A Needs Assessment for Medical Screening of Construction Workers at the Portsmouth and Paducah Gaseous Diffusion Plants

Introduction

In 1993 the U.S. Congress enacted Section 3162 of the Defense Authorization Act, which directed the Department of Energy (DOE) to initiate programs to evaluate the health of former DOE defense nuclear facility workers. Consistent with the mandate to DOE from Congress, this project implements a notification, health evaluation (including medical screening) and intervention program for former building and construction trades workers at the DOE Oak Ridge, TN site and the Gaseous Diffusion Plants (GDP) at Portsmouth, OH and Paducah, KY, who may have been exposed to health hazards as a result of work at these sites. Based on congressional language, current workers at GDP's may request exams.

The specific aims of this Needs Assessment are outlined in the following tasks:

1. Review of existing site-specific information.
2. Identify most significant radiation and non-radiation exposures, problems, and concerns.
3. Identify and develop viable means of contacting former construction workers.
4. Identify approaches for conducting the project in partnership with interested parties.
5. Attend meetings of DOE investigators.

A consortium led by the University of Cincinnati has demonstrated both the feasibility and the benefits of conducting medical screening for former construction workers at several DOE sites. We have successfully operated such a program for former construction workers at DOE's Oak Ridge K-25, X-10 and Y-12 sites since 1998. In so doing, we have learned and documented important lessons about how such a task can best be approached.

This report provides important background information to support such a program for construction workers at the Portsmouth Gaseous Diffusion Plant in Ohio and the Paducah Gaseous Diffusion Plant in Kentucky. This information documents both the value of conducting such a project, and the feasibility of the proposed approach.

This Needs Assessment builds on a Needs Assessment for former construction workers at the Oak Ridge Reservation (K-25, X-10, and Y-12), the Former Worker Screening Program for construction workers at Oak Ridge, (the approach and outcomes) especially at the K-25 site which is a Gaseous Diffusion Plant (GDP), and the Needs Assessment and medical findings by the PACE program for production workers at the Portsmouth and Paducah GDP's. The information collected by these programs has been particularly important to the tasks of identifying existing information relevant to exposure and health outcomes and providing an initial determination of the most significant worker hazards, problems, and concerns, and most effective approaches for partnering with interested parties.

The experience of the University of Cincinnati consortium in providing medical screening for former construction workers at the Department of Energy's Oak Ridge sites—and specifically former construction workers whose predominant exposures occurred at the K-25 gaseous diffusion plant—provides strong evidence of the value to be realized by implementing a similar program for construction workers at the Portsmouth and Paducah gaseous diffusion plants.

Identify Information Relative to Exposures and Health Outcomes

Special Issues for Construction Workers and Trade-Specific Exposures

This project is limited to building and construction trade workers who have been employed mainly by subcontractors at DOE sites in Paducah, Kentucky and Portsmouth, Ohio. The building trades have a long history of concern for their members on DOE sites. Implementing this type of program for building and construction trades workers poses a number of unique challenges that cannot easily be addressed in general programs aimed mainly at permanent site production and management employees:

- According to DOE, it is likely that the greatest risks to workers on its sites involve mainly the construction workers, including those who are involved in decommissioning, dismantling of facilities, and in maintenance or repair activities (1).
- Because numerous subcontractors employed these workers, records of their employment histories at the sites may be virtually non-existent.
- Building and construction trades workers are members of fifteen different unions that have traditionally operated autonomously and separately from the industrial workers on site. The University of Cincinnati, together with our consortium partners, has demonstrated our ability to create programs that have the broad support of all the building trades unions who will be required to identify and notify the workers who have been employed in the past.

Exposure data have been demonstrated to be very limited for construction workers at DOE sites, especially in the earlier years of construction and renovation. This is even true of radiation exposure data, as construction workers were often not considered to be "radiological workers" during the early years when the bulk of construction activity occurred. Even if available, data do not generally cover incidents where construction workers Adiscover@ contamination or are on-site during unplanned releases.

In addition to exposures related to the unique aspects of construction work at DOE sites, the exposures that former construction workers experienced at Portsmouth and Paducah are very dependent upon their specific trades and the technologies and materials employed in those trades at the time. Painters would have been likely to have significant solvent exposure, carpenters significant asbestos exposure from cutting and otherwise working with transite materials, and insulators significant asbestos exposure from their work in applying thermal insulation. A useful compendium of information on the types of exposures, by trade, in the early years of construction work at a DOE site (Hanford) is especially helpful in this regard. Wing and Wolf at the University of North Carolina at Chapel Hill have provided access to information abstracted by them for other DOE-supported studies (HEXFILE) (Appendix 1). It is likely that the range of craft-specific hazard rating values from the HEXFILE is fairly representative of types of exposures that would have occurred at Portsmouth and Paducah during construction within the same time period (1950's-1970's).

History of Portsmouth Gaseous Diffusion Plant

In August 1952 the Atomic Energy Commission selected a tract of land near Piketon, Ohio in Pike County, approximately 25 miles northeast of Portsmouth, Ohio, as the location for the Portsmouth Gaseous Diffusion Plant. The entire site is approximately 3,714 acres, of which 640 are occupied by the plant and 93 acres contain the plant process buildings. Site selection was based on the availability of a large expanse of relatively flat ground, large amounts of electrical power, a dependable source of water, local labor, and suitable transportation routes. The purpose of the Portsmouth Gaseous Diffusion Plant was to produce uranium enriched in the uranium-235 isotope (U-235) to be used in the production of nuclear weapons; but in the mid-1960's the mission changed to producing fuel for commercial nuclear power plants (2).

Peter Kiewit & Sons of Nebraska began work in 1952 and completed the plant in March of 1956 at a cost of $1.2 billion (3). Construction required 69 million man-hours, with a workforce that peaked at 22,500 construction workers in the summer of 1954. Construction workers were continuing their work when the first production cells went "on stream" in September 1954 (4). The plant eventually consisted of 109 permanent buildings, containing over 10 million square feet of floor area (5).

In September 1952, AEC officials selected Goodyear Tire & Rubber Corp. as the operating contractor. Goodyear created the Goodyear Atomic Corp., which operated the plant until November 1986 when Martin Marietta Energy Systems, Inc. took over operations (4).

Portsmouth Gaseous Diffusion Plant underwent a major facility upgrade program between 1974 and 1981. This program was referred to as the "Cascade Improvement Program/Cascade Uprating Program" (CUP/CIP). The CIP program involved the installation of improved barriers in the process equipment and modification to the compressors, piping and cooling systems. The CUP program involved the uprating of electrical equipment and increasing the efficiency of the process cooling system. The Upgrade processes required opening, purging, and performing work internal to the system on a scale, frequency, and degree of invasiveness not encountered during routine operations and maintenance. This increased the number of workers, including construction workers, that could be exposed to numerous hazards including fluorine containing materials associated with the release of UF_6, or from process equipment conditioned and maintained using fluorine gas. A Gaseous Centrifuge Enrichment Plant

(GCEP) was constructed in the early 1980s. This facility only operated for its initial testing, and was never used for production (5).

History of Paducah Gaseous Diffusion Plant

The Paducah Gaseous Diffusion Plant is located in McCracken County, Kentucky, approximately ten miles west of the City of Paducah and three miles south of the Ohio River. The site occupies about 3,425 acres, 750 of which are within a security fence, and contains uranium enrichment process equipment and support facilities (6).

In August 1950, the U.S. government determined that it would need to double the capacity for domestic fissionable materials production that existed at the Oak Ridge K-25 Plant. The Atomic Energy Commission (AEC) selected a design for what would become the Paducah Plant's Building C-331, consisting of 400 stages modeled after the K-31 building at the Oak Ridge K-25 Plant, and for Building C-333, consisting of 480 stages—twice the size of the Oak Ridge K-31 building. In December 1950 the site formerly used by the Kentucky Ordnance Works in Paducah was chosen for the location of the new plant (6). F. H. McGraw and Co. of Hartford, CT was awarded the construction contract. Carbide and Carbon Chemicals Co. was named operating contractor for the more than $800 million project. Eventually there would be 161 buildings of which four were cascades (7).

The initial construction of the Paducah GDP lasted from1951 through 1956 and was conducted in two phases. Construction of the first phase began January 2, 1951, and included erection of the following process and production facilities: C-331 and C-333 (the gaseous diffusion process buildings), C-410/420 (UF6 Feed Plant), C-310 (Purge and Product Withdrawal Building), C-315 (Surge and Waste Building) and C-300 (Central Control Building). Union Carbide began to hire approximately 1,700 permanent plant workers in 1951. The first process buildings, C-331, C-333, C-310, and C-315 were completed and started operations in September 1952, and the first product was withdrawn in November of that year (6). The first 2.5-ton product cylinders with partially enriched uranium were shipped to Oak Ridge (7). Authorization to proceed with the second phase of plant construction was received on July 15, 1952. Two additional enrichment cascades, C-335 and C-337, were added and construction was completed (6). Construction workers were on site after the first two buildings were operating to build the second two.

In the 1960's, the Paducah plant's mission changed from enriching uranium for nuclear weapons to producing fuel for commercial nuclear power plants. For most of their history, the Paducah GDP and its sister plant in Ohio, the Portsmouth Gaseous Diffusion Plant, worked in tandem. Uranium-235 is highly fissionable, unlike the more common isotope uranium-238. Enrichment involves increasing the percentage of uranium-235 in the material (UF6) used for creating reactor fuel (4). Paducah enriched uranium-235 from about 0.7% uranium-235 to a range from 1.95% to 2.75% U-235. The product, low enriched uranium (LEU), was then shipped to Portsmouth for further enrichment to up to 5% uranium-235. Paducah has processed more than 1,000,000 tons of uranium, about one-third of which went to Portsmouth for further enrichment. The process of enriching uranium involves heating UF6 into a gas, which is in turn fed through a series of diffusion stages. Paducah has over 1,800 diffusion stages while Portsmouth has 4,000 diffusion stages. The diffusion process generates enriched uranium product and tails. The tails, typically containing less than 0.5% uranium-235, remain on site in cylinders (2) (6).

In 1984, Martin Marietta Energy Systems took over Union Carbide's operating contract, and in July 1993, USEC assumed responsibility for Portsmouth and Paducah gaseous diffusion plants. The Department of Energy retains responsibility for environmental restoration and waste management activities at the sites (7).

Exposures at Portsmouth

Many operations and maintenance activities at Portsmouth involved hazardous conditions and the potential for exposure of personnel to chemical and physical hazards including radioactivity. Numerous plant facilities had the potential for exposures to toxic and radioactive materials, e.g., cascade and other process buildings, a feed manufacturing plant, an oxide conversion plant, decontamination, cleaning, and uranium recovery facilities, a smelter, and incinerators. Conditions in many work areas were extremely hot, dusty, and noisy. Leaks and off-gassing from process equipment or components being repaired or modified exposed workers to airborne uranium, transuranics, fission products, fluorine, and hydrogen fluoride (HF) gas. Many other hazardous materials and chemicals such as asbestos, trichloroethylene (TCE) and other solvents, polychlorinated biphenyls (PCBs), acids, chromium, nickel, lithium, welding fumes, gases, and mercury were present. Spills or releases of radioactive and hazardous materials frequently entered the work environment (2).

One of the most hazardous operations at Portsmouth involved the operation of the oxide conversion plant. Decontamination of process equipment in X-705 and similar activities elsewhere involved potential exposures to hazardous solvents and generated the largest amount of radioactive and hazardous liquid waste on site. Personnel performing instrument calibration and trap cleaning were frequently exposed to mercury. Welders were exposed to asbestos fibers and noxious fumes from welding on materials containing various nickel compounds and Freon® piping, and PCB-contaminated oils posed long-term personnel exposure hazards. Hundreds of UF6 releases occurred from equipment failures and during maintenance, sampling, cylinder handling, and connection and disconnection of feed and product cylinders. They contaminated the environment and work area, and caused many intakes of uranium and HF burns (2).

Maintenance and process system modification activities resulted in much of the radiation exposure, airborne contamination, and releases of UF6 at Portsmouth. The gaseous diffusion cascades are large complexes with thousands of components. Maintenance and modifications of these often required construction workers to open systems that contained UF6, deposited uranium compounds, technetium, or other hazardous materials. Many components were removed from the cascades and taken to shops for decontamination, repair, or replacement. Welding, cutting, grinding, decontamination, and "pipe crawling" (all construction worker tasks) to remove debris and perform maintenance led to many hazardous conditions and opportunities for exposure. Workers were regularly exposed to UF6, HF, TCE and other solvents, PCB-contaminated oils, welding gases, mercury, and other toxic metals (2).

Exposures at Paducah

Information on worker exposures to ionizing radiation at Paducah can be found in a report, *Exposure Assessment Project at the Paducah Gaseous Diffusion Plant*, by PACE and the University of Utah (8). This report is concerned with internal and external exposures to ionizing radiation. While the focus is on production workers, construction workers in carrying-out their trades and tasks would be in the same work environments. Information on the "radiation" buildings and areas where the highest exposures to radiation and radioactive materials would have been likely to occur is identified.

