number of entry records for tank farm access	975	246
2.4 3.4	Tank_Yrs (def=3)	BMI Quartiles	Age	Number of years with at least one entry record for tank farm access	975	246
2.5a 3.5a	Expall_Med Expall_Hi (def=4b)	BMI Quartiles	Age	Alternate three-level job classification system	975	246
2.5b 3.5b	Expr2_Med Expr2_Hi (def=4c)	BMI Quartiles	Age	Alternate three-level job classification system	975	246
2.6 3.6	Low_Med Low_Hi Med_Lo Med_Med Med_Hi High_Lo High_Med High_Hi (def=4e)	BMI Quartiles	Age	Combination of the three-level job classification used in model 1.1a (first variable) and tertiles of the total number of entry records prior to case conversion (second variable)	825	206

Table 7A. Liver Enzyme Analysis, All Cases, Job Classification, Three-Level Definition 4a, Model 2.1a, 825 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Med_Job	0.221	6.03	0.0141	1.247 (1.046, 1.488)
	High_Job	0.129	1.39	0.2382	1.138 (0.918, 1.410)
	BMI_MISS	0.359	6.82	0.0090	1.432 (1.094, 1.876)
	BMI_QTR2	0.809	20.93	<.0001	2.247 (1.588, 3.178)
	BMI_QTR3	1.261	53.04	<.0001	3.527 (2.513, 4.952)
	BMI_QTR4	1.479	62.36	<.0001	4.389 (3.040, 6.335)
	Age (+1 yr)	-0.027	5.01	0.0252	0.973 (0.950, 0.997)
	Age (+5 yrs)				0.873 (0.776, 0.983)
	Age (+10 yrs)				0.763 (0.602, 0.967)
Job Risk Model	Med_Job	0.264	9.80	0.0017	1.302 (1.104, 1.536)
	High_Job	0.229	5.08	0.0242	1.258 (1.030, 1.535)
BMI Only Model	BMI_MISS	0.354	6.69	0.0097	1.424 (1.089, 1.862)
	BMI_QTR2	0.803	21.76	<.0001	2.232 (1.593, 3.127)
	BMI_QTR3	1.272	54.06	<.0001	3.567 (2.541, 5.006)
	BMI_QTR4	1.474	63.56	<.0001	4.367 (3.040, 6.275)
Age Only Model	Age (+1 yr)	-0.026	5.78	0.0162	0.974 (0.953, 0.995)
	Age (+5 yrs)				0.876 (0.786, 0.976)
	Age (+10 yrs)				0.767 (0.618, 0.952)

Table7B. Liver Enzyme Analysis, All Cases, Job Classification, Four Level Definition 4d, Model 2.1b, 825 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Exnew_Lo	-0.123	1.21	0.2704	0.884 (0.710, 1.101)
	Exnew_Med	0.096	0.85	0.3560	1.101 (0.898, 1.350)
	Exnew_Vhi	-0.084	0.09	0.7619	0.920 (0.535, 1.580)
	BMI_MISS	0.360	6.83	0.0090	1.433 (1.094, 1.877)
	BMI_QTR2	0.814	21.07	<.0001	2.256 (1.594, 3.194)
	BMI_QTR3	1.262	53.15	<.0001	3.533 (2.516, 4.960)
	BMI_QTR4	1.478	62.34	<.0001	4.384 (3.038, 6.328)
	Age (+1 yr)	-0.027	4.93	0.0263	0.973 (0.951, 0.997)
	Age (+5 yrs)				0.874 (0.776, 0.984)
	Age (+10 yrs)				0.764 (0.603, 0.969)
Job Risk Model	Exnew_Lo	-0.218	4.47	0.0346	0.804 (0.656, 0.984)
	Exnew_Med	0.044	0.22	0.6411	1.044 (0.870, 1.254)
	Exnew_Vhi	-0.138	0.23	0.6352	0.871 (0.494, 1.539)
BMI Only Model	BMI_MISS	0.354	6.69	0.0097	1.424 (1.089, 1.862)
	BMI_QTR2	0.803	21.76	<.0001	2.232 (1.593, 3.127)
	BMI_QTR3	1.272	54.06	<.0001	3.567 (2.541, 5.006)
	BMI_QTR4	1.474	63.56	<.0001	4.367 (3.040, 6.275)
Age Only Model	Age (+1 yr)	-0.026	5.78	0.0162	0.974 (0.953, 0.995)
	Age (+5 yrs)				0.876 (0.786, 0.976)
	Age (+10 yrs)				0.767 (0.618, 0.952)

Table 7C. Liver Enzyme Analysis, All Cases, Job Classification, Three-Level, Definition 4c, Model 2.5b, 975 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Expr2_Medium	-0.055	0.33	0.5653	0.946 (0.783, 1.143)
	Expr2_High	0.148	2.18	0.1400	1.160 (0.952, 1.413)
	Age (+1 yr)	-0.037	12.13	0.0005	0.963 (0.943, 0.984)
	Age (+5 yrs)				0.830 (0.747, 0.922)
	Age (+10 yrs)				0.688 (0.558, 0.849)
	BMI_MISS	0.429	10.91	0.0010	1.536 (1.191, 1.982)
	BMI_QTR2	0.842	25.95	<.0001	2.321 (1.679, 3.209)
	BMI_QTR3	1.212	56.82	<.0001	3.361 (2.452, 4.606)
	BMI_QTR4	1.575	79.55	<.0001	4.832 (3.418, 6.831)
Expr2 Risk Model	Expr2_Medium	0.029	0.11	0.7454	1.029 (0.864, 1.226)
	Expr2_High	0.274	8.77	0.0031	1.315 (1.097, 1.576)
BMI Only Model	BMI_MISS	0.430	11.27	0.0008	1.537 (1.196, 1.976)
	BMI_QTR2	0.835	26.95	<.0001	2.305 (1.682, 3.159)
	BMI_QTR3	1.227	60.24	<.0001	3.411 (2.502, 4.651)
	BMI_QTR4	1.572	82.50	<.0001	4.816 (3.431, 6.761)
Age Only Model	Age (+1 yr)	-0.033	10.66	0.0011	0.968 (0.949, 0.987)
	Age (+5 yrs)				0.849 (0.770, 0.937)
	Age (+10 yrs)				0.721 (0.593, 0.878)

Table 7D. Liver Enzyme Analysis, All Cases, Job Classification, Three-Level Definition 4a, Model 2.5a, 975 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Expall_Medium	-0.044	0.20	0.6530	0.957 (0.791, 1.159)
	Expall_High	0.111	1.24	0.2651	1.117 (0.920, 1.357)
	Age (+1 yr)	-0.038	12.40	0.0004	0.963 (0.943, 0.983)
	Age (+5 yrs)				0.828 (0.745, 0.919)
	Age (+10 yrs)				0.685 (0.555, 0.845)
	BMI_MISS	0.433	11.15	0.0008	1.542 (1.196, 1.989)
	BMI_QTR2	0.843	26.10	<.0001	2.322 (1.681, 3.209)
	BMI_QTR3	1.224	58.31	<.0001	3.399 (2.483, 4.654)
	BMI_QTR4	1.585	80.68	<.0001	4.877 (3.452, 6.892)
Expr2 Risk Model	Expall_Medium	0.052	0.33	0.5668	1.054 (0.881, 1.260)
	Expall_High	0.221	5.93	0.0149	1.247 (1.044, 1.490)
BMI Only Model	BMI_MISS	0.430	11.27	0.0008	1.537 (1.196, 1.976)
	BMI_QTR2	0.835	26.95	<.0001	2.305 (1.682, 3.159)
	BMI_QTR3	1.227	60.24	<.0001	3.411 (2.502, 4.651)
	BMI_QTR4	1.572	82.50	<.0001	4.816 (3.431, 6.761)
Age Only Model	Age (+1 yr)	-0.033	10.66	0.0011	0.968 (0.949, 0.987)
	Age (+5 yrs)				0.849 (0.770, 0.937)
	Age (+10 yrs)				0.721 (0.593, 0.878)

Table 7E. Liver Enzyme Analysis, All Cases, Combined Job Classification and Number of Entry Records, Definition 4e, Model 2.6, 825 Case/Control Pairs.

Model	Variable JobClass-Records	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Low_Med	-0.283	2.97	0.0848	0.754 (0.546, 1.040)
	Low_Hi	-0.329	1.74	0.1868	0.719 (0.441, 1.173)
	Med_Lo	0.224	2.89	0.0894	1.251 (0.966, 1.620)
	Med_Med	-0.234	2.36	0.1247	0.791 (0.587, 1.067)
	Med_Hi	0.166	1.28	0.2577	1.180 (0.886, 1.572)
	High_Lo	0.206	1.39	0.2385	1.229 (0.872, 1.732)
	High_Med	0.121	0.30	0.5846	1.128 (0.732, 1.740)
	High_Hi	-0.234	1.94	0.1640	0.791 (0.569, 1.100)
	BMI_MISS	0.333	5.59	0.0180	1.396 (1.059, 1.839)
	BMI_QTR2	0.813	20.76	<.0001	2.254 (1.589, 3.198)
	BMI_QTR3	1.244	51.24	<.0001	3.468 (2.467, 4.874)
	BMI_QTR4	1.455	60.74	<.0001	4.285 (2.972, 6.178)
	Age (+1 yr)	-0.024	3.81	0.0509	0.976 (0.953, 1.000)
	Age (+5 yrs)				0.887 (0.786, 1.000)
	Age (+10 yrs)				0.787 (0.618, 1.001)
Hi Entry Model	Low_Med	-0.387	6.43	0.0112	0.679 (0.503, 0.916)
	Low_Hi	-0.513	4.58	0.0324	0.599 (0.374, 0.958)
	Med_Lo	0.190	2.38	0.1225	1.210 (0.950, 1.540)
	Med_Med	-0.225	2.46	0.1164	0.798 (0.603, 1.058)
	Med_Hi	0.137	0.95	0.3300	1.146 (0.871, 1.509)
	High_Lo	0.239	2.09	0.1487	1.270 (0.918, 1.756)
	High_Med	0.212	1.06	0.3027	1.236 (0.826, 1.848)
	High_Hi	-0.229	2.24	0.1346	0.795 (0.589, 1.074)
BMI Only Model	BMI_MISS	0.354	6.69	0.0097	1.424 (1.089, 1.862)
	BMI_QTR2	0.803	21.76	<.0001	2.232 (1.593, 3.127)
	BMI_QTR3	1.272	54.06	<.0001	3.567 (2.541, 5.006)
	BMI_QTR4	1.474	63.56	<.0001	4.367 (3.040, 6.275)
Age Only Model	Age (+1 yr)	-0.026	5.78	0.0162	0.974 (0.953, 0.995)
	Age (+5 yrs)				0.876 (0.786, 0.976)

