20000501.1

WEMS
Wastren-EnergX Mission Support, LLC

Portsmouth Information Release Approval Request

I. Document / Information Description
(To be filled out by Requestor)

ID Number: ~~DOE 2000~~ N/A

Originated Date: ~~10-01-12~~ 05/2000

Document Title or Identification: Office of Oversight, Environment, Safety and Health, Independent Investigation of the Portsmouth Gaseous Diffusion Plant, Volume 1

Original Author(s) / Organization: U.S. Department of Energy

Technical Editor(s) /Organization: U.S. Department of Energy

Format: ☒ Document: 99 Total # Pgs ☐ Transparencies / Presentations
☐ Photos: ____ # Prints ☐ Electronic Media: Type ____

Audience: ☐ Public Meeting ☐ Private Meeting ☐ Presentation to Congress
☒ Distribution List ☐ Internet Publication ☐ Publication/Press Release

Justification: For inclusion in Waste Disposition Administrative Record

Requestor: Sue Chabot-Mack Date: 10-01-12
Legible Signature or Print Name & Signature

II. Patent, Classification and Protected Information Review
To be completed by the PORTS Classification Office)

	Yes	No	
Patent/Proprietary Review:	☐	☑	Contains Patentable or Proprietary and/or has clearance patent information
Classification Review:	☑	☐	Document is Unclassified
	☐	☑	Document is Classified
Sensitive Information Review:	☐	☑	Contains Official Use Only (OUO)
	☐	☑	Contains Export Controlled Information (ECI)
	☐	☑	Contains Unclassified Controlled Nuclear Information (UCNI)
	☐	☑	Contains Personal Identifiable Information (PII)
	☐	☑	Contains other Protected Information, describe:

[signature] 4/2/13

III. Information Release Approved or Denied
To be completed by the PORTS Classification Officer

☑ Approved for Public Meetings, Widespread Distribution, or Presentation to Congress
☑ Approved for Publication, Media Broadcast, and/or Public Website
☐ Approved for Internal Distribution Only
☐ Approved for Publication on the Internal Network only (access restricted to network users only)
☐ Not Approved for Release
☐ Approved with restrictions (describe): ____

H A Thomas 10/2/12
Classification Officer/Technical Information Officer Signature / Date

Send to OSTI? ☐ Yes ☒ No

Note: Requestor must retain a record copy of all requests (approved or rejected) and material being released.
Classification Officer send a copy of this form to TPMC Records Management and Document Control.

FSSF-4101 (3-10)

1-GEN-00-71-20000501.1

Office of Oversight
Environment, Safety and Health

Independent Investigation of the

Portsmouth Gaseous Diffusion Plant

Volume 1: Past Environment, Safety, and Health Practices

May 2000

Table of Contents - Volume 1

EXECUTIVE SUMMARY 1

1.0 INTRODUCTION 7

2.0 HISTORICAL OVERVIEW OF ACTIVITIES AT PORTSMOUTH 16

2.1 Background 16
2.2 Operations 16
2.3 Maintenance and Modifications 20
2.4 Unusual Events and Accidents 20
2.5 Worker Safety and Health Programs 22
2.6 Waste Management 25
2.7 Air and Water Emissions 27
2.8 Management and Oversight 28

3.0 PAST OPERATIONAL PRACTICES 30

3.1 Worker Safety and Health Programs 30
3.2 Operations and Maintenance 44
3.3 Operations Summary 58

4.0 PAST ENVIRONMENTAL MANAGEMENT PRACTICES 59

4.1 Waste Management 59
4.2 Management and Disposal of Scrap and Surplus Materials 66
4.3 Liquid Effluents 67
4.4 Atmospheric Releases of Radioactivity and Fluorine/ Fluorides 71
4.5 Environmental Management Summary 74

5.0 PAST MANAGEMENT AND OVERSIGHT PRACTICES AND EMPLOYEE RELATIONS 76

5.1 Oversight 76
5.2 Labor Relations 77

APPENDIX A – HISTORICAL HAZARDS 81

APPENDIX B – PRINCIPAL ACTIVITY EVALUTION SUMMARY 91

OVERSIGHT

Abbreviations Used in This Report

ALARA	As Low As Reasonably Achievable
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
CIP	Cascade Improvement Program
CPT	Cone Penetrometer Test
CUP	Cascade Uprating Program
DAC	Derived Air Concentration
DCG	Derived Concentration Guide
DMSA	DOE Material Storage Area
DOE	U.S. Department of Energy
D&D	Decontamination and Decommissioning
EH	Office of Environment, Safety and Health
EMP	Environmental Monitoring Plan
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ES&H	Environment, Safety, and Health
GAO	Government Accounting Office
HF	Hydrogen Fluoride or Hydrofluoric Acid
ISMS	Integrated Safety Management System
JHA	Job Hazard Analysis
LDB	Legionnaire's Disease Bacteria
LLW	Low-level Waste
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MSDS	Material Safety Data Sheet
NCRP	National Committee on Radiation Protection and Measurement
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
OCAW	Oil, Chemical, and Atomic Workers (Union)
OR	Oak Ridge Operations Office
OSHA	Occupational Safety and Health Administration
PAL	Plant Allowable Limit
PCB	Polychlorinated Biphenyl
PORTS	Portsmouth Gaseous Diffusion Plant
P/QA	Performance and Quality Assurance (Department)
RCG	Recommended Concentration Guide
RCRA	Resource Conservation and Recovery Act
RCW	Recirculating Cooling Water
RFI	RCRA Feasibility Investigation
RPG	Radiation Protection Guide
RWP	Radiation Work Permit
SAR	Safety Analysis Report
SOMC	Southern Ohio Medical Center
TCE	Trichloroethene
TLD	Thermoluminescent Dosimeter
TSCA	Toxic Substances Control Act
TSR	Technical Safety Requirement
UF6	Uranium Hexafluoride
UNH	Uranyl Nitrate Hexahydrate
UPGWA	United Plant Guard Workers of America
USEC	United States Enrichment Corporation
USQ	Unreviewed Safety Question
VOC	Volatile Organic Compound

Executive Summary - Historical ES&H Practices

EVALUATION:	Office of Oversight Investigation
SITE:	Portsmouth Gaseous Diffusion Plant
DATES:	January-May 2000

Background/Scope

The Department of Energy (DOE) Office of Oversight, within the Office of Environment, Safety and Health (EH), conducted an investigation of the Portsmouth Gaseous Diffusion Plant (PORTS or Plant) from January through May 2000. This investigation was performed at the direction of the Secretary of Energy, who instructed EH to examine concerns about past operations and work practices, and current management of legacy materials at PORTS. The purposes of this investigation were to: (1) determine whether past environment, safety, and health (ES&H) activities and controls associated with uranium enrichment and supporting operations were in accordance with the knowledge, standards, and local requirements applicable at the time; (2) identify any additional ES&H concerns that had not been documented; and (3) determine whether current work practices for DOE-controlled areas of the site adequately protect workers, the public, and the environment.

Specific areas examined by the EH investigation team included past operations of the Plant, including operation of the cascades and the oxide conversion and feed manufacturing plants; historical and current maintenance and modification programs; worker health and safety programs and practices; historical and current programs and practices for the treatment, storage, and disposal of legacy and newly generated waste; and site remediation. The team also attempted to identify any evidence of potentially hazardous work that PORTS might have performed for others or that was directly related to weapons systems. This investigation examined programs and activities of various organizations responsible for ensuring protection of the workers, the public, and the environment at PORTS, including the Goodyear Atomic Corporation and subsequent management and operating contractors, DOE Headquarters offices, the DOE Oak Ridge Operations Office (OR), Portsmouth Site Office, Bechtel Jacobs, and key subcontractors. This investigation did not evaluate current Nuclear Regulatory Commission (NRC)-regulated United States Enrichment Corporation (USEC) activities, except at interfaces with DOE-controlled areas and activities.

The team interviewed former and current employees; observed work; performed walkdowns of facilities, work areas, and site grounds; conducted environmental sampling and analysis; conducted radiological surveys; and reviewed documents. Interviews were conducted with over 300 current and former employees, including DOE Headquarters, OR, and Portsmouth Site Office personnel; Bechtel Jacobs and subcontractor managers, supervisors, and workers; selected USEC personnel; and stakeholders. The team conducted facility and work area walkthroughs examining Plant operations, work practices, and hazard controls. The investigation team visited essentially all DOE-controlled Plant facilities, waste and material storage areas, and site grounds. The team collected environmental samples from groundwater wells, surface water sources, and sediments both inside and outside the perimeter security fence. The investigation team also reviewed thousands of current and historical documents, including plans, procedures, operations logs, assessments, analyses, and memoranda.

The intent of this investigation was to identify and address the overall ES&H concerns and questions of current and former workers and the public, not to determine the validity of specific allegations. Several ongoing or proposed EH initiatives should provide greater understanding of certain aspects of these issues, including a mass balance project, a medical surveillance project, and an exposure assessment project. This volume, Volume 1, addresses past ES&H activities and practices and their effectiveness in protecting workers, the public, and the environment. The second volume, Volume 2, deals with current ES&H issues in DOE-controlled areas.

Results

External conditions and influences have had a significant effect on the ES&H-related behavior and intentions of both management and workers at PORTS, especially during the first two decades of operation. When PORTS began production activities, World War II and the Korean conflict had recently ended, and the Cold War was a reality. The work being done was classified, involved high technology, and was important to the national defense. The “need to know” was an ingrained security policy that had a major effect on attitudes toward sensitive operations and materials. The Plant was one of the biggest employers in the area, paying wages significantly higher than available elsewhere locally. Work at PORTS was an attractive alternative to other agricultural or industrial employment options to people in the surrounding region. Management and the Atomic Energy Commission (AEC) were under pressure to maximize production. While most of the hundreds of workers interviewed by the team indicated, in response to specific questioning, that they were unafraid to ask questions about safety and they had no fear of reprisals, a few interviewees did express concerns about both. Industries of the 1950s, including AEC facilities, were largely self-regulated, and guidance and regulatory requirements were evolving. Significant industrial and environmental legislation that would focus attention and actions toward greater protection of workers and the environment was not enacted until the 1970s. Ensuring worker protection was a key part of the Oil, Chemical, and Atomic Workers Union (OCAW) activities since the union’s inception in 1954.

Operations and Maintenance

Many operations and maintenance activities at PORTS involved hazardous conditions and the potential for exposure of personnel to physical, radioactive, and chemical hazards. Enrichment process facilities with the potential for such exposures included the 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 replaced exposed workers to airborne uranium, transuranics, fission products, fluorine, and hydrogen fluoride (HF) gas. Others worked with, or were exposed to, various hazardous materials and chemicals such as asbestos, trichloroethene (TCE) and other solvents, polychlorinated biphenyls (PCBs), acids, chromium, nickel, lithium, welding fumes and gases, and mercury. Radioactive or hazardous materials were spilled or released to the environment from production related facilities and attendant work activities.

Probably the most hazardous operations at PORTS involved the operation of the oxide conversion plant, which had continuous airborne and surface radioactive contamination problems over its 21-year lifetime, from 1957 to 1978. Personnel working in this facility were exposed to transuranics from recycled reactor fuel feed and to insoluble airborne uranium oxides. Several workers, later put on permanent restriction from working in airborne-contamination areas, received significant intakes that were still detectable in their lungs decades later. Maintenance and modification activities that required breaching process systems or components also exposed workers to radioactive uranium hexafluoride (UF_6) process gas and HF. Decontamination activities in X-705 (Decontamination and Cleaning Building) and elsewhere involved 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 nickel compounds and Freon piping. PCB-contaminated oils posed long-term personnel exposure hazards.

Hundreds of UF_6 releases occurred from equipment failures and during maintenance, sampling, cylinder handling, and connection and disconnection of feed and product cylinders. These releases caused many intakes of uranium and HF burns, and they contaminated work areas and the environment. Personal protective equipment was usually available, often recommended by industrial hygiene and health physics personnel, or specified in procedures. However, compliance by workers and enforcement by supervision was very inconsistent. Lack of understanding or acceptance of the consequences of non-compliance, insufficient oversight by supervision, and discomfort associated with respirators and extra clothing all contributed to this inconsistency.

The investigation team did not identify any evidence that PORTS performed any work for others that directly involved work with or burial of nuclear weapons components. With the exception of the burial of a dismantled, DOE nickel fabrication plant in the classified landfill in 1979, no evidence was found that PORTS performed any work for others involving hazardous materials. Incidental use of beryllium was identified, including the disposal of sealed plutonium/beryllium sources, use of welding rods, use of early fluorescent bulbs with a beryllium coating, use of tools fabricated from beryllium, and machining of piping components containing beryllium. Several interviews with former workers indicated that there might have been beryllium bar stock on site and in the machine shop, although no specific evidence of that was discovered. Concentrations of beryllium above background levels have been identified in a number of environmental samples taken in the late 1980s and early 1990s from various Plant locations.

Worker Safety and Health Programs

Worker safety and health programs were established when the Plant started operation and have evolved significantly. The implementation and effectiveness of these programs varied widely and, in many ways, failed to adequately protect the safety and health of PORTS workers. Overall, however, occupational illness and injury statistics consistently reflected a much better record than industry averages for comparable manufacturing work settings.

Safety and health training methods and effectiveness also varied greatly. Initial training of operations and maintenance workers was extensive and involved the basics of radiation and industrial safety. However, the rigor of training efforts diminished quickly and, until the 1980s, on-the-job training from supervisors and more experienced workers was standard practice. Monthly safety meetings, posters, newsletters and bulletins, and safety handbooks supplemented the on-the-job training. These materials provided good information on health and safety fundamentals, including radiation protection and the use of personal protective equipment, as well as basic industrial safety information. It was not until the 1990s that a more focused and rigorous ES&H training program was established.

Protection of the safety and health of workers was a line management responsibility, and hazard identification and controls were primarily contained in work procedures and work permits developed by line organizations. Industrial safety, industrial hygiene, and health physics staff performed surveys, inspections, and event analysis and made recommendations for hazard controls and personnel protective actions. However, they had little oversight or enforcement authority until the 1970s. Staffing for all safety and health organizations was very limited well into the 1970s and was insufficient to provide adequate attention for up to 2500 employees working in numerous and varied hazardous conditions. Organizationally, these safety and health groups were located in the Industrial Relations Department and had little direct visibility and access to senior management. When Occupational Safety and Health Administration regulations were issued in the 1970s, the industrial safety group became more proactive and performed comprehensive compliance inspections.

Radioactive contamination and control limits were established to minimize personnel exposures and prevent exceeding regulatory limits. A network of stationary air samplers and portable and breathing zone samplers provided data on airborne contamination. This monitoring frequently showed that limits had been exceeded. PORTS' assumption that all uranium intakes were soluble compounds that would be excreted quickly and could be monitored effectively by urinalysis was not conservative for some locations and activities where insoluble aerosols were generated, such as in the oxide conversion plant and from maintenance activities involving grinding, cutting, and buffing. Respirator use was encouraged and recommended for high-risk operations and activities, but event investigations, safety and health staff inspections, and appraisals by OR identified frequent and continuing non-compliance with respirator requirements. As a result of OR appraisal findings in mid-1972, the site instituted several major program improvements, including issuing new procedures, surveying work areas, procuring additional respirators, training workers, and implementing a respirator fit testing program.

The exposure of workers to radioactive materials was monitored, and with some exceptions, documented exposures were within the limits applicable at the time. However, monitoring deficiencies caused exposures to airborne radioactivity to be underestimated, and actual exposures were likely higher than indicated by PORTS monitoring records. Extremity monitoring was not employed; exposures of hands, feet, and eyes in high beta radiation fields were underestimated and could have resulted in exposures exceeding limits. A bioassay (urinalysis) program monitored internal uranium exposures and provided a means of verifying and monitoring excretion rates to limit overexposures and identify otherwise unmonitored intakes from releases or airborne contamination at work locations. In 1965, an in-vivo body counting program was initiated to monitor for insoluble enriched uranium, a material for which the urinalysis program was not sufficiently sensitive or reliable. Studies performed in 1990 indicated that the in-vivo counter's capability for analyzing transuranics was questionable, making it difficult to demonstrate that all internal exposures have been accurately detected and assessed.

Goodyear Atomic Corporation established and operated a robust and sophisticated occupational health program in the 1950s and 1960s that provided comprehensive medical examinations and maintained records for accidents and injuries, bioassay programs, and workers compensation cases. In the 1970s and 1980s, the performance of the occupational medicine program declined, as it experienced staffing difficulties and quality-of-care complaints. Under Martin Marietta Utility Services the program was strengthened in the early 1990s, with new procedures and added staffing.

Environmental Management

Over the operating lifetime of the Plant, activities to manage wastes and liquid and air process effluents evolved in response to internal and external requirements. PORTS personnel monitored emerging regulations and established plans and strategies in response to new requirements. However, implementation of necessary changes and new compliance programs often required an extended period of time and was not always fully effective.

General guidelines for handling, storing, and disposing of waste existed in the early days of Plant operations. Throughout the Plant's history, efforts were made to minimize the loss of valuable enriched uranium in Plant waste streams. However, onsite sanitary landfills likely received some contaminated material, since waste segregation practices were not fully understood or effective. As new requirements were enacted, additional waste streams, such as hazardous wastes, were restricted from disposal in onsite landfills. Oils contaminated with PCBs and uranium were spread on roads, disposed of in oil biodegradation plots, burned in open containers, and incinerated.