The report indicated areas with "moderate" to "high" potential for increased internal and external radiation exposures. These included the Feed Plant (C-410/420), Decontamination Building (C-400), Metals Building (C-340), and the Cascade Buildings (C-331, C-333, C-335, and C-337). From the written and electronic records, the report noted, it is apparent that there was a potential for increased external radiation exposures in Buildings C-410/420, C-400, C-340 and C-720 (8).

Maintenance on major components in the cascade (compressors, converters, and process block valves presented some of the most significant opportunities for exposures of Paducah GDP maintenance personnel during the Cascade Improvement Program (CIP) and Cascade Uprating Program (CUP). Workers opening cells and dismantling cell components could be exposed to UF6, HF, UO2F2, and to a lesser extent, transuranics and fission products (9). The first CIP/CUP at Paducah began in 1954, before the plant was completed. Major components were replaced to increase diffusion process reliability. In 1973, the most extensive campaign was initiated to improve Paducah technology and exchange or replace aging equipment. All of the industrial, radiological, and chemical hazards discussed for normal compressor and converter maintenance were present with an additional challenge of a demanding, manpower-intensive schedule for completing each task. Original cell components were disassembled, cleaned, modified, refurbished, reassembled, conditioned, and pre-positioned for another cell change-out, even as the original cell was being repopulated. Many workers were hired to support CIP/CUP, but they never received the same level of training as older workers. Cell housings were opened even as operators worked to establish a UF6 negative. New workers were told to rely on older workers to learn their jobs, principally through on-the-job training (6).

Surveys, performed as recently as 1991, indicate transuranic materials in many of the process buildings at the site. It was determined that some workers could have had internal radiation exposures that may have exceeded regulatory limits. This may include on the order of 10% of the 2,500 to 4,000 workers with the potential for increased radiation exposures. Some of the areas where workers were more likely to have had increased internal radiation exposures included C-400, C-410/420, C-340, C-720 Converter Shop and Cascade Maintenance (8)

Work areas with potential for elevated worker radiation exposures were identified from worker interviews, dosimetry database queries and historic health physics summary reports and inspection reports, and included: Feed Plant (C-410/420), Decontamination Building (C-400), Metals Building (C-340), and the Cascade Buildings (C-331, C-333, C-335, C-337) (8).

Worker interviews emphasized that contamination control was limited. Personnel monitoring (frisking) did not occur routinely until the 1990s. Respirator usage was reported as inconsistent. Workers noted that radiation monitoring badge readings in excess of the limits were in many cases assumed to be invalid (8)

Database Of Portsmouth And Paducah Building Histories And Exposures

Medical screening of construction workers at Oak Ridge (University of Cincinnati), Hanford and Savannah River Site (CPWR) starts with worker interviews to obtain work/occupational exposure histories. These histories are used to select the medical examination/testing procedures that are based on the individual's history of workplace exposures. The worker interview provides information for this selection in two ways: (1) the interview identifies specific hazardous conditions or work practices that suggest screening procedures; and (2) the interview identifies buildings or facilities where the worker spent significant time, and background research identified certain hazardous conditions that existed in those buildings during the time when the worker was present. (Former construction workers did not always know what activities were taking place, other than those that directly involved them.)

To facilitate the use of building information during the worker interview, the University of Cincinnati has begun developing institutional history databases on the Portsmouth Gaseous Diffusion Plant and Paducah Gaseous Diffusion Plant. Researchers begin by accumulating available unclassified documents for each site, e.g., Reading Rooms, libraries, the Internet, old needs assessments, etc. Information is extracted on dates of construction and renovation, construction materials used, size of facility and unique features, functions or processes, contamination incidents or accidents, known or documented physical and/or chemical hazards, with references for each citation. Industrial hygiene and safety experts may add inferred hazards based on their experience and knowledge of the site. Information on each facility at a site is updated as new information is obtained. The Needs Assessment for Portsmouth and Paducah prepared by PACE was used as a source of additional information for the databases. Information derived from risk mapping has been included in the databases. Samples of the pages for selected buildings at Portsmouth and Paducah can be found in Appendix 2.

Health Outcomes Relevant To Construction Workers At Portsmouth And Paducah

The screenings by PACE at Portsmouth and Paducah (10, 11) have produced findings that are significant for possible exposure of construction workers to beryllium:

(1) Medical screening by PACE at Portsmouth has found evidence of beryllium sensitization in 21 of 934 workers. Seventeen of 934 had one abnormal test result. (Five of the seventeen had not yet been tested a second time.) The four included a machinist, a chemical operator, a "mobile mechanic" who worked in all buildings, and a worker who had been both a maintenance mechanic and a chemical operator.

Medical screening by PACE at Paducah has found evidence of chronic beryllium sensitization in 37 of 995 workers. Thirty-one had one abnormal test result. (Ten of the thirty-one had not yet been tested a second time.) Most of the six with two abnormal test results had been mechanics or technicians, including one who for most of his tenure at Paducah had been a construction worker.

(2) Occupational exposure histories, risk mapping sessions, and DOE investigation reports have been used to identify the buildings at Portsmouth and Paducah where the most former workers reported exposure to beryllium.

Worker interviews, risk mapping, and DOE records (Table 1) indicate a potential for beryllium exposure that was finally identified a year after the PACE screening began.

Table 1.

	Risk Mapping	DOE Investigations	Worker Interviews
X-720	Machining	Machining	19/64 exposure reports
X-326, X-330, X-333			18/64 exposure reports
X-705			14/64 exposure reports
X-700			6/64 exposure reports
X-710			5/64 exposure reports

Table 2 summarizes the most significant findings by PACE from the three different sources of information about beryllium exposures at Paducah.

Table 2.

	Risk Mapping	DOE Investigations	Worker Interviews
C-720	Machining	Machining	46/108 exposure reports
C-400			22/108 exposure reports
C-410/420			13/108 exposure reports
C-331,333/335			10/108 exposure reports
C-746 Smelter Bldg.	Be components handled	Received Be-contaminated foam, plastics	8/108 exposure reports
C-710	Plating		4/108 exposure reports

Evidence Of Beryllium Exposure To Former DOE Construction Workers At Oak Ridge

The University of Cincinnati consortium's own experience in screening former construction workers for beryllium sensitization in Oak Ridge demonstrates that construction workers have in fact come into significant contact with beryllium in these facilities. Of 1,445 former construction workers screened for beryllium sensitization, 22 have had a single abnormal BeLPT test result; of those, 16 have been confirmed by a second abnormal BeLPT result. Of eight who have completed clinical evaluation, one has been diagnosed with chronic beryllium disease. This rate of confirmed positives in construction workers is similar to that seen in the PACE populations of production workers at the Oak Ridge K-25, Portsmouth and Paducah GDP's (Table 3) (12) although the development of CBD appears less at this time in construction workers.

Table 3.

	AGGREGATE NUMBER SINCE START OF SCREENING
Number of participants who received one or more beryllium screening exams	4514
Single Be-LPT- abnormal participants	192
Confirmed Be-LPT- abnormal participants	66
Be-LPT- abnormal participants who have completed clinical evaluation for CBD	42
Single borderline abnormal participants	135
Participants with a reported diagnosis of chronic beryllium disease (CBD)	9

Outcomes From Screening at a Gaseous Diffusion Plant at Oak Ridge (K-25)

The results of the University of Cincinnati consortium's medical screening of former construction workers in Oak Ridge provides an excellent basis for predicting the health outcomes that are likely to occur in the Portsmouth and Paducah cohorts of former construction workers. Oak Ridge had significant construction activity that would have used essentially the same materials (for example, transite sheet and asbestos thermal insulation material) and technologies as at Portsmouth and Paducah. In addition, the K-25 gaseous diffusion plant used essentially the same technology as the Portsmouth and Paducah sites, and was for the most part constructed at about the same time, so site-specific hazards would likely have been similar.

In Oak Ridge, fewer than 10% of the construction workers had worked at only one of the sites (X-10, Y-12 or K-25). So it is difficult to differentiate outcomes related to a specific site. The results for the Oak Ridge cohort as a whole show that in 1,476 completed medical examinations, the most prevalent diagnoses are:

Sensorineural hearing loss	784	53%
Arthritis, degenerative joint disease	482	33%
Asbestosis	266	18%
Chronic obstructive lung disease	174	12%
Chronic bronchitis	167	11%

Thus, it is readily apparent in this overall group of former DOE construction workers that the most common health outcomes possibly related to their work are those that may be related to occupational noise exposure—ubiquitous throughout the construction industry, musculoskeletal problems, many of which demonstrated in construction workers to be related to repeated trauma in their work, and respiratory disease associated with exposure to dusts and welding fumes. In particular, note that 18% of all former Oak Ridge construction workers screened had been diagnosed with asbestosis. These results are presented in more detail in Appendix 3.

Among a group of 1,254 construction workers screened who had worked 5 years or more at Oak Ridge, 170 have cancers that are listed as compensable under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA). These 170 cases may have had exposures at the site that contributed to their disease.

It is possible to use work histories from the Oak Ridge cohort to identify those former construction workers who worked primarily at K-25 (See Appendix 4), to determine how their health outcomes differ from the Oak Ridge cohort as a whole. The most prevalent health outcomes for the workers whose three longest jobs at the Oak Ridge Reservation were at the K-25 Gaseous Diffusion Plant are:

Sensorineural hearing loss	192	61%
Arthritis, degenerative joint disease	122	39%
Asbestosis	63	20%
Chronic obstructive lung disease	38	12%
Chronic bronchitis	40	13%

It appears, then, that there is a consistent pattern of illness among the former Oak Ridge construction workers that does not change much based on whether their primary workplace was at the gaseous diffusion plant, or at the other sites (X-10, Y12). We predict that a similar pattern of disease will be found in the former construction workers at the Portsmouth and Paducah gaseous diffusion plants. A high prevalence of diagnosed asbestosis among former Oak Ridge and K-25 construction workers demonstrates a need and justification for a medical screening program for the former Portsmouth and Paducah construction workers.

Reports of Epidemiologic Studies and Oversight Investigations

Epidemiologic studies of workers at Department of Energy sites have rarely included construction workers. Nonetheless, awareness of the findings of studies of production and other workers can provide some insight into site-specific health hazards to which construction workers may be exposed.

Plant or process-specific and reservation-wide cohort mortality studies have been conducted at Oak Ridge. Among K-25 employees, excess mortality has been shown among production workers, including statistically significant excess risks of malignant and non-malignant respiratory diseases and bone cancer (13). Among K-25 personnel exposed to nickel powder in manufacture of the barrier material, there was no increased mortality; however non-statistically significant mortality due to cancers of the buccal cavity, pharynx and digestive system was observed in nickel workers compared with those not exposed (14). Reservation-wide evaluation of the mortality of welders showed no increase in SMRs for lung cancer and diseases of the respiratory system among those employed at K-25 and presumably exposed to nickel, compared with employees at other plants on the Oak Ridge Reservation (15). An update of this study (16) provided evidence of increased risk of lung cancer and prostate cancer, although neither increase appeared to be related to surrogates of nickel exposure, e.g., duration. White males exposed to mercury were not found to have excess deaths from diseases of the liver and kidney, central nervous system (14); however, there was suggestion of an association between mercury exposure and brain cancer. An excess in lung cancer was not related to intensity or length of exposure in the mercury-exposed cohort study (14). Excess mortality primarily due to lung cancer and diseases of the respiratory system has been shown among white males employed at least one month at any of the three Oak Ridge plants (17).

Brown and Bloom in 1987 (18) conducted a retrospective cohort mortality study at Portsmouth Gaseous Diffusion Plant. Primary hazards included inhalation exposure to uranyl fluoride containing uranium-235 and uranium-234, technetium-99 compounds, and hydrogen fluoride. Uranium-238 presented a nephrotoxic hazard. Analysis covered the period from September 1, 1954 to December 1982. White males working for at least 1 week during this time were included (total 5,773). Statistically significant mortality deficits were found for all causes, accidents, violence, and diseases of nervous, circulatory, respiratory, and digestive systems based on U.S. death rates. Deaths from stomach cancer and lymphatic/hematopoietic cancers were insignificantly increased. In 1996, Rinsky (19) reported on and updated the work of Brown and Bloom. The cohort consisted of all employees who worked at least one day at the facility between September 1954 and December 31,1991. The final cohort included 8,877 individuals. Rinsky used industrial hygiene and health physics data to assess mortality risk by exposure. He used the data from urine alpha counts for uranium, and specific chemical exposures. He noted limitations. All samples were area samples and it was a crude process to apply the data to departments, job titles, or individuals. Some years, few samples were taken. Data for nickel was so limited that it was dropped. There were 1,088 deaths, or 12%, in the cohort during the study period. Overall mortality and death rates by major category of disease were significantly lower in the cohort compared to the U.S. population in general. There were small excesses that were not statistically significant for selected cancers including stomach, female genital organs, bone, lymph-reticulosarcoma, and Hodgkin's disease.