Table 7F. Liver Enzyme Analysis, All Cases, Duration of Employment, Model 2.2, 975 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Duration (+1 yr)	-0.125	37.93	<.0001	0.882 (0.848, 0.918)
	Duration (+5 yrs)				0.534 (0.438, 0.652)
	Duration (+10 yrs)				0.285 (0.191, 0.425)
	Age (+1 yr)	-0.021	3.22	0.0728	0.980 (0.958, 1.002)
	Age (+5 yrs)				0.902 (0.806, 1.010)
	Age (+10 yrs)				0.814 (0.650, 1.019)
	BMI_MISS	0.464	12.58	0.0004	1.591 (1.231, 2.056)
	BMI_QTR2	0.870	27.78	<.0001	2.388 (1.728, 3.300)
	BMI_QTR3	1.228	58.25	<.0001	3.415 (2.491, 4.682)
	BMI_QTR4	1.571	79.32	<.0001	4.812 (3.405, 6.800)
Linear Dur. Model	Duration (+1 yr)	-0.138	51.47	<.0001	0.871 (0.839, 0.905)
	Duration (+5 yrs)				0.501 (0.415, 0.605)
	Duration (+10 yrs)				0.251 (0.172, 0.367)
BMI Only Model	BMI_MISS	0.448	11.96	0.0005	1.565 (1.214, 2.018)
	BMI_QTR2	0.844	26.26	<.0001	2.326 (1.684, 3.213)
	BMI_QTR3	1.243	60.63	<.0001	3.465 (2.534, 4.737)
	BMI_QTR4	1.599	83.13	<.0001	4.950 (3.510, 6.981)
Age Only Model	Age (+1 yr)	-0.033	10.66	0.0011	0.968 (0.949, 0.987)
	Age (+5 yrs)				0.849 (0.770, 0.937)
	Age (+10 yrs)				0.721 (0.593, 0.878)

Table 7G. Liver Enzyme Analysis, All Cases, Number of Entry Records, Model 2.3, 975 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Hi_Ent	0.048	0.16	0.6908	1.050 (0.827, 1.333)
	Age (+1 yr)	-0.038	12.13	0.0005	0.963 (0.943, 0.984)
	Age (+5 yrs)				0.829 (0.745, 0.921)
	Age (+10 yrs)				0.687 (0.556, 0.848)
	BMI_MISS	0.449	12.02	0.0005	1.567 (1.216, 2.020)
	BMI_QTR2	0.846	26.33	<.0001	2.331 (1.687, 3.220)
	BMI_QTR3	1.239	60.17	<.0001	3.453 (2.525, 4.723)
	BMI_QTR4	1.597	82.78	<.0001	4.936 (3.500, 6.963)
Hi Entry Model	Hi_Ent	0.140	1.66	0.1978	1.150 (0.930, 1.422)
BMI Only Model	BMI_MISS	0.430	11.27	0.0008	1.537 (1.196, 1.976)
	BMI_QTR2	0.835	26.95	<.0001	2.305 (1.682, 3.159)
	BMI_QTR3	1.227	60.24	<.0001	3.411 (2.502, 4.651)
	BMI_QTR4	1.572	82.50	<.0001	4.816 (3.431, 6.761)
Age Only Model	Age (+1 yr)	-0.033	10.66	0.0011	0.968 (0.949, 0.987)
	Age (+5 yrs)				0.849 (0.770, 0.937)
	Age (+10 yrs)				0.721 (0.593, 0.878)

Table 7H. Liver Enzyme Analysis, All Cases, Number of Years with One or More Entry Record, Model 2.4, 975 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Tank Exp. (+1 yr)	-0.015	0.69	0.4059	0.985 (0.950, 1.021)
	Tank Exp. (+5 yrs)				0.926 (0.772, 1.110)
	Tank Exp. (+10 yrs)				0.857 (0.596, 1.233)
	Age (+1 yr)	-0.036	11.31	0.0008	0.964 (0.944, 0.985)
	Age (+5 yrs)				0.834 (0.750, 0.927)
	Age (+10 yrs)				0.695 (0.562, 0.859)
	BMI_MISS	0.443	11.68	0.0006	1.558 (1.208, 2.008)
	BMI_QTR2	0.845	26.43	<.0001	2.328 (1.687, 3.212)
	BMI_QTR3	1.242	60.37	<.0001	3.463 (2.531, 4.737)
	BMI_QTR4	1.596	82.75	<.0001	4.934 (3.498, 6.958)
Tank_Yrs Only Model	Tank Exp. (+1 yr)	-0.019	1.31	0.2527	0.981 (0.950, 1.013)
	Tank Exp. (+5 yrs)				0.910 (0.775, 1.069)
	Tank Exp. (+10 yrs)				0.829 (0.601, 1.144)
BMI Only Model	BMI_MISS	0.430	11.27	0.0008	1.537 (1.196, 1.976)
	BMI_QTR2	0.835	26.95	<.0001	2.305 (1.682, 3.159)
	BMI_QTR3	1.227	60.24	<.0001	3.411 (2.502, 4.651)
	BMI_QTR4	1.572	82.50	<.0001	4.816 (3.431, 6.761)
Age Only Model	Age (+1 yr)	-0.033	10.66	0.0011	0.968 (0.949, 0.987)
	Age (+5 yrs)				0.849 (0.770, 0.937)
	Age (+10 yrs)				0.721 (0.593, 0.878)

4.5 RESULTS OF LIVER EVALUATION

The data in Tables 7A through 7H show a statistically significant result in only one of eight models examining exposure, that employ Job Classification definition 4a (High or Medium compared to Low – Table 7A), did any statistically significant increased likelihood of becoming a case emerge. This was for the medium job risk classification which demonstrated a small increase in the odds of becoming a case (20 percent) compared to those in the low risk category. However, the high job classification from that same model did not display a significantly increased risk.

When BMI is included in the model, the odds of becoming a case increases with greater BMI value. In fact, increased BMI is the strongest and most consistent predictor of case status.

Of the eight potential exposure variables, only the Job Classification variable (Model 2.1a) and the Duration of Employment variable (Model 2.2) were associated with significant changes in the odds.

The second case definition is a subset of the first and examines a more restrictive sub-group, those in the top 25 percent (highest) of the distribution of the SGPT values. The results of each of the eight models for the top 25 percent of the SGPT values are presented in Tables 8A through 8H. The BMI-case association is in the same direction, but stronger than in risk sets defined by the first case criteria. The job risk variables in Models 3.1a, 3.3, and 3.6 showed significantly increased ORs. As in the analyses with the first case definition, the case odds decreased with increasing years of employment at the Hanford Site. Thus, in general, potential exposure intensity and BMI effects are more important in these analyses than those using the first case definition.

Table 8A. Liver Enzyme Analysis, High SGPT, Job Classification, Three-Level Definition 4a, Model 3.1a, 206 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Med_Job	0.251	1.84	0.1754	1.285 (0.894, 1.847)
	High_Job	0.472	3.93	0.0474	1.604 (1.005, 2.558)
	BMI_MISS	1.790	14.35	0.0002	5.991 (2.373, 15.13)
	BMI_QTR2	1.746	11.90	0.0006	5.733 (2.126, 15.46)
	BMI_QTR3	2.601	25.51	<.0001	13.48 (4.913, 37.00)
	BMI_QTR4	2.545	25.71	<.0001	12.75 (4.766, 34.10)
	Age (+1 yr)	0.007	0.07	0.7904	1.007 (0.958, 1.058)
	Age (+5 yrs)				1.034 (0.808, 1.324)
	Age (+10 yrs)				1.069 (0.652, 1.753)
Job Risk Model	Med_Job	0.515	9.50	0.0021	1.673 (1.206, 2.321)
	High_Job	0.626	8.14	0.0043	1.870 (1.217, 2.876)
BMI Only Model	BMI_MISS	1.872	15.83	<.0001	6.503 (2.586, 16.36)
	BMI_QTR2	1.816	12.78	0.0003	6.150 (2.272, 16.65)
	BMI_QTR3	2.693	27.57	<.0001	14.78 (5.408, 40.39)
	BMI_QTR4	2.635	28.08	<.0001	13.94 (5.261, 36.95)
Age Only Model	Age (+1 yr)	-0.003	0.01	0.9097	0.997 (0.954, 1.043)
	Age (+5 yrs)				0.987 (0.791, 1.233)
	Age (+10 yrs)				0.975 (0.625, 1.519)

Table 8B. Liver Enzyme Analysis, High SGPT, Job Classification, Four-Level Definition 4d, Model 3.1b, 206 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Exnew_Med	0.268	2.10	0.1472	1.307 (0.910, 1.878)
	Exnew_Hi	0.434	3.26	0.0711	1.543 (0.963, 2.473)
	Exnew_Vhi	0.408	0.31	0.5762	1.503 (0.360, 6.277)
	BMI_MISS	1.787	14.32	0.0002	5.974 (2.367, 15.08)
	BMI_QTR2	1.746	11.91	0.0006	5.733 (2.127, 15.45)
	BMI_QTR3	2.589	25.35	<.0001	13.32 (4.860, 36.48)
	BMI_QTR4	2.537	25.63	<.0001	12.64 (4.734, 33.76)
	Age (+1 yr)	0.006	0.05	0.8188	1.006 (0.957, 1.057)
	Age (+5 yrs)				1.030 (0.802, 1.321)
	Age (+10 yrs)				1.060 (0.644, 1.746)
Job Risk Model	Exnew_Med	0.525	9.89	0.0017	1.691 (1.219, 2.347)
	Exnew_Hi	0.589	7.05	0.0079	1.802 (1.167, 2.783)
	Exnew_Vhi	0.857	1.79	0.1808	2.357 (0.672, 8.272)
BMI Only Model	BMI_MISS	1.872	15.83	<.0001	6.503 (2.586, 16.36)
	BMI_QTR2	1.816	12.78	0.0003	6.150 (2.272, 16.65)
	BMI_QTR3	2.693	27.57	<.0001	14.78 (5.408, 40.39)
	BMI_QTR4	2.635	28.08	<.0001	13.94 (5.261, 36.95)
Age Only Model	Age (+1 yr)	-0.003	0.01	0.9097	0.997 (0.954, 1.043)
	Age (+5 yrs)				0.987 (0.791, 1.233)
	Age (+10 yrs)				0.975 (0.625, 1.519)