The State of Ohio mandated closure of important site landfills and the incinerator in the late 1980s and early 1990s, because of concerns over continued disposal of regulated wastes. The Plant ceased offsite shipment of radioactive waste, and without approved commercial treatment and disposal facilities, large amounts of radioactive waste, mixed hazardous and radioactive waste, and radioactively contaminated PCB waste accumulated and were stored on site; much of this waste remains in storage today. Numerous inspections and appraisals by the State of Ohio Environmental Protection Agency (EPA), DOE (e.g., Tiger Team assessment), OR, and internal organizations identified performance problems in the treatment, storage, and disposal of hazardous waste. By 1988, the State of Ohio EPA sent DOE and the Plant a notice of intent to file suit for hazardous waste violations.

In the 1950s, Goodyear Atomic Corporation management was aware that contaminated surplus materials could only be shipped to properly licensed and authorized recipients and that radiological monitoring was required for all potentially contaminated materials being offered for public sale. Although significant efforts were taken to properly segregate clean and contaminated materials intended for sale to the public, there were continued segregation compliance problems and limited health physics manpower to perform surveys of sale materials, indicating a possibility that material exceeding radiological release guidelines was released from the site from the 1950s through the 1980s.

The environmental monitoring program at PORTS was initiated in 1955. In the 1970s, several new wastewater treatment systems were constructed to meet new permit requirements and to significantly reduce the levels of radionuclide emissions. The PORTS National Pollutant Discharge Elimination System permit, issued by the State of Ohio in the 1970s, required testing and reporting of specific chemical and physical properties and set limits on Plant chemical discharges. Radiological discharges have always been subject to the regulations of the AEC and its successors. Despite the discharge restrictions, legacy environmental contamination exists in ponds, local ditches, and streams.

Although 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, and subsequently transuranic contamination, was unexpectedly discovered in liquid effluents from X-705. Technetium was also detected in airborne discharges. This discovery triggered significant long-term efforts by Plant personnel to isolate sources of technetium and transuranic contamination, develop or improve control methods, and establish appropriate monitoring protocols.

Since the Plant's inception, PORTS was proactive in tracking, assessing, and documenting the potential public dose impact from releases of fluorine or UF_6 to the environment. Dose estimates and release summaries are provided in annual reports starting from the early 1970s in response to AEC requirements. While it is likely that PORTS air emission estimates were done in good faith, these estimates did not reflect all the potential historical releases, including some that could have been significant, such as cell jetting. Evidence of contamination on roofs and grounds and recurring high workplace air sample results in various locations, such as the oxide conversion facility, point to significant unmonitored releases that had not been previously included in monitoring results. The Plant did not perform continuous vent monitoring of radionuclides or fluorides until the mid-1980s, and previous methods for estimating releases have been shown to be unreliable and in some cases non-conservative.

Fluorine and fluoride compounds were used in significant quantities at PORTS and both by design and by accident were vented to the atmosphere. Plant personnel have repeatedly complained of offensive fluorine fumes, breathing difficulty, and respiratory tract damage from releases at the fluorine generating facility and process buildings. The PORTS medical department rarely confirmed significant health effects, but confirmatory surveys to establish release concentrations provided unreliable results due to the rapid dissipation of released gases. Continuous environmental monitoring for fluorides has been conducted for many years, and ambient samplers sometimes indicated fluoride concentrations that exceeded release limits.

Management, Oversight, and Industrial Relations

The AEC, the Environmental Research and Development Administration (ERDA), and DOE have always had a site presence at PORTS, but until 1989 had limited ES&H oversight capability or responsibility. OR conducted very cursory annual safety and health program appraisals from 1957 to at least 1980. However, these appraisals typically involved two or three persons for three or less days on site "addressing" a broad scope of ES&H functions, as well as corrective actions from previous appraisals. There was little evidence of field observation in these appraisals. When OR personnel did conduct field inspections, they identified numerous and significant performance problems. OR also performed detailed investigations of major UF_6 releases or other accidents. Although the Plant appeared to be responsive to the concerns and recommendations raised by OR, root causes and programmatic issues were rarely identified and addressed; the adverse conditions and performance reoccurred, or remained uncorrected in other Plant areas. In the 1980s, OR ES&H oversight became more rigorous and proactive, especially after the Tiger Team assessment in 1989 identified significant programmatic deficiencies and unsafe conditions and performance in the Plant. The AEC and its successors also investigated worker allegations of unsafe conditions and practices, but with inconsistent rigor and effectiveness. A 1980 review by the General Accounting Office sharply criticized DOE oversight of ES&H at the gaseous diffusion plants.

Goodyear Atomic Corporation management oversight of ES&H was reactive and often ineffective, as reflected in continuing ES&H problems through the years. The Plant responded well when Federal and state regulators raised major concerns or when new regulations were issued, implementing corrective actions and developing new programs and controls. However, Plant management often failed to ensure that ES&H staff recommendations were executed, or that ES&H requirements were implemented and enforced by first-line supervision.

Since its inception in 1954, OCAW took an aggressive approach to protect and improve employee welfare. This aggressiveness has resulted in strained relations between management and labor over the years and numerous strikes have occurred, four lasting longer than three months and two lasting well over six months. These strikes presented administrative and operational challenges to the Plant to maintain continuous production of enriched uranium. OCAW union members had filed an estimated 17,000 grievances by 1993, many addressing ES&H concerns. This process brought attention to adverse conditions and resulted in safer and healthier working conditions and work practices.

Relations between the United Plant Guard Workers of America (UPGWA) union and Plant management were much less confrontational. Although protective forces have been an integral part of Plant activities due to security considerations, the ES&H protection provided to production workers (such as respirators and shoe covers) were not always considered or provided to security personnel when they worked in close proximity to hazardous operations or were stationed, ate lunch, and took breaks in contaminated areas. In addition, in the late 1980s and early 1990s, protective forces performed extensive training drills in radioactively contaminated buildings without appropriate protective clothing or monitoring. Hazard communications and ES&H training have not always been provided on a timely and consistent basis for protective force workers.

Conclusions

Historical operations and practices were significantly influenced by various external conditions related to local wages, industry practices, and world political conditions. With some exceptions, documented exposures to radioactivity were monitored and did not exceed the standards of the time. Due to weaknesses in monitoring programs, such as the lack of extremity monitoring, exposure limits may have unknowingly been exceeded. In addition, communication of hazards, the rationale for and use of protective measures, accurate information about radiation exposure, and the enforcement of protective equipment use were inadequate. Further, workers were exposed to various chemical hazards for which adverse health effects had not yet been identified. Environmental practices prior to Federal and state legislation in the 1970s and 1980s resulted in many adverse impacts to the environment, although essentially all on Federal property. AEC/ERDA/DOE and contractor management failed to proactively identify ES&H vulnerabilities, clearly communicate high expectations for ES&H performance, and implement consistent, effective corrective actions to known problems. Management also failed to ensure that hazard controls were implemented by supervisors and workers, resulting in additional and higher exposures to personnel and continuing unnecessary radioactive contamination.

1.0 Introduction

1.1 Purpose and Scope

The Department of Energy (DOE) Office of Oversight, within the Office of Environment, Safety and Health (EH), conducted an investigation of the Portsmouth Gaseous Diffusion Plant (PORTS or Plant) from January through May 2000. The purposes of this investigation were to (1) determine whether historical, environment, safety, and health (ES&H) activities and controls associated with uranium enrichment and supporting operations from initiation of Plant operations in 1954 until 1997 were in accordance with the knowledge, standards, and local requirements applicable at the time; (2) identify any additional ES&H concerns that have not been documented; and (3) determine whether current DOE and DOE contractor work practices since 1997 (when the Nuclear Regulatory Commission [NRC] assumed regulatory authority of the gaseous diffusion processes, facilities, and personnel) for DOE-controlled areas of PORTS adequately protect workers, the public, and the environment. This investigation was performed at the direction of the Secretary of Energy, who instructed EH to examine concerns about past operations and work practices, and current management of legacy materials at PORTS.

The activities at PORTS are being evaluated as a single, integrated investigation coordinated with other organizations that have regulatory authority at PORTS, including the State of Ohio, the NRC, the Environmental Protection Agency (EPA), and the Occupational Safety and Health Administration (OSHA). The scope of the investigation includes: (1) ES&H practices associated with operating (i.e., uranium enrichment) and support facilities from 1954 to March 3, 1997; (2) ES&H issues associated with these facilities and properties from 1997 to the present; and (3) facilities and properties under current DOE jurisdiction. Specific PORTS operations examined by the EH investigation team include: cascade operations; feed production; oxide conversion; landlord infrastructure activities; treatment, storage, and disposal of legacy and newly generated waste; site remediation; uranium hexafluoride (UF_6) cylinder storage; maintenance; facility decontamination and decommissioning; and polychlorinated biphenyl (PCB) collection, treatment, and cleanup. This investigation also examined the programs and activities of the organizations responsible for ensuring protection of the workers, the public, and the environment at PORTS, including the Oak Ridge Operations Office (OR), Portsmouth Site Office, Bechtel Jacobs, and key subcontractors, as well as the effectiveness of PORTS' implementation of its management and integration contract, including the complete transfer of agreed-upon ES&H functions to subcontractor organizations.

Specific areas excluded from this investigation include all current NRC-regulated activities at PORTS, and all United States Enrichment Corporation (USEC) activities specifically involving gaseous diffusion operations. Similarly, the results of other related evaluations being conducted by DOE—such as the mass balance, exposure assessment, and medical surveillance projects—are outside the scope of this investigation.

1.2 Current Operations and Hazardous Materials

PORTS is located near Piketon, Ohio, approximately 25 miles northeast of Portsmouth, Ohio, and two and a half miles east of the Scioto River. PORTS is approximately 3,714 acres, of which the gaseous diffusion plant occupies about 640 acres, of which 93 acres contain Plant process buildings. The current mission of the Plant is to "enrich" uranium for use in domestic and foreign commercial power reactors. In the past, the mission also included providing materials for weapons production and naval reactor fuel. Enrichment involves increasing the percentage of the uranium-235 isotope in the material used for creating reactor fuel (UF_6). Uranium-235 is highly fissionable, unlike the more common isotope uranium-238. PORTS receives slightly enriched UF_6 from the Paducah Gaseous Diffusion Plant (which enriches 0.7 percent uranium-235 to about 1.95 percent uranium-235 currently) and further enriches the UF_6 up to 5 percent uranium-235. Figures 1, 2, and 3 are site maps and an aerial view of PORTS.

Over its operating lifetime, PORTS estimates that it has processed more than 336,000 metric tons of uranium. The uranium enrichment process involves moving UF_6 as a compressed gas through a series of diffusion stages; PORTS has over 4,000 diffusion stages. The diffusion process generates enriched uranium product and depleted uranium tails. The product is shipped to commercial customers for conversion to fuel rods and use in reactors. The tails, containing less than 0.5 percent uranium-235, remain at PORTS in cylinders and are shipped to Paducah for use as depleted feed.

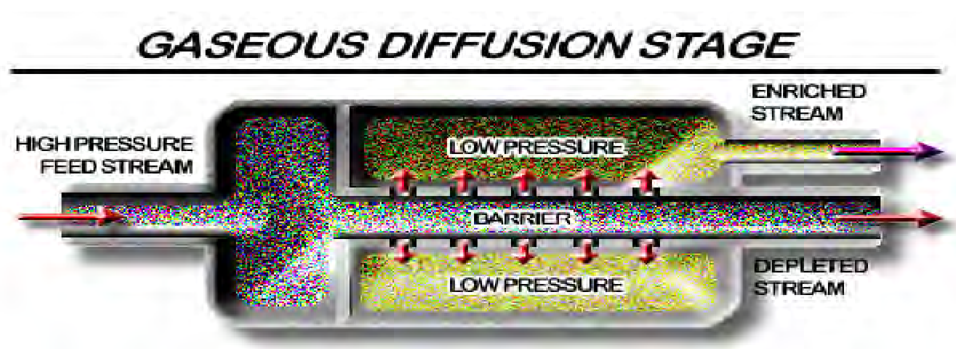
DOE is the site "landlord," owns the physical plant, and is responsible for some activities in X-326, the X-326 "L Cage" and its glovebox, the X-345 high assay sampling area, and the X-744G glovebox. DOE retains responsibility for legacy waste treatment, storage, and disposal; management of the depleted UF_6 cylinders; completion of the highly enriched uranium shutdown and removal program; and remediation of environmental contamination. In April 1998, DOE selected Bechtel Jacobs as the management and integrating contractor for PORTS. This contract mandates that Bechtel Jacobs subcontractors perform the majority of the work. Bechtel Jacobs recently awarded the last two major subcontracts to WASTREN to perform site services and waste management operations. Figure 4 provides organization charts for the DOE Portsmouth Site Office and Bechtel Jacobs.

USEC leased the enrichment production facilities on July 1, 1993, and contracted with Martin Marietta Utility Services, which became Lockheed Martin Utility Services, as the maintenance and operating contractor until May 1999, when USEC assumed responsibility for enrichment activities. The NRC performs regulatory oversight of USEC activities. OSHA regulates USEC occupational safety and worker health, and the State of Ohio and the EPA regulate USEC environmental activities. USEC is responsible for the process of separating uranium isotopes through gaseous diffusion and support operations. Support operations include feed and withdrawal of material from the primary process, potable and cooling water treatment, steam generation for heat, decontamination of equipment removed from the process for maintenance or replacement, recovery of uranium from various waste materials, and treatment of industrial wastes.

During the Plant's operating history, the process of enriching uranium for military and commercial applications has generated higher enriched product, tails, and radioactive and non-radioactive wastes. In addition, other radioactive and non-radioactive waste materials, not associated with naturally occurring uranium, have been introduced to the Plant and include transuranic elements (isotopes with atomic numbers greater than uranium) such as neptunium-237 and plutonium-239, fission products such as technetium-99, PCBs, and volatile organic compounds such as trichloroethene (TCE). These waste materials present differing levels of risk to workers and to the public depending upon their concentration, pathway of release, and method of exposure. Figure 5 shows the historical process of uranium enrichment and its byproducts.

1.3 Investigative Approach

The overall objectives of this investigation were to determine whether historical ES&H activities and controls were in accordance with the knowledge, standards, and local requirements applicable at the time; whether any additional ES&H concerns have not been documented; and whether current work and safety management practices for DOE-controlled areas of PORTS are sufficient to protect workers, the public, and the environment. Issues identified by the investigation team that are associated with the current implementation of ES&H programs are summarized in Volume 2.



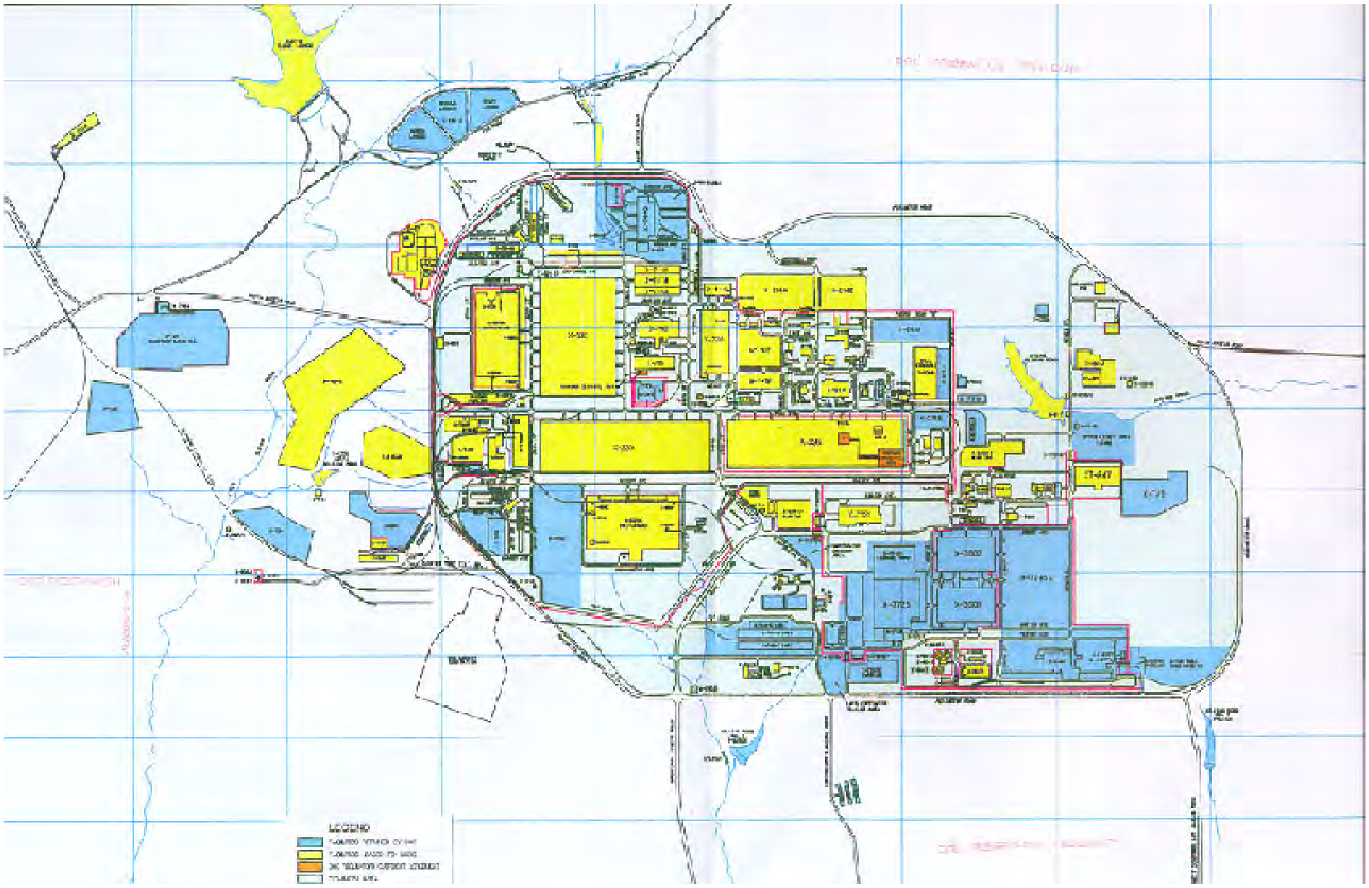


Figure 1. Map of Portsmouth Gaseous Diffusion Plant, Leased and DOE Controlled Areas