The National Institute for Occupational Safety and Health (NIOSH) conducted an updated study of mortality at the Portsmouth Gaseous Diffusion Plant in Piketon, Ohio published July 2000 (5). Overall mortality was significantly less than expected, as was the death from "All Cancers" including stomach and lympho-hematopoietic tissue cancers, both of which had been noted in an earlier NIOSH study of the facility. The authors of the study acknowledged a number of limitations to their study including an early assessment of the cohort. Only 12% of the cohort was deceased December 31, 1991. Less than a third of the person-years occurred after 20 years of latency. The workers were younger than some other sites. Another issue was the presence of the healthy worker effect bias. The exposure data was collected for compliance purposes and not epidemiological application or in some cases there was no personal data available, and estimates were made by complex models. There was essentially complete lack of information about concomitant exposures resulting from non-inventoried chemicals, neutron, and medical exposures, and transuranics. Lastly, the inability to study an illness that does not result in death limited the work (5).

Cardarelli (20) reported on an evaluation of worker exposure at Portsmouth. He discovered that a potential chronic low-level neutron exposure existed where uranium was stored, handled, or solidified within the cascade. Areas most likely associated with neutron exposures include the Feed and Withdrawal areas, cylinder storage yards, and places where uranium deposits were formed within the cascade. Area neutron doses ranged from less than the detection limit (0.2 mSv) to 7.1 mSv and varied with the amount of uranium present. Its enrichment level, geometric configuration, and time spent near the source. While area measurements confirmed the presence of a chronic low-level exposure to neutrons, all personal doses were below the limit of detection.

It was reported in medical screenings performed in the 1990's by a law firm that asbestos disease was found at the three Gaseous Diffusion Plants at Oak Ridge K-25 (1990), Paducah (1991), and Portsmouth (1997). How workers were selected for participation is not known. The job titles participating included most maintenance trades as well as some operators. The prevalence of asbestos related fibrosis on chest X-ray was 85/147 (58%) at Oak Ridge; 49/316 (16%) at Paducah; and 107/296 (36%) at Portsmouth (21).

Mortality is the endpoint usually reported. Exposures at any of the plants could be associated with morbidity, which might not be a cause of death and hence be missed in studies limited to causes of death. For example, nickel is associated with skin disease, which would not be fatal. Not all cancer hazards at Portsmouth are from radiation. Known or suspected non-radiation lung carcinogens used include asbestos, beryllium, machining fluids. Brain cancer has been associated with solvents and metal machining operations and among maintenance personnel throughout the reservation (22).

<u>Radiological Hazards</u>

The radioactive hazards associated with Portsmouth operations and supporting activities include uranium, uranium compounds, and its daughter products, transuranics, and fission products. From 1957 into the mid-1960s, numerous studies found low concentrations of these impurities in incoming reactor tails. They tended to concentrate in certain areas of the oxide conversion plant, cascade, equipment, and process piping (2). The Portsmouth Oversight report indicates that Plant management was aware since the 1960s that transuranics and fission products had been introduced into Plant facilities as early as 1957, until 1975 radiological effluent monitoring was only conducted for uranium isotopes and related indicator parameters. In 1975, technetium-99, and subsequently transuranics contamination, was unexpectedly discovered in liquid effluents from X-705. Technetium was also detected in airborne discharges. In 1980, analysis of cascade deposits confirmed the presence of neptunium and plutonium in the process system. While Goodyear Atomic Corporation management was aware of transuranics and technetium contaminants from incoming feed materials, they failed to recognize or evaluate potential radiological problems resulting from their concentrations in the cascade (2).

The quality of monitoring at Portsmouth was questionable as can be seen from the testimony of Jeff Walburn at the DOE Public Meeting on October 30, 1999 who revealed that, "in 1996 two dosimetry people – and that is the badge that you wear, the one thing we trusted on that site to tell us if we had an uptake of uranium – came forward and said, 'two men came to us to zero your readings because you are going to file suit'." He subsequently testified that he later learned that badges were routinely changed. "And so the badges were put in an administrative bucket dose. We got buildings a quarter of a mile long. If someone got in the PW, they would average two other people somewhere down the other end of the building and assign that dose to the man. So he didn't get his own dose. He got two other people's dose, the average." (23)

Uranium

Uranium is a naturally occurring element that is mined for commercial purposes. Natural uranium is 99.3% percent uranium-238 (U-238) and 0.7% uranium-235 (U-235). U-235 is used as nuclear reactor fuel. Enriched uranium contains more U-235 and depleted uranium contains less U-235 than natural uranium. U-238 has a radioactive half-life of 4.47 billion years (2)(6).

Many opportunities for uranium exposure existed during the enrichment process at the GDP's. While UF6 is the material used during enrichment, other chemical forms of uranium exist in the process. Each form presents different risks to the workers. All of the uranium isotopes emit alpha particles during radioactive decay, so they should be considered to have tumorigenic potential (5). Once in the body, uranium may concentrate in the kidneys, bones, or lungs depending on its solubility (2)(6).

Neutron exposure went virtually unmonitored at all gaseous diffusion plants, and it is unclear whether there is a realistic way to reconstruct this exposure over the years at the site. The assay process areas and the product withdrawal, sampling and storage area are of particular concern (21). For insoluble forms, radiation doses to the lung are a predominant concern (2). Animal studies have shown metaplastic changes in lung epithelium and lung tumors. Generally speaking the more insoluble the form of uranium, the longer the material is retained in the lung, and the higher the radiological dose is to the lung from the inhalation exposure to more highly enriched, less soluble, uranium compounds (5). Some areas at Portsmouth that had exposures to insoluble compounds are in the oxide conversion (X-705E) and feed production (X-344) facilities. UF6 exists at Portsmouth and Paducah as a gas, liquid, and solid. Other components of uranium, such as UF4, UO3 and UO3O8, have been present is significant quantities in the feed manufacturing plant and the oxide conversion plant. There is evidence that workers were exposed to uranium forms that could cause adverse health effects (2).

During enrichment at Paducah UF6 was used as a gas for processing, as a liquid for feeding and withdrawing, and as a solid for storing and transporting. When released as a gas, UF6 hydrolyzes with moist air to produce HF and UO2F2. Also UF4 and UO3 were present in significant quantities in many Paducah processes (6). Most of the early releases of uranium were attributed to C-410 and C-340. Paducah also performed uranium recovery in C-400 from fluorination tower ash, sintered metal filters, decontamination solutions, UF6 scrubber solutions, particulates from ventilation filters and vacuum cleaners, laboratory wastes, and materials from spills. The system was not leak-tight and leaks were common. Uranium metal was produced by reducing green salt with magnesium in C-340. Uranium dust was the primary hazard during weighing, blending, and pouring (6).

It has been reported for soluble compounds, that uranium's chemical toxicity to the kidney predominates over its radiological hazards. For insoluble forms radiation doses to the lung can be the predominant concern. At Paducah the principal sources of internal uranium exposures relate to inhalation of both soluble and insoluble compounds (6).

Several evaluation reports on UF6 releases at Paducah and their effects, as well as other site documents, identified approximately 50 UF6 releases, each in excess of 10 pounds of uranium; however reviews of health physics reports and the site quarterly reports from the early 1960s reveal references to hundreds of releases of varying sizes. These reports identified many employees who were exposed to these releases and required medical examinations and bioassay. At least 15 events were identified in the first ten years of Paducah plant operation that each released a minimum of 100 pounds of uranium, with a 1960 event releasing approximately 6,800 pounds and a 1962 event releasing approximately 3,400 pounds (6).

Uranium Daughter Products

Uranium daughter products are produced when uranium decays by the emission of alpha radiation to produce other radioactive isotopes (called daughters). When uranium is melted or separated by chemical or physical means, less-dense daughter products, such as thorium-234 and protactinium-234m, can be concentrated. Further processing can leave significant quantities of these daughter products in oxides or ash, or on the surface of process vessels. Daughter products were present in varying amounts at the Portsmouth feed manufacturing plant fluorination towers (primarily from ash receivers and the sintered metal filter baths) in X-705 and X-720, from converter and compressor disassembly work, product feed/withdrawal stations, cylinder cleaning stations, raffinate from uranium recovery, in cylinder heels, and other areas of the cascade. The beta radiation dose rate from residual concentrated daughter products is much higher than from the original uranium. In addition, daughter products in the form of fine particulate (like dust) are easily transferred by contact. Protactinium-234m emits a high-energy beta particle, which contributes most of the beta dose from the uranium-238 daughter products (2).

At Paducah, locations where uranium daughter products were found include: the feed plant fluorination towers (primarily from ash receivers and the sintered metal filter baths), in C-400 and C-720 from converter disassembly work, in C-400 at the cylinder wash facility, in C-310 and C-315 in cylinder heels (feed and withdrawal), in C-340 from shell and crucible cleaning, and in C-400 and C-710 in the neptunium and uranium recovery process raffinate (6). Uranium daughter products tended to concentrate in certain areas. In the feed plants these include: dust collection system, the fluorination towers, and the ash receivers downstream of the fluorination towers. Vacuum system bag rooms exposed workers to fine particle dust containing appreciable concentrations of the impurities. The impurities plated out on the inside of the fluorination towers, making them radiation areas and creating intense beta radiation fields when opened for maintenance or unplugging operations. The ash resulting from the fluorination of UF4 contained the most radioactive impurities and was sometimes in the form of small particles. The ash receivers at Paducah provided one of the highest potentials for exposure to workers and the task of unplugging the towers also had high exposure potential (6).

Transuranic Elements

Transuranic elements have atomic numbers greater than 92 (greater than uranium) and can be produced when U-238 adsorbs neutrons as part of a nuclear reaction. The principal transuranic elements of concern are neptunium and plutonium. Both are alpha emitters that have a very long clearance time in the body. Transuranic elements were introduced to Portsmouth from processed spent reactor fuel or from reuse of cylinders containing transuranic contamination (2).

- Neptunium-237 has a radioactive half-life of 2.14 million years and is far more hazardous than natural uranium. The specific radioactivity of neptunium-237 is 2,000 times higher than the radioactivity of depleted uranium, an alpha emitter. Neptunium concentrated at certain points in the uranium conversion, enrichment, and recovery process. The highest concentrations were associated with oxide conversion and the waste streams associated with that process (X-705E and X-701B at Portsmouth) (2).
- Plutonium-239 has a half-life of 24,056 years, and is significantly more radioactive than neptunium but it was reportedly present in much lower concentrations. Plutonium concentrated in the oxide conversion facility at Portsmouth. Because it remained in the ash material, most plutonium may have been removed with the ash residues and particulate filters in the conversion of uranium oxides to UF6. Individuals most likely exposed were those changing particulate filters and emptying the ash collectors. There were small quantities of plutonium in the cascade feed areas, which could have had the potential for exposure during CIP/CUP activities. Once plutonium reaches the blood stream, it accumulates primarily in the liver and skeleton. Plutonium exposure may produce acute health effects (e.g., ingestion may lead to damage to the walls of the gastrointestinal tract) or long term effects, such as increased risk of cancer. When plutonium is inhaled, the lungs are exposed to alpha-particle radiation, increasing the risk of lung cancer, and the plutonium is eventually carries to other organs where the radiation can cause cell damage and increase the likelihood of biological effects (2).

As early as 1953 feed made from recycled reactor fuel processed through the Paducah enrichment cascade contained trace quantities of plutonium. The Paducah Health and Hygiene Department discovered that neptunium-137 and plutonium had also entered the process stream from the reactor return feed materials (6). Soon after neptunium was identified at Paducah in 1957, a neptunium recovery program was developed, and began operations in 1958. The highest concentrations of neptunium at Paducah were associated with the recovery process. In mid-1959, neptunium contamination was first discovered on a piece of Paducah cascade equipment. Approximately 25 percent of the neptunium in the feed material remained in the feed plant as dust or ash. Approximately 50 percent remained in cylinder heels after feeding, and approximately 25 percent was vaporized in the cascade, plating out at the upper end of the cascade. Ninety-nine percent of the plutonium was deposited in the ash, filters, and dust of the Paducah feed plant. Approximately 0.9 percent remained in the cylinder heel or on the cylinder walls, and the remaining 0.1 percent was vaporized to the cascade and plated out primarily in the first stage of the cascade it encountered. In addition to the hazard of plutonium and neptunium in the cascades and in the feed plants, Paducah workers faced additional risks from plutonium and neptunium recovery operations in C-400. "Air samples collected from areas contaminated with neptunium indicate the potential for high radiation doses to workers in these areas…." Transuranics were found in solid deposits in the converters being rebuilt in C-409 (6).