Table 8C. Liver Enzyme Analysis, High SGPT, Job Classification, Three-Level Definition 4b, Model 3.5a, 246 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Expall_Medium	-0.070	0.11	0.7381	0.933 (0.619, 1.404)
	Expall_High	0.291	1.80	0.1791	1.338 (0.875, 2.045)
	Age (+1 yr)	-0.018	0.65	0.4218	0.982 (0.940, 1.026)
	Age (+5 yrs)				0.914 (0.733, 1.139)
	Age (+10 yrs)				0.835 (0.537, 1.297)
	BMI_MISS	1.367	17.04	<.0001	3.924 (2.050, 7.511)
	BMI_QTR2	1.353	12.66	0.0004	3.868 (1.836, 8.149)
	BMI_QTR3	2.069	24.43	<.0001	7.916 (3.485, 17.98)
	BMI_QTR4	2.182	32.82	<.0001	8.865 (4.202, 18.70)
Expr2 Risk Model	Expall_Medium	-0.009	0.00	0.9596	0.991 (0.693, 1.417)
	Expall_High	0.392	4.52	0.0336	1.480 (1.031, 2.126)
BMI Only Model	BMI_MISS	1.424	18.25	<.0001	4.153 (2.161, 7.980)
	BMI_QTR2	1.451	13.97	0.0002	4.267 (1.994, 9.132)
	BMI_QTR3	2.136	25.09	<.0001	8.465 (3.670, 19.52)
	BMI_QTR4	2.253	33.77	<.0001	9.515 (4.451, 20.34)
Age Only Model	Age (+1 yr)	-0.022	1.14	0.2855	0.978 (0.940, 1.018)
	Age (+5 yrs)				0.897 (0.735, 1.095)
	Age (+10 yrs)				0.805 (0.540, 1.199)

Table 8D. Liver Enzyme Analysis, High SGPT, Job Classification, Three-Level Definition 4c, Model 3.5b, 246 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Expr2_Medium	-0.057	0.07	0.7853	0.945 (0.627, 1.423)
	Expr2_High	0.273	1.55	0.2125	1.313 (0.856, 2.016)
	Age (+1 yr)	-0.016	0.52	0.4689	0.984 (0.942, 1.028)
	Age (+5 yrs)				0.922 (0.740, 1.149)
	Age (+10 yrs)				0.850 (0.548, 1.319)
	BMI_MISS	1.381	17.33	<.0001	3.978 (2.077, 7.619)
	BMI_QTR2	1.378	13.06	0.0003	3.967 (1.879, 8.378)
	BMI_QTR3	2.090	24.94	<.0001	8.083 (3.559, 18.35)
	BMI_QTR4	2.201	32.87	<.0001	9.037 (4.258, 19.18)
Expr2 Risk Model	Expr2_Medium	0.016	0.01	0.9325	1.016 (0.709, 1.454)
	Expr2_High	0.367	3.96	0.0467	1.444 (1.005, 2.074)
BMI Only Model	BMI_MISS	1.424	18.25	<.0001	4.153 (2.161, 7.980)
	BMI_QTR2	1.451	13.97	0.0002	4.267 (1.994, 9.132)
	BMI_QTR3	2.136	25.09	<.0001	8.465 (3.670, 19.52)
	BMI_QTR4	2.253	33.77	<.0001	9.515 (4.451, 20.34)
Age Only Model	Age (+1 yr)	-0.022	1.14	0.2855	0.978 (0.940, 1.018)
	Age (+5 yrs)				0.897 (0.735, 1.095)
	Age (+10 yrs)				0.805 (0.540, 1.199)

Table 8E. Liver Enzyme Analysis, High SGPT, Combined Job and Number of Entry Records, Model 3.5b, 206 Case/Control Pairs.

Model	Variable JobClass_Records	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Low_Med	1.006	7.70	0.0055	2.736 (1.344, 5.568)
	Low_Hi	0.763	2.47	0.1160	2.144 (0.828, 5.548)
	Med_Lo	0.618	4.99	0.0254	1.856 (1.079, 3.192)
	Med_Med	1.127	10.09	0.0015	3.085 (1.540, 6.184)
	Med_Hi	0.639	3.83	0.0504	1.894 (0.999, 3.592)
	High_Lo	0.898	4.59	0.0321	2.454 (1.080, 5.579)
	High_Med	0.831	2.86	0.0905	2.296 (0.877, 6.012)
	High_Hi	1.080	7.65	0.0057	2.946 (1.370, 6.333)
	BMI_MISS	1.893	18.78	<.0001	6.637 (2.820, 15.62)
	BMI_QTR2	1.915	14.92	0.0001	6.784 (2.568, 17.92)
	BMI_QTR3	2.837	32.87	<.0001	17.06 (6.470, 45.01)
	BMI_QTR4	2.745	33.85	<.0001	15.56 (6.173, 39.22)
	Age (+1 yr)	-0.006	0.05	0.8196	0.994 (0.946, 1.045)
	Age (+5 yrs)				0.971 (0.757, 1.246)
	Age (+10 yrs)				0.944 (0.573, 1.553)
Hi Entry Model	Low_Med	0.710	4.92	0.0266	2.034 (1.086, 3.810)
	Low_Hi	0.620	1.97	0.1600	1.859 (0.783, 4.413)
	Med_Lo	0.837	10.82	0.0010	2.310 (1.403, 3.803)
	Med_Med	1.049	10.66	0.0011	2.854 (1.521, 5.356)
	Med_Hi	0.817	6.95	0.0084	2.263 (1.233, 4.154)
	High_Lo	0.852	5.01	0.0253	2.344 (1.111, 4.942)
	High_Med	1.090	4.89	0.0270	2.974 (1.132, 7.810)
	High_Hi	1.117	9.45	0.0021	3.054 (1.499, 6.223)
BMI Only Model	BMI_MISS	1.872	15.83	<.0001	6.503 (2.586, 16.36)
	BMI_QTR2	1.816	12.78	0.0003	6.150 (2.272, 16.65)
	BMI_QTR3	2.693	27.57	<.0001	14.78 (5.408, 40.39)
	BMI_QTR4	2.635	28.08	<.0001	13.94 (5.261, 36.95)
Age Only Model	Age (+1 yr)	-0.003	0.01	0.9097	0.997 (0.954, 1.043)
	Age (+5 yrs)				0.987 (0.791, 1.233)
	Age (+10 yrs)				0.975 (0.625, 1.519)

Table 8F. Liver Enzyme Analysis, High SGPT, Duration of Employment, Model 3.2, 246 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Duration (+1 yr)	-0.099	6.24	0.0125	0.905 (0.838, 0.979)
	Duration (+5 yrs)				0.609 (0.412, 0.898)
	Duration (+10 yrs)				0.370 (0.170, 0.807)
	Age (+1 yr)	-0.005	0.05	0.8188	0.995 (0.951, 1.040)
	Age (+5 yrs)				0.974 (0.780, 1.217)
	Age (+10 yrs)				0.949 (0.608, 1.482)
	BMI_MISS	1.528	20.31	<.0001	4.611 (2.372, 8.964)
	BMI_QTR2	1.588	16.62	<.0001	4.895 (2.281, 10.50)
	BMI_QTR3	2.194	27.18	<.0001	8.974 (3.933, 20.48)
	BMI_QTR4	2.321	35.17	<.0001	10.18 (4.729, 21.93)
Linear Dur. Model	Duration (+1 yr)	-0.076	4.23	0.0396	0.927 (0.862, 0.996)
	Duration (+5 yrs)				0.684 (0.476, 0.982)
	Duration (+10 yrs)				0.468 (0.227, 0.965)
BMI Only Model	BMI_MISS	1.419	18.07	<.0001	4.132 (2.148, 7.949)
	BMI_QTR2	1.451	13.92	0.0002	4.267 (1.991, 9.146)
	BMI_QTR3	2.128	25.01	<.0001	8.399 (3.648, 19.34)
	BMI_QTR4	2.243	33.43	<.0001	9.421 (4.404, 20.15)
Age Only Model	Age (+1 yr)	-0.022	1.14	0.2855	0.978 (0.940, 1.018)
	Age (+5 yrs)				0.897 (0.735, 1.095)
	Age (+10 yrs)				0.805 (0.540, 1.199)

Table 8G. Liver Enzyme Analysis, High SGPT, Number of Entry Records, Model 3.3, 246 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Hi_Ent	0.636	4.73	0.0297	1.890 (1.065, 3.354)
	Age (+1 yr)	-0.007	0.09	0.7665	0.993 (0.950, 1.038)
	Age (+5 yrs)				0.967 (0.776, 1.206)
	Age (+10 yrs)				0.935 (0.602, 1.454)
	BMI_MISS	1.394	16.16	<.0001	4.029 (2.042, 7.949)
	BMI_QTR2	1.372	12.11	0.0005	3.942 (1.821, 8.536)
	BMI_QTR3	2.102	23.51	<.0001	8.180 (3.498, 19.13)
	BMI_QTR4	2.214	30.62	<.0001	9.157 (4.179, 20.06)
Hi Entry Model	Hi_Ent	0.734	7.77	0.0053	2.083 (1.244, 3.489)
BMI Only Model	BMI_MISS	1.424	18.25	<.0001	4.153 (2.161, 7.980)
	BMI_QTR2	1.451	13.97	0.0002	4.267 (1.994, 9.132)
	BMI_QTR3	2.136	25.09	<.0001	8.465 (3.670, 19.52)
	BMI_QTR4	2.253	33.77	<.0001	9.515 (4.451, 20.34)
Age Only Model	Age (+1 yr)	-0.022	1.14	0.2855	0.978 (0.940, 1.018)
	Age (+5 yrs)				0.897 (0.735, 1.095)
	Age (+10 yrs)				0.805 (0.540, 1.199)

Table 8H. Liver Enzyme Analysis, High SGPT, Number of Years with One or More Entry Record, Model 3.4, 246 Case/Control Pairs.

Model	Variable	Parameter Estimate	Chi-Sq.	P-Value	OR (95% C.I.)
Full Model	Tank Exp. (+1 yr)	0.067	2.43	0.1191	1.069 (0.983, 1.164)
	Tank Exp. (+5 yrs)				1.399 (0.917, 2.133)
	Tank Exp. (+10 yrs)				1.956 (0.841, 4.550)
	Age (+1 yr)	-0.017	0.56	0.4544	0.983 (0.940, 1.028)
	Age (+5 yrs)				0.919 (0.736, 1.147)
	Age (+10 yrs)				0.844 (0.541, 1.316)
	BMI_MISS	1.440	17.95	<.0001	4.221 (2.168, 8.218)
	BMI_QTR2	1.426	13.29	0.0003	4.163 (1.933, 8.962)
	BMI_QTR3	2.143	24.93	<.0001	8.526 (3.676, 19.77)
	BMI_QTR4	2.256	32.66	<.0001	9.549 (4.404, 20.70)
Tank_Yrs Only Model	Tank Exp. (+1 yr)	0.048	1.48	0.2236	1.049 (0.971, 1.133)
	Tank Exp. (+5 yrs)				1.271 (0.864, 1.870)
	Tank Exp. (+10 yrs)				1.615 (0.746, 3.496)
BMI Only Model	BMI_MISS	1.424	18.25	<.0001	4.153 (2.161, 7.980)
	BMI_QTR2	1.451	13.97	0.0002	4.267 (1.994, 9.132)
	BMI_QTR3	2.136	25.09	<.0001	8.465 (3.670, 19.52)
	BMI_QTR4	2.253	33.77	<.0001	9.515 (4.451, 20.34)
Age Only Model	Age (+1 yr)	-0.022	1.14	0.2855	0.978 (0.940, 1.018)
	Age (+5 yrs)				0.897 (0.735, 1.095)
	Age (+10 yrs)				0.805 (0.540, 1.199)

4.6 DISCUSSION OF LIVER EVALUATION

Some of the results for the liver function tests were statistically significant. However, the absence of a dose response relationship is noteworthy and does not support a causal relationship between liver test results and exposure surrogates. Further complicating the interpretation of the test results is the number of factors that could result in an increase in the clinical test. One such factor, BMI, for which some data were available, did show a strong relationship with the clinical test results. Data on other potential confounders, such as alcohol consumption, hepatitis, and other measures of metabolic syndrome were not available and therefore could not be evaluated. These unmeasured potential confounders would need to be considered to fully evaluate the relationship between exposure measures and liver function tests.