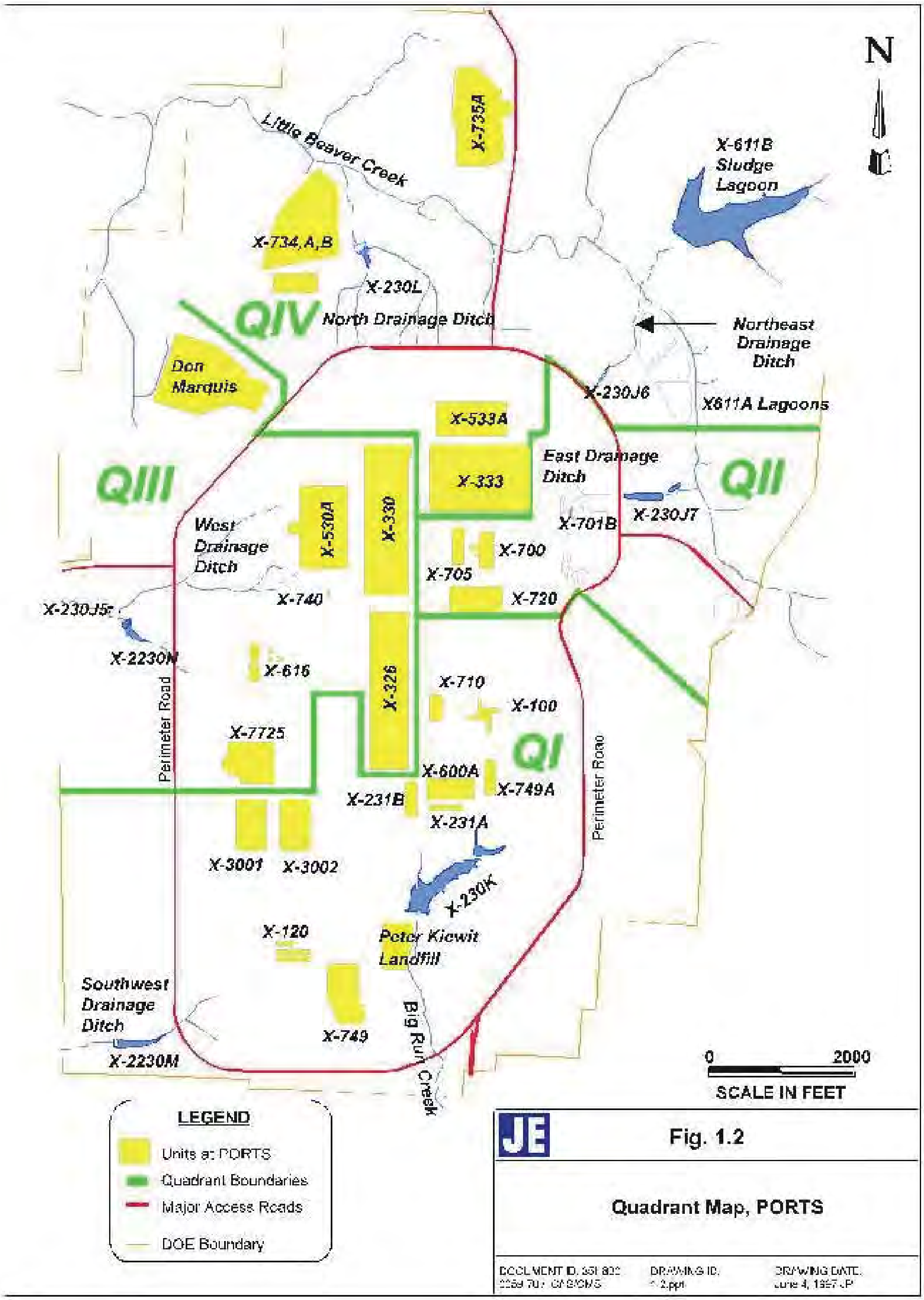
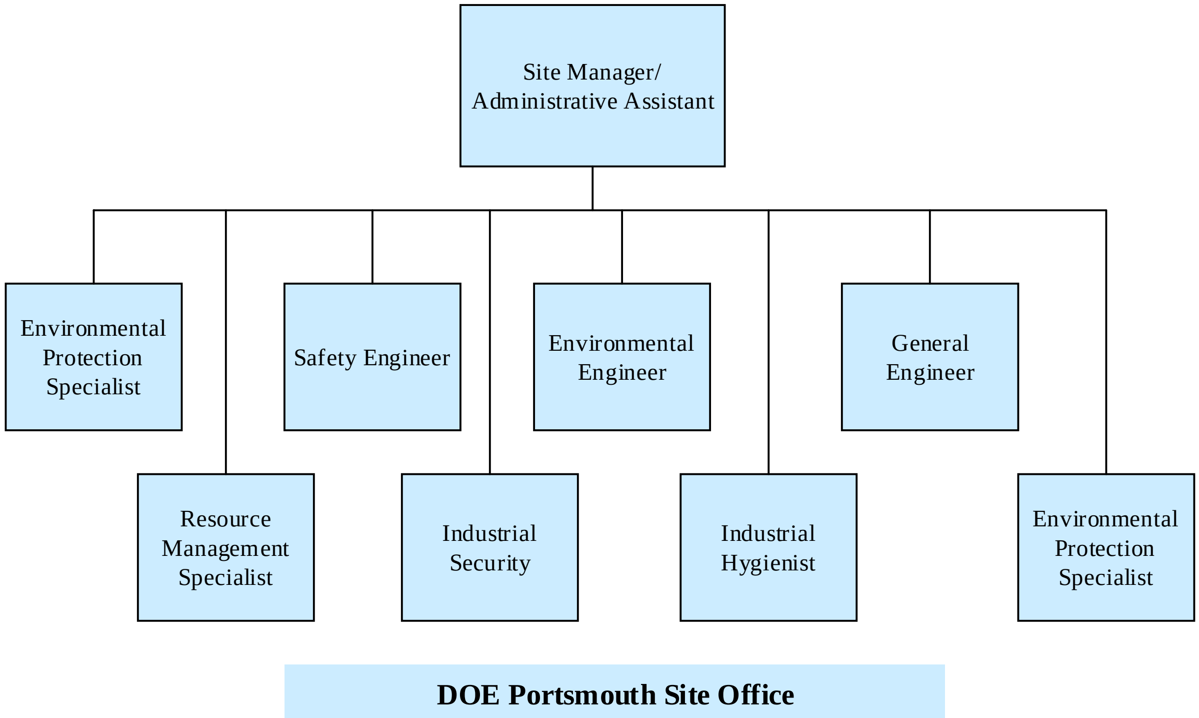


Figure 2. Map of Portsmouth Gaseous Diffusion Plant, Major Boundaries and Features

Figure 3. Aerial View of Portsmouth Gaseous Diffusion Plant



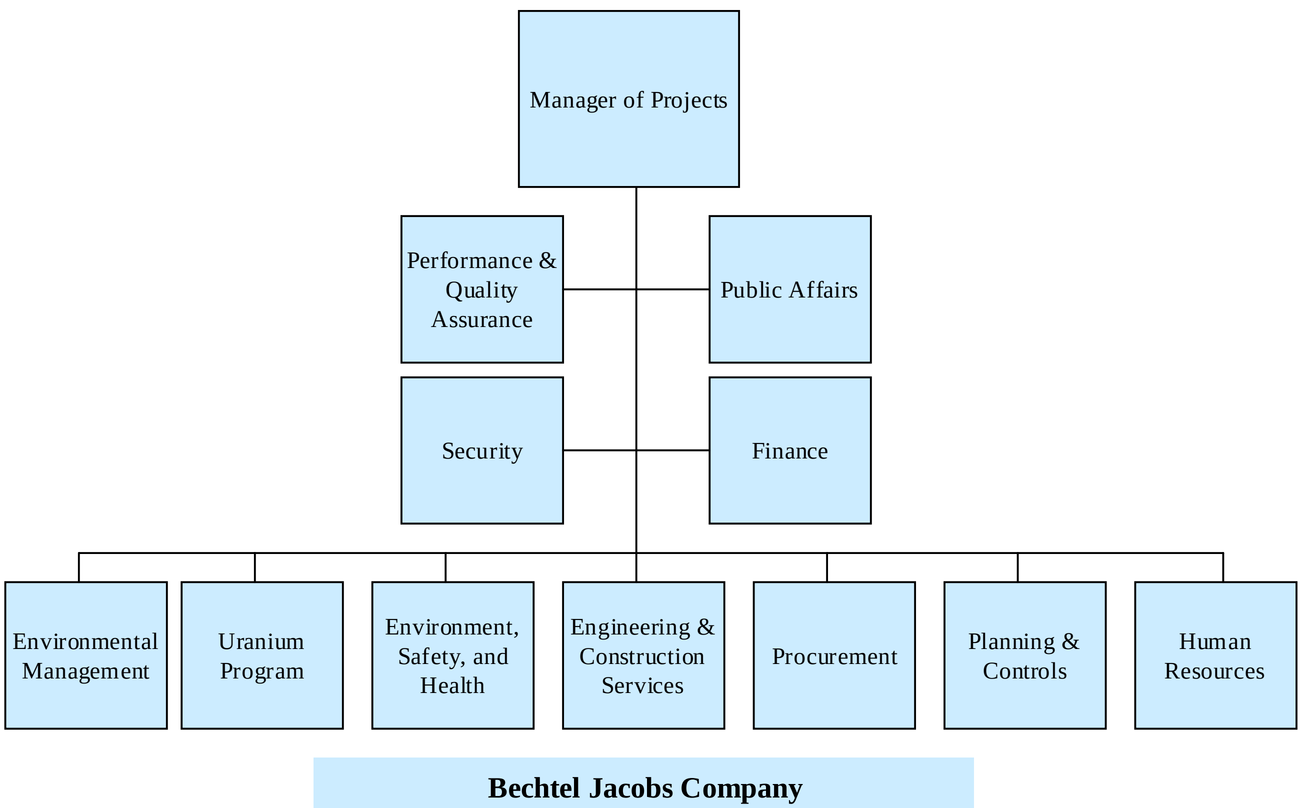


Figure 4. Organization Charts for the DOE Portsmouth Site Office and Bechtel Jacobs

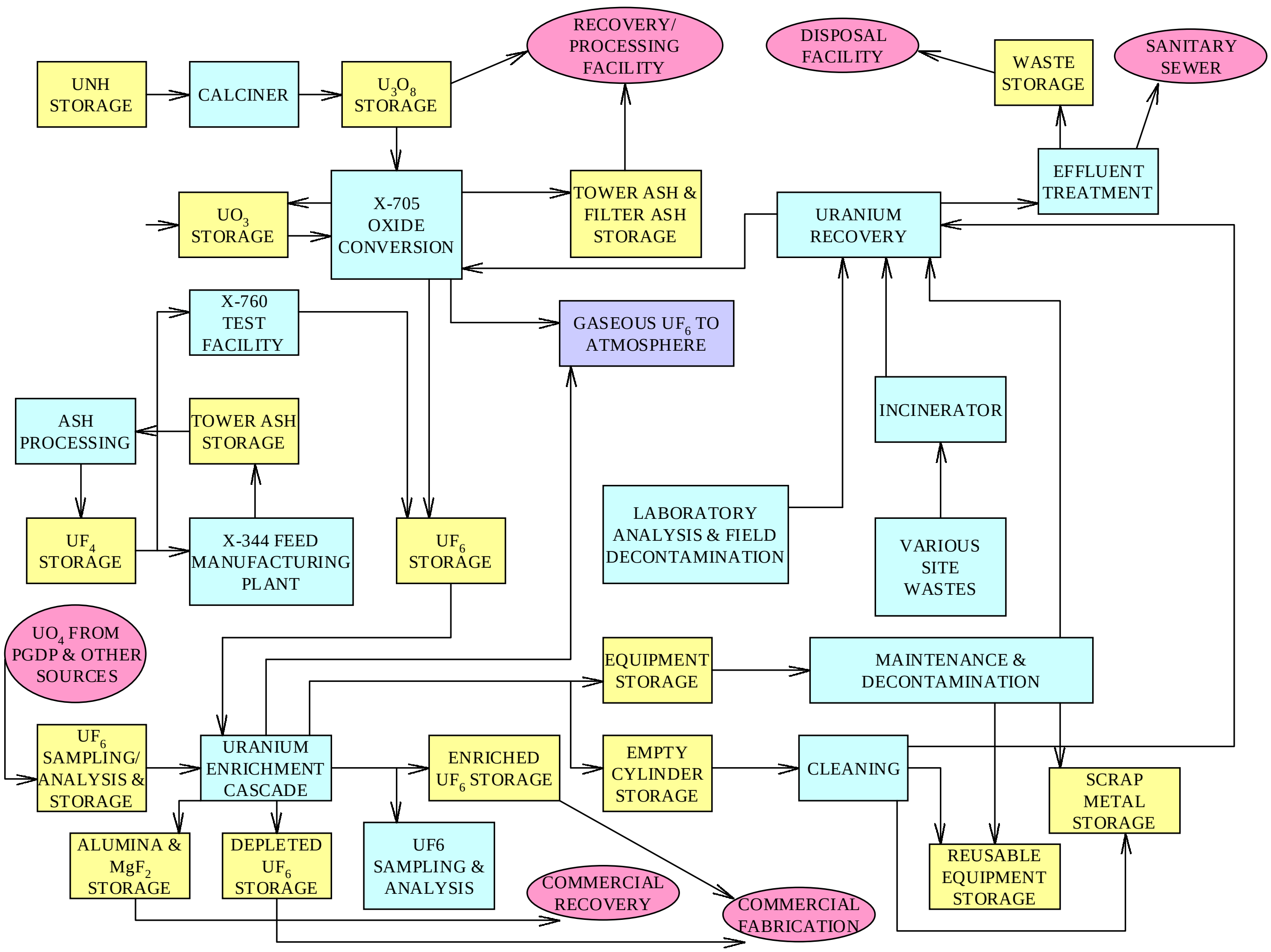


Figure 5. Schematic of Historical Uranium Enrichment Process

Interviews were conducted with over 300 current and former employees, including DOE Headquarters, OR, and Portsmouth Site Office personnel; Bechtel Jacobs and subcontractor managers, supervisors, and workers; selected USEC personnel; and stakeholders. USEC personnel were interviewed to clarify the nature of DOE activities conducted in USEC-controlled space and to better understand how USEC performs work for Bechtel Jacobs. Over 240 of these interviews resulted from a solicitation that the investigation team placed in local newspapers requesting information on past Plant operations, ES&H practices, and specific events that could have affected worker and public health and safety and environmental protection. These interviews also provided the investigation team with a preliminary indication of the degree to which ES&H practices and controls were consistent with and appropriate to the standards of the day, both past and present. This information allowed the investigation team to identify certain ES&H practices for more detailed document review.

The investigation team conducted numerous facility and work area walkthroughs examining Plant operations, work practices, and hazard controls. Essentially all DOE-controlled Plant facilities, waste and material storage areas, and grounds were visited by the investigation team. Many facilities and storage areas were examined multiple times. Job planning, maintenance, and operational activities were also observed to understand how work activities are planned and executed.

The investigation team collected 25 samples from groundwater wells, surface water sources, sediments, and soil (see Volume 2 of this report for more information). Samples were collected both inside and outside the perimeter security fence. These samples were evaluated for the presence of radioactive and non-radioactive contaminants. All samples were "split" or separated into two samples for running parallel tests, and samples were maintained under a strict chain of custody.

Boxes of Records Reviewed by the Investigation Team

To supplement the interview, observation, and sampling processes, the investigation team reviewed thousands of current and historical documents, including plans, procedures, log books, assessments, analyses, and reports and correspondence. These reviews supplemented the information from interviews and clarified the chronology of events at PORTS. The investigation team also examined documents addressing past standards to provide a framework for understanding ES&H requirements and expectations. Many records were obtained from PORTS archives documenting past releases of radioactive and hazardous materials and their potential impacts on workers, the public, and the environment.

This extensive process for gathering information enabled the team to proceed in a structured fashion to (1) understand past conditions; (2) fully comprehend the issues being raised regarding past operations, past work practices, and management of legacy materials; (3) evaluate the effectiveness of actions taken by PORTS to address ES&H issues; and (4) assess current conditions at PORTS and their impact on worker and public health and safety, and the protection of the environment.

1.4 Data Considerations

The scope of this investigation required that the investigation team examine current as well as legacy data and information. This involved both the review and evaluation of archived material and the assessment of recorded interviews documenting individuals' recollections of previous events and conditions. The investigation team recognized the inherent difficulty of current and former workers' accurately recalling details related to activities and events happening up to and perhaps more than 40 years ago. While the interview solicitation indicated the team's desire to speak with personnel who were involved in a variety of functions at the Plant, many individuals were self-selected for the interviews; that is, their participation resulted from their personal interest in the investigation. Accordingly, the team cross-checked information from multiple sources before making judgments contained in this report.