Fission Products are formed when neutrons split uranium-235 atoms during a nuclear reaction. They typically have atomic numbers in the range of 80 to 108 and 125 to 153. The predominant fission product of concern at Portsmouth was technetium (2). Technetium-99 is a weak beta emitter with a radioactive half-life of 213,000 years and was introduced at Portsmouth in recycled reactor feed. The primary exposure pathways are ingestion or inhalation. Technetium passed through the Portsmouth cascade as a volatile compound of fluorine, depositing on the internal surfaces of the cascade and contaminating the uranium product, and many areas, including cascade equipment. There was evidence that workers had some exposure to technetium (2).

Technetium-99 was received at Paducah in recycled feed from Hanford and Savannah River Sites. It passed through the cascades as a volatile compound of fluorine. It was deposited on internal surfaces of the cascades and contaminated the enriched uranium product. Technetium migrated to the top of the cascade, and much of it was drained off into the product or vented to the atmosphere. Demand for this substance in the early 1960s prompted Paducah to begin a campaign to recover this material from cylinder wash water and raffinate. Traps for technetium were installed in the feed plant and at the C-310 withdrawal stations (6).

Non-Radiological Hazards

Asbestos

Asbestos, as airborne fibers, can be inhaled or swallowed, and these fibers can become embedded in the tissues of the lungs' alveoli (air sacs), they cannot be removed. Exposure to asbestos has caused disabling and fatal diseases, including asbestosis; lung cancer, mesothelioma, and gastrointestinal cancer (2).

Asbestos was widely used as a traditional thermal insulation. A cement- asbestos board known as transite was used for the outside walls of some of the very large buildings. There were no industrial hygiene data (air-sampling or bulk sampling) or location inventory available (21). Before the 1970's asbestos was widely used at Portsmouth because of its resistance to heat and corrosive chemicals. Asbestos was used extensively for construction, welding, and insulation after initial plant construction. Asbestos was used in cooling towers cooling tower structures, duct curtains, expansion joint coverings, building siding, and by workers for protection against heat and weld splattering. Several former workers reported cutting asbestos blankets to size without any respirators or gloves. In the late 1970's in X-333 and X-330, workers would lie on asbestos blankets with large fans blowing over them to work in hot areas. In the 1950s to 1970s a number of workers were exposed to asbestos without knowledge of the hazard. It was not until 1980 that the first control procedures and "divisional asbestos control managers" were assigned (2). Construction workers often were those most involved with and subjected to the highest levels of asbestos. Carpenters were often the workers involved in sawing, nailing, removing, or installing transite siding. Pipefitters and boilermakers also would have a frequent asbestos exposure due to removing insulation containing asbestos from pipes.

Asbestos was used in much the same way at Paducah as at Portsmouth—thermal insulation and transite wall covering. C-400 and C-410 are mentioned as two buildings where asbestos was found (21) (24). Asbestos was disposed of in C-746U Sanitary/ Industrial Landfill (25).

The uses of asbestos at the Portsmouth and Paducah sites are similar to the uses reported at the K-25 gaseous diffusion plant at Oak Ridge, TN (22).

Nickel/ Nickel Carbonyl (NiCO)4

Nickel barriers were manufactured at the K-25 Plant at Oak Ridge, TN to be used at all three gaseous diffusion plants. Excess lung and nasal cancers have been found in nickel workers primarily in nickel refineries, but also among nickel alloy workers. Nickel was cited as a hazard at Portsmouth (2). "Workers at PORTS have had and continue to have exposure to nickel and nickel alloys from welding and metal cutting during maintenance and fabrication of process equipment" (5).

Nickel carbonyl, a volatile liquid and a very toxic gas, is the most acutely toxic nickel compound known, causing immediate poisoning, hemorrhagic pneumonia, and delayed lung effects. Nickel-plating workers can suffer from dermatitis caused by skin contact with nickel salts and nickel compounds can cause chronic eczema. Some individuals are susceptible to becoming sensitized to nickel, and once sensitized, they respond to contact with nickel alloys. In industry, nickel plating workers and welders exposed to various nickel compounds have developed allergic lung reactions, such as asthma, loss of the sense of smell, and severe nasal injuries, such as perforated septa and chronic sinus infections. Increased susceptibility to respiratory infections is also possible (2).

At Portsmouth, in addition to welding, melting, and cutting, one of the most hazardous operations, nickel spraying, took place in the X-720 welding shop. A 1982 industrial hygiene survey of nickel spraying in X-720 identified airborne nickel concentrations up to 15 times the acceptable limits. Other hazards in X-720, from the mid-1950s onward, included nickel sulfate crystals and nickel plating operations. In 1973, nickel welding fume concentrations were measured in the X-700 converter shop, X-720 weld shop, and the X-705 seal dismantling booth and were well above the limits. In addition to nickel welding and plating, grinding operations on nickel-plated tube sheets and process gas pipe flanges were common throughout the Plant's history (2).

Building C-746A at Paducah contained much of the work with nickel. There was a nickel induction furnace in the building. When off-specification monel feedback and monel recovered from off-specification barrier tubes accumulated, it was smelted to be destroyed for classification concerns, and sold for recycling (26). Welding and cutting on metal in the four cascade buildings at Paducah exposed workers to nickel fumes (21). Also, a nickel stripper was located in C-400 (24). Barriers were taken to C-400 for washing, disassembly and scrap recovery.

From 1978 to April 1979, Portsmouth received a dismantled DOE nickel-plant and associated equipment from Huntington, West Virginia that was contaminated with nickel carbonyl, asbestos, and uranium. Fifty truckloads of material were taken to the Portsmouth GDP site and buried in X-749 (2). Construction workers may have received hazardous exposures in dismantling, transporting, and burying the contaminated building.

Union Carbide reported average nickel exposures during welding and cutting operations at K-25 to be approximately 0.2 to 0.3 mg/m^3. A NIOSH health hazard evaluation conducted in 1972 reported breathing zone air concentrations of 3.8 mg/m^3 during welding operations with high (10%) nickel steel (21). These findings are corroborated by the K-25 urine data showing high average urinary concentrations in selected buildings extending into the 1970's. The current NIOSH REL for nickel is 0.015 mg/m^3, which is one hundred times lower that the levels found at parts of Oak Ridge (21). Although the Union Carbide data was for Oak Ridge, there was no reason to think that the exposures to nickel for construction workers was any different at Portsmouth or Paducah than at Oak Ridge when they were also welding and cutting on the same nickel-containing metal.

Fluorine and Fluoride Compounds

UF6 was the feed product used at Portsmouth and Paducah. The main process buildings, the cascades, were in X-330, X-333, and X-326. The process buildings were the source of many UF6 releases during the connection and disconnection of sample bottles and feed and product cylinders, and from broken instrument lines (2). Well over 400 releases of process gas containing fluorine have been documented over the years, and many more minor releases occurred that may not have been documented. Quantities ranged from very small amounts (commonly referred to as puffs or wisps) to significant amounts that escaped outside buildings, caused building evacuations, or resulted in HF burns, or uranium uptakes requiring bioassay or medical attention for dozens of workers. Plant reports reflect approximately 90 UF6 releases in excess of 10 pounds of uranium (2).

Many workers at Portsmouth and Paducah have been exposed to fluorides, fluorine, and hydrogen fluoride aerosols (hydrofluoric acid) primarily in the enrichment process buildings and equipment. UF6, which is solid at room temperature, is heated to a gaseous state to be introduced into the cascade process. The potential for exposures to uranium and fluorine compounds may occur anywhere that UF6 is released to the atmosphere. This is due to the reaction of UF6 with moisture in the air, which results in the exothermic production of uranyl fluoride (UO2F2) and hydrogen fluoride (5). Exposure to hydrofluoric acid, uranium hexafluoride, and other fluoride compounds were widely reported. There were often episodic- "puffs of smoke"- throughout the process buildings, feed buildings, and withdrawal buildings especially before 1975 (21).

Fluorine and its compounds HF, UF4, and UF6, were used throughout the Paducah plant processes particularly in C-340, C-410, C-420, and cascade process buildings (6). Fluorine emissions to the atmosphere commenced with startup operations. These emissions were from process stacks, diffuse and fugitive emission sources, accidental releases, and a limited number of planned releases. Fluorine and anhydrous HF were used in the fluorination of uranium dioxide. HF was a byproduct when moisture in the air combined with UF6. HF was also a byproduct of metal production. Fluoride hazards were identified early in the Plant's history. Most quarterly Health Physics and Hygiene reports from 1953 through 1972 routinely reported urine levels of uranium and fluorides in selected groups of workers. As late as 1970, overexposures to HF were being reported. After this period little evidence of workers' exposures were found until 1980. After 1980, fluoride levels as measured in urine samples, remained constant at around 1mg/L. Typically one to four workers per quarter exceeded the plant Concentration Guide of 4mg/L and were placed on restricted duty. Later urine samples were principally used to supplement monitoring the air in a workers' breathing zone. C-340's UF4 production was most likely responsible for most of the ecological damage that occurred in the northeast quadrant in the early years of plant operation. In another operation that produced a fluorine compound, a former supervisor reported that if the plant recovered 99 percent of the HF produced, a significant amount of HF would still have been released (6).

At Portsmouth, the potential for exposure to fluorine compounds in the absence of uranium was limited to those activities where fluorine gas or hydrogen fluoride (HF) was used to condition equipment, cascade maintenance, and in X-342-A where fluorine gas was generated (5). Industrial hygiene data for fluoride, fluorine, and hydrogen fluoride are limited and the specific fluorine containing agent is often uncertain. The greatest number of samples were collected between 1986 and 1991, with a large increase in sampling in one cascade building (X-333). This may have occurred because there was an increase in site industrial hygiene capabilities, and an increase in sampling for airborne contaminants as maintenance activities increased following the passage of time since the Cascade Improvement Program/Cascade Uprating Program CIP/CUP (1974-1981) (5). Construction workers frequently would be present and exposed to these chemicals in their work.

Workers exposed to airborne fluoride concentrations of 5 milligrams per cubic meter (mg/m^3) of air or greater, complain of eye and respiratory tract irritation and nausea. Excess fluoride storage in bone and teeth occurs from the ingestion of as little as 3 mg/day. The development of crippling fluorosis may occur after 10-20 years of absorbing 20-80 mg of fluoride daily (5).

The potential for exposure to fluorides existed in several areas/ processes common to all Gaseous Diffusion plants including: Feed Vaporization Buildings, Product Withdrawal Buildings, Fluorine Plants, Process Building, Oxide Conversion Plants, and Decontamination and Maintenance Buildings. Elevated levels of fluoride were discovered in urine samples taken from workers at Oak Ridge K-25 Plant. When comparing the averages to the average for an unexposed population (0.4 mg/liter) it is apparent the significant exposures took place (21). Data from K-25 can be applied to Portsmouth and Paducah since the same processes took place there.

Solvents

The cascade process required strict cleanliness of parts, which necessitated the use of large quantities of solvents (21). Trichloroethylene (also known as trichloroethene or TCE) was the most commonly used solvent in the 1970s and 1980s. Trichloroethylene is a colorless liquid that is used as an industrial degreaser. TCE is a mild irritant to the respiratory tract and the skin, and is considered a potential carcinogen based on animal studies. Critical exposure pathways are inhalation, ingestion, and skin or eye contact. TCE concentrations in the heart, liver, kidneys, central nervous system, and skin (2).

Large components at Portsmouth were frequently cleaned in one of several vapor degreasers located in X-705, and X-720. Leaking vapor degreaser lids causing vapors and high TCE concentrations prompted a ventilation project for the building in the mid-1990s. A 1976 Industrial Hygiene and Health Physics report told of an incident in the welding area near the X-720 Compressor shop where airborne concentrations of TCE exceeded 700 ppm (maximum permissible concentrations is 150 ppm). This occurred when an operator sprayed a suspended part with TCE over a vapor degreaser. This was a violation of previous recommendations. If a welder had been in operation, which was common, phosgene gas could have been produced. An improperly operating ventilation system did not provide sufficient exhaust from the chemical cleaning area to prevent TCE vapors from flowing into the converter shop, but eventually this was upgraded (2).

Some of the earliest use of TCE at Paducah occurred inside C-745, which fabricated pipe during plant construction (27). Degreasing of small parts with TCE took place in C-720, but the most significant use of TCE took place in building C-400 where the large components were degreased. While excavating to upgrade an unfiltered storm water line, a subcontractor discovered a large volume of TCE associated with the C-400 compressor pit operations. Leaks were found in transfer lines (6). Releases and spills have led to contamination underneath the building (8).

Other chlorinated hydrocarbon solvents, such as carbon tetrachloride and methylene chloride, have been used as degreasing solvents. Chlorinated hydrocarbons cause skin irritations due to the removal of skin oils, and they are central nervous system depressants. Carbon tetrachloride is absorbed readily through the skin or lungs and produces kidney and liver damage after continued exposure. Methylene chloride is a central nervous system depressant, and when metabolized in the lung produces carbon monoxide, which readily combines with blood hemoglobin and restricts the body's uptake of oxygen. A worker at Portsmouth in 1980 complained of lightheadedness while using 20 percent methylene chloride. Several former workers described using carbon tetrachloride to clean the inside of equipment, and subsequently cleaning up dust and deposits inside converter shells with a bucket of carbon tetrachloride and a sponge (2).