Serum transaminase concentrations (levels) have been a mainstay of clinical assessment of an exposure effect upon the liver for more than 40 years and are commonly measured both in medical practice and in occupational surveillance programs (Zimmerman 1978, *Hepatotoxicity: The Adverse Effects of Drugs and Other Chemicals on the Liver*). While liver transaminase tests are considered a sensitive measure of acute liver cell injury (Harrison 1990, "Medical surveillance for workplace hepatotoxins"), the variability and short persistence of any abnormal elevation (approximately 48 hours) after an acute exposure (Zimmerman 1978) including moderate alcohol consumption, complicate the interpretation of this clinical metric.

These clinical tests are also not very specific. The origin of these enzymes which spill into the blood upon cellular injury is primarily, but not exclusively, the liver. The origin of SGOT in serum derives from injured muscle, myocardium, and kidney as well as from the liver, and even the more significantly liver-associated SGPT has a small portion of its production originating from muscle (Johnston 1999, "Special Considerations in Interpreting Liver Function Tests"; Nathwani et al. 2005, "Serum alanine aminotransferase in skeletal muscle disease"; Tiidus and Ianuzzo 1983, "Effects of intensity and duration of muscular exercise on delayed soreness and serum enzyme activities"). Therefore, some clinical acumen is required in interpreting enzyme elevations as to first, in which organ an effect is being implicated, and second, from which of several different types of exposure related injury that organ is responding.

Because these enzymes are also measured in the National Health and Nutrition Examination Surveys (NHANES) conducted by the Centers for Disease Control, there are rich data sources that have facilitated the interpretation of the clinically available normal values and documented effectors of elevated measures. Strong predictors of SGPT elevations besides hepatitis infection include beverage alcohol consumption and BMI as well as male gender, decreasing age, and other measures of the metabolic syndrome (e.g., diabetes, obesity, and certain other body measures) (Ioannou et al. 2006, "The prevalence and predictors of elevated serum aminotransferase activity in the United States in 1999-2002"). The inverse relationship between transminase level and age that was observed in this study is consistent with the findings from NHANES (Ioannou et al. 2006).

In solvent exposed occupational cohorts, particularly where halogenated solvents are involved, liver transaminase measures have been used in surveillance protocols to characterize subtle or latent liver dysfunction caused by such chronic chemical exposure. In contrast to the relatively high sensitivity of these tests in acute liver injury in the occupational context of chronic, low intensity, intermittent chemical exposure, Chen argues that changes in a single liver test result be interpreted with caution given non-occupational effectors and decreasing exposure intensities which are generally being encountered more recently in work settings (Chen et al. 1997, "Effects of occupational and nonoccupational factors on liver function tests in workers exposed to solvent mixtures").

Distinguishing clinically significant transaminase measures from those that are merely statistically significant has been challenging physicians for many years. Indeed, the results reported here do not distinguish between a transient liver enzyme elevation that resulted from the unmeasured causes described above and a sustained elevation that result from a chronic liver condition. Wright and colleagues have suggested that in surveillance of presumably healthy workers not exposed to known hepatotoxicants, the positive predictive value of liver enzyme measures is enhanced by discounting a single elevation in a panel of otherwise normal results (Wright et al. 1988, "Liver function testing in a working population: three strategies to reduce false-positive results"). Although this Hanford Site cohort has had the opportunity for exposure to a variety of potential hepatotoxicants in tank farm head spaces, the episodic nature of the exposure opportunities makes the observation in the Wright paper (that a single transaminase excursion may not predict disease) potentially applicable here.

It is in this complex context of sensitivity, specificity, and the equivocal predictive value of a single transaminase test result that we interpret our findings among Hanford Site tank farm workers.

With the first case definition of a SGPT transaminase test result greater than 20 percent above the normal cutoff while simultaneously having a ratio of SGPT to SGOT >1, we observed little to no apparent effect from exposure to tank farm vapors on that outcome. The data were also analyzed in a more restrictive way, examining only the "highest high" cases of SGPT elevations, the top 25 percent of the SGPT distribution, to see if, in this group, there was an association with tank farm work.

In five of nine categories that were used to classify the exposure, an association was found with this more restrictive definition of elevated liver transaminase as measured; however, there was no clear dose-response pattern. Nevertheless, both the number and strength of the associations, with some OR >2, suggest the need to further investigate possible hepatic effect in tank farm workers. Additionally, our measuresof potential exposure are associated with potential classification error. Therefore, lack of a response gradient with increasing levels of potential exposure should be interpreted with caution.

5.0 CONCLUSIONS

Strengths of the study include the large sample (n = 5,126) and the wide range of years covered. The study included more than 35,000 person-years of observation. Exposure was assessed from indirect indicators such as job title and employment years; however, several separate approaches were employed to evaluate exposure so as to increase the likelihood of finding exposure-health effect associations if they truly exist.

Several factors should be considered, including:

1. Data for the study were limited to available information from medical records that were not specifically collected to support a study. Steps were taken in the design of the study to ensure compatibility between cases and controls on variables that might be time-dependent and related to the health outcomes.

2. The last medical records reviewed for each employee reflected their health while they were still employed at the Hanford Site. For former employees, medical information since they left the site was not available. If medical conditions developed subsequent to their employment at the site, those conditions were not reflected in this study.

3. Exposure was not measured systematically but estimated from existing records. Both cases and controls were assessed in the same manner and exposure assessment was done blinded as to case-control status. The methods used are generally used in these types of studies.

4. The periodic nature of the medical evaluations were effective in capturing chronic medical outcomes, but may have missed temporary or episodic outcomes. However, there is no reason to suspect a systematic difference between cases and controls.

The respiratory health status was assessed using spirometry, a test that is likely to have detected individuals with clinically significant CAO. The results support the conclusion that CAO, such as COPD, is unlikely to be a consequence of tank farm work.

The available data limited the ability to assess the possibility that asthma or related conditions may be associated with tank farm work. This limitation is related to both exposure estimates, which are less likely to reflect brief excursions, and to the periodic spirometry testing, which may miss episodes of asthma.

For the liver data, the first case definition was not significantly associated with any measure of exposure. The more restrictive case definition led to an association in five of nine potential exposure categories, but without a clear "dose response relationship." In addition, for both case definitions, the risk of the BMI effect was generally greater than any exposure variable. The data are also interpreted in light of the known variability of the liver transaminase measures and the caution exhorted by other authors to beware of using a single transaminase result to label liver dysfunction. Finally, however, the observation suggesting an association between exposure and the second definition of a raised SGPT result is biologically plausible and does suggest further exploration is needed.

6.0 RECOMMENDATIONS

The analysis of the available data was limited in scope, but it provides a clear basis for several recommendations.

6.1 HEALTH SERVICES

The medical surveillance activity should be continued. The available data have been extremely helpful in assessing whether there were respiratory health effects. Medical surveillance data should be collected in a standardized fashion to include sufficient information to allow aggregate as well as single case interpretation. The majority of the medical data examined was historical. The following recommendations for medical data collection have already been implemented for new data, and should be continued:

1. Medical surveillance data collection and data management:

   a. Standardized questionnaires should be used for all health data gathering. A standardized respiratory questionnaire should be based upon a well accepted epidemiologic instrument such as the American Thoracic Society questionnaire (an updated version will be available in the near future).

      Status: The medical provider has a standard questionnaire based on the "Occupational Safety and Health Administration (OSHA) required" questions for respirator qualification and asbestos. This questionnaire is used routinely, and in most cases, annually. Based on these recommendations, the medical provider is evaluating the American Thoracic Society questionnaire for future use.

   b. Add supplemental questions related to the potential exposures at the Hanford Site.

      Status: This has been addressed. There is a provision to account for any exposures when they present for an exposure incident and it is accounted for on the interim health and occupational history questionnaires. There are also other supplemental questions for specialty items such as for lead and mercury.

   c. In addition, a well-qualified individual should periodically perform quality assurance on the testing done.

      Status: This has been addressed. Medical support staff completes competency testing on an annual basis. In addition, a Medical Support Staff checklist (a version of peer review) is in development. External audit by Federal Occupational Health is performed quarterly.

d. The data should be stored in a consistent fashion in a computer/electronic database. Each individual record should include information about the testing data, the ambient conditions, and purpose of test.

Status: This has been addressed. Results are stored both electronically and in hard copy. Ambient conditions are verified by the medical assistant prior to daily calibrations. Medical profiles indicate when PFTs are required and written orders are given by the provider when warranted. The purpose of the test is documented by a list of required tests per medical surveillance protocol or by the provider for an acutely ordered test.

e. Further standardize spirometry testing. Those performing the testing should be certified for successful attendance of a National Institute of Occupational Safety and Health (NIOSH) approved "cotton dust" spirometry course.

Status: This has been addressed and is completed according to a standard protocol. All AMH medical support staff obtains a NIOSH approved spirometry course (for the past 18 years).

2. A specific questionnaire should be developed and implemented to address potential adverse symptoms related to use of self-contained breathing apparatus in the tank farm and other areas.

Status: This has been generally accounted for in the OSHA required questions already used on the current questionnaire. Further enhancements will be considered in the evaluation of future questionnaires.

3. A specific and consistent approach to assessing workers after possible intermittent peak exposures should be implemented. This has been addressed by the medical provider. A protocol is established and followed for each incident when a patient presents. Deviation from the protocol occurs only when the patient declines testing. Even though patients are strongly encouraged to participate with the testing, it cannot be required of them if they decline. The medical provider is implementing a process improvement by developing a written guideline that will be provided to the patient, who will be asked to sign that they have received the guidance on exposure testing. This improvement is not fully implemented but is nearing completion. The HEP recommended specific items to be included in the assessment of post incident health:

a. Standardized questionnaire.

Status: A standardized questionnaire is in place.

b. Medical evaluation and appropriate tests are performed on day of incident, 1 week later, and after 6 weeks, as clinically indicated.

Status: This response is in place per policy and procedure. Training has been provided to AMH providers, and feedback on this has been provided to worker groups.

c. A 6-month follow-up visit should be used for all those with persistent symptoms at the 6 week follow-up and/or abnormal test results (spirometry and other tests) at 1 week or later follow-ups.