The identification and review of historical documentation was a tedious and time-consuming process. Due to the volume of records and other documentation generated over almost 50 years, the investigation team made a "best effort" to locate and review all pertinent documentation. Documents were examined based on focused subject searches and targeted sampling.

1.5 Report Structure

The results of this investigation are structured in two volumes to provide the reader with a comprehensive understanding of past and current activities at PORTS and a thorough description of operational, maintenance, and environmental management practices and their effectiveness in minimizing impacts on workers, the public, and the environment. Volume 1 describes historical ES&H practices. Volume 2 presents an assessment of current ES&H programs. To ensure that the full range of information is provided in an understandable manner, the balance of this volume is organized into a series of discussions outlining various elements of the Plant's operation in the context of when and how they were conducted.

Accordingly, Section 2 of this volume provides a historical overview and description of past activities at PORTS, within a series of functional areas that summarize key operations relating to the safety and health of workers, the public, and the environment. The objective of Section 2 is to provide an overall understanding of the major activities performed at PORTS and to indicate how these activities may have changed over time. More detailed discussions of historical operations and maintenance activities, environmental management, and line management and oversight practices are presented in the subsequent three sections.

Section 3 describes the hazards that historically existed at PORTS; past operational and maintenance activities; practices used to identify, monitor, and control these hazards; and the effectiveness of these practices in addressing hazards. Similarly, Section 4 describes past environmental management practices at PORTS and their effectiveness in mitigating impacts to the public and the environment. Finally, Section 5 reviews historical management and oversight practices as well as a discussion of employee relations.

Appendix A of Volume 1 outlines the radiological, chemical, and physical hazards present at the Plant.

Appendix B of Volume 1 summarizes the principal activities conducted at PORTS from 1952 to 1997 and provides a general assessment of the hazards presented by these activities, the controls used to mitigate the hazards, and the effectiveness of the controls.

Volume 2 of this report documents current conditions at PORTS in terms of public and environmental protection, worker health and safety, and line oversight. It examines existing pathways for hazardous materials to be transported to the environment and the extent of contamination in groundwater and in surface waters, efforts undertaken by PORTS to control contamination, results from the sampling and analysis conducted by the investigation team, the effectiveness of efforts to provide information to the public and other stakeholders, the nature and extent of risks that workers currently face at PORTS from both radiological and non-radiological hazards, the use of engineering and administrative controls to mitigate these hazards, the systems for planning and managing work, and the effectiveness of DOE and contractor management functions for ensuring protection of workers, the public, and the environment.

Appendix A of Volume 2 highlights significant issues in the implementation of current ES&H programs. The roster of the Office of Oversight investigation team is provided in Appendix B of Volume 2.

2.0 Historical Overview of Activities at Portsmouth

This section contains an overview of historical Plant activities at PORTS, presented chronologically within a series of functional areas, identifying key Plant conditions, operations, and practices. This section also summarizes the actual or potential effects of these conditions, operations, and practices on the safety and health of workers and the public, as well as on the environment. Sections 2.2 and 2.3 describe the historical hazards at PORTS; past operational and maintenance activities; practices used to identify, monitor, and control these hazards; and the effectiveness of these practices. Section 2.4 discusses unusual events and accidents. Sections 2.5 through 2.7 describe past practices in worker safety and health, waste management, and air and water emission control at PORTS and their effectiveness in mitigating impacts to the public and the environment. Section 2.8 reviews historical management and oversight practices and discusses employee relations.

2.1 Background

In July 1952, funds were designated for expansion of the domestic gaseous diffusion program, including additions to the gaseous diffusion plant at Oak Ridge, development of a new plant at Paducah, Kentucky, and construction of new $1.2 billion plant at a site to be selected later. In August 1952, the U.S. Atomic Energy Commission (AEC) announced that a 4,000-acre tract of land near the Scioto River in Pike County, Ohio, would be the location of the new gaseous diffusion plant. Selection of this site was based on the availability of sufficient acreage of relatively flat terrain, significant amounts of electrical power, a dependable water source, local labor supply, and suitable transportation systems. Construction of the Portsmouth Plant was completed in March 1956, six months ahead of schedule and more than $460 million under budget. The peak construction period was in 1954, when 22,500 workers were on site.

Major Facilities at PORTS

- *X-330, X-333, and X-326 – Gaseous Diffusion Process Buildings – 1954 to present*
- *X-344 – UF_6 Feed Manufacturing Plant – 1958 to 1962*
- *X-300 – Central Control Building – 1954 to present*
- *X-342, X-343 – Feed Facilities – 1954 to present*
- *X-705E – Oxide Conversion Plant – 1957 to 1978*
- *X-705 – Decontamination and Cleaning Building – 1954 to present*
- *X-700 – Maintenance Building – 1954 to present*
- *X-720 – Compressor Shop – 1954 to present*
- *X-334A – Transfer and Sampling Facility – 1975 to present*
- *X-342 – Fluorine Generation Facility – 1954 to present*

The Goodyear Tire & Rubber Company was named as the original management contractor. Goodyear Atomic Corporation was established as a wholly owned subsidiary of Goodyear Tire & Rubber for the purposes of managing and operating the Portsmouth Gaseous Diffusion Plant. Goodyear Atomic Corporation operated PORTS for the AEC and its successor agencies, the Energy Research and Development Administration (ERDA) and DOE, until Goodyear was replaced in 1986 by Martin Marietta Energy Systems, Inc., following Goodyear Atomic Corporation's decision not to participate in the rebid of the contract.

2.2 Operations

The first production cells went on line in September 1954, and the first product was withdrawn in October 1954. The purpose of the gaseous diffusion plant has been and continues to be the enrichment of uranium, initially for military applications and subsequently for commercial reactor fuel. PORTS enriched the feed material in the form of UF_6 gas to assays up to more than 97 percent uranium-235. The enriched product from PORTS was sent to other DOE sites and fuel fabricators. Most UF_6 feed material came from Paducah, K-25, the PORTS feed manufacturing plant, and commercial customers. From 1958 through 1962, some of the PORTS UF_6 feed material was produced from uranium tetrafluoride or UF_4 (called "green salt") in the X-344 Feed Manufacturing Plant. In addition, from 1957 to 1978 a small amount UF_6 feed was produced in the Oxide Conversion facility in X-705E.

The main process buildings at PORTS (X-330, X-333, and X-326) contain the "cascades," which are a series of compressor, heat exchanger, control valve and motor, converter stages, and supporting piping arranged in stages, cells, and units that progressively enrich the UF_6 feed. Enrichment occurs as the UF_6 passes through barriers in the converters that allow isotopes of lower molecular weight to pass through and is slightly enriched in uranium-235 by each stage from the feed point to the top of the cascade. Conversely, the feed is depleted in uranium-235 assay from the feed point to the bottom of the cascade. At PORTS, UF_6 could be fed from product and withdrawn from cylinders at any part of the cascades, using mobile units. Later, fixed feed facilities were installed in X-342A and X-343 using autoclaves to heat the cylinders and feed UF_6 gas to the cascade. The mobile withdrawal facilities have not been used since 1991. The product withdrawal stations are located in X-333 and X-326 and the tails withdrawal station in X-330. High-assay product is withdrawn at the X-326 product withdrawal station, intermediate-assay product at the extended range product (ERP) station in X-326, and lower-assay material in X-333. Both the enriched product and the depleted tails are fed into cylinders and allowed to cool until solid; the product is shipped to customers, and the depleted material is either re-fed to the cascade or stored on site.

The process building work areas were physically hot, but generally clean and uncontaminated, except when cascade equipment was opened due to equipment failure or for maintenance or modification. The process buildings were also the source of many UF_6 releases during connection and disconnection of sample bottles and feed and product cylinders, and from broken instrument lines. Generally, in the cascades, the use of respirators was only specified for maintenance or non-routine work activities. For feed, withdrawal, and sampling (activities where connections to the process systems are made and broken) additional personal protective equipment requirements and precautions were specified. These activities accounted for the majority of UF_6 releases and personnel exposures to process gas and hydrofluoric acid (HF) at PORTS. In 1974, as releases continued in these work tasks with the resulting spread of contamination, releases to the environment, and worker exposures, OR pressured Goodyear Atomic Corporation to conduct a focused review to identify ways to minimize releases from cascade operations. Subsequently, operational and procedural requirements were strengthened, cylinder connection hardware was redesigned, more frequent inspections and tests were conducted, ventilation systems were installed, and additional respirator use was specified. Although performance improved, compliance with operations procedures and the wearing of personal protective equipment remained inconsistent, and accidental releases still occurred. Cascade operations also routinely released small amounts of UF_6 to the environment through process system vents as a result of an operation called "jetting." Jetting involved venting of residual purge products from the evacuation of process piping, assisted by compressed air, in preparation for maintenance or replacement of components. These process line vents, although constructed with various traps and monitoring devices, also provided easy pathways to the environment from inadvertent or intentional valve positioning errors or overloading of traps.

During early 1952, the AEC approved the enrichment processing of production reactor tails through the gaseous diffusion process, and feeding of reactor tails from Paducah product commenced at Portsmouth in 1955. In 1957, radiological surveys at the Paducah Plant found neptunium-237 in the enrichment cascade. Although the AEC recognized the potential for transuranic contamination of the cascades, it was not until a 1965 appraisal that OR identified a potential problem with transuranics and fission products in X-705E, and recommended studies to determine where they could concentrate in the process. Although records indicate that PORTS reviewed the potential problems posed by feeding reactor returns to the oxide conversion plant, detailed studies were not performed. Goodyear Atomic Corporation concluded that transuranics were not a significant radiological concern when compared to uranium, and tower ash (where transuranics were expected to concentrate) could be monitored to measure the existing hazard. However, this monitoring program was not implemented. PORTS was also aware of the presence of technetium on process equipment as early as 1962, but also assumed that transuranics and fission products would not be a significant hazard to workers. No special monitoring or personnel protection controls were established. This posture persisted until 1975, when sampling and analysis of media, including pond sludge and waste samples, identified technetium-99. In 1979, a release in the X-705 annex during disassembly of a converter resulted in the internal contamination of six workers with technetium levels as high as five times the Plant restriction levels (but not in excess of regulatory limits). In 1980, analysis of cascade deposits confirmed the presence of neptunium and plutonium in the process system. These data indicate that, while Goodyear Atomic Corporation management was aware of both transuranics and technetium contaminants from incoming feed materials, they failed to recognize or evaluate potential radiological problems resulting from their concentration in the cascade.

The X-344 feed manufacturing plant converted UF_4 to UF_6 by passing the powdered green salt through elemental fluorine gas in four reaction towers. UF_6 was withdrawn, filtered, solidified in cold traps, reheated and transferred to cylinders, and re-fed to the cascade. Excess F_2 was recovered, and unreacted material fell into collectors as ash. After cooldown and decay, the ash was recycled by blending it with the green salt being fed into the top of the towers. When the plant closed in 1962, residual ash from X-344 was transported to Paducah for processing and uranium recovery. Operating conditions in the plant buildings were harsh, especially in the tower areas: high temperatures, noise, dust, and smoke. Leaks and spills of green salt and ash presented continuing problems with surface and airborne contamination. However, no reactor-returns green salt was processed in this facility. Radiation levels were high near the fluorination towers and the ash receivers, where uranium daughter products tended to concentrate. Workers in the feed plant were constantly exposed to these hazards. Although respiratory protection was required by procedure for many "dirty" jobs in the feed plant, industrial hygiene and health physics department reports and OR assessments reflected poor compliance. A 1961 OR appraisal noted that, although procedures required respiratory protection, operators in the area were not masked and

Construction of X-344

did not have masks, and the supervisor stated that they did not normally wear masks in that area.

Oxide conversion work in X-705E likely presented the most hazardous radiological and chemical exposures to workers at PORTS. The original plant design was inefficient, and many health physics concerns with airborne and surface contamination resulted from manual handling of fine uranium oxide powder. In 1965, these problems prompted a new plant design in preparation for future oxide feed from recycled reactor fuel, which would involve handling transuranics and fission products. The old system was dismantled and removed, and the new system, with more automatic processes and glovebox enclosures, was installed in X-705E in 1967. In the new design, oxide powder, in the form of U_3O_8, was ground and fed into a fluorination reactor (several designs were used over the years of plant operation), and the UF_6 was withdrawn into cold traps, where it solidified. Cold traps were removed and heated, and the liquefied UF_6 was drained into cylinders for feeding to the cascade. However, safe operation and maintenance of the new system was also beset with airborne uranium contamination problems including burn-through of the fluorination tower, leakage from cold traps and product withdrawal, and breaches into the system. Although respirators were recommended by the health physics staff and required by some procedures in oxide conversion operations, compliance was again inconsistent. This inconsistency was identified in industrial hygiene and health physics inspection reports from the late 1960s stating that respirators were not worn and gloves were removed from gloveboxes for some work. In 1973, an OR inspection cited numerous radiological occurrences in X-705E, including high airborne contamination, eating and drinking in the contaminated cold trap room, numerous instances of workers not wearing required respiratory protection, and increasing lung burdens for chemical operators. In-vivo monitoring was performed on oxide conversion plant workers, and, in 1965, significant intakes of insoluble uranium were detected in at least two of these workers. These employees were put on permanent restriction and had measured lung burdens over 50 percent of allowable limits many years later. One worker still had a significant lung burden when he retired in 1985. Raw material for the oxide conversion facility was generated on site through uranium recovery operations or conversion of uranyl nitrate hexahydrate (UNH) from offsite sources, or came from oxides from commercial processors and government sources. Oxide conversion production was greatest from 1968 to 1977, when the plant generated 10,000 to 50,000 kilograms per year of uranium as UF_6.

The continual, and often extensive, maintenance and modification activities on contaminated process systems and the oxide conversion plant were supported by significant efforts to decontaminate and clean removed components in X-705. Large items were processed in an automated decontamination tunnel, where parts were sprayed with acid solutions several times, rinsed with water, and then hot-air dried. The acid solutions were recycled until uranium levels exceeded discard limits and were then processed to recover the uranium. Until the 1980s, rinse water was discharged through building drains; it now goes to the sanitary waste system. Fans exhaust air from the tunnel to the atmosphere through roof vents. In the early 1980s an annex was built onto X-705 to facilitate decontamination of potentially heavily contaminated cascade components, such as compressors and converters. Some smaller parts were also decontaminated by hand in the seal disassembly room. Airborne activity was high, and respirators were required until air-supplied hoods were installed in the disassembly room in the mid-1970s. Empty feed/product cylinders were washed out in the low-bay area of X-705 to remove heels. In the 1950s and 1960s, cylinder cleaning was done in an open area and rinse water went into building drains. In 1971, a closed and automated cleaning system was installed, where cleaning and rinse solutions were collected and processed through the uranium recovery system.

Smelter Activation

Due to the monetary and strategic value of uranium, a wide variety of liquid and solid wastes containing uranium were processed through a solvent extraction recovery process in X-705. These operations concentrated radioactive materials, including technetium and transuranic compounds, and posed airborne hazards from both concentrated liquids and oxide powder. The uranium oxide (U_3O_8) produced from the calciner at the end of the recovery process provided potential exposure to insoluble uranium and transuranics. Transuranics were a special problem in 1965, 1966, 1975, and 1976, when recycled foreign reactor feed in the form of UNH was converted to oxide in the calciner. Raffinate waste was initially discharged to an onsite ditch leading to the Scioto River. Later, the X-701B settling pond was constructed; this reduced offsite contaminated effluents but increased onsite soil and groundwater contamination. In 1984, new systems in X-705 were effective in removing heavy metals and reducing radioactive materials from the building effluents.

From 1961 through 1983, a smelter operated in X-744G, melting scrap aluminum primarily from compressor improvement programs and damaged compressors. Although material went through a decontamination process before being placed in the furnace, industrial hygiene and health physics surveys indicated potential problems with airborne contamination during loading, melting, unloading, and removal. Former industrial hygiene and health physics department personnel stated during interviews that uranium contamination tended to stay with the melted aluminum. Aluminum ingots were sold for unrestricted commercial reuse or were used to make replacement parts for cascade equipment.

Non-operations and maintenance (i.e., support) personnel working in PORTS facilities, including guards, janitors, and delivery personnel, were also exposed to Plant hazards, especially unplanned releases, "wisps," "puffs," and chemical spills. From

Plant startup until the early 1990s, protective force personnel were often posted in close proximity to workers who were wearing respirator protection, while guards were not. From the early 1980s until the mid-1990s, guard force personnel performed security drills without protective clothing in spaces that were radiologically and chemically contaminated, while workers in these same spaces generally used such protection.

2.3 Maintenance and Modifications

Maintenance and process system modification activities have resulted in much of the radiation exposure, airborne contamination, and releases of UF_6 experienced at PORTS. The gaseous diffusion cascades are large complexes with thousands of components, many operating at high speeds and temperatures. Maintenance and modifications on these systems and components often required opening of systems that contained UF_6, deposited uranium compounds, technetium, or other hazardous materials. Many components had to be removed from the cascade buildings and taken to shops for decontamination, repair, or replacement. Maintenance and decontamination activities involved many tasks that created more hazardous conditions and opportunities for releases and exposures to workers, including welding, cutting, grinding, decontamination, and pipe crawling to retrieve debris and perform maintenance. Maintenance personnel and chemical operators decontaminating, maintaining, and modifying equipment were regularly exposed to UF_6, HF, TCE and other solvents, PCB-contaminated oils, welding gases, mercury, and other toxic metals. Work techniques, engineering controls, procedural requirements for personal protective equipment use, and the quality and availability of personal protective equipment (principally respirators) improved through the years, but lack of compliance was a recurring problem.