Aromatic hydrocarbons were in frequent use at Portsmouth, but generally in lesser quantities than the chlorinated hydrocarbons. Benzene is volatile, and extended exposure to the vapors causes damage to the central nervous system, the gastrointestinal tract, and bone marrow. Prolonged exposure has been linked to an increased risk of cancer, particularly leukemia. Benzene was used in the X-720 electrical and instrument shops in the mid-1950's (2).

These solvents include the same compounds used at the K-25 gaseous diffusion plant (22).

Mercury

Early symptoms of mercury poisoning include salivation and tenderness of the gums. Mercury vapor can reach the brain cells, where it is oxidized to produce toxic effects. The major effects of chronic exposure to mercury vapor are on the central nervous system, resulting in increased excitability and tremors (2).

Evidence indicates that mercury was a significant hazard to workers from the 1950s to the 1980s. During the 1970s, a monthly Industrial Hygiene and Health Physics report had a separate section for reported mercury spills. Airborne mercury levels greater than Permissible Action Levels (PAL's) were identified in the instrument shop cleaning room after a spill. Mercury was handled extensively, sometimes without adequate personal protection, and could have adverse effects on the health of the workers (2).

The principal uses of mercury at Portsmouth included thermometers, manometers, chemical traps, vacuum pumps, switches, and fluorescent lights.. Manometers were used to measure differential pressure, flows, and absolute pressure. Line recorders (spectrometers) used mercury in chemical traps to remove UF6 from sample streams to allow detection of low molecular weight gas contaminants contained in the process gas. Diffusion pumps were used to sustain vacuums necessary to properly operate assay and line recorder spectrometers. Mercury-contaminated equipment was also cleaned in X-720, leading to several mercury spills. Also, mercury airborne levels in excess of PAL's were identified. Line recorder chemical traps reportedly were cleaned and refurbished by pouring contaminated mercury into other containers for recovery and disposal, and the flushing of residual mercury with steam before the 1980's. Mercury is identified as a hazard from the early years of the Portsmouth plant (2).

Mercury was used in the same way at Paducah. Cold traps in the cascades contained mercury (21). Chemical filters containing mercury were left lying in a sink in C-720 while engineers devised a way to extract the mercury (28). Recovery of mercury also took place in C-400 (8).

It should be noted that mercury was one of the most significant chemical hazards at Y-12 when it was used in the electromagnetic isotope separation process. While this process was never at the GDP's, there is still evidence of substantial mercury contamination at the GDP's for the reasons cited above.

Beryllium

Beryllium is a silver gray metallic element used as a pure metal, as beryllium copper and other alloys, and beryllium oxide. Beryllium is useful in manufacturing due to its strength, lightweight, machinability, and a relatively high melting point. Severe health hazards can result from even minimal contact. Beryllium can enter the body through inhalation, skin absorption, skin wounds, and ingestion. The most serious health effects come from inhaling airborne insoluble particles that deposit in the lungs. Chronic beryllium disease (CBD), which occurs in one to six percent of exposed workers, has a latency period of up to 20 years and has no known cure (2). In 1977, the National Institute for Occupational Health and Safety (NIOSH) recommended that OSHA adopt an exposure limit of 0.5 ug/m^3. In 1998, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed a more protective standard of 0.2 ug/m^3 averaged over an 8-hour work period (29).

Besides the use and/or disposal of sealed plutonium-beryllium neutron sources, one Portsmouth stores department worker indicated that he had stocked beryllium bars that were sent to the X-720 machine shop. Another worker and supervisor believed that they had machined beryllium there in the mid-1970s. There may have been incidental machining of beryllium copper-alloy process piping components such as valves. Some tools plated with beryllium were also used. Other uses may have included use and disposal of fluorescent light bulbs containing beryllium oxide, and the use of beryllium-containing welding rods until the mid-1990s. In the early 1990s, routine sampling detected beryllium concentrations above background in several areas (2).

As part of the "Work for Others" program, Paducah workers machined beryllium and beryllium-copper alloys. Work performed in the 1960's in C-720 under this program included the Lunar Lander for NASA. Beryllium plating was reportedly done in C-710 laboratories. Also, beryllium components were reportedly handled at the C-746A smelter and at one time foam contaminated with beryllium, tritium, and uranium oxide was piled in a corner (30).

The concern for beryllium exposure has increased as a result of the medical findings by PACE for production workers at the three GDP's: Oak Ridge K-25, Portsmouth and Paducah shown in Table 3 and the study by Bird, et. al., at K-25 (31)

Lithium

Lithium is intensely corrosive and may produce burns on the skin. Chronic exposure to lithium at elevated levels can result in impaired functioning of the kidneys, changes in blood pressure and blood volume, and neural and hormonal effects. From the early 1960s, 187,000 drums of lithium hydroxide monohydrate (LiOH), transferred from Oak Ridge were stored at Portsmouth in five warehouses. It also contained 2-15 ppm mercury. Originally lithium was in 55-gallon fiberboard drums, which corroded because of leaks in the roof. The lithium was moved and the warehouses dismantled to provide space for construction of the Gas Centrifuge Plant. Some workers reported that when the drums where relocated, the dust was so thick that you could hardly see the lights of the forklifts (2). Construction workers performing roof repairs and dismantling warehouses may have been exposed to lithium. Construction of the Gas Centrifuge Plant would have brought many building and construction trades workers onto the main plant site.

Heat, Dust, Noise, and Illumination.

Many workers at Portsmouth and Paducah were exposed to high nuisance particulate (dust) concentrations and excessive noise from machinery, and sometimes work was performed in inadequate light. Complaints of high levels of dust, noise, and poor illumination were heard especially in the process cascades. The process buildings were physically hot. Historical documents indicate that many practices led to excess worker exposure to dust, noise, and other common industrial hazards. At Portsmouth in X-705E, workers were exposed to dust containing uranium, fission products, thorium, and transuranics (including neptunium and plutonium) during pulverizer and maintenance operations. Ash handlers were exposed to dust containing uranium and concentrated daughter products, transuranics, and fission products (2).

At Paducah, the cascades were hot and noisy (21). C-410 (Feed Plant), and C-420 (Oxide Conversion) had high noise levels, and temperatures in excess of 100 degrees and the smelter in C-746A was one of the hottest areas (6). The pulverizer in C-400 generated dust and in C-340, locations with the potential for dust inhalation included the ash receivers in the reaction towers, reducing green salt to uranium metal, bomb crushing, derby sawing, derby cleaning, and breaking molds to remove derbies High temperature was also a problem in C-340. Carpenters tore down and replaced wooden portions of the fluorine cooling tower, which was apparently covered with radioactive dust. When bag house filters were changed in the cascades, C-310, C-315, C-410, and C-420, much dust was released into the air (6) (8).

In conclusion, it has been recognized for many years that former construction workers at DOE sites experienced exposures to a variety of health hazards at levels that would place them in populations at *increased risk* or at *high risk* (32). As former employees of subcontractors, they no longer have access to occupational medicine physicians at the workplace (if they ever did). It should be noted that primary care health providers often lack information on work-related disease, leading to incomplete diagnoses of medical conditions in a timely fashion. Interventions of secondary prevention, which recognize disease at the pre-clinical stage, will decrease the rates of illness, disability or death related to workplace exposures. Specifically, the needs of these workers are to 1) develop an individual profile of past potential exposures, 2) identify disease at the pre-clinical stage (where possible), 3) diagnose clinical disease at an early stage, 4) assist the worker in identifying resources for further diagnosis and medical treatment, and 5) provide documentation necessary for obtaining compensation/benefits for work-related disease.

Individual occupational histories, linked to institutional history databases, can be used to define a potential exposure profile for each participating worker. Documentation of individual exposure profiles will prevent unnecessary testing and reduce the volume of interventions necessitated by "false positive" test results. A graded response to medical screening is necessary to conserve valuable resources required to deliver a medical monitoring program to a target population of former DOE workers (32). Evaluation of exposure histories helps to determine selection of appropriate screening tests for individual workers.

This linkage of work history and institutional history provides each worker a record of all of his or her work-related activities and potential exposures. A worker needs to know the risks associated with the level of his/her exposures, to make informed decisions about future participation in medical monitoring and to develop an awareness of sentinel symptoms for which he/she should seek medical attention (33). Former workers need to be informed that future occupational activities or hobbies may increase levels of cumulative exposure to an agent where he/she already has achieved a level of increased risk (34).

Medical screening that is targeted reduces the allocation of resources for repeat testing and communication of significance of "non-normal" test results. The screening test cannot be an end in itself, but should be a means to direct the worker to additional diagnostic testing and medical treatment, if needed. Workers are more likely to comply with post-screening recommendations if implications of test results are explained in a manner that they can integrate the information. Workers also need assistance in identifying resources for tests and/or treatment.

Identify and Develop Viable Methods Of Contacting Workers

In Oak Ridge former worker screening, the University of Cincinnati Consortium was able to take advantage of personnel records from more than 30 years of construction management by a prime contractor for construction—Rust Engineering from 1966 to 1989 and MK Ferguson thereafter. We were also able to tap limited records from HK Ferguson before 1966, as well as records yielding over 13,000 names, social security numbers and (very out-of-date) addresses from Maxon Construction and its subcontractors when they built the K-27, K-29, and K-33 buildings at the Oak Ridge Gaseous Diffusion Plant in the 1950s. The Portsmouth and Paducah GDP's are different from the Oak Ridge Reservation sites because there were no M&O contractors for construction. No records have been located in the National Archives or in DOE records repositories with names of construction workers at Paducah or Portsmouth. Efforts with contractors and DOE to locate lists will continue.

Size of Portsmouth Cohort

As noted in the History of Portsmouth, the construction workforce at Portsmouth GDP peaked at 22,500 in 1954. The youngest of these workers would be in their late 60s today. The surge in construction between 1974 and the early 1980s undoubtedly involved another generation of construction workers, but no documentation has been found as to the size of the construction workforce during that time period. The average age of this group today is probably around 58-60 years, with the youngest over 40 years old.

Because there was no permanent "M&O" (Maintenance and Operations) contractor for construction at Portsmouth, less information on size of the construction workforce over the years is available for Portsmouth than the University of Cincinnati consortium found regarding Oak Ridge construction workers. One recent estimate of the population available to be served by this project in the geographical area around Portsmouth comes from Mr. Steven Burton, Business Manager of the Tri-State Building and Construction Trades Council, AFL-CIO. In a February 15, 2002 letter to Senator George Voinovich, he estimated the number of building trades workers in the area who have worked at Portsmouth at 9,000. The workers would be in an area of 50—100 miles from the plant. Based on these numbers from the Tri-State Building and Construction Trades Council, and the fact that some workers were at the site in the earlier years, 1950's—1970's, who may be retired for several years, there are in the range of 10,000 to 12,000 construction workers who comprise the cohort. If 15%—20% are interested in screening, the size of the pool could range from 1,500 to over 2,000.

Size of Paducah Cohort

Based on a history of the Paducah GDP published by the *Paducah Sun* newspaper (35), 29,000 construction workers were employed at Paducah during the initial plant construction in the 1950s. We estimate that the youngest of these workers would likely be about 70 years old.

Because there was no permanent "M&O" (Maintenance and Operations) contractor for construction at Portsmouth, less information on size of the construction workforce over the years is available for Portsmouth than the University of Cincinnati consortium found regarding Oak Ridge construction workers. One recent estimate of the population available to be served by this project in the geographical area around Paducah comes from Mr. Larry Robinson, Business Agent for Plumbers and Steamfitters Local Union No. 184 in Paducah. In a February 25, 2002 letter to Senator Mitch McConnell, he estimated the current number of building trades workers in the area who have worked at Paducah and who would be available for this program at 8,000. Based on the experience of labor representatives, other comparably sized facilities and the likely ages of workers and survival from the early years, 1950's—1970's, we estimate that there may be as many as 10,000 construction workers who would qualify. Experience with other Former

Worker Programs suggests 15—20% will participate. This means that the estimate of the cohort size is similar to the Portsmouth estimate of 1,500—2,000.

This project differs from the Oak Ridge experience in an important and more positive way: Based on the reception we have received from the local Building and Construction Trades Councils at Portsmouth and Paducah, we anticipate very active involvement by the Councils and their constituent local unions earlier in the screenings than was the case in Oak Ridge. We believe this active role on the part of the unions will more than make up for the lack of an initial list of former workers. However, the local unions have indicated that they can either supply a list of names and addresses of workers and mail information regarding the screening program when the project is funded and IRB approval is received.

Letters And Other Communications From Local Unions

In a follow-up questionnaire completed by former construction workers in Oak Ridge after they had completed their medical screening, on a question as to how they had heard about the program, 262 of 401 responses cited their union and letters from the Knoxville/Oak Ridge Building and Construction Trades. These were, far-and-away, the most important sources of information. The University of Cincinnati consortium has learned this lesson well: In designing our outreach for Portsmouth and Paducah, we will take advantage of this understanding to design an efficient approach with maximum impact.