Status: Currently, a 30 to 60-day follow-up is actively solicited. In addition, providers are encouraged to follow up on past events (within the last year) when patients are seen for other reasons such as annual examination, return to work, or work restriction review. Personnel without symptoms or restrictions are not required to receive follow-up evaluations, but the evaluations are encouraged.

Aspects of this recommendation dealing specifically with respiratory evaluation include:

d. The frontline practitioners, particularly the physician's assistants, should have an adequate educational program about the causes and detection of irritant induced asthma.

Status: This topic has been added to the training agenda to be completed in the next 2 to 3 months.

e. Methacholine challenge testing as an option for those who appear to have possible asthma from possible work-related exposures.

Status: This test is currently available to providers and can be ordered based on clinical determination.

f. Careful examination of nasal and oropharynx areas.

Status: This is in the examination protocol.

4. Worker questionnaires concerning current and past exposure should be implemented and incorporated in the health record in a consistent fashion. Alternatively, if there is concern that this might be perceived to adversely affect reporting or benefits, an independent questionnaire and interview system should be considered. The latter system would be considered a research tool and protected from routine access.

Status: A current avenue exists for workers to report past or current exposures. The research based option could be considered but would have to be based on the DOE approved funding.

5. Methods of incorporating information from personal physicians into the AMH record should be developed, although medical privacy considerations require that this be done on a voluntary basis.

   Status: Information from treating physicians is actively solicited for various situations, including exposures and fitness for duty evaluations. It depends highly on the participation of the patient/worker and their physician and is primarily limited by this level of cooperation, including frequent refusal of the patient to provide the information.

6. Workers and other stakeholders should be provided clear descriptions of the roles of the several health care provider groups. Specifically, the roles of the occupational medical provider, the groups providing treatment under the workers compensation system, the groups providing medical evaluation for the DOE in the Former Workers Program, and the personal health care provider should be defined explicitly.

   Status: This information has been addressed by multiple methods, including direct education, posters, discussion with worker groups, announcements in worker meetings, and other approaches.

6.2 EMPLOYMENT AND EXPOSURE RECORDS

In addition to the clinical recommendations, which should be considered by the contract care provider, additional recommendations apply to the employer, CH2M HILL:

1. The multi-approach exposure characterization efforts currently underway should be continued. These have proved invaluable in assessing health impacts of prior work and have a high likelihood of being at least as important in the future.

   Status: The approach combining source and work area characterization, personal exposure monitoring, and medical surveillance will continue.

2. Personnel records should be adequately standardized to include specific date of employment and job assignment information in an electronic database.

   Status: Employment history within CH2M HILL is standardized, but information regarding historical employment for other contractors at the Hanford Site and other DOE sites is outside the control of CH2M HILL.

3. A systematic approach to documenting episodes of potential airway irritant excursions and of worker reports of such should be implemented.

   Status: CH2M HILL currently documents these episodes in controlled records. Methods of enhancing the records to capture additional information will be evaluated.

4. The employer should investigate the development of a short summary of the study findings for distribution to workers, clinicians who may care for workers, and appropriate government agencies.

   Status: CH2M HILL will prepare a summary of the study findings and recommendations for distribution to interested parties.

5. The collaborative approach to the occupational health surveillance for the tank farm workers used in this project appears to be successful both from the scientific and end-user satisfaction standpoints.

6.3 ADDITIONAL ANALYSIS

The data compiled in this evaluation are maintained at AMH in a controlled database that may support future evaluations. The DOE may consider additional data analyses that could be performed on the current database.

The current work focused upon chronic airflow obstruction, such as COPD. However, it did not thoroughly evaluate the role of the tank farm work exposure in potentially affecting asthma. Analysis based upon a measure of spirometry variability should be considered.

Cross-sectional analyses relying upon spirometry data as continuous variables may be useful as a complement to the dichotomous classification method used in the recent analysis. Regression and mixed models would permit use of the extensive exposure indices as predictor variables.

Longitudinal analyses of the lung function data should be considered in conjunction with indices of exposure generated for this study.

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APPENDIX A

PROCESS DESCRIPTION AND DATA VALIDATION – ESTABLISH COHORT AND COMPILE INITIAL INFORMATION

APPENDIX A

PROCESS DESCRIPTION AND DATA VALIDATION – ESTABLISH COHORT AND COMPILE INITIAL INFORMATION

Goal:

Identify all people who have entered the tank farms at least once over a defined period of time.

Available Data Sources:

The ACES database is an electronic database that tracks the use of Radiological Work Permits. It has been used since mid-1995 to track to work done in any radiological area on the Hanford Site. Each time work is to be done in a radiological area, the worker's name, identification number, and permit number are entered into the electronic system. Some permits require that the entry be logged on a daily basis; others allow extended work periods (up to 1 month) after the initial log in.

The WRAM system is an electronic database compiled from paper records collected between 1990 and 1995. The paper records included worker name, identifying number, and permit number. The data were subsequently transcribed into the electronic system.

Expectation:

If a worker has entered the tank farms since 1990, that information will be captured in either the ACES or the WRAM system. Searching these systems for permit numbers associated with tank farm work will identify the workers of interest.

System Level Quality:

Both ACES and WRAM use modern database technology with standard query capability.

Process Quality:

The data in ACES is captured electronically. The worker provides an identification number which is entered into the computer. The ACES operator confirms the identity of the worker before proceeding with the log in, so key stroke errors associated with worker identity are minimized. Key stroke errors associated with the permit number are possible only if another valid permit number is entered in the place of the requested number. Tank farm permits have a limited number of prefixes, so mis-entry of a tank farm permit number would likely result in another tank farm permit number.

The data in WRAM was compiled from paper records. Since the source information was hand-written without a systematic cross-check, some entries were difficult to read, or incomplete, leading to incomplete or inaccurate information in the electronic system.

Limitations of Data for This Purpose:

The ACES system entries do not directly correspond to individual entries into the tank farm area because some permits allow multiple entries. An entry on a permit may not correspond to an actually entry in some cases, because a job may be cancelled after log-in. It is unlikely that a worker entered the tank farms and worked without logging in (it is a procedural requirement to log in).

The WRAM system entries generally correspond to single work days. It is still possible that a worker logged in, but the job was cancelled. The hand documentation of permit number and worker identification number leads to higher frequency of mis-classification.

Problems and Resolution:

The databases were queried twice. The first query was formulated only to obtain the number of permit entries per year for each individual and the role the individual played during that entry. The second query requested more information (e.g., actual date of permit entry, permit description, company for whom the individual worked). Although the queries were formulated in the same manner, the output was not identical. Out of more than 5,000 workers in the first query, there were 98 workers who did not show any permit entries in the second query. Many of the workers had slightly different total number of entries in one or more years.

The differences were evaluated to determine the cause. The following two causes were identified:

- During 2002 and 2003, the variable that showed the company employing the worker was used. In some cases, that variable contained a null value. During the first query, that variable was not part of the query and had no impact on the output. During the second query, those permit entries with a null value in that variable were excluded from the output. This error was corrected and the second query reformulated. The output from the two queries then matched for those years.

- In the queries of the WRAM system, the first query included explicit permit numbers for tank farm work, as well as allowing permit numbers that were similar to the correct permit numbers. This approach allowed the inclusion of permit entries where an incorrect entry on the paper forms, or a transcription error, had led to a permit number that was not a valid tank farm permit. The second query only included the explicit correct permit numbers. It was recognized that the first approach would also include some permit entries that did not actually reflect real tank farm entries. However, since the goal was to include everyone who likely entered tank farms, the decision was made to use the output of the first query.

The review of the causes also considered the following potential sources of error:

- Exclusion of an entire year of data (i.e., one input file) in one dataset.
- Inconsistent matching of employee numbers to final encrypted identifier number in the final dataset.
- Loss of data during integration with the medical records database.

The review concluded that these steps had been performed consistently in both cases, and errors had not been introduced at these steps.

Outcome:

More than 5,000 individuals were identified, for whom there is strong reason to believe at least one tank farm entry occurred from 1990 to 2004.

It is probable that this approach missed some individuals who entered during between 1990 and 1995, and whose permit number data or worker identification number was incorrectly written down at time of entry or incorrectly transcribed into the electronic system. Conversely, some people may have been included who actually used a non-tank farm permit. The queries were designed to err on the side of being more inclusive, i.e., there are probably some people in the cohort who did not enter tank farms, but fewer people were missed. There is no reason to believe that the inclusion/exclusion would be related to any health outcome.

The actual number of entries into the tank farms cannot be determined from the number of log-ins. In general, individuals who logged in many times entered tank farms more often than those who rarely logged in, but this information can only be used as a rough estimator.

Data Validation Process:

Fifteen cases and fifteen controls were selected at random. The initial data files regarding number of tank farm permit entries per year for each selected individual were compared with the final information in the composite database.

APPENDIX B

HPM CORPORATION DOCUMENTATION FOR CH2M HILL TANK FARM ENTRY EXPOSURE STUDY

APPENDIX B

DOCUMENTATION FOR CH2M HILL TANK FARM ENTRY EXPOSURE STUDY

Documentation on creating databases and obtaining medical records information for the CH2M HILL tank farm entry exposure study included the following:

1. Establishing cohort to conduct study:

   a. The CH2M HILL project manager provided the HPM Corporation (HPMC) records manager and staff with Microsoft Excel[1] spreadsheets of lists containing approximately 7,951 names and identification information gathered at the time of entry for individuals who were documented as entering the tank farms between January 1990 and September 2004, sorted by year of entry.

   b. The HPMC records manager converted each of the tables into a Microsoft Access database. With the help of AMH programmers, duplicates were combined into one identifying name by comparing social security numbers, Hanford identification (HID) numbers, or payroll numbers. For any of the approximately 850 names that did not have identification numbers, HPMC staff then searched both electronic medical record databases (i.e., ACES] and WRAM) for each unidentifiable name to establish a social security number. There were approximately 247 individuals that had no Hanford Site medical record established, therefore, HPMC staff were unable to identify those individuals.

   c. After HPMC staff identified every individual possible, programmers then tallied all entries for those individuals per year. Programmers then encrypted the social security numbers for those identified so that all privacy issues were complied with.

   d. A database was established containing a total of 5,166 eligible participants, identified by an encrypted social security number. This database was sent to RTI to begin analysis of this portion of the data.

   e. A quality check was conducted to ensure an individual who had entered the tank farms and had a medical record was not left out of the cohort. This was done by searching for the individual by a name, social security number, or Hanford

   identification number in both of the medical record databases. If nothing was located in either database, that individual had no medical record on the Hanford Site and therefore, could not be included in the study.