Essentially from initial startup into the 1980s, some form of process modification was in progress, with the most comprehensive and longest campaign, performed between 1972 and 1983, called the cascade improvement program and cascade uprating program (CIP/CUP). These programs replaced or upgraded key cascade components, such as converters, compressors, transformers, and motors to increase diffusion process reliability, capacity and efficiency. Line management, specifically first-line supervision, was responsible for specifying and enforcing safety and health controls for workers performing maintenance and modification activities. The industrial hygiene and health physics department personnel performed routine surveys, monitoring of work areas, special surveys, and other activities as requested by workers or supervision. Recommendations for controls, including decontamination and personal protective equipment, were provided by industrial hygiene and health physics but were inconsistently implemented by workers and line management. Instrument technicians were exposed to mercury, UF_6, HF, and TCE, and in later years to technetium, when performing cleanout, decontamination, calibration, and replacement of process line instruments and chemical traps associated with line recorders.

2.4 Unusual Events and Accidents

During almost 50 years of operation there have been numerous operational or work related events that posed potential safety and health risks to workers and the public, and damage to the environment. Well over 400 releases of process gas or fluorine have been documented over the years, and many more minor releases occurred that may not have been documented and tabulated as events. The most frequent and notable unusual event was the release of UF_6 gas into work areas or the environment. These releases ranged from very small amounts (commonly referred to as puffs or wisps) that stayed within work enclosures or buildings, to significant amounts that escaped outside buildings, caused building evacuations, or resulted in HF burns or uranium intakes requiring bioassay or medical attention for dozens of workers. Plant reports reflect approximately 90 UF_6 releases in excess of 10 pounds of uranium. The largest release was in 1978, when over 13,000 pounds of UF_6 was released to the environment when a 14-ton cylinder dropped from a transporter and ruptured, emptying its contents. Releases resulted from cascade system upgrade work, equipment failures, improper valve lineups, trap overloading, and maintenance activities; cylinder handling and movement; cylinder connection and disconnection activities at feed, withdrawal, and sampling stations; and process equipment disassembly during shop maintenance activities.

The documentation of releases and subsequent evaluations and investigations at PORTS were extensive, including technical department engineering reports, release reports, production memoranda to file, Goodyear Atomic Corporation and OR investigations, industrial hygiene and health physics department reports, and log books from the industrial hygiene and health physics, security, and fire departments. For releases greater than small puffs or wisps, analysis of the conditions, causes, and personnel exposures were analyzed to identify actions to correct causes and mitigate future events, identify personnel for special bioassays, and ensure proper survey, decontamination, and monitoring of work areas or the environs. These reports identified many employees who were exposed from these releases and required medical bioassay examinations. However, workers interviewed by the team recalled that for smaller releases (puffs), personnel were not always sent to the medical group for bioassay. Typically, after releases of UF_6 or F_2, workers directly involved or in adjacent areas would be required to provide urine specimens for bioassay to determine whether there was any internal intake and, if so, how much. If the bioassay indicated the presence of uranium or fluorides above certain limits, personnel were required to submit subsequent samples (called "recall") to monitor excretion rates until levels reached the initial threshold. If intakes were high, the person would be put on work restriction, limiting further exposure until levels returned to normal. If supervision or industrial hygiene and health physics considered that the person might have had a significant intake, the worker would be placed on work restriction immediately until the actual exposure could be determined by bioassay. The number of persons placed on recall for bioassay was as high as 40 or more per month in the 1950s, but declined significantly to a few persons per month in the 1980s.

While the documented injuries or illnesses linked directly to releases or exposures to UF_6 and F_2 were relatively infrequent, many workers did receive treatment for burns and respiratory ailments. A tails withdrawal release resulted in traumatic injuries requiring a five-day hospital stay for one worker and lengthy work restriction for another. Several worker compensation cases in the late 1950s and 1970s resulted in compensation for workers exposed to HF and other toxic materials at PORTS. Some workers had extremely high intakes of uranium detected by bioassay or in-vivo testing that put them on work restriction for months or years. For example, in 1965 ten employees sustained lung exposures greater than one-half the permissible level, and eight were reported to the AEC as overexposures in accordance with AEC regulations. In addition, a worker who had a massive intake of UF_6 in 1973 was still excreting uranium six months later, and two workers in 1965 were exposed to uranium levels high enough that, as late as 1973, in-vivo testing showed greater than 50 percent of the maximum allowable body burden for uranium. Finally, one worker, still living, was put on permanent restriction in 1981, and his in-vivo monitoring before his 1985 retirement still showed high uranium readings in his lungs.

In the first few years of operation, many routine bioassays (scheduled and not the result of known events or potential exposures) came back positive. Each was investigated for source, and actions were taken where warranted. Although the response was laudable, the fact that so many routine bioassays revealed unexpected intakes indicates a lack of adequate awareness and control of contamination and/or inadequate understanding of the required response to exposure, or possible exposure. There was evidence that industrial hygiene and health physics department recommendations for engineering controls (i.e., added ventilation or containment) or cleanup of contamination were often implemented.

As better equipment was installed, major system upgrade work ended, and operational practices improved, the number and quantity of UF_6 releases decreased significantly. The total yearly number of documented releases also fluctuated with the amount of enrichment or maintenance activity, dropping from about 160 in the 1950s to 50 in the 1960s when the Plant operated at reduced power levels, 85 in the 1970s, and back to 120 in the 1980s. However, the average size of the releases decreased markedly in the 1980s, many less than one gram (an amount that might not have been reported in the early years). About 45 UF_6 releases over ten pounds occurred in the first six years of operations, with only six in the 1980s. The AEC directed several concerted attempts to reduce UF_6 releases in the 1970s: in 1974 after several big releases in succession, and in 1978 after the 14-ton cylinder drop accident. Following several significant releases from Plant vents in the mid-1980s, continuous monitors were installed to measure releases, piping and procedures were modified to prevent inadvertent venting, and training and management direction were provided to maximize the return of UF_6 to the cascade. Although many releases were due to equipment failures, the preponderance of events and unnecessary exposures and contamination spread were caused by personnel errors, including failure to follow procedures related to operations or maintenance, failure to wear proper personal protective equipment, and improper emergency response to the release. Logbook entries by health physics technicians and event reports from the early 1980s noted repeated instances where personnel performing normal work activities or exposed in releases were not wearing respirators as required or were observed re-entering work areas after a release before required surveys and air monitoring were performed.

The spread of contamination to the environment and exposure to personnel away from the release point is affected by many things, such as release location, openings in the buildings, ventilation, immediate response by workers, weather conditions, quantity, and assay of material released. UF_6 gas is hydrolyzed with moisture in the air into HF gas and solid UO_2F_2, most of which drops quickly from the vapor cloud. HF gas is highly corrosive, and exposure can result in burns to exposed skin and the respiratory tract. Both HF and UO_2F_2 are environmental contaminants; HF primarily reacts with vegetation and soil, and highly soluble UO_2F_2 is washed into low points on the ground and into waterways. Many other events involving spills of various hazardous materials have had negative impacts on the environment. Spills of antifreeze, gasoline, sodium hydroxide, PCB oils, TCE, chromates, and lithium hydroxide, as well as UF_6 and F_2, have affected plant life and fish and contaminated waterways both on and off site. Section 4 of this report further discusses the effects of releases on the environment and monitoring programs for accidental releases.

The only work-related fatalities at PORTS identified by the investigation team resulted from several construction accidents in the 1950s and one in the 1980s. Other significant events that did not involve the release of hazardous materials or injury to personnel were not reviewed by this investigation.

Cleanup of March 1978 Cylinder Drop

2.5 Worker Safety and Health Programs

Programs for worker safety and health were in existence from the beginning of Plant operation. Initial training classes for workers included the theory and protective actions for working with radioactive and hazardous materials. *Guide to Safety* handbooks including information on respirators, radiation, and industrial safety and industrial hygiene hazards and controls were developed and given to employees as early as 1955, but were infrequently updated. There were policies and procedures that addressed the radiological protection of workers. Personal protective equipment was provided and was available to workers and in work areas where hazards were greatest and protection was deemed necessary, although availability and quality were variable. The amount of formal training given to employees diminished after startup, and much of the knowledge concerning both operations and hazard communication and controls resulted from on-the-job training of new workers by more experienced personnel and supervisors. In later years, health and safety training was often given directly only to supervisors, who then trained the hourly workers, typically through monthly safety meetings. There appeared to be little effective oversight of safety meeting content or other supervisor training activities by Plant management or safety and health organizations.

The medical group, part of the Industrial Relations Division, initially administered the industrial safety, industrial hygiene, and health physics programs, with separate sections for each. In 1957, industrial hygiene and health physics were combined into a separate department and later combined with environmental management under a Superintendent of General Safety and Environmental Management. In 1977 these organizations achieved more autonomy under a newly created Technical Services group, headed by an Assistant General Manager. Documentation indicates that Goodyear Atomic Corporation had a sophisticated occupational health program providing comprehensive medical examinations for employees, including physicals and typical laboratory testing of vision and hearing. The industrial safety and industrial hygiene and health physics staff was actively involved in responding to, evaluating, and making recommendations for corrective actions for accidents and events. The medical group administered the bioassay and in-vivo monitoring programs as well as radiological, chemical, and environmental sampling and monitoring. Increasing concerns and apparent weaknesses in the occupational medicine program were reflected in audits, AEC appraisals, safety committee meetings, and union negotiations in the 1970s. Issues with staffing, quality of service, and program management continued into the 1980s.

Many of the details on controls for radiological, industrial and chemical hazards in the workplace for routine operations were identified in work procedures, hazardous work permits, and electrical work permits issued for specific tasks, such as system entries or maintenance. In 1970 the OSHA standard drove introduction of additional permits for lockout/tagout, welding, and confined spaces. Responsibility for worker safety and health protection was delegated to line supervisors, and the role of the health and safety organizations was to provide support and advice. It was not until the 1970s that the health and safety staff had direct input or authority to review procedures and permits and took on a stronger role in hazard identification and control, and compliance inspections. Safety committees and union safety representatives were active in identifying safety and health issues, but less effective in consistently bringing about satisfactory resolution. The union grievance process was often used to identify health and safety concerns, a process that again achieved mixed results.

The focus of the industrial safety program until the 1970s was on safety awareness, not on compliance or hazard analysis. Safety goals were set and statistics on accidents and occupational illnesses were kept and reported to the AEC as required. Staffing for the safety effort varied from about eight engineers in the 1950s to two during the 1960s, when production and Plant worker populations were significantly reduced. In the 1970s, with new OSHA standards, new construction, and increased production activities, the safety organization became much more involved in hazard identification and controls. In 1973, OR conducted a comprehensive safety compliance review against the new OSHA regulations, resulting in extensive upgrading of safety systems and controls.

The evolution of awareness and the application of protection and controls for significant non-radiological hazards, such as asbestos and PCBs, essentially paralleled that of the regulatory bodies and general industry. Air monitoring of hazardous job sites existed from Plant startup, and health physics personnel monitored air and surface contamination in work areas and recommended revisions to existing engineering controls or personal protective equipment, if deemed necessary. Identification of asbestos and PCBs as hazards did not emerge until the late 1970s. Procedures for the handling, storage, and disposal of PCB-contaminated oils were in place in 1977, and no formal asbestos program existed until 1980.

Workers were also exposed to a variety of toxic gases, solvents, and metals at PORTS. The hazards associated with a number of these materials were known in 1955, and precautions were included in safety bulletins and manuals. It is not clear that work procedures always addressed proper personal protective equipment or controls. Surveys and instructions from industrial hygiene appeared to be reactive to events rather than proactive. Instrument

Basic Radiation Definitions

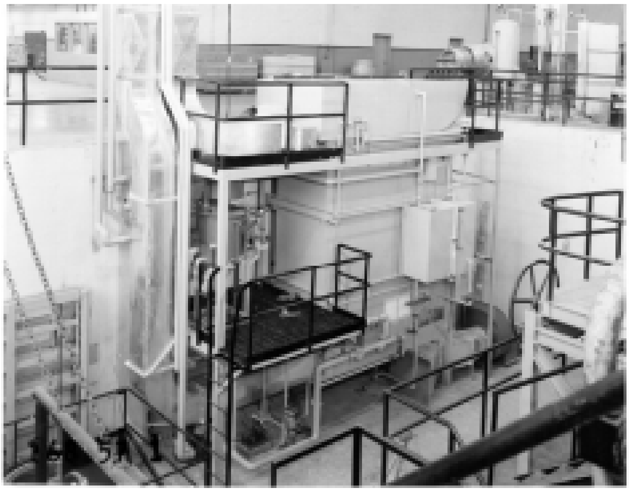
Employees at PORTS could encounter four types of radiation during their employment: alpha, beta, gamma, and neutron.

***Alpha particles** are heavy, charged particles emitted from the nucleus of an atom and are primarily an internal exposure hazard through inhalation or ingestion. Because of their relative size and energy, alpha particles are much more hazardous than beta particles or gamma rays inside the body. Uranium, neptunium, and isotopes of plutonium are alpha emitters.*

***Beta particles** are charged particles emitted from the nucleus of an atom and may be either internal or external exposure hazards. Enriched uranium, technetium-99, and isotopes of plutonium produce beta particles.*

***Gamma rays (and x-rays)** are penetrating forms of radiation produced during decay of radioactive materials and are an external exposure hazard. Isotopes of uranium, neptunium, and plutonium produce penetrating radiation in the form of either gamma or x-rays.*

***Neutron radiation** is a particulate radiation resulting from nuclear reaction and is an external exposure hazard. The main sources of neutron exposures at PORTS are spontaneous fissions in UF_6 cylinders in cylinder storage yards.*



X-720 Degreasing Apparatus

technicians and chemical operators frequently worked around mercury used in numerous process instruments and chemical traps. TCE was used in large quantities as an effective degreaser and general cleaning agent; its use was discontinued in the late 1970s, and bulk quantities of the solvent were removed. However, PORTS had lingering problems with continued use of residual supplies of TCE. A special industrial hygiene survey in 1986 identified TCE levels above the Threshold Limit Value in X-326. There was also limited evidence of incidental use of beryllium at PORTS. These may have been incidental machining of beryllium copper-alloy piping components. Tools plated with beryllium were also used. Beryllium was also used as a coating on early fluorescent light bulbs and was contained in some welding rods. Beryllium was routinely sampled in the environment in the early 1990s, and detectable beryllium concentrations above background were identified in several areas at PORTS.

In the 1950s and 1960s, the health physics staff provided exposure monitoring services, recommended training and protective measures to supervisors, maintained exposure and radiation measurement records, administered the bioassay program, investigated air samples and personnel exposures that were outside of specifications, studied Plant hazards and needed controls, and performed Plant environmental monitoring. However, the size of the health physics staff (i.e., one or two health physicists and approximately five technicians doing both industrial hygiene and health physics surveys) during the first 20 years of operation limited the amount and effectiveness of monitoring and control for the activities of up to 2,500 people in numerous and diverse hazardous work environments. While line supervision had always been responsible for implementing recommended controls and protective measures, supervisory oversight and enforcement of personal protective equipment use were inconsistent. Non-compliant personal protective equipment use by workers can in part be attributed to the pressures to maintain normal process operations, a lack of knowledge and full understanding of the risks involved and why the protection was needed, and the physical discomfort and vision impairment associated with wearing personal protective equipment, such as respirators, in hot, dirty environments.

Most radiological work controls, including time limits on worker exposures to uranium, were based on the assumptions that the primary risks for uranium exposure were chemical, not radiological, and that uranium was soluble and would be eliminated by the body quickly through the kidneys. Thus, inhalation protection was encouraged, and bioassay urinalysis was employed from PORTS startup to monitor intakes by workers who might be exposed to uranium or fluoride materials. However, the solubility assumption may not have been appropriate for areas such as the feed and oxide conversion plants and grinding and welding operations, where small particle sizes and relatively insoluble uranium compounds were present. Limitations were established for uranium and fluoride levels and excretion rates, and work area restrictions were placed on workers with elevated uranium until concentrations returned to acceptable levels. However, urinalysis would not detect intakes of insoluble uranium reliably and at sufficient sensitivity. In the early 1960s, in-vivo radiation monitoring for insoluble radionuclides by lung counting was initiated, first by sending workers to Fernald or Oak Ridge, and later using a mobile counter periodically sent to PORTS from Oak Ridge. However, lung-counting methods were not sufficiently sensitive and were only effective for assessing relatively large intakes. In-vivo monitoring was performed primarily on a sampling basis and, in the early years, typically relied on volunteers from work areas subject to uranium exposure. Film badges were used from the beginning of Plant operation to monitor personnel exposures to beta and gamma radiation; they were assigned based on expected exposure in work areas. Until the mid-1980s, extremity monitoring was not employed, although a number of activities presented opportunities for extremity exposures significantly higher than monitored whole body exposures. Some components that required significant manual handling had contact radiation levels above 1 rem/hour, and such a dose rate could quickly result in overexposures.