Letters from local union leaders will use union stationery wherever possible, to provide an instantly recognizable link in the recipient's awareness. For example, a letter in an envelope from the University of Cincinnati to a worker living in West Virginia is more likely be viewed as "junk mail" than a letter from his/her union with a local return address. In every case where the union leader is willing to sign his name to the cover letter, this will be done. Here again, we believe a personalized letter from an union elected leader will have more impact than a letter from a professor who is unknown to the recipient.

A number of local unions in the Portsmouth and Paducah areas have already agreed that they will do mailings on our behalf, or will give us their mailing lists. Given the enthusiasm with which these local union leaders have embraced this program, we are convinced that all or nearly all will sign letters to their constituents. The issue regarding doing their own mailings or giving us mailing lists has in large part to do with the privacy of union members. Some of these unions have an internal policy against providing personal information about their members. We have both the sensitivity to this concern and the rapport with the unions to handle this effectively on a union-by-union basis.

Letters will be sent to all current and retired members on the local unions' mailing lists, whether or not the local union or we have specific information about whether they worked at Portsmouth or Paducah. The reasons are several:

- The local unions do not generally keep that type of information in their records.

- In areas so dominated by the presence of these sites, when there was significant construction activity at the site over a period of years, a large percentage of the union members probably found their way there at some point.
- Even if a union member did not work at the site himself, in these small communities and with the history of following one's family members into a skilled trade, we can expect that many recipients who did not work at the site themselves have relatives or friends who did work there, and to whom they can pass this information.

Newspapers

Our experience in Oak Ridge has taught us that local newspapers are often very cooperative in helping to publicize important information about projects like this one. Both the Oak Ridge and Knoxville, Tennessee daily newspapers published our written information about upcoming public meetings, in the form of news articles. Both newspapers also covered our meetings and reported to their readers about them.

The University of Cincinnati consortium will ask the Department of Energy public affairs offices for a list of their press contacts, and will also query local union leaders and other leaders about helpful contacts in newspapers and broadcast media. We will use these contacts to place news stories, beginning with an announcement in each locality about the opening of our outreach office and the beginning of our medical screening.

Radio and Television

In Oak Ridge, we sent public meeting announcements to local radio and television outlets based on contact information provided by the local DOE public affairs office. We do not know how effective public service announcements are, but notifying the electronic media is a low-cost venture so that any response makes the effort worthwhile.

Other Methods Per Advice From Our Local Partners

The University of Cincinnati consortium will listen to the advice of the leaders we contact initially, and follow that in shaping additional outreach efforts. In Oak Ridge such efforts included addressing retiree club meetings, addressing joint labor-management meetings at the invitation of the DOE Assistant Manager for Environment, Safety and Health, and briefings for other opinion leaders. Retiree events provide a significant source of workers who were employed in the past. These events will be used for recruitment. The supporting approaches we use in the Portsmouth and Paducah areas will be shaped according to local conditions and local advisors.

Initial Determination of Most Significant Hazards, Problems, And Concerns

Hazards:

As has been discussed earlier, the most ubiquitous health hazard for construction workers at Department of Energy sites—especially during the 1950s-1970s—was asbestos. This conclusion is supported emphatically by the finding of asbestosis in 18-20% of the former Oak Ridge construction workers screened by the University of Cincinnati consortium. We note in particular the two cases of mesothelioma among the former construction workers whose three longest jobs were at the K-25 gaseous diffusion plant.

Clearly, ionizing radiation is a hazard of significant concern to former construction workers at these gaseous diffusion plants. These workers' exposure to radiation has not been systematically studied—and, in fact, was not consistently monitored during much of the period of greatest concern to our project.

The prevalence of chronic obstructive pulmonary disease and chronic bronchitis in the Oak Ridge former construction workers—including those with longest work at the gaseous diffusion plant—suggests that exposure to dusts and metal fumes (welding fumes) is another set of health hazards of significant concern for the screening project in Portsmouth and Paducah. This is supported also by the exposure study by trade (HEXFILE) based on information from Hanford.

Beryllium exposure is certainly of great concern. Our data from Oak Ridge K-25 and PACE's medical findings for production workers at Portsmouth and Paducah show that, in fact, there is a potential for construction workers at all three GDP's to have beryllium exposure.

Finally, occupational noise exposure and ergonomic hazards are hazards of concern. The Oak Ridge screening results (Appendix 3) indicate exposure to these hazards.

Problems

The best predictor of the types and frequencies of medical conditions that we expect to find among the Portsmouth and Paducah cohorts can be found in the results of the medical examinations of former construction workers at Oak Ridge, particularly K-25. The most common adverse medical conditions among that group were sensorineural (presumed to be mostly occupational) hearing loss, musculoskeletal disorders (also presumed to have at least a substantial occupational component), and respiratory diseases—including asbestosis, chronic obstructive pulmonary disease and chronic bronchitis. Asbestosis, in particular, is certainly occupational. We anticipate finding a very similar pattern of health problems among the former construction workers at Portsmouth and Paducah. A large percent of the workers who participated in the Oak Ridge screening worked a substantial portion of their career at the site (more than 16 years). Based on the isolation of the Portsmouth and Paducah sites, the same may be true for these construction workers.

Concerns

We anticipate that workers' concerns at Portsmouth and Paducah will be similar to those expressed by former DOE construction workers at Oak Ridge. In our interviews:

- 98% said they believe they were exposed to hazardous materials or conditions during their work at the DOE site.
- 33% said they believe that they have or possibly have a medical condition related to their work at the site.
- 24% said they have been told by a doctor that they have a medical condition related to their work at the site.

Partnerships

The University of Cincinnati consortium will take the same approach to partnerships in both Portsmouth and Paducah: We have held or will hold consultations prior to starting screening with key local representatives of the Department of Energy, the U.S. Enrichment Corporation, Bechtel Jacobs (the environmental contractor for DOE at both Portsmouth and Paducah), and the local unions and building and construction trades councils in both locations. The purposes of these initial consultations will be to solicit their ideas on how best to tailor our program to local conditions and local needs, to solicit any information resources they may have that will benefit this project, and to establish a basis for ongoing consultation as we begin implementation and outreach. We will keep each of these "stakeholders" informed through briefings, planned for every six months or as otherwise needed based on developments with the program.

DOE site leadership

DOE's Site Manager at Portsmouth is Mr. Anthony Takacs. Dr. Bingham will discuss this program with him. DOE's willingness to cooperate with the University of Cincinnati in this effort is critical.

DOE's Site Manager at Paducah is Gary Hettler. Dr. Bingham will discuss this program with him and seek to keep him informed. He has expressed his willingness to cooperate with the University of Cincinnati in this effort.

The DOE Environment, Safety and Health organization in the Oak Ridge Operations Office has responsibility for safety and health at Portsmouth and Paducah. Mr. Robert Poe, the Assistant Manager for Environment, Safety and Health, has been very cooperative with and supportive of the Former Construction Workers Program in Oak Ridge. We will brief Mr. Poe when this program is initially funded for Portsmouth and Paducah, and will brief him approximately every six months as well on our progress.

In Oak Ridge, the DOE Operations Office made their Public Relations/Community Outreach contact lists available to the University of Cincinnati consortium. We will request the same assistance in Portsmouth and Paducah.

Site DOE contractor

Bechtel Jacobs LLC is the site Management and Integrating (M&I) contractor for environmental restoration at both Portsmouth and Paducah, as well as for Oak Ridge. The Bechtel Jacobs program contact at Portsmouth is Mr. Andrew Petty. He has expressed interest in the screening program for construction workers and we have sent him some preliminary information. Mr. Greg Cook from Bechtel Jacobs at Paducah initially contacted us, but subsequently advised that the Bechtel Jacobs program contact at Paducah will be Mr. Larry Payne.

Our experience in Oak Ridge suggests that many of the craft workers involved in environmental restoration work at these facilities are likely to be former construction workers; and many also have family members who are former construction workers at Portsmouth and Paducah. For this reason, liaison with and outreach through the environmental contractors—Bechtel Jacobs and their subcontractors—is a potentially useful path that we will pursue.

USEC

USEC is a "stakeholder" in the sense that the plants they currently operate are those where these former construction workers may have received toxic exposures. In addition, however, our experience at Oak Ridge has taught us that many—if not most—of the skilled maintenance workers who are part of the operating workforce today probably learned their craft skills as construction workers, beginning with the apprenticeship programs of the building and construction trades unions. Therefore, current and retired USEC employees may be former DOE site construction workers. We will pursue liaison with USEC both as a courtesy to inform a potentially interested local company know about our program; and as a potential path for outreach to former DOE construction workers. Both in Portsmouth and Paducah, our effort will focus on contacting the environment, safety and health organizations at the plants.

Unions

The local Building and Construction Trades Councils and individual local unions in both the Portsmouth and Paducah areas have already shown very strong support for this program. Their enthusiasm and active participation will be a very great benefit to the success of our medical screening program. In particular, Mr. Steven Burton, Business Manager for the Tri-State Building and Construction Trades Council and Mr. Michael Vaughn of the Western Kentucky Building and Construction Trades Council have been very supportive of this initiative. Messrs. Burton and Vaughn will play an important role as we introduce the medical screening program to former DOE construction workers in the Portsmouth and Paducah areas.

The Tri-State Building and Construction Trades Council, and the Western Kentucky Building and Construction Trades Council, AFL-CIO, comprise more than twenty local unions in their respective areas whose members may have worked at Portsmouth or Paducah. The following trades are represented: electricians, millwrights, painters, carpenters, operating engineers, plumbers and pipefitters, asbestos workers, sheet metal workers, ironworkers, glaziers, bricklayers, cement masons, boilermakers, laborers and teamsters.

Dr. Bingham has already met with these Councils. The meetings were well attended by leaders of the local crafts. These leaders have pledged their cooperation with this effort, and in some instances have already taken steps to inform their members about the prospect of this program.

Other community stakeholders / media

In our initial consultations on this program, the University of Cincinnati consortium will ask the union leaders, contractors, and DOE officials about what other organizations in these communities should be approached, kept apprised of our progress, and asked to help us reach out to the former workers.

In addition to community organizations, we will ask our initial contacts about local newspaper, radio and television contacts. Our experience in Oak Ridge has been that local newspapers, in particular, have been useful in publicizing community meetings and the availability of free medical screening, and in informing the community about our progress and findings.

Attend semi-annual DOE-coordinated meetings

The Principal Investigator currently attends DOE-coordinated meetings of investigators to share information on the on-going Former Worker Program projects and will continue doing so for this project.

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HEXFILE
Exposures Rated On A Scale Of 1 To 10
For Various Crafts At The Hanford Site

Craft	Potential Exposure	Hazard Rating
Asbestos Worker	asbestos	1 - 10
	cement	1 - 5
	fiberglass	1
	heat	1-6
	mineral wool	1
	noise	1-7
Carpenter	acetic acid fumes	1
	asbestos	1 - 3
	fabricating PVC/other plastics	1
	wood dust	0 - 3
	noise	1-3
	Plexiglas cement	1
Cement masons	cement dust	1
	epoxy resins	1 - 2
	noise	1 - 3
Boilermakers	acetone	1
	aluminum	1
	asphalt	1
	asbestos	1 - 4
	bronzes	1
	carbon steel fumes	1
	carbon tetrachloride	1 - 7
	cast iron	1
	cement	1
	fly ash/soot	1
	heat	1 - 10
	inconel	1
	metal shavings	1
	stainless steel dust/fumes	1 - 3
	methyl ethyl ketone	1
	nickel	1
	noise	1 - 5
	perchloroethylene	1
	Stoddard solvent	1
	titanium fumes	1
	trichloroethylene	1 - 3
	vanadium	1
	welding fumes	1 - 4

Electricians	acetone	1
	aerosol varnish	1
	aluminum	1
	asphalt	1
	asbestos	1 - 3
	carbon steel fumes	1
	copper	1
	cleaners/Freons	1
	galvanized metals	1
	solder	1 - 2
	heat	1 - 6
	lead	1
	metal shavings	1
	noise	1 - 5
	perchloroethylene	1
	stainless steel fumes	1
	Stoddard solvent	1
	trichloroethylene	1
Heavy equipment	kerosene	1
Ironworkers	aluminum	1
	carbon steel fumes	1
	heat	1 - 10
	metal shavings	1
	naphtha	1
	noise	1 - 6
	perchloroethylene	1
	stainless steel fumes	1
	Stoddard solvent	1
	welding fumes	1
Machinist	acetone	1
	aluminum	1
	beryllium	0 - 1
	carbon steel fumes	1
	copper	1
	metal fumes	1
	nickel	1
	cutting fluids	1
	stainless steel fumes	1
	Stoddard solvent	1
	titanium fumes	1
	trichloroethylene	1

Millwrights	acetone	1
	aerosol spray cleaners	1
	aluminum	1
	carbon steel fumes	1
	cement dust	1
	machinery grout	1
	heat	1 - 6
	metal shavings	1
	stainless steel dust/fumes	1 - 3
	noise	1 - 6
	perchloroethylene	1
	Stoddard solvent	1 - 3
	trichloroethylene	1
	welding fumes	1-3
Painters	asphalt	1
	paints/enamels	1 - 9
	thinners	1 - 5
	benzene	1
	methyl ethyl ketone	1 - 3
	neoprene/rubber coatings	1
	removers	1
	sandblasting	1 - 3
	Stoddard solvent	1 - 3
	toluene	1
	trichloroethylene	1
	vinyl plastics	1
Plumbers/steam fitters	acetone	1
	aerosol spray cleaners	1
	asbestos	1 - 4
	carbon steel fumes	1
	copper	1
	welding fume	1 - 4
	heat	1 - 5
	lead	1 - 3
	metal shavings/buffing	1
	carbon steel dust	1 - 3
	nickel	1 - 3
	noise	1 - 6
	perchloroethylene	1
	plastics/cement	1
	stainless steel fumes	1 - 5
	Stoddard solvent	1
	titanium fumes	1
	trichloroethylene	1
	welding fumes	1 - 3

Sheetmetal worker	acetone	1
	aerosol spray cleaners	1
	aluminum	1
	asbestos	1
	carbon steel fumes	1
	cement/plastics	1
	copper	1
	metal filings/shavings	1
	welding fumes	1
	lead	1
	noise	1
	solder	1
	stainless steel fumes	1
	titanium fumes	1

Source: AOld HEXFILE@, identified as HEXCREN (09/23/76), an historical, qualitative assessment of non-radiological hazards by job classification for the years 1944 through 1972.