2. Incorporating additional information using ACES/WRAM databases:

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[1] Microsoft and Excel are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

a. The CH2M HILL project manager provided HPMC records manager and staff with Excel spreadsheets containing information found in the ACES and WRAM databases to again identify individuals who had entered the tank farms in the 1990 to 2004 time frame. The goal was to obtain Radiological Work Permit information for the individuals in the already established cohort. The HPMC records manager followed the same procedure of converting the Excel tables into Microsoft Access[2] tables, assigning each individual with an encrypted social security number and populated the ACES/WRAM information database with these tables sorted by year. This database was then sent to RTI to begin analysis of the additional data found in the ACES/WRAM database.

b. After analyzing the ACES/WRAM information, RTI discovered that there were 98 workers from the tank farm entry database who did not show permit entries and therefore, were not included in the ACES/WRAM database.
The CH2M HILL project manager and the Pacific Northwest National Laboratory (PNNL) records manager determined this error was due to a difference in the way each database was queried. Since the goal was to include individual workers who entered the tank farms between 1990 and 2004, a decision was made to use the information from the tank farm entry database only.

3. Incorporating job title information:

a. The HEP determined it was necessary to obtain as much information on an individual as possible. The Hanford Site does not have a universal database that contains all employment information for all individuals who may have worked on the Hanford Site. This made it necessary to obtain information from different companies that controlled sufficient databases. HPMC was able to obtain job title information from Fluor Hanford, Inc. (FH). Some hire dates were also included with this information. Access tables were sent to the HPMC records manager from a FH records manager. The encryption process was repeated for the individuals in the cohort and that information was sent to RTI as well.

4. Obtaining smoking information for individuals in cohort:

a. It was determined by RTI that there was not enough smoking status information for the 300 cases and controls identified from the cohort. This information had to be obtained from the individual's medical chart. HMPC records manager and staff were able to obtain an individual's smoking status by locating the physical chart or by looking at the copied chart via microfilm. A worker's smoking status was obtained by medical records that the individual would fill out at an annual physical examination. HPMC staff would find the most recent examination report and determine weather the individual was a non-smoker, an ex-smoker, or a

[2] Microsoft and Access are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

current smoker, and if a current smoker or ex-smoker, how many years had the individual smoked. This information was sent to RTI for their analysis.

g. Quality assurance (QA) process for abstraction information:

a. A list of 15 cases and 15 controls was sent to the HPMC records manager for a QA process in which data determined by the HEP was checked for accuracy. Laboratory results for the liver function test, PFT results, smoking status, gender, birth year, and job title were all abstracted from the medical records by chart or by microfiche. Random test results and medical forms were selected for 2 to 3 years per individual. That data was then compared in an Access database to the OHS and Flow Gemini electronic data provided to RTI. PFT and liver test results were compared and all resulted with a match. Smoking data was compared by pulling two random medical questionnaires with an individual's smoking status and compared to the electronic data. It was found to only have one discrepancy. According to the electronic data, there should have been 11 current smokers, 4 ex-smokers, and 14 non-smokers. Smoking information abstracted from 2 medical forms for each individual indicated 12 current smokers, 4 ex-smokers, and 13 non-smokers. This could be attributed to not abstracting the full medical record for each year for each individual. Personal information filled out year by year by an individual tends to be inconsistent. Job titles were compared as well by abstracting personal information from a medical chart and comparing it to the job title FH provided to CH2M HILL. All job titles matched with a few exceptions of an individual calling themselves an engineer and the FH information representing them as an operating engineer.

APPENDIX C

ANALYSIS FILE CREATION

PULMONARY FUNCTION TEST ANALYSIS DATASET CREATION FLOWCHART

Subsetting Notes

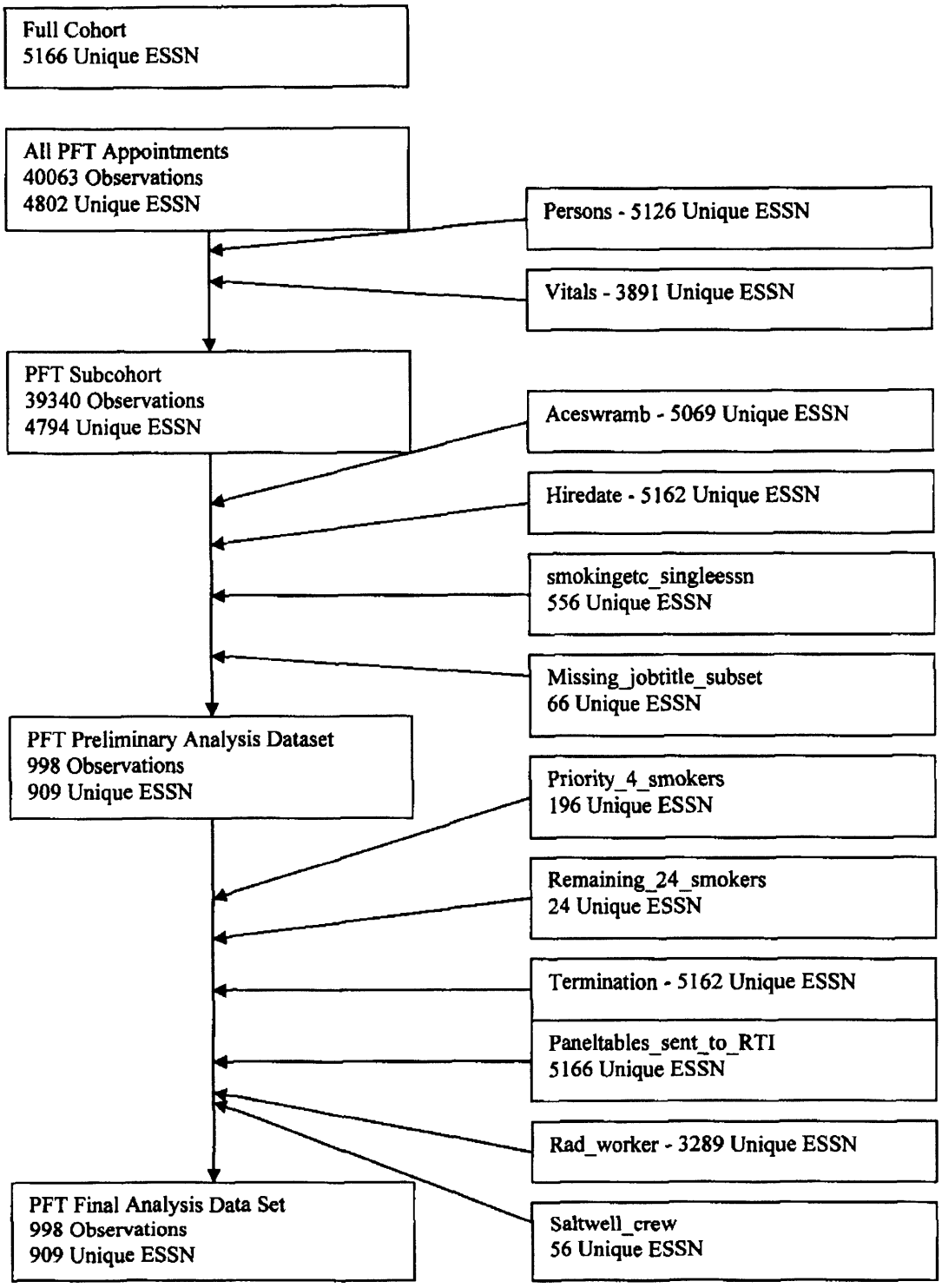
Subsetting from "All PFT Appointments" to "PFT subcohort" takes place as the data is subset to the time frame of interest. The subcohort is subset to all appointments prior to, and including, December 31, 2004.

Merging Data Set Notes

Below is the list of datasets merged onto the PFT cohort in preparation for the analysis file and the reasons they were merged in.

- Persons: To get birth year, gender, and smoking status information.
- Vitals: To get height information.
- Aceswramb: Originally the source of tank farm entry data.
- Hiredate: The primary source of employment information such as dates of employment start and employment end, and possible breaks in employment.
- Smokingetc_singleessn: Abstracted smoking and employment information.
- Missing_jobtitle_subset: Abstracted job title information.
- Priority_4_smokers: Abstracted smoking data.
- Remaining_24_smokers: Abstracted smoking data.
- Termination: Same as Hiredate data set except with a marker for whether the time period designated someone as active or not.
- Paneltables_sent_to_RTI: Final source of tank farm entry data.
- Rad_worker: List of workers who had radiological worker training, used for defining exposure.
- Saltwell_crew: List of members of the saltwell crew, used for defining exposure.

Figure C-1. Pulmonary Function Test Analysis Dataset Creation Flowchart.



LIVER FUNCTION TEST ANALYSIS DATASET CREATION FLOWCHART

Subsetting Notes

Subsetting from "All LFT Lab Outcomes" to "LFT subcohort" takes place for several reasons. The subcohort is subset to all appointments in the time frame of January 1, 1990, to December 31, 2004, inclusive. The subcohort is also subset to only those who have non-missing values for both birth year and the ratio of SGOT to SGPT values.

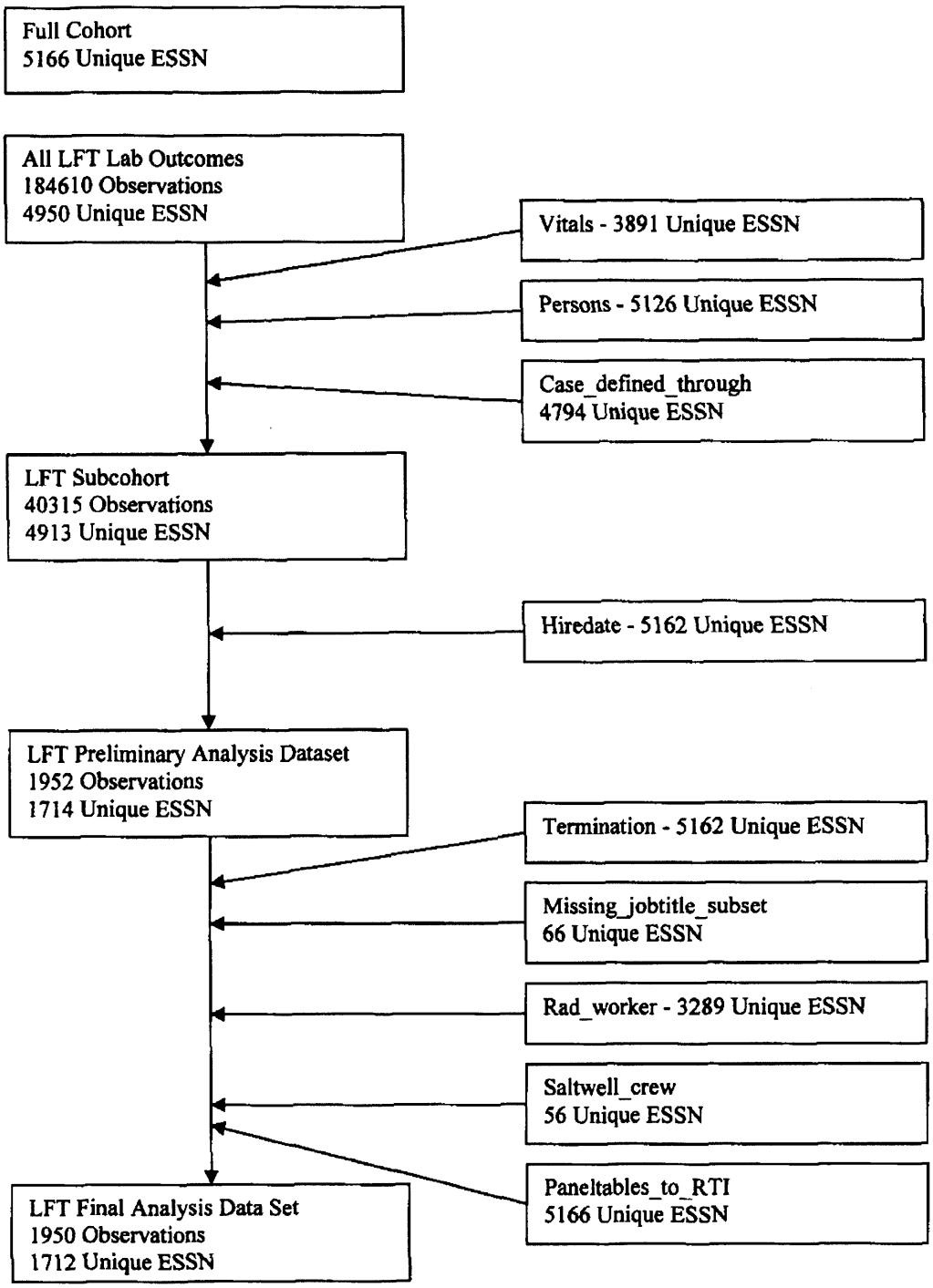
Subsetting from "LFT Preliminary Analysis Dataset" to "LFT Final Analysis Data Set" removes an individual case, and his risk set control, whose weight fell out of our desired allowable range of 90 to 400 pounds.