PORTS established conservative local limits as Plant Allowable Limits (PALs) for surface contamination control, compared to other gaseous diffusion plants and regulatory limits. Industrial hygiene and health physics department surveys were conducted both routinely and for specific work activities, and after events or condition changes. Portable survey instruments were available in many work areas for use by workers and supervisors, although the frequency of use and proper techniques were not monitored or enforced. Fixed hand and foot monitors were in place for some consistently contaminated areas. However, pervasive contamination problems persisted into the 1980s. It was not until 1991 that clothing and whole body monitors for exiting radiological areas were instituted Plant-wide. Respiratory protection was employed to minimize personnel exposures to airborne radiological and chemical hazards. The enrichment of high-assay uranium compounds (over 20 percent) complicated personnel protection efforts due to the higher specific activity of highly enriched uranium. In the 1950s and 1960s, the respiratory protection program principally utilized dust masks and the Army assault mask. In the late 1960s and early 1970s, better respirators were obtained, individual respirators were fitted and assigned to individuals, fit testing requirements were instituted, and additional respiratory protection training was performed. Observations by the industrial hygiene and health physics department, investigations of releases, and OR health and safety appraisals in the 1960s and 1970s collectively indicated chronic problems with workers' failure to wear respiratory protection where required and poor enforcement of respiratory requirements by line supervision. Bioassay and in-vivo monitoring results reflect the results of an inadequate respiratory protection program in the first two decades of Plant operation.

2.6 Waste Management

PORTS has generated large quantities of both hazardous and non-hazardous waste materials that have required storage, treatment, or disposal. These materials include construction waste, general office and kitchen trash, classified equipment, highly toxic or caustic chemicals, contaminated tools and clothing, and various radioactive substances. External requirements, treatment and disposal methods, and the overall waste management program evolved over time, resulting in more sophisticated, rigorous, and environmentally friendly processes for handling solid, hazardous, and radioactive wastes. However, as discussed below, the progression of waste handling practices and the closing of disposal locations have resulted from failures to comply with previously established guidelines and requirements for controlling hazardous and radioactive wastes.

Initially, the handling and control of hazardous waste were the responsibility of the Chemical Operations Division. Gradually, the Industrial Hygiene and Health Physics department assumed environmental compliance responsibilities. In 1986, a waste management division was created, and in 1991 this organization was elevated to being a department. Formal procedures were established as early as 1955 detailing guidelines for handling, storing, and disposing of wastes. In 1970, the position of Pollution Coordinator was created and a Pollution Control Committee was formed to establish and oversee policy. In 1979, formal procedures and associated training were developed for the use of Plant landfills, and, in 1981, additional procedures were implemented for operating the sanitary landfill, including a ban on burning of wastes. In 1990, all waste management programs and organizations were integrated, leading to a major overhaul of waste management procedures.

Starting with groundbreaking in 1952, construction wastes were disposed of in a landfill created south of the Plant, which operated until 1968. In 1998, it was closed in accordance with State of Ohio EPA and Resource Conservation and Recovery Act (RCRA) requirements. In 1982, X-734A was created as a new construction spoils area, but was closed in 1985 because requirements for excluding hazardous substances had been continuously violated. This former spoils area is currently undergoing RCRA closure. Subsequently, construction spoils were sent to the X-735 sanitary landfill. However, the sanitary landfill had to be partially shut down in 1990 when an external inspection found improper disposal of rags containing RCRA-regulated solvents. In 1998, when a new landfill was needed to meet stricter environmental controls, DOE closed X-735 and shipped non-radioactive solid wastes off site to the Pike County landfill.

Before hazardous wastes were regulated, most liquid wastes were processed in various pits and lagoons prior to discharge. Therefore, minimal quantities of waste were containerized for disposal.

Burning was also used extensively at PORTS to dispose of oily wastes until the mid-1970s. In the early 1970s an experimental program of oil biodegradation was established in two plots near X-600, identified as X-231A and X-231B. Many thousands of gallons of solvent-contaminated oil, chlorinated solvents, and over 100,000 pounds of oil soaked fuller's earth absorbent were tilled into the ground at X-231A until it was closed in 1977. X-231B operated until it was shut down in 1988 as part of a RCRA action after an Ohio EPA inspection identified significant problems and served DOE with a notice of intent to file suit for hazardous waste violations. Internal documents also reflected repeated problems with the controls on the process and management of the biodegradation program.

Large quantities of PCBs existed at the Plant, principally in electrical transformers and capacitors, but also as a contaminant in process building lubricating oils and ventilation duct gaskets. Although the industry and the AEC provided safety information concerning PCBs in 1972, the Plant did not issue specific guidance on the disposal of PCB-contaminated items until 1979 after Federal regulations were issued. Additional procedures were issued in 1983 addressing the handling of PCB waste when PCB-contaminated sludge was identified at the site sewage treatment plant. However, PORTS had continuing problems managing PCB-contaminated materials; in 1988 DOE noted that controls were insufficient to comply with commitments to the EPA, and in 1989 the DOE Tiger Team identified a lack of formal Plant procedures to implement PCB cleanup standards. These concerns resulted in the formation of PCB Implementation Teams. Currently PCB waste, regulated under the Toxic Substances Control Act (TSCA), is being stored in DOE Material Storage Areas in the process buildings.

A similar process occurred for RCRA regulated waste. After an initial aggressive approach to compliance, DOE determined that RCRA regulations did not apply and a self-regulated approach was taken. After an agreement was reached with EPA in 1987 on RCRA applicability, PORTS took several actions to return to compliance. In the early 1990s, X-7725 was upgraded to a compliant permitted RCRA facility and currently houses all stored mixed and hazardous wastes, except for some enriched mixed and radioactive wastes that are stored in the X-326 L Cage area to provide additional security.

Low-level radioactive wastes were buried in the X-749 contaminated material disposal facility starting in the late 1950s. This continued to be the primary disposal site for low-level waste until operations ceased in 1992 at the direction of the Ohio EPA. Equipment and scrap were generally subjected to decontamination prior to disposal, primarily to salvage residual uranium for re-feeding to the process. Hundreds of tons of material were disposed of in X-749 just before shutdown. A 1976 report determined that unsealed chemical trap residues disposed of in X-749 during the previous 20 years contained very water-soluble technetium. Subsequently this material was sealed prior to disposal.

Right after Plant startup, two oil-fired incinerators were used for classified burnables and uranium-contaminated wastes, including waste oil. (Waste oil was also buried in salamanders near Building X-705.) Little documentation exists concerning these incinerators, but 1962 OR assessment results were favorable. In 1971 these incinerators ceased operation after Goodyear Atomic Corporation determined that they were inefficient and did not meet smoke or particulate emission standards. A new incinerator was built in 1971. Ash was sampled for salvageable uranium and sent to the recovery process or disposed of in X-749. Again, there were problems with operation of the new incinerator. Until an enclosure was built in the late 1970s, contaminated burnables and ash were scattered by winds. Severe smoking due to plastics disposal and several events involving smoke incursion into adjacent buildings caused medical problems for occupants. In the mid-1980s, reports indicated improper incineration of materials as a result of unclear operating limits. DOE subsequently shut down the incinerator, and the State of Ohio revoked its registration. The facility was finally closed under RCRA authorities in the 1990s.

Huntington, West Virginia, Plant

In 1978, the DOE INCO nickel plant in Huntington, West Virginia, was dismantled, transported to PORTS, and buried in the X-749A classified landfill due to security concerns and the fact that some of the INCO plant materials were somewhat contaminated with uranium, nickel carbonyl, and asbestos.

Large volumes of scrap and surplus materials generated at PORTS were collected and stored onsite. Much of this material was sold at public auctions from the 1950s into the 1980s. These activities led to documentation of many health and safety concerns, including the failure to consistently segregate contaminated and clean materials, insufficient industrial hygiene and health physics staff to perform pre-sale surveys, inadequate controls on buyer access to scrap yards prior to sale, and surveys indicating that highly contaminated items were in the scrap yards. Therefore, it is possible that some contaminated materials were sold to the public, and buyers may have been contaminated during the auction process.

2.7 Air and Water Emissions

Routine, accidental, diffuse, fugitive, and planned emissions of radioactive materials and fluorine to the environment have occurred at PORTS since the beginning of operation in 1954. Site records and subsequent analysis estimated that over 23,000 pounds of uranium and 27 curies of technetium had been released into the atmosphere from 1954 to 1993. Workers complained of fluorine emissions from X-342 into the 1980s. Environmental monitoring in the early years consisted of liquid effluent sampling and sampling of vegetation and soils after identified accidental releases. Air sampling, both onsite and offsite, did not begin until the mid-1960s. Although known to exist in process systems since the early 1960s, significant amounts of technetium were not detected until 1975 when a marked increase in beta and gamma activity was measured. This increase in technetium emissions may be linked to disturbances caused by process equipment changeout and maintenance activities.

Vent emissions at PORTS were not monitored continuously until the mid-1980s. Grab sampling and radiation detectors in the vent line piping (called space recorders) provided some means of monitoring and calculating releases of uranium and fluorine. However, the unreliability of space recorders and the inaccuracy of grab sampling when compared to continuous monitoring indicate that emissions may have been underestimated. An event in 1985 released over 110 pounds of uranium into the atmosphere from the X-333 wet air evacuation vents over a period of 21 days when traps were overloaded and operators ignored space recorder alarms. Piping and valve configurations associated with process building vents also provided opportunities for operator error or intentional bypassing of traps and monitors, resulting in unmonitored releases to the atmosphere. An atmospheric vent committee in 1985 recommended that continuous monitors be installed on a number of vents. The feed production plant also contributed significant amounts of radioactive emissions to the environment from its operations between 1958 and 1962. Fluorine releases from the X-342 fluorine plant stack have been frequent and have resulted in numerous complaints from workers in the area, especially during temperature inversions, fog, or rain, when the vented gases are forced to ground level.

Accidental releases of UF_6 have contributed a significant portion of the estimated emissions at PORTS. The 1978 cylinder rupture event contributed almost 50 percent of those estimated emissions. Diffuse and fugitive emissions were not typically calculated until 1994, and contamination found later on roofs, grounds, and work areas reflect notable unmonitored releases. The oxide conversion facility in X-705E was the source of known fugitive emissions during its operation between 1959 and 1978. Planned releases, including venting of purge gases from the cascade cells while obtaining “negatives” for maintenance, also contributed an unknown quantity of radioactive emissions to the atmosphere.

Liquid effluents from Plant operations were typically released to the environment via drains to sanitary sewers and the cooling tower blowdown system, discharges to holding ponds, or runoff to the storm water drainage system. Discharges other than those treated or held up prior to release flowed to site outfalls and the east and west drainage ditches to Little and Big Beaver Creeks and then to the Scioto River. Effluents from the two main ditches and the south holding pond have always been routinely analyzed for radioactivity, and cooling tower blowdown has been monitored for chromium prior to discharge to the river. In 1970 the Ohio Pollution Control Board established standards for public water supplies. The Plant environmental management structure, procedures, and monitoring programs were strengthened to ensure compliance with these new regulations. In 1976, a chromium reduction facility was built for treating blowdown cooling water before discharge to the Scioto River.

The X-705 decontamination and cleaning activities have always generated the most significant liquid radiological effluent at PORTS. Decontamination solutions and other wastewater were discharged to the X-701B holding pond at rates as high as 50,000 gallons a month until the pond was closed in 1988. Other waste chemicals from laboratories in X-705, and the X-700 cleaning solvents, such as TCE, also went to the holding pond. When the holding pond was closed, a recirculation system for the treated water was installed in X-705 and a micro filtration system was added to process all waste solutions prior to discharge.

In 1975, when the beta-gamma activity in the east drainage ditch increased markedly, PORTS determined that it resulted primarily to technetium from X-705, via the X-701B holding pond. From 1974 to closure in 1988, lime was added to the influent of X-701B, causing a large sludge buildup that necessitated annual dredging and disposal. Accidental spills of TCE and other solvents, PCBs, sodium hydroxide, ethylene glycol, gasoline, and UF_6 have caused damage to the environment, including several significant fish kills in surrounding creeks, one of which resulted in restitution payments to the state.

2.8 Management and Oversight

Although, the AEC, ERDA, or DOE have had a nearly continuous site presence at PORTS, oversight of ES&H performance was not rigorous or proactive for much of PORTS history. This oversight was sometimes effective when vigorously exercised; however, consistency and follow-through on corrective actions were often lacking. On numerous occasions, the positions of management and labor differed widely, and resolution was accompanied by extreme measures, as evidenced by one unauthorized and six authorized strikes between 1954 and 1997. While economic issues were common to most strikes, safety and health were an important element in three of these seven actions. Workers compensation claims, which began to appear in the early 1950s, reveal discord between management and labor. Interviews with past and present employees and review of records indicate that there were allegations by employees that management would go to great lengths to deny or avoid compensation claims, including being untruthful and pursuing legal loopholes to avoid accountability. Collectively, the number of grievances filed, workers compensation claims submitted, and alleged acts of retaliation committed provide further support that management and labor relations were strained. From 1954 through 1993, it is estimated that more than 17,000 union worker grievances were filed, addressing a variety of issues in addition to safety and health, including work jurisdiction, discipline, overtime, work rules, and benefits.

SIGNIFICANT PORTSMOUTH PLANT MILESTONES AND EVENTS – 1952 TO 1999

August 1952	*Portsmouth selected as site for new gaseous diffusion plant*
September 1952	*Goodyear Tire & Rubber Company selected as the plant operator; Goodyear creates Goodyear Atomic Corporation to operate the Plant*
November 1952	*Groundbreaking and start of construction*
June 1953	*Portsmouth Training School opens*
September 1954	*First production cells go on line*
November 1954	*Portsmouth Oil, Chemical, and Atomic Workers Union (OCAW) established*
January 1955	*Goodyear Atomic starts 40-hour Basic Supervisional Training Program*
June 21, 1955	*United Plant Guard Workers established at Portsmouth*
November 1955	*First burial in classified disposal yard — X-749A*
March 1956	*Plant construction completed*
October 3-4, 1956	*Unauthorized walkout by 48 workers in X-700; later joined by 260 other workers*
1957	*Initial oxide conversion begins in X-705E*
1957	*Hearing conservation programs established*
May 10-16, 1957	*OCAW strikes*
1958-1962	*Feed production plant operates*
May 2-20, 1969	*OCAW strikes*
1970	*OSHA Act becomes law*
1972-1983	*CIP/CUP activities conducted*
May 2-August 8, 1974	*OCAW strikes*
January 1975	*NRC and ERDA assume regulatory responsibility for AEC functions*
August 28-December 13,1976	*OCAW strikes*
October 1977	*DOE assumes regulatory responsibilities from ERDA*
March 1978	*Emergency declared following cylinder rupture during which over 21,000 pounds of material are lost*
October 1978	*Oxide conversion placed in standby status and never operated again*
November 1978-April 1979	*Burial in X-749A of dismantled nickel plant and equipment from West Virginia*
1979	*Lithium relocation project completed*
May 3-December 15, 1979	*OCAW strikes*
1983	*OSHA Hazard Communication Standard issued*
July and November 1985	*EPA issues Findings of Non-Compliance with RCRA*
September 1986	*EPA and DOE sign Federal Facilities Compliance Agreement addressing 1985 RCRA violations*
November 1986	*Martin Marietta Energy Systems replaces Goodyear as the operating contractor*
September 1989	*EPA and DOE sign Administrative Consent Order (ACO) to ensure compliance with RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)*
October-November 1989	*DOE conducts Tiger Team assessment of PORTS*
May 1990	*X-749 landfill closed*
December 1990	*Waste Management Division created*
June 1991	*Initiated shipment of waste oil to the Oak Ridge K-25 TSCA incinerator*
June 11, 1991-April 6, 1992	*OCAW strikes*
November 1992	*Energy Policy Act creates USEC to manage the Federal government's uranium enrichment enterprise*
July 1993	*USEC contracts with Martin Marietta Utility Services for operation and maintenance of enrichment plants*
June 1995	*Martin Marietta becomes Lockheed Martin following merger*
June 1995	*First shipment to USEC of Russian low enriched uranium derived from highly enriched uranium*
October 1995	*Ohio EPA approves PORTS Site Treatment Plan*
1996	*Completed decontamination and decommissioning of X-705A incinerator*
April 1996	*USEC Privatization Act is signed into law*
November 1996	*NRC grants certificate of compliance for enrichment operations*
March 1997	*Regulatory oversight of enrichment enterprise transferred from DOE to NRC*
June 1997	*EPA, Ohio EPA, and DOE sign ACO giving Ohio EPA regulatory authority for day-to-day activities*
1998	*In settlement with Ohio EPA and Ohio Attorney General, PORTS pays a $193,000 penalty related to improper storage of lithium hydroxide and uranium hexafluoride*
April 1998	*Bechtel Jacobs awarded DOE management and integration contract*
May 1999	*USEC takes over direct operation of all enrichment activities*

3.0 Past Operational Practices

This section focuses on the work activities and hazards encountered by workers at PORTS from 1954 through 1997. While not all-inclusive, it is intended to provide specific information on most of the activities and significant chemical and radiological hazards encountered during normal operations and maintenance. It is structured in two parts. Section 3.1 discusses the worker safety and health programs in place to address identified hazards. Section 3.2 discusses the specific activities performed by workers, emphasizing the specific hazards and controls implemented to reduce the hazards. Appendix A discusses the PORTS radiological, chemical, and physical hazards and the potential effects of exposure to those hazards. Appendix B summarizes the principal activities conducted at PORTS from 1952 to 1997 and provides a general assessment of the hazards presented by these activities, the controls used to mitigate these hazards, and the effectiveness of the controls.