Building Number: X-344C

Report of Building No *X-344C*

Date Constructed: **Year Closed:**

Construction Type: Butler-type (909.02, p. A-73)

Size: ~ 1700 sq. ft. (909.02, p. A-73)

DRAFT

Unique Features:

Renovations:

Function-Table

Year	Function
	X-344C- HF(Hydrogen Fluoride) Storage Building (9, p. A-73)

Process-Table

From year	To year	Process
	1986	X-344C HF Storage Building houses three 10,000 gal. storage tanks which contained 70,000 to 80,000 lb. of HF. Use of the tanks was discontinued in 1986. The tanks were equipped with a disc rupture system for protection against overpressurization and a vent system for purging in preparation for maintenance. X-344C was surrounded by concrete dikes, and the floor sloped toward a covered drain which discharges into the X-344D Neutralization Pit. (909.02 p. A-73)

Hazards: HF (914.02, p. 17)

Inferred hazards:

References

909.02 Information Briefing on the Natural Resource Damage Assessment Rule, Presented to the Portsmouth Gaseous Diffusion Plant Trustees, U.S. Department of Energy Field Office, Oak Ridge, December 18, 1991.

914.02 Recycled Uranium Mass Balance Project Portsmouth, Ohio Site Report, BJC/PORTS-139/R1, Environmental Management & Enrichment Facilities Management and Integration Contract, June 19, 2000.

Report of Building Number: *X-710A*

Construction Date: 1955 **Closure Year:**

Construction Type: Acid-proof brick with a brick baffle in its center to increase mixing. It is covered with boiler plate doors (909.02, p. A-52)

Size: 5000 gal.; ~15 X 9 X 8 ft. (909.02, p. A-52)

DRAFT

Unique Features:

Renovations:

Function-Table

Year	Function
	Acid Neutralization Pit (909.02, p. A-52)

Process-Table

From year	To year	Process
1955		The Acid Neutralization Pit was located underground just west of Building x710. It allowed detention so that liquid effluents from the sink drains in the laboratories could be chemically treated with lime to adjust the pH and remove metal contaminants by precipitaion before the water went to the sewage treatment plant. Prior to 1985, laboratory solvents were included in the sink-drain discharges to the pit. Sampling at the pit has indicated elevated levels of barium concentrations, uranium concentrations, metals such as aluminum, calcium, chromium, copper, iron, mercury, nickel, silicon, silver, and zinc. Other possible contaminants are uranyl nitrate, TCE, acetone, iron, isopropyl alcohol, and cyanide. (909.02, p. A-52)
1991		It was assumed that the pit would be taken out of use in the next 5 years. The assumed RAs would be to pump the pit (half full), treat the effluent by neutralization and detoxification by lime addition, and then treat the effluent as a mixed waste. The pit and the surrounding soil would be removed for an area 5 ft. below the pit and 5 ft. laterally. Fifty feet of process lines would be removed and the remaining lines would be backfilled with clean soil. The soil and pit were considered for treatment and disposal. (909.02, p. A-53)

Hazards: barium concentrations, uranium concentrations, aluminum, calcium, chromium, copper, iron, mercury, nickel, silicon, silver, zinc; possibly uranyl nitrate, TCE, acetone, isopropyl, cyanide (909.02, p. A-53)

Inferred Hazards:

References

909.02 Information Breifing on the Natural Resource Damage Assessment Rule, Presented to the Portsmouth Gaseous Diffusion Plant Trustees, U.S. Department of Energy Field Office, Oak Ridge, December 18, 1991.

Report of Building Number: *X-710B*

Construction Date: **Closure Year:**

DRAFT

Construction Type:

Size:

Unique Features:

Renovations:

Function-Table

Year	Function
	Explosion-Proof Testing Facility (909.01, p. 13)

Process-Table

From year	To year	Process
		West of Builiding X-710 was an explosion-proof testing facility. As of 1977, dangerous laboratory and pilot-plant site experiments were carried out in the building. (909.01, p. 13)

Contaminations

Year	Contamination
	Occasionally dilute chlorine trifluoride and fluorine were vented to the roof. (909.01, p. 13)

Hazards: chlorine trifluoride, fluorine (909.01, p. 13)

Inferred Hazards:

References

909.01 A Guide to Key Facilities at the Portsmouth Gaseous Diffusion Plant, Mary Byrd Davis; Uranium Enrichment Project, Yggdrasil Institute, undated.

Report of Building No *C-337*

DRAFT

Date Constructed: 1952 **Year Closed:**

Construction Type:

Size:

Unique Features:

Renovations: 1954-1961-beggining of first Cascade Improvement Program/ Cascade Improvement Program (CIP/CUP)-replaced major components to increase diffusion process reliability, capacity, and efficency (414.01, p. 14)
Early 1960s water baths were replaced with autoclaves in C-337A (404.01, p. 52)
1963: Technetium traps installed to reduce contamination of enriched uranium (404.01,p 25-26)
1973-1981- second CIP/CUP involved cell by cell removal of components while the remainder of the cascades remained in operation (404.01, p. 18)

Function-Table

Year	Function
1954	Cascade (404.01, p. 25)

Process-Table

From year	To year	Process
1954		Use of reactor tails feed materials begins. (404.01, p. 25)
1954		July 1954- C-335 and C-337 began operations. The cascades were a series of compressors, converter stages, and supporting equipment arranged in cells and units that progressively enriched the UF6 feed. Enrichment occurred as the UF6 passed through barriers in the converters allowing isotopes of lower molecular weight to pass through. Highly enriched uranium-235 moved to the product withdrawal station in C-310, and progressively lower-percentage uranium-238 moved toward the tails withdrawal station in C-315. (404.01, p. 16, 25)

Contaminations/Incidents

Year	Contamination
	Radiation exposure occurred due to machining depleted uranium in the machine shop. Exposure from this source was probably minimal because of the need to keep the uranium cool with lubricating oil to prevent magnesium fires. Finally, there was potential exposure to dust when radioactive deposits were removed

from equipment components by grinding. (414.01, p. F-15)

Technetium-99 was a fission product that was received at Paducah in recycled feed from Hanford and Savannah River Sites. Technetium passed through the Paducah cascade as a volatile compound of fluorine, depositing on internal surfaces of the cascades and contaminating the enriched uranium product. Technetium migrated to the top of the cascade, and much was drained off into the product or vented to the atmosphere. (404.01, p. 17, 60)

Maintenance on major components in the cascades (compressors, converters, and process block valves) presented some of the most significant opportunities for exposure of maintenance personnel. Work on these components required that they be removed from the system, cleaned, rebuilt or repaired, and then reinstalled. Workers opening a cell and dismantling cell components were exposed to UF6, HF, UO2F2, transuranics and fission products, such as technetium. UF6 as a gas or solid was sometimes trapped within components and be released when exposed to air. Remaining solids became airborne, when pneumatic tools were used. The resulting white smoke and pungent odor made the releases apparent to the mechanics and the other workers in the area, resulting in evacuation of the area. These inhalation hazards occurred with removal and disassembly of shaft seals, compressor deblading, removal of converter internal hardware, cutting of the valve purge pigtail, opening or removal of the bonnet flange of a stuck-shut valve, and disassembly of the stem gland of a valve with a leaking bellows. (404.01, p. 61)

"Crawling the pipes" occurred when the cascade system was opened for maintenance or repairs. Operators would be sent into pipes to remove debris. A variation of this occurred during the cascade upgrade programs when decontamination workers scrubbed out the pipes. Exposures included uranyl fluoride, dust with TRUs in it. (414.01, p. 50)

1953 As early as 1953, Paducah management was aware that feed from recycled reactor fuel processed through the enrichment cascade contained trace quantities of plutonium. (404.01, p. 45)

1954 "Puffs" were minor releases of UF6 from process gas equipment and were a common occurrence, despite efforts to minimize the amount of material available for release. One instrument mechanic estimated that puffs occurred weekly in the late 1970s. (404.01, p. 54)

1954 Carl Walter stated that 100,000 to 500,000 lbs of freon were lost per year mostly from the condensers. This figure represents losses from all four cascades. (967.01, p. 26)

1954 Pu, Np, and Tc-99 were concentrated in cylinder heels. Np and smaller amounts of Pu exited cylinder with UF6 collected at feeder head leading to cascade and within cascade near feed point. Cylinder heels were composed of non-volatile corrosion products, U salts and oxides, and residual TRU and U daughter product compounds remaining in the cylinders when UF6 was fed to the cascade. Cylinders were re-used for five-year periods between cleaning and testing. (414.02, p. 80, 414.02, p. 11)

1957 Health and Hygiene Department discovered, during surveys, that neptunium-237 and plutonium had also entered the process stream from the reactor return feed materials. (404.01, p. 45; 414.01, p. 13)

1959 Mid-1959- neptunium contamination was first discovered on a piece of cascade equipment. (cascade number not specified) (404.01, p. 30)

1962 Dec. 1962-Explosion and fire in C-337. Harold Hagan reported a side of the building was blown out, and huge pieces of equipment reduced to 2- or 3- foot piles of melted metal. Carl Walter attributed the cause of this fire to be the direct result of high pressure put on production.(404.01, p. 25; 967.1, p. 27; 420.07, p. 3)

2000 Radiation exposure occurred during baghouse changing.(414.01, p. F-13)

Hazards: UF6, U-235, U-238, HF, UO2F2, Np-237, Pu, Tc-99, uranyl fluoride, fluorine (404.01, p. 14, 17, 45, 50, 55, 61), freon (967.01, p. 26), transuranics (414.01, p. F-13), uranium, radiation,UF4 (ground floor), PCBs (contamination and storage), chlorine trifluorine (conditioning gas), Nickel (welding/cutting), magnemium fluoride (Cold traps), mercury, heat, noise, phschological stress (967.01, p. 27); possibly beryllium (418.01)

Inferred hazards:

References

404.01 Independent Investigation of the Paducah Gaseous Diffusion Plant, Phase II, Prepared by Office of Oversight, Office of Environment, Safety, and Health, U.S. Department of Energy, February 2000..

414.01 Exposure Assessment Project at the Paducah Gaseous Plant Submitted by Paper, Allied Industrial, Chemical and Energy Workers (PACE) International Union, University of Utah Division of Radiology, Center for Advanced Medical Technologies Center by U.S. Department of Energy Office of Environment, Safety and Health, December 2000.

418.01 Personal Comunication from Steven Markowitz to Don Seaborg Concerning Beryllium Sensitivity Testing, March 6, 2000.

420.07 "Former Worker Now Believes Paycheck Came With a Price", part of Cold War Poison, The Courier-Journal, James Malone, Sunday, June 25, 2000.