Merging Data Set Notes

Below is the list of datasets merged onto the LFT cohort in preparation for the analysis file and the reasons they were merged in.

- Vitals: To get height and weight information.
- Persons: To get birth year and gender information.
- Case_defined_through: To get imputed height information for use in calculating BMI.
- Hiredate: The primary source of employment information such as dates of employment start and employment end, and possible breaks in employment.
- Termination: Same as Hiredate data set except with a marker for whether the time period designated someone as active or not.
- Missing_jobtitle_subset: Abstracted job title information.
- Rad_worker: List of workers who had radiological worker training, used for defining exposure.
- Saltwell_crew: List of members of the saltwell crew, used for defining exposure.
- Paneltables_sent_to_RTI: Source of tank farm entry data.

Figure C-2. Liver Function Test Analysis Dataset Creation Flowchart.



APPENDIX D

LIST OF JOB CLASSIFICATIONS

APPENDIX D

LIST OF JOB TITLES AND CATEGORIES USED FOR JOB CLASSIFICATION

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Account Mgr	Admin	1
Activity Manager	Admin	1
Adm/Fac Svcs Spec	Admin	1
Administrative Spec	Admin	1
Analyst-Health Physics	Engineer/Scientist	1
Analyst-Telecommunicatns	Engineer/Scientist	1
Architect	Admin	1
Auditor	Admin	1
Boilermaker	Other craft	2
Boilermaker-Jrn	Other craft	2
Bus Driver	Driver/Equipment Operator	2
Business Systems Analyst	Admin	1
Carpenter	Carpenter	2
Carpenter-Apprentice	Carpenter	2
Carpenter-Jrn	Carpenter	2
Cement Finisher-Plstr-Jrn	Other craft	2
Cement Mason	Other craft	2
Chemical Technologist	Laboratory	2
Chief Engineer	Manager	1
Clerk	Admin	1
Clerk-Mail	Admin	1
Comm Spclst-Mstr Crftsmn	Other craft	2
Communications Spec	Other craft	2
Communication-Spclst	Other craft	2
Conductor	Driver/Equipment Operator	2
Construction Engineer	Engineer/Scientist	1
Construction Engr Assoc	Engineer/Scientist	1
Consultant	Engineer/Scientist	1
Consultant/Independent Assmnt	Engineer/Scientist	1
Contract Admin	Admin	1
Contract Rad Cntrl Technician	Health Physics Tech	3
Coord-Communications	Admin	1
Crane Operator	Driver/Equipment Operator	2

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Crane Oper-Process-Master	Driver/Equipment Operator	2
Decontam-Decomm Worker	Other craft	2
Deputy Mgr Tank Wst Rem Syst	Manager	1
Deputy Mgr WTF Transition Proj	Manager	1
Design Spec	Engineer/Scientist	1
Designer	Engineer/Scientist	1
Diesel Elec Loc Mech-Jrn	Driver/Equipment Operator	2
Diesel Elec Loc Mech-WL	Driver/Equipment Operator	2
Dir Adm/Fac Svcs	Manager	1
Dir Audit	Manager	1
Dir Communications	Manager	1
Dir Contracts	Manager	1
Dir Engineering	Manager	1
Dir Finance	Manager	1
Dir Info Svcs	Manager	1
Dir PUREX Transition Project	Manager	1
Dir Quality Assr	Manager	1
Dir Radiation Protection	Manager	1
Dir Solid Waste Disposal	Manager	1
Dir Technical	Manager	1
Dir TWRS Characterization Proj	Manager	1
Dir TWRS Oprns & Maint Prgms	Manager	1
Dir TWRS Plant	Manager	1
Dir/Mgr Operations	Manager	1
Dir/Mgr Planning/Scheduling	Manager	1
Dir/Mgr Safety	Manager	1
Director	Manager	1
Drafter	Admin	1
EDS-Hot Cell Technician	Laboratory	2
Electrician	Electrician	2
Electrician-Apprentice	Electrician	2
Electrician-Jrn	Electrician	2
Electrician-Jrn Safety Rep	Electrician	2
Electrician-Mstr Crftsmn	Electrician	2
Electrician-Wk Ldr	Electrician	2
Emergency Prep Spec	Field	2
Employee-Student-CA	Admin	1

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Employee-Student-CC	Admin	1
Employee-Student-CT	Admin	1
Engineer	Engineer/Scientist	1
Engineer Sr Prin	Engineer/Scientist	1
Engineer/Analyst	Engineer/Scientist	1
Engineer-Activity	Engineer/Scientist	1
Engineer-Contract	Engineer/Scientist	1
Engineer-Fire & Safety	Engineer/Scientist	1
Engineering Designer	Engineer/Scientist	1
Engineering Tech	Engineer/Scientist	1
Engineering Writer	Engineer/Scientist	1
Engineer-Plant	Engineer/Scientist	1
Engineer-Plant QC	Engineer/Scientist	1
Engineer-Project	Engineer/Scientist	1
Engineer-Rotational	Engineer/Scientist	1
Engineer-Software	Engineer/Scientist	1
Env Compliance Officer	Engineer/Scientist	1
Environmental Specialist	Engineer/Scientist	1
Estimator	Admin	1
Exec Secretary	Admin	1
Exec Vice President	Manager	1
Exempt	Admin	1
Fire Protection Engr	Engineer/Scientist	1
Firefighter Capt Tech Rescue	Fire/Patrol	2
Firefighter Captain	Fire/Patrol	2
Firefighter Captain Platoon	Fire/Patrol	2
Firefighter Capt-Plt Tech Resc	Fire/Patrol	2
Firefighter-Area	Fire/Patrol	2
Firefighter-Area I	Fire/Patrol	2
Firefighter-Area-Emt	Fire/Patrol	2
Firefighter-Area-EMT I	Fire/Patrol	2
Firefighter-Area-EMT II	Fire/Patrol	2
Firefighter-Area-EMT III	Fire/Patrol	2
Firefighter-Area-Emt WL	Fire/Patrol	2
Firefighter-Area-EMT WL III	Fire/Patrol	2
Firefighter-Lieutenant-Plt III	Fire/Patrol	2
Firefighter-Lieutenant-Pltn II	Fire/Patrol	2

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Firefighter-Paramedic-Pltn I	Fire/Patrol	2
Firefighter-Platoon-Emt	Fire/Patrol	2
Firefighter-Platoon-EMT I	Fire/Patrol	2
Firefighter-Platoon-EMT II	Fire/Patrol	2
Firefighter-Platoon-EMT III	Fire/Patrol	2
Glazier-Glassmaker-Spec	Other craft	2
HAMTC	Field	2
Hazardous Materials Spec	Field	2
Health Physicist	Professional - field	2
Health Physics Tech	Health Physics Tech	3
Health Physics Tech-Ld Assgnmt	Health Physics Tech	3
Health Physics Tech-Sr	Health Physics Tech	3
Heavy Duty Mechanic-Jrn	Mechanic	2
Heavy Duty Mechanic-Wk Ldr	Mechanic	2
Heavy Equip Parts Handler	Mechanic	2
Heavy Equipment Operator	Driver/Equipment Operator	2
HPT-Sr Safety Rep	Health Physics Tech	3
Hygienist-Industrial	Industrial Hygienist	2
Industrial Hygiene Tech	Industrial Hygiene Tech	3
Industrial Hygiene Technician	Industrial Hygiene Tech	3
Industrial Hygiene Tech-WL	Industrial Hygiene Tech	3
Industrial Hygienist	Industrial Hygienist	2
Inspector-Security	Field	2
Instructor	Admin	1
Instructor-Maintenance	Admin	1
Instructor-Operations	Admin	1
Instructor-Technical	Admin	1
Instrument Specialist	Instrument Specialist	2
Instrument Spec-Mstr Crftsmn	Instrument Specialist	2
Instrument Spec-Wk Ldr	Instrument Specialist	2
Insulator	Insulator	2
Insulator-Jrn	Insulator	2
Insulator-Wk Ldr	Insulator	2
Ironworker	Ironworker	2
Ironworker Rigger-Jrn	Ironworker	2
Janitor	Other craft	2
Laborer	Laborer	2

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Laborer-Apprentice	Laborer	2
Laundry Worker	Other craft	2
Lineman	Other craft	2
Lineman-Wk Ldr	Other craft	2
Locksmith-Safemaster-Jrn	Other craft	2
Locksmith-Safemaster-Wk Ldr	Other craft	2
Locomotive Engineer	Driver/Equipment Operator	2
LTA - Construction Engineer	Engineer/Scientist	1
LTA - Criticality Safety Engr	Engineer/Scientist	1
LTA - Designer	Engineer/Scientist	1
LTA - Engineer/Analyst	Engineer/Scientist	1
LTA - Engineering Tech	Engineer/Scientist	1
LTA - Engr - Civil/Structural	Engineer/Scientist	1
LTA - Engr - Electrical	Engineer/Scientist	1
LTA - Engr - Environmental	Engineer/Scientist	1
LTA - Engr - Mechanical	Engineer/Scientist	1
LTA - Engr - Nuclear Safety	Engineer/Scientist	1
LTA - Estimator	Admin	1
LTA - Industrial-Hygienist	Industrial Hygienist	2
LTA - Maintenance Spec	Field	2
LTA - Mgr Operations	Manager	1
LTA - Mgr Safety & Health	Manager	1
LTA - Operations Specialist	Field	2
LTA - Planner/Scheduler	Planner	1
LTA - Process/Spec Engr	Engineer/Scientist	1
LTA - Project Controls Spec	Planner	1
LTA - Project Mgr	Manager	1
LTA - Safety Engineer	Professional - field	2
LTA - Safety Specialist	Professional - field	2
LTA - Scientific Tech	Laboratory	2
LTA - Scientist	Engineer/Scientist	1
LTA - Superintendent D&D	Supervisor	2
LTA - Supervisor - Maint	Supervisor	2
LTA - Technical Specialist	Engineer/Scientist	1
LTA - Training Spec	Admin	1
LTA-Consult/Independent Assess	Engineer/Scientist	1
Lube & Tireman	Other craft	2

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Maintenance Specialist	Other craft	2
Manager	Manager	1
Manager - Maint	Supervisor	2
Manager - Maintenance	Manager	1
Marketing Services Rep	Admin	1
Material Control Spec	Admin	1
Material Coordinator	Admin	1
Mechanic-Auto-Jrn	Mechanic	2
Mechanic-Auto-Wk Ldr	Mechanic	2
Meter Relay Technician	Other craft	2
Meter Relay Tech-Wk Ldr	Other craft	2
Mgr 200A Evaporatr Trtmt Fclty	Manager	1
Mgr 200A Inact Fac Surv/Maint	Manager	1
Mgr Adm/Fac Svcs	Manager	1
Mgr B Shift	Supervisor	2
Mgr C Shift	Supervisor	2
Mgr CCS West	Manager	1
Mgr Characterizatn Proj ESQ	Manager	1
Mgr Charctrztn Equipmt Dev	Manager	1
Mgr Consequence Analysis	Manager	1
Mgr Construction	Supervisor	2
Mgr Construction Forces	Supervisor	2
Mgr Construction Services	Supervisor	2
Mgr Control Systems Engr	Manager	1
Mgr Crane & Rig Fab Serv	Manager	1
Mgr E Shift	Supervisor	2
Mgr Engineering	Manager	1
Mgr Environ Cleanup/Compl Proj	Manager	1
Mgr Environ Waste Operations	Manager	1
Mgr Environmental Projects	Manager	1
Mgr Er Field Sampling	Manager	1
Mgr Field Interg/Char Operns	Manager	1
Mgr FSAR Development	Manager	1
Mgr Grout Operations	Manager	1
Mgr Industrial Hygiene	Manager	1
Mgr Instrument & Elec Upgrades	Manager	1
Mgr Maintenance	Supervisor	2

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Mgr MWTF/CSTS	Manager	1
Mgr Operations	Supervisor	2
Mgr Operations-Platoon	Manager	1
Mgr PFP T Shift	Supervisor	2
Mgr Planning/Scheduling	Manager	1
Mgr Process/Spec Engr	Manager	1
Mgr Production Control	Manager	1
Mgr Progm Mgmt & Integration	Manager	1
Mgr Project II-KEH	Manager	1
Mgr Project Integration	Manager	1
Mgr Quality Assurance	Manager	1
Mgr Rad Cntl Proj Field Supt	Supervisor	2
Mgr Rad Engineering/Dosimetry	Manager	1
Mgr Radiation Protection	Manager	1
Mgr Radiological Control	Manager	1
Mgr Reqmts Mgmt/Communications	Manager	1
Mgr Risk Assessment	Manager	1
Mgr Safety	Manager	1
Mgr Safety/Environ Proj	Manager	1
Mgr Scientific	Manager	1
Mgr Senior Project-ICF KH	Manager	1
Mgr Sfty & Envrnmtl Documntatn	Manager	1
Mgr Solid Waste Training	Manager	1
Mgr Special Projects	Manager	1
Mgr Staff	Manager	1
Mgr SWM Operations Engineering	Manager	1
Mgr T Shift	Supervisor	2
Mgr Tank Farm Eco	Manager	1
Mgr Tank Farm Upgrades	Manager	1
Mgr Tech Writing/Editing	Manager	1
Mgr Technical Support	Manager	1
Mgr TF Restor/Safe Opertns Prj	Manager	1
Mgr Training	Manager	1
Mgr TWRS Equipment Engineering	Manager	1
Mgr TWRS Info Mgmt Systems	Manager	1
Mgr TWRS Project	Manager	1
Mgr West Tank Farm Trans Proj	Manager	1

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Mgr West TF Mechanical Maint	Supervisor	2
Mgr X Shift Health Physics	Supervisor	2
Millwright	Millwright	2
Millwright-Apprentice	Millwright	2
Millwright-Jrn	Millwright	2
Millwright-Wk Ldr	Millwright	2
Non Destructive Testing	Other craft	2
Non-Exempt	Admin	1
Nuc Chem Operator Safety Rep	NCO	3
Nucl Matrl Cntrl Spec	Field	2
Nuclear Chemical Operator	NCO	3
Nuclear Chemical Operator-Jrn	NCO	3
Nuclear Chemical Oper-Wk Ldr	NCO	3
Officer-Environmntl Compliance	Admin	1
Oiler-Heavy Equipment	Driver/Equipment Operator	2
Operations Specialist	Field	2
Operator	NCO	3
Operator Trainee	NCO	3
Painter	Painter	2
Painter-Carpet Instl-Jrn	Painter	2
Painter-Carpet Instl-Wk Ldr	Painter	2
Painter-Carpet-Instl Sfty Rep	Painter	2
Painter-Sign-Jrn	Painter	2
Personnel Escort	Field	2
Pipefitter	Plumber/pipfitter	2
Pipefitter-Apprentice	Plumber/pipfitter	2
Planner/Scheduler	Plumber/pipfitter	2
Plumber-Steamfitter-Jrn	Plumber/pipfitter	2
Plumber-Steamfitter-Wk Ldr	Plumber/pipfitter	2
Power Operator	Power Operator	2
Power Operator-Chief	Power Operator	2
Power Operator-Jrn	Power Operator	2
President & General Mgr-WHC	Executive	1
President/General Manager	Executive	1
Procurement Spec	Admin	1
Professional	Engineer/Scientist	1
Professional Support	Engineer/Scientist	1

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Project Administrator	Admin	1
Project Controls Engr	Admin	1
Project Controls Spec	Admin	1
Project Cost Analyst	Admin	1
Project Dir	Manager	1
Project Engr	Engineer/Scientist	1
Project Mgr	Manager	1
Property Administrator	Admin	1
Property Mgmt Spec	Admin	1
Quality Assr Engr	Engineer/Scientist	1
Quality Assr Tech	Quality Assr Tech	2
Quality Assurance Technician	Quality Assr Tech	2
Quality Control	Quality Assr Tech	2
RadCon Specialist	Health Physics Tech	3
Reactor Fuels Operator	NCO	3
Reactor Fuels Operator-Jrn	NCO	3
Reactor Operator	NCO	3
Records Management Spec	Admin	1
Regulatory Compliance Spec	Admin	1
Safety Spec	Professional - field	2
Salaried Non-Exempt	Admin	1
Scientific Tech	Laboratory	2
Scientist	Engineer/Scientist	1
Sec Police Officr/Canine Hndlr	Fire/Patrol	2
Secretary	Admin	1
Security Police Officer II	Fire/Patrol	2
Security Police Officer III-C	Fire/Patrol	2
Security Spec	Field	2
Senior Director	Executive	1
Sheetmetal Worker	Ironworker	2
Sheetmetal-Jrn	Ironworker	2
Spec-Haz Matrls Transptn	Field	2
Special Assistant to the Dir	Admin	1
Spec-Investigation	Admin	1
Spec-Photography	Admin	1
Spec-Photography Lab	Admin	1
Spec-Quality Assurance	Engineer/Scientist	1

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Spec-Video Producer	Admin	1
Sprinkler Fitter	Plumber/pipfitter	2
Sr Dir Project Controls	Executive	1
Sr Vice President	Executive	1
Sr. Technical Advisor II	Engineer/Scientist	1
Staff Assistant	Admin	1
Stationary Operating Engineer	Stationary Operating Engineer	2
Stationary Operating Engr/WTPO	Stationary Operating Engineer	2
Stationary Operating Engr-WL	Stationary Operating Engineer	2
Stock & Tool Attendant	Other craft	2
Storekeeper	Other craft	2
Substation Operator	Electrician	2
Substation-Elect-Jrn	Electrician	2
Substation-Elect-Wk Ldr	Electrician	2
Superintendent - D&D I	Supervisor	2
Superintendent Construction	Supervisor	2
Superintendent Construction-Sr	Supervisor	2
Superintendent Constructn-Prin	Supervisor	2
Superintendent-Construction	Supervisor	2
Superintendent-Operations	Supervisor	2
Supv Hanford Patrol Ops	Fire/Patrol	2
Supv Health Physics	Engineer/Scientist	1
Supv Operations	Supervisor	2
Supv Radiation Protection	Supervisor	2
Surveyor	Field	2
Switchman	Other craft	2
Systems Engineering Mgr	Manager	1
Teamster	Driver/Equipment Operator	2
Tech-Audio/Visual	Admin	1
Tech-Drafting	Engineer/Scientist	1
Tech-Engineering	Engineer/Scientist	1
Technical Spec	Engineer/Scientist	1
Technical Specialist	Engineer/Scientist	1
Technical Writer/Editor	Admin	1
Tech-Quality Assurance	Quality Assr Tech	2
Tech-Scientific	Laboratory	2
Tech-Summer	Laboratory	2

Table D-1. Job Titles and Categories Used for Job Classification. (11 Sheets)

Job Title	Generic Title	Value*
Track-Inspector	Field	2
Training Spec	Admin	1
Truck Driver-Heavy	Driver/Equipment Operator	2
Truck Driver-Heavy-Wk Ldr	Driver/Equipment Operator	2
Truck Driver-Hvy-Safety Rep-WL	Driver/Equipment Operator	2
Truck Driver-Light	Driver/Equipment Operator	2
Undergraduate-Intern	Admin	1
Vice President	Executive	1
Vice President/Chief Counsel	Executive	1
Vice President/Chief Engineer	Executive	1
VP & Mgr TWRS	Executive	1
VP Finance	Executive	1
VP Human Resources	Executive	1
Welder-Blmkr-Jrn	Other craft	2
Welder-Plbr Fitr-Jrn	Other craft	2
Work Activity Planner	Planner	1

Note:

* Value of 1 = Lowest Potential Exposure, 2 = Medium Potential Exposure, 3 = Highest Potential Exposure