OPERATIONAL PRACTICES

- ***Worker Safety and Health***
- ***Operations and Maintenance***

3.1 Worker Safety and Health Programs

Safety and health programs at PORTS were established from the start of Plant operations and continue to the present day. However, the evolution of these programs varied throughout the decades from 1954 through the 1990s. Interviews and review of historical documents indicated a multitude of cases where procedures and safety precautions were not followed, personal protective equipment was not used or was inappropriate for the hazards, and workers were exposed to a variety of hazardous substances.

- *Hazard Identification and Analysis*
- *Safety and Industrial Hygiene*
- *Hazard Communication and Training*
- *Radiological Programs*
- *External Exposure Monitoring*
- *Bioassay*
- *Air Sampling*
- *Contamination Control*
- *Respiratory Protection*
- *Medical Programs*

3.1.1 Hazard Identification and Analysis

Historically, the Safety Department has maintained ownership of the non-radiological hazards assessment program. Fundamental tools for performing and documenting a hazard analysis were either the safety permit system or operating and maintenance procedures. From 1954 until 1972 the work permit system consisted of electrical work permits and hazardous work permits. The OSHA Act in 1970 resulted in an expansion of the safety work permit system to include permits for lockout/tagout, welding, and confined spaces. Radiological hazards and controls have been documented in radiation work permits since the late 1950s and have continued until the present time.

As early as the 1950s, hazards, precautions, and controls have been documented primarily in operating and maintenance procedures. However, it was not until the early 1970s that the Safety Department became proactive in evaluating the hazards of work activities and ensuring that procedures describing these activities included the appropriate hazard identification and controls. During the 1970s and 1980s, hazard identification and analysis activities centered on procedure reviews. A primary activity of the Safety Department during these two decades was the identification and analysis of hazards through the review of procedures, engineering design documents, and procurements. In lieu of job hazard analyses (JHAs), PORTS stressed the use of the permit system and integrating hazards and controls into operating and maintenance procedures. For major work evolutions and some accidents, management oversight risk tree analyses were performed.

The JHA process at PORTS did not evolve until the 1990s. In 1992, the safety and health work permit replaced the longstanding hazardous work permit. The safety and health work permit provided line management with increased data on potential hazards and controls. OR assessments, union safety meetings, and Goodyear Atomic Corporation corporate safety reports documented significant problems with adherence to electrical work permits and hazardous work permits from the 1950s through the 1980s.

3.1.2 Safety and Industrial Hygiene Programs

The safety program originated as a section within the Industrial Relations Department and remained within Industrial Relations through the mid-1970s, when the Safety Department became a section within the Technical Management Division. During these early years the safety program focused on safety awareness, rather than safety compliance or hazard analysis, as was evidenced in the significant safety poster and caption campaigns that were prevalent during this period. Early safety engineers were transitioned staff from the Human Resources Department, with no formal safety background, training, or preparation for becoming safety engineers. During this period, there were eight safety engineers. In 1958, AEC published a set of "Minimum Safety Requirements" that established safety goals, which could not always be achieved. Other safety guidance documents included industry standards, such as American Society of Mechanical Engineers (ASME) and American National Standards Institute (ANSI) standards, and DuPont safety practice guidance documents. The program was constructed on the insurance industry's loss control concept. During the 1960s, Plant activities were at a lower level, and the safety department downsized to two safety engineers and four certified code inspectors. In the early 1970s the Safety Department became more proactive in hazard identification and controls as a result of a movement of the department to the Technical Division, establishment of ERDA and OSHA, new Plant construction, and a resumption of work to the levels experienced in the 1950s. In 1973, the first comprehensive safety compliance review was performed by the AEC with respect to the new OSHA laws. Retrofits in excess of six million dollars were proposed, and numerous Plant modifications were implemented. Safety training during this period was hierarchical, with safety engineers training line management who in turn trained the workforce. During the 1970s and 1980s, the Safety Department became more actively involved in improving safe work practices. Safety experienced an increasing level of support with the OCAW and Plant management. For example, during the first two decades, Safety Department interface with management was limited to an annual safety presentation, whereas in the 1970s and 1980, Safety was a participant in daily senior management planning meetings.

The industrial hygiene program also had its origin in the 1950s. In 1954, the Industrial Hygiene section was an autonomous organization within the Medical Group. In 1957, Industrial Hygiene combined with Health Physics, and this union remained until 1985 when the two sections split. Until 1985, the Industrial Hygiene section was minimally staffed, typically with fewer than five personnel including technicians. According to an audit by an outside agency, there was no industrial hygiene program at Goodyear Atomic Corporation in 1972. By the mid-1970s, the industrial hygiene staff consisted of only two industrial hygienists and one technician. However, by 1989 industrial hygiene staffing levels increased to almost 20 as a result of DOE's insistence in assigning one industrial hygienist to each major industrial hygiene program. In 1993, the Industrial Hygiene Department merged with the Safety Department, and the number of hygienists was cut in half.

During the first three decades, radiation control technicians also performed work typically assigned to Industrial Hygiene technicians (e.g., air sampling for chemicals, noise surveys). In the 1950s and 1960s industrial hygiene activities were performed in reaction to Plant incidents and complaints. Industrial hygiene programs in the early years focused on occupational noise, fluorine, and some solvents. TCE was phased out by the 1980s, although some of the older workers maintained inventories for personal use in violation of requirements. Compliance with personal protective equipment requirements varied throughout the decades. Although monitoring and sampling were performed before the 1970s, standards and toxicological data for interpreting the sampling results were minimal. While sampling for airborne contaminants, noise, and dust was evident throughout the Plant's history, the OSHA Act in 1970 resulted in the Industrial Hygiene Department becoming more proactive in these areas. From 1973 through 1974, Industrial Hygiene personnel sampled hazardous environments throughout the Plant and evaluated ventilation systems for compliance with the new OSHA ventilation regulations.

Safety and health procedures, to a limited extent, were evident from the commencement of Plant operations. For example, a 1954 four page Goodyear Atomic Corporation Standard Practice Procedure addressed the control of toxic, radioactive, and contaminated material. However, safety and industrial hygiene procedures were generally few, since safety precautions were generally invoked through operating and maintenance procedures and the safety permit system. Both industrial safety and industrial hygiene programs have had a positive impact on worker safety and health throughout the decades, as evidenced by low recordable injury rates, no fatalities other than construction activities, and few disabling injuries. For many years, the recordable injury rates and lost workday case rates were considerably lower than in commercial chemical processing plants.

3.1.3 Hazard Communication and Training Programs

Information on most safety and health hazards associated with radiation, chemicals, and related operations at PORTS was available to Plant personnel from the beginning of Plant operation. While data supporting the level of rigor to effectively communicate health and safety information to workers was limited, there is evidence that workers understood that they were working with hazardous materials and processes and that safety precautions were needed. However, there is also evidence that in many cases hazard communications were ineffective. Interviews revealed that some supervisors seriously undermined workers' understanding of PORTS hazards by telling hourly employees that they could "eat" uranium without harmful effects.

Early Fire Fighting Training

In 1953, shortly after initiation of Plant construction in November 1952, engineers were sent from PORTS to Oak Ridge and Paducah to receive training in gaseous diffusion plant operations and safety. These individuals subsequently formed the initial staff of the PORTS Training School in June 1953. A structured training course was planned and implemented that included seven days of orientation addressing safety, first aid, security, Goodyear Atomic Corporation policies, rules, regulations, and an overview of PORTS and the gaseous diffusion process.

The process flow and associated duration of instruction topics for PORTS personnel enrolled in the training school in the early 1950s is shown in Figure 6. Production, power, utilities, and maintenance personnel attended the same training on safety, orientation, the diffusion process, and security. However, their respective levels of training in basic subjects (e.g., mathematics, chemistry, and physics), process and Plant description, and on-the-job training were different. The duration and content of formal training changed after the initial operations and maintenance workforce was established, as the demand for increased production eventually led to a reduction

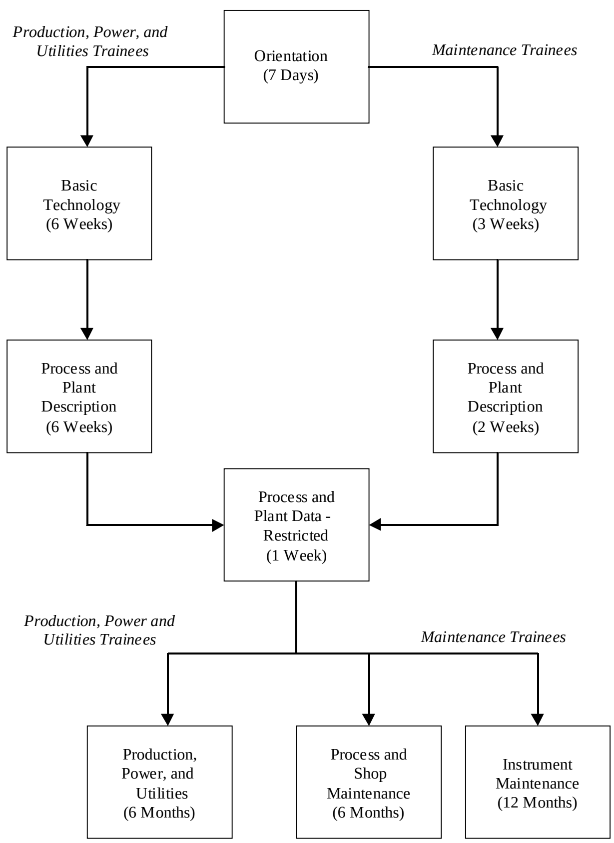


Figure 6. Portsmouth Training School Program Timetable: Circa 1953-1954

in formal classroom instruction and greater reliance on on-the-job training.

Non-operations personnel at PORTS were also informed of Plant hazards and associated safety precautions. However, it is not clear when this training was initiated or the level of rigor applied. A September 1957 grievance filed by the PORTS guard force requesting monitoring equipment to check clothing and shoes for radioactive contamination indicates that they were aware of such hazards. Internal Goodyear Atomic Corporation correspondence in November 1958 indicated that 36 janitorial workers attended eight hours of classroom instruction on personal protective equipment and associated practices; this provides additional evidence that some Plant support personnel received training on hazards and associated safety precautions.

The *Training Manual, Basic Technology*, prepared jointly by Goodyear Atomic Corporation and Carbide and Carbon Chemicals Company, dated June 1, 1953, was the first of several manuals used to train personnel responsible for operating and maintaining PORTS. Collectively, these training manuals provide evidence that the initial workforce received information on Plant hazards and safety precautions, as they contain information on harmful chemicals such as UF_6, carbon tetrachloride, TCE, and mercury; radiation and its effects; chemical safety; hazard controls; and protective equipment. The level of detailed safety information contained in these manuals varied, and in some cases supplemented the Training School courses. For example, the manual for maintenance personnel has more information on safety than the manual for utility personnel, but classroom instruction for maintenance employees was half that provided to utility personnel.

Models, mockups, lectures, workshops, field exercises with actual equipment, and motion pictures (later converted to videos) were also used to familiarize workers with Plant hazards and associated safety precautions. As of April 1954, Goodyear Atomic Corporation maintained a library of 263 motion picture films (16mm and 35mm) for training purposes, 32 of which were devoted specifically to safety, first aid, and orientation to atomic energy. These films eventually supplanted much of the formal classroom instruction, and may have contributed to the ineffectiveness of the PORTS safety-training program cited in OR assessments in later years.

Goodyear Atomic Corporation remained attentive to communicating safety and health hazard information to its workers throughout the 1950s and 1960s, as indicated by the training statistics tracked and presented in *Goodyear Atomic Corporation Monthly Activity Reports* for that period. However, apparently due to increasing Plant operations and the size of the workforce, the amount of formal classroom instruction provided to new hourly personnel decreased significantly. Orientation was reduced from seven to two days, and on-the-job-training became a principal means by which workers received information on operations and on safety and health hazards associated with work activities.

Classroom Training

In 1955, Goodyear Atomic Corporation focused attention on supervisor training and developed a 40-hour classroom program that was attended by 250 supervisors. "Safety reminders" were developed for the balance of the workforce, as hourly personnel received a variety of safety-related publications. For example, in August 1954 Goodyear Atomic Corporation's Inspection and Safety Subdivision initiated regular publication of *Supervisional Safety Letters*. By 1955 additional safety literature surfaced, including *Maintenance Safety Notes*, *Electrical Safety Notes*, and the pocket-sized *Safety Handbook for Power Operators*. In late 1956 Goodyear Atomic Corporation expanded its promotional safety activities, which included erecting a billboard at the Plant entrance road for posting weekly safety-related information, initiating personal protective equipment campaigns, and issuing *Guide to Safety*, a compilation of basic safety practices applicable to PORTS. During the late 1950s and early 1960s Goodyear Atomic Corporation distributed to the workforce pocket-sized pamphlets prepared by The Industrial Commission of Ohio that addressed a variety of safety and health areas. Additionally, in August 1962, Goodyear Atomic Corporation revised the *Guide to Safety* handbook and in January 1966 issued a companion handbook entitled *A Guide to Nuclear Safety*.

In the late 1960s and 1970s, less rigor was applied to formal training. Interviews with workers indicated that safety and health instruction in the mid-1970s was less rigorous than earlier years, as it was included in a four-week training course. A December 1978 packet prepared for Goodyear Atomic Corporation foremen containing notes and slides concerning safety policy and responsibilities, industrial hygiene, and health physics also suggests a less thorough approach to safety and health instruction. In 1976, fourteen years after the first revision to its *Guide to Safety*, Goodyear Atomic Corporation issued a second revision, thereby exhibiting a relaxed approach to routinely updating safety guidance. Nonetheless, throughout the 1970s there is evidence that hazards were being communicated to workers, albeit not as part of a formal training program. For example, Goodyear Atomic Corporation "safety letters" from 1976 and 1977 addressed technetium and ear protection, and a 1978 "notice" emphasized employee and employer rights and responsibilities, occupational safety and health training, compliance with safety standards, and safety concern resolution using the Industrial Hygiene and Health Physics and Safety Departments. In May 1979, Goodyear Atomic Corporation issued the third and final revision to its *Guide to Safety* handbook; no further revisions or distributions were made after this version was issued to employees.

Although OR assessment reports from 1980 and 1982 revealed deficiencies in the PORTS safety and health program, hazard communication to workers during the remainder of the 1980s continued to include limited structured classroom training supplemented with safety meetings and frequent safety notices. For instance, the Goodyear Atomic Corporation *IH-HP Bulletin* (later renamed the *IH-HP Employee Bulletin*) continued to disseminate safety- and health-related information on topics such as technetium, including its hazards and associated safety precautions, and updates to the hearing conservation program. Despite these informal initiatives, a December 1986 technical safety report identified Plant-wide inadequacies in the use of safety information signs, placards, and barriers. Subsequent training materials dated September 4, 1987, on chemical operations and contamination control address hazard placards and warning signs, permanent and temporary contamination zones, DOE standards, industrial hygiene and health physicist duties, and adverse safety impacts.

In the early 1990s, there are indications that PORTS was concerned about its safety and health program. For example, several pieces of 1993 internal correspondence show that Martin Marietta Utility Services directed all supervisors to conduct safety briefings at each shift to effectively communicate hazards and required all Plant personnel to adapt lessons learned from Paducah, such as its "Think Safety" and "Safety First" programs. Also evident in the 1990s is more focused attention on communicating the hazards associated with transuranics, as demonstrated by the health physics technician training program module focusing on uranium and technetium.

The effectiveness of the early and subsequent classroom instruction, on-the-job-training and other hazard communication activities, and worker understanding of chemical and radiation hazards varied considerably. Numerous self-assessments, OR audits, and occurrences routinely identified training deficiencies. While there is evidence that management took many actions to communicate hazard information to workers, these efforts were not fully effective. For example, there is evidence that protective force personnel received hazard and safety instruction from 1990 to 1995 in such topics as carcinogens, hazards, radiation, personal protective equipment, and operation of hand-held monitors. However, despite this training, from 1983 until 1995 protective force personnel continued to conduct drills (routine practice) in radioactively and chemically contaminated spaces without appropriate protection, while operations and maintenance workers generally took more rigorous precautions in these same spaces. (Protective force personnel were protected and monitored during exercises, which were staged, formal demonstrations of security capability.) This suggests deficiencies in the hazard communication and training program throughout the life of the Plant.

3.1.4 Radiological Programs

Since the beginning of Plant operation, policies and procedures were established for the PORTS radiation protection program. Radiation protection program policy documents stated the intent that "every reasonable effort would be undertaken to protect personnel from the potential hazards inherent in the handling and processing of radioactive materials." Controls and action points were developed to minimize personnel exposure and prevent exceeding established limits.

The health physics staff provided exposure monitoring services, recommended training and protective measures to supervisors for personnel protection, and maintained exposure and radiation measurement records. Health physics staff also administered the bioassay program, analyzed air samples and personnel exposures that were outside of specifications, studied Plant hazards and required controls, and performed Plant environmental monitoring. However, the small size of the health physics staff (e.g., five to ten people during the first 20 years) limited the effectiveness of surveillance and monitoring of hazards and work activities for the 1,500 to 2,500 employees working in many diverse environments. While the line organization supervisors were responsible for implementing radiological controls and protective measures, supervisory oversight and worker implementation of personal protective equipment and related protective measures were inconsistent. Non-compliant personal protective equipment use by workers is attributed to the pressures to maintain process operations, a lack of knowledge and understanding of the risks and why the protection was required, and the physical discomfort and sensory impairment associated with personal protective equipment, such as respirators, in hot and dirty work environments.

During the 1952-1953 period, the AEC approved the enrichment processing of production reactor tails through the gaseous diffusion process. In 1957, radiological surveys at the Paducah Plant identified that neptunium-237 was present in the enrichment cascade. Although the AEC recognized the potential for transuranic contamination of the cascades, it was not until a 1965 appraisal that OR identified a potential problem with transuranics and fission products in X-705E and recommended studies to determine where these materials could concentrate in the process. Records reflect that PORTS then reviewed the potential problems posed by feeding reactor returns to the oxide conversion plant; however, detailed studies were not performed. PORTS correspondence also indicates that health physics staff did not fully understand the presence of transuranics and technetium-99, and appropriate analytical procedures were not developed as late as 1976. During the 1970s, PORTS health physics and Plant managers participated in pre-planning for receipt and subsequent processing of recycled uranium known to contain trace quantities of neptunium-237, plutonium-239/240, and technetium-99. Planning activities included development of recommendations for material receipt specifications and specific controls to minimize personnel exposures, including the use of containment devices and ventilation systems. Many recommendations were implemented but were not sufficient to safely operate the facility, and it was subsequently placed in standby.

During the 1960s, the PORTS health physics group became concerned with increasing alpha radiation levels in process and support facilities at the site. While no records were identified to demonstrate that this issue was satisfactorily resolved, the period coincides with the processing of recycled uranium at the Paducah Plant. In 1979, isotopic analysis of two cascade deposits revealed relative high concentration of neptunium-237 (i.e., 55 percent and 60 percent of the total alpha activity in the samples was due to Np-237, respectively). However, there was no indication of a change in the radiological control program to address this issue, even though data was available to indicate that some level of transuranic contamination was present in the cascade. Transuranic sampling for work planning and control was not actively conducted until the 1990s.

The Health Physics group actively encouraged respirator use; however, many instances of improper respirator use or non-use were identified by Health Physics, by Operations management, and in union

X-705E Withdrawal Stations

safety meeting minutes. For example, Plant management undertook disciplinary action for an individual's failure to use required personal protective equipment. Conversely, the Health Physics group repeatedly cited Operations supervision for failing to utilize respiratory protection devices as required by Plant procedures, as well as a general reluctance to implement and/or enforce Health Physics recommendations. Management's failure to enforce the use of respiratory protection devices and other protective action recommendations by Industrial Hygiene and Health Physics group adversely impacted PORTS' ability to control the potential for personnel exposure to radioactive materials including transuranics.

3.1.5 External Exposure Monitoring Program

Personnel external exposures were primarily monitored by the use of film badges that were assigned based upon anticipated tasks, work areas, and the results of routine and special surveys. In early Plant operations, film badges were recommended where personnel could receive or were likely to receive a dose above prescribed levels for a period of seven consecutive days. Early documents note that in many cases film badges were issued to personnel who normally were not expected to receive any significant exposure but could be called into areas requiring badges. If personnel not normally assigned film badges were required to enter areas in excess of the seven-day criteria, visitor badges were furnished. Records indicated that in several departments the employees' need for film badges varied. In those cases, film badges were issued on a statistical basis, and if some exposures were indicated, a larger percentage of employees or entire departments were issued dosimetry. This was a reasonable approach to expanding sampling.

PORTS established administrative exposure limits below regulatory quarterly exposure limits and utilized a four-week interval to trend and correct before restricting employees who exceeded the Plant control criteria. In March 1975, the Industrial Hygiene and Health Physics Department initiated a monthly monitoring program for all women assigned to areas where exposure to penetrating radiation was possible; the limit was 0.5 rem during the entire period of gestation. The site noted that neither the NCRP nor ERDA guidelines required additional monitoring for fertile women. Subsequently, Goodyear Atomic Corporation initiated a monitored monthly program. Goodyear Atomic Corporation conducted several investigations of exposures to technetium during the late 1970s to early 1980s, and only one was deemed to require a documented dose calculation. The calculation indicated a fetal thyroid dose of 800 millirem for an employee in her first trimester of pregnancy. Goodyear Atomic Corporation evaluated this instance and required no further action.

The low specific activity and the self-shielding properties of uranium handled at the site limited dose rates at PORTS. However, certain operations were known to result in higher exposure potential. Routine whole body beta exposures in excess of PORTS investigation levels existed primarily in areas where uranium daughter products tended to concentrate. Documents reviewed and interviews conducted with former production workers and Industrial Hygiene and Health Physics Department staff members indicated that these areas included ash receivers, sintered metal filter baths, converter disassembly work, cylinder washing, oxide conversion, and the technetium and uranium recovery processes. Exposure evaluations during the mid to late 1950s indicated numerous instances of workers being placed on work restriction based on whole body exposures that were determined to be in excess of PALs. Documents also indicated that before the mid-1980s, Goodyear Atomic Corporation had never performed extremity monitoring for any operation or work activity. Documents indicated that various valves associated with pigtail operations had recorded beta readings as high as 1 rad/hour. Feed production plant ash receiver areas had floor readings of 5 rad/hour beta. Operators routinely handled these valves and equipment in X-705 and other locations where significant hand exposures could occur.

Dosimetry programs at PORTS from 1954 to 1992 were neither calibrated nor monitored for neutron exposures. A National Institute of Occupational Safety and Health (NIOSH) evaluation for PORTS studied the neutron radiation issue in 1997 and concluded that there was potential for chronic low-level neutron exposures in areas where uranium was stored (cylinder yards), handled (feed and withdrawal areas), or solidified within the cascade (deposits).

PORTS implemented a thermoluminescent dosimeter (TLD)-based dosimetry program in 1981. Shortly after implementation of the new TLDs, routine processing indicated a potential exposure of 4.8 rem for one person. An investigation concluded that the probable cause of the high reading was contamination of the sulfur TLD chips with sulfur from an adjoining sulfur pellet, producing an erroneous reading. As a stopgap measure, PORTS placed tape over the sulfur pellets until a permanent solution could be found. In addition, coverage of the TLD chip with the company photo identification prevented monitoring of beta (skin) determinations for the 1981 calendar year.

In the mid-1990s there were allegations of falsification of dosimetry records. An internal Lockheed Martin Utility Services investigation into health physics management practices concluded that improprieties might have existed in the Plant's dosimetry program that resulted in assignment of inaccurate exposures. While the Lockheed Martin Utility Services reviewers believed the employee's allegations to be true, they could not definitively prove it. Further, they could not understand why such improper actions were taken for otherwise negligible levels of exposure.

In 1998, OSHA cited USEC for failing to preserve and maintain records of employee exposure of all employees for at least 30 years. OSHA found that "records of radiation exposures for all company employees were not adequately maintained from 1993 to 1995 in that some employees' exposures were arbitrarily assigned and based solely upon their past exposures which may have differed from exposures experienced during the period relating to the assigned dose." Furthermore, "records of radiation exposures were not accurately preserved and maintained. For the period 1993 through 1995, some TLDs that were used to measure and create a record of employee radiation doses were not evaluated, and a zero dose was assigned to an employee where the exposed TLD which was assigned to the employee was damaged." In response to the outstanding OSHA dosimetry citation, USEC initiated a dosimetry reconstruction effort. Although many adjustments were made to individual dose records for the period 1993 to 1995, these numerical adjustments appear to be minor, and adjusted exposures were found to be well below DOE limits. Administrative corrections to the site's dosimetry program to prevent reoccurrence of these issues were implemented, however the documents indicate that "the DOELAP [Laboratory Accreditation Program] TLD database, although reliable, still had overall validity concerns." Inconsistent and incomplete external exposure monitoring and data management practices have impacted PORTS' ability to demonstrate that all exposures to personnel have been measured and recorded accurately.

3.1.6 Bioassay Programs

Urinalysis Program

Workers exposure to uranium was assessed by periodically measuring the concentration of uranium in urine samples. Urine samples were collected and analyzed more frequently from individuals who had shown positive uranium bioassay results in the past. During the 1950s and 1960s, urine samples were typically analyzed for uranium, and in most cases for alpha activity. Typically, the sample collection procedure involved the collection of Monday morning urine specimens (the morning following two or more days off the job). This was non-conservative, and the collection date evolved to a "Friday" sample during the 1970s and 1980s. Considering that numerous routine urinalysis results reflected uranium intakes in the years of operation and the rate at which soluble uranium is excreted, some uranium intakes were likely not identified or properly investigated. Technetium analysis was added in the 1970s.

The PORTS restriction criterion from the start of operations to December 1956 was based on the most conservative urinary uranium excretion limit at the time. The minimum level of activity reported for uranium was 5 µg uranium/L and/or 0.3-dpm/100 ml for alpha activity. These limits were based on insoluble uranium in the lungs. However, after several years of Plant operation and experience it was determined that the allowable excretion level of uranium would be more realistic if it were based on soluble materials and

Mass Spectrometer Used to Improve Isotopic Analysis of Process Gas

toxicological consideration for the kidney. Investigation levels were subsequently raised to 50 µg uranium/L and/or 10 dpm/100 ml for alpha activity, which was not a conservative decision because actual solubility in some areas was not always known.

Positive urinalysis samples resulted in an increased frequency of collection, and each case appears to have been given individual attention, with separate records being maintained by the Industrial Hygiene and Health Physics Department. In cases of suspected inhalation of uranium, such as during releases, the department supervisor was responsible for recommending that the personnel involved submit a urine sample. Personnel were placed on accelerated sampling schedules if they were engaged in special projects or were in contact with high-assay material; worked in areas with air sampler results indicating significant levels of airborne contamination; or as a direct request from the Medical Director. All samples above a predetermined recall guide for uranium or alpha activity were followed by an immediate recall sampling until a negative result was obtained.

Throughout Plant history, there were numerous administrative restrictions for concentrations of uranium in urine above the administrative guidelines. These employees were reassigned to areas with less potential for uptake. Biological retention times for these exposures are closely related to the solubility of the compound. Information from interviews with former workers and much of the sample analysis data from the late 1950s assumed intakes to be from soluble compounds. This assumption may not have been conservative for some aerosols generated during all operations. Health and safety activity reports from the mid-1960s identified that excessive inhalation of uranium compounds was the major radiation and contamination risk at PORTS. PORTS documents also reveal that internal deposition became a problem in 1965 from handling insoluble enriched uranium, and that urine sample results were neither reliable nor as sensitive as analysis for soluble forms. Consequently, an in-vivo body counter program was initiated in 1965.

Documents reviewed for the first quarter of 1978 indicated that "Based on the weight analysis via fluorimetric detection and the monitoring frequency it is possible to exceed, undetected, the maximum permissible weekly uptake." The documents also indicated that samples were collected and analyzed for technetium. Correspondence dated as late as 1988 related to oxide repackaging stated that "Oxides of uranium are known to have different chemistry from the uranium fluoride compounds generally encountered at the site. The current urine monitoring program is not adequate to detect significant exposures to uranium oxides in a timely fashion." This correspondence also noted that "available analysis of the oxide does not include sufficient information to determine whether exposure controls are appropriate since they are based on [transuranics] being insignificant for the purposes of dose assessment and control."

In-Vivo Radiation Monitoring

Since the inception of the in-vivo monitoring program at PORTS in 1965, the selection of individuals for in-vivo analysis was based on work history, work environment, airborne concentrations, and past in-vivo and urine sample results. The PORTS Medical Director, upon recommendation of Industrial Hygiene and Health Physics, approved the individuals selected for restriction and subsequent removal. There were two classes of work restrictions: 1) an individual was neither to be exposed to any form of uranium material nor assigned to areas where there was potential for airborne uranium compounds; and 2) the individual was limited to work in areas where the average airborne alpha activity should not exceed a small percentage of the limit. There were two problems with the criteria. First, the large number of unexpected releases in most buildings made the first criteria difficult and unrealistic to administer. Second, a restricted individual should not have been placed in a work location with any potential airborne radiation activity. In-vivo radiation monitoring (lung counting) was initially conducted by sending individuals to either Fernald or Oak Ridge. Later, PORTS used a mobile laboratory from Oak Ridge. Data indicated that personnel were monitored at about six-month intervals for uranium, neptunium, and technetium. The analysis was generally reliable for insoluble forms of uranium since the lung was the critical organ.

In a report prepared for Martin Marietta Utility Services in 1990, the effectiveness of the mobile whole body counter was evaluated for analysis of uranium, neptunium, plutonium, and americium. Additionally, a review was conducted of historical lung counting data from Martin Marietta Utility Services sites, with particular emphasis on neptunium-237. A summary of the findings indicated that the counter's capability for analysis of those radionuclides, with the exception of uranium-235, was somewhat questionable due to system hardware limitations (i.e., use of sodium iodide detectors, resolution of spectra insufficient to identify peaks in the presence of background radiation, efficiency calibrations did not use multiple source strength measurements for isotopes other than uranium-235). The studies of historical data indicated difficulties, including the inability to retrieve the appropriate data, lack of system access, and insufficient documentation. The root cause for most of the problems could be attributed to physical limitations of the system, lack of understanding of these limitations, and the lack of adequate training. Incomplete isotopic and uranium solubility characterization, coupled with design and analytical limitations, has impacted the Plant's ability to demonstrate that all internal exposures have been accurately detected and assessed.

3.1.7 Air Sampling

PORTS utilized a network of stationary air samplers at various production and non-production areas throughout the Plant. Portable and breathing zone samplers supplemented the stationary air-sampling network. Data documented frequent air sampling results in excess of PORTS limits. Industrial Hygiene and Health Physics summary reports for the late 1950s to late 1960s indicated that it was common to have stationary and portable air samples in excess of limits. These above-limit samples typically were related to process upsets, equipment failure, or maintenance activities, and were valid high readings. Although logbooks indicated many dusty operations or smoky conditions in all buildings, most of these samples were related to operations in X-326 and X-705.

In 1977, the health physics staff initiated a comprehensive air monitoring program to evaluate employee exposures to transuranic elements during compressor disassembly activities and during conversion of uranyl nitrate hexahydrate to oxide. The study concluded that a cursory review of the processes indicated that the potential for employee exposures was minimal and that controls were adequate to reduce the exposure potential in high-risk situations. However, the same monthly summary discussed two workers being placed on restriction following entrance into an oxide conversion facility glovebox with inadequate respiratory protection and without a hazardous work permit. These issues indicate that management did not have adequate control of the program designed to protect workers from both physical and radiological hazards and that, at a minimum, respirator use at PORTS was inconsistent.

Air Monitoring

Documents during the early 1980s revealed that the methods/calculations pertaining to the air monitoring system contained three non-conservative assumptions: (1) constant sampling rates for the area air monitoring systems were determined to be non-conservative for over ten percent of the permanent sampling locations (primarily in X-705), which were noted as experiencing heavy dust loading that routinely resulted in lowering flow rates; (2) the absorption effect of the dust buildup on filters was not considered when the samples were counted, and relatively small amounts of dust on filters will prevent alpha radiation from being detected; (3) the air monitoring system utilized cellulose filters for sample collection, but the effect of particle penetration into the filter medium was not considered. This submersion of radioactive particles within the filter medium was discussed in ANSI N13.1, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities," the consensus standard at the time. This guide stated that cellulose filter papers were not well suited for detection of alpha-emitting radioisotopes by direct counting.

It is evident that there were elevated airborne radioactive concentrations and non-conservative air sampling assumptions, coupled with continuing management and supervisory failures to actively enforce the use of appropriate respiratory protection devices. Additionally, workers were reluctant to use this equipment. Consequently, personnel exposures were likely during a variety of operations at PORTS.

3.1.8 Contamination Control

PORTS had a fairly conservative contamination control policy; however, historical evidence suggests that management expectations for contamination control were often not met in the field. This was particularly true in the buildings with the highest potential for contamination, such as the main process buildings, the X-344 feed manufacturing plant, and X-705. Historical health physics records indicate that the control of radioactive contamination was considered a high management priority from the very beginning of Plant operations. A *Supervision Safety Letter* issued by Goodyear Atomic Corporation in November 1954 describes contamination as a more serious problem than exposure because it involves actual contact with a radioactive substance that can remain on or be deposited internally in the body for long periods of time. Proper contamination control practices for workers were highlighted in the safety letter. Another *Supervision Safety Letter* issued in September 1960 points out that hand counters are provided at strategic places throughout the Plant and are intended for daily use by employees, but health physics reports indicate inconsistent usage.

From the beginning of operations, PORTS had PALs for assessment and control of radioactive contamination. The PALs for contamination were primarily based on fixed and removable alpha contamination levels. There were different limits for floors, hands, clothing, and shoes. Although evidence suggests that contamination control was problematic throughout Plant life, Goodyear Atomic Corporation's limits were much more conservative than other gaseous diffusion plants, and often an order of magnitude lower than other facilities and regulatory requirements. Thus, areas considered contaminated under the Goodyear Atomic Corporation program might have been considered clean under the Oak Ridge or Paducah radiation protection programs. One reason for the lower contamination thresholds was concern over the higher-assay material at PORTS that would have resulted in higher radioactivity for the same amount of uranium released or spilled. However, the lower limits were frequently exceeded. In the 1950s to the 1970s, personnel "spot checks" indicated many readings above PAL limits.

Records of radiation and contamination surveys were readily available from the start of Plant operation. Survey records for all major buildings indicate contamination levels above limits over many years. Recommendations for decontamination of locations exceeding PALs were typically made and noted by Industrial Hygiene and Health Physics personnel on the survey forms. In some cases, follow-up surveys noted that areas continued to be contaminated above limits, with continued recommendations for decontamination. However, rigorous enforcement of decontamination requirements was not evident. Difficulties in contamination control can likely be attributed to the pervasive nature of uranium discharges from process equipment and lack of sufficient staff and/or upper management commitment to enforce contamination control guidelines on