967.01 Wages, R., et al. Former Worker Medical Sueveillance Program at Department of Energy.

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Report of Building No *C-720*

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Date Constructed: **Year Closed:**

Construction Type:

Size:

Unique Features:

Renovations:

Function-Table

Year	Function
	Supervisory Offices (414.01, p. C-7)
	Maintenance and Stores Building (406.01)

Process-Table

From year	To year	Process
		This building contained the shops for machinists, maintenance mechanics, instrument mechanics, sheet metal workers, electricians, inspection workers, stores workers and janitors
		While large components were degreased in C-400, others were cleaned and degreased in smaller vats of TCE in C-720. (404.01,p. 33)
		A "white room" was established in C-720 for the purpose of manufacturing a portion of the Lunar Lander for NASA and other contaminant sensitive equipment. (414.04, p. 5)
1954		During CIP/CUP, compressors and converters were moved from C-400 for disassembly, cleaning, and decontamination and then to C-720, where they were modified and reassembled prior to reinstallation. At the completion of CIP/CUP activities, converter and compressor disassembly remained a routine operations. (404.01, p. 18)
1965		Beryllium and beryllium-copper alloys were machined. (967.02, p. 5)

1965		Much of the "Work for Others" was performed in this facility. The identified work of concern in this facility is the melting and machining of lead and the machining of beryllium and beryllium-copper compounds. The hazards associated with beryllium were recognized to some extent, but the records and recollection of plant personnel do not show clear evidence that the recommended protective measures such as ventilation or respirators, were used. (414.04, p. ES-3, 12)
1968		An internal memo indicated that a heat-treat furnance contaminated by beryllium at another AEC installation was cleaned in C-710 (404.01, p. 35)
1993	1999	Between 1993 and 1999 contained large degreaser. (417.01, p. 170)

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Contaminations/Incidents

Year	Contamination
	TCE releases were likely to be associated with C-720 ccompressor pit operations, as evidenced by the existence of the southwest plume (404.01, p. 74)
	The primarily structure of interest from the standpoint of radiation safety was the compressor disassembly area. This was located in a pit at one end of the building and was several stories high. Occasional releases of UF6 occurred during compressor disassembly (414.01, p. C-7).
	Routine whole-body beta exposures over PGDP investigation levels existed primarily at areas where uranium daughter products and tranuranics tended to concentrate including the dissambly areas in C-720. (404.01, p. 39)
	Machine shop employees working in C-720, adjacent to the compressor maintenance shop reported that although they may have been routinely exposed to process gas and contaminated dust, they were not required to have protective equipment or participate in mandatory medical examination programs. (404.01, p. 49)
1957	Management directed C-720 Control Valve Shop employees to use personal clothing, even though evidence suggested that personnel routinely exceeded personal clothing contamination limits. Health physics surveys measured personnel clothing contamination levels at 2.5 mrad/hour and 1,250 dpm alpha. (404.02, p. 38)
1965	Beryllium and Beryllium-copper (Be-Cu) alloys were machined in Building C-720 in 1965. Nine workers, who worked in C-720 among other buildings, had positive Be-LPT result when tested by the PACE program. (418.01, p. 3)
1970	In the early 1970s, a worker was involved in removing the top of a 20-inch G-17 valve using air arcing near the pump shop. Even though the valve was tagged that it had been decontaminated in C-400, when th top flange was lifted with the crane, gray smoke came pouring out, affecting much of C-720. The crane operator directly over the valve, passed out and had to be rescurd. Before evacuation the worker and his supervisor, without any respiratory protection, tried to close the opening by using sledge hammers. Finally, they had to leave the building due to burning eyes and throats. Three workers exceded the threshold action levels for uranium on urinalysis. (404.01, p. 62)

1980 Health physics survey of the C-720-C converter shop in 1980 for the CIP/CUP indicated that plant guides for airborne alpha activity were exceeded for uranium by a factor of 1680, neptunium-237 by a factor of 2121, plutonium-239 by a factor of 2483, and thorium-230 by a factorr of 55. Even using conservative protection factors for the repirators used, these exposure levels were significant. (404.01, p. 64)

1986 In February 1986, an event similar to the leaking G-17 valve in the early 1970s occurred. A 100 people were evacuated and 40 were put on urinalysis, with seven on recall. (404.01, p. 62)

1995 Thirty-five chemical filters containing mercury were left lying around a sink in the C-720 maintenance building while engineers devised a way to extract the mercury. (420.12, p. 3)

2000 Maintenance mechanics and machinists had an increased risk of exposure when flange grinding. Contaminated material would build up on various joints which was removed by grinding, either in situ or at the machine shop. This removed UF4 and other materials (414.01, p. F-11)

Hazards: beryllium (414.04, p. ES-3, 12), TCE (404.01, p. 33), alpha radiation, uranium, neptunium-237, plutonium-239, thorium-230 (404.01, p. 64), UF4 (414.01, p. F-11), mercury (420.12, p. 3)

Inferred hazards:

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References

404.01 Independent Investigation of the Paducah Gaseous Diffusion Plant, Phase I, Prepared by Office of Oversight, Office of Environment, Safety, and Health, U.S. Department of Energy, October 1999.

404.02 Independent Investigation of the Paducah Gaseous Diffusion Plant, Phase Ii, Prepared by Office of Oversight, Office of Environment, Safety, and Health, U.S. Department of Energy, February 2000.

414.01 Exposure Assessment Project at the Paducah Gaseous Plant Submitted by Paper, Allied Industrial, Chemical and Energy Workers (PACE) International Union, University of Utah Division of Radiology, Center for Advanced Medical Technologies Center by U.S. Department of Energy Office of Environment, Safety and Health, December 2000

414.04 Report on the Paducah Gaseous Diffusion Plant "Work for Others" Program Including Weapons Support and Disposition, Department of Energy Oak Ridge Operations, December 2000.

417.01 The Paducah Gaseous Diffusion Plant: An Assessment of Worker Safety and Environmental Contamination; Hearings before the Subcommittee on Oversight and Investigations of the Committee on Commerce House of Representatives, One Hundred and Sixth Congress, Firsst Session, Sept. 22, 1999, U.S. Government Printing Office, 2000.

418.01 Personal Comunication from Steven Markowitz to Don Seaborg Concerning Beryllium Sensitivity Testing, March 6, 2000.

420.12 "Kentucky Has Gone Easy on Uranium Plant", part of Cold War Poison, James Malone and James R. Carroll, The Courier Journal, James Malone and James R. Carroll, June 27,2000, p. 3.

Building Number: C-720

967.02 Needs Assessment for screening Former Paducah and Portsmouth GDP Workers for Beryllium Exposure.

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OAK RIDGE RESERVATION MEDICAL EXAMS

Health Conditions by Duration of Oak Ridge Reservation Work from History, Lab Results, or Physician Report

Preliminary Data

Diagnosis Description	Possible Workplace Causative Exposures	Number in All Workers Tested	Number in Workers 5 or More Years at Site
Abnormal Liver Function	Solvents	80	62
Anemia	Radiation, Benzene	132	100
Arthritis, Degen, Joint Disease	Lifting, hammering, repetitive motion	482	365
Asbestosis	Asbestos	266	211
Asthma	Dusts, chemicals	101	75
Bronchitis, Chronic (Unspec.)	Particulates	167	129
Bursitis Disorders	Lifting, hammering, repetitive motion	100	77
Cancer: Bladder	Chemical carcinogens, radiation	12	9
Cancer: Bone	Radiation	7	5
Cancer: Brain	Radiation	1	1
Cancer: Breast	Radiation	6	3
Cancer: Chronic lymphocytic leukemia	Benzene	2	1
Cancer: Colon	Radiation	30	24
Cancer: Esophageal	Radiation	1	
Cancer: Hodgkin's disease	Radiation	1	1
Cancer: Kidney	Radiation, heavy metals, solvents	3	3
Cancer: Laryngeal	Radiation	1	
Cancer: Leukemia (OT chr.lymph.leuk.)	Radiation, Benzene	5	3
Cancer: Liver	Radiation, solvents	4	3
Cancer: Lung	Radiation, nickel, welding fumes, asbestos	26	18
Cancer: Lymphoma	Radiation, benzene	2	2

Diagnosis Description	Possible Workplace Causative Exposures	Number in All Workers Tested	Number in Workers 5 or More Years at Site
Cancer: Mesothelioma	Asbestos	4	4
Cancer: Multiple myeloma	Radiation, benzene	4	3
Cancer: Non-Hodgkin's lymphoma	Radiation, Benzene	7	4
Cancer: Oral-pharyngeal	Radiation, benzene	1	1
Cancer: Pancreatic	Radiation	2	2
Cancer: Prostate	Radiation	65	52
Cancer: Rectum	Radiation, wood dust, metals	1	1
Cancer: Skin cancer of face	Radiation, sunlight	19	17
Cancer: Skin, ear	Radiation, sunlight	7	4
Cancer: Skin, Melanoma	Radiation, sunlight	11	7
Cancer: Skin, non-melanoma	Radiation, sunlight	8	4
Cancer: Skin, Site Unspecified	Radiation, sunlight	72	55
Cancer: Stomach	Radiation	6	5
Cancer: Testicular	Radiation	3	2
Cancer: Throat	Radiation	2	2
Cancer: Tonsils	Radiation	1	1
Cancer: Uterine	Radiation	1	1
Carpal Tunnel Syndrome	Repetitive motion	12	9
Chronic beryllium disease	Beryllium	1	1
COPD	Dusts, metals, welding fumes	174	124
Dermatitis, Contact, due to metals	Chromium, nickel, metals	1	1
Dermatitis, Contact, NEC	Allergens e.g. cement dust, nickel	76	59
Hearing Loss, Sensorineural	Noise	784	578
Hepatitis, Unspecified	Solvents	6	3
Hyperthyroidism	Radiation	26	22

Diagnosis Description	Possible Workplace Causative Exposures	Number in All Workers Tested	Number in Workers 5 or More Years at Site
Hypothyroidism, Acquired, Unspec.	Radiation	94	76
Interstitial Fibrosis, NOS	Asbestos, Silica	5	2
Lead Poisoning	Lead	1	1
Lung mass	Radiation, asbestos, metals	7	7
Lung nodule(s)	Radiation, asbestos, metals	32	27
Lung nodule, questionable	Radiation, asbestos, metals	59	44
Mercury Poisoning	Mercury	3	1
Neuropathy, Peripheral	Solvents	39	35
Nodule, thyroid	Radiation	1	1
Pleural Plaques	Asbestos	229	185
Renal Failure	Metals, solvents	26	22
Rhinitis, Allergic	Dusts, solvents	99	81
Sarcoidosis	Beryllium, organic dusts	1	1
Silicosis	Silica	5	4
Thyroid disease	Radiation	21	16
Tremor (Unspecified)	Mercury	6	6

OAK RIDGE RESERVATION MEDICAL EXAMS

Prevalence of Health Conditions from History, Lab Results, or Physician Report

Workers with Longest Jobs at the Oak Ridge K-25 Gaseous Diffusion Plant

Results of Exams Through December 31, 2002

Diagnosis Description	Possible Workplace Causative Exposures	Number in All Workers Tested	Prevalence
Abnormal Liver Function Test	Solvents	15	4.8%
Anemia	Radiation, Benzene	31	9.9%
Arthritis, Degen, Joint Disease	Lifting, hammering, repetitive motion	122	39.0%
Asbestosis	Asbestos	63	20.1%
Asthma	Dusts, chemicals	29	9.3%
Bronchitis, Chronic (Unspec.)	Particulates	40	12.8%
Bursitis Disorders	Lifting, hammering, repetitive motion	29	9.3%
Cancer: Bladder	Chemical carcinogens, radiation	4	1.3%
Cancer: Bone	Radiation	2	0.6%
Cancer: Breast	Radiation	2	0.6%
Cancer: Colon	Radiation	9	2.9%
Cancer: Leukemia (OT chr.lymph.leuk.)	Radiation, Benzene	1	0.3%
Cancer: Lung	Radiation, nickel, welding fumes, asbestos	8	2.6%
Cancer: Mesothelioma	Asbestos	2	0.6%
Cancer: Prostate	Radiation	25	8.0%
Cancer: Skin cancer of face	Radiation, sunlight	7	2.2%
Cancer: Skin, ear	Radiation, sunlight	1	0.3%
Cancer: Skin, Melanoma	Radiation, sunlight	4	1.3%
Cancer: Skin, Site Unspecified	Radiation, sunlight	15	4.8%
COPD	Dusts, metals, welding fumes	38	12.1%

Diagnosis Description	Possible Workplace Causative Exposures	Number in All Workers Tested	Prevalence
Dermatitis, Contact, NEC	Allergens e.g. cement dust, nickel	20	6.4%
Hearing Loss, Sensorineural	Noise	192	61.3%
Hyperthyroidism	Radiation	5	1.6%
Hypothyroidism, Acquired, Unspec.	Radiation	17	5.4%
Lead Poisoning	Lead	1	0.3%
Lung nodule(s)	Radiation, asbestos, metals	6	1.9%
Lung nodule, questionable	Radiation, asbestos, metals	11	3.5%
Neuropathy, Peripheral	Solvents	11	3.5%
Pleural Plaques	Asbestos	58	18.5%
Renal Failure	Metals, solvents	9	2.9%
Rhinitis, Allergic	Dusts, solvents	24	7.7%
Thyroid disease	Radiation	6	1.9%
Tremor (Unspecified)	Mercury	1	0.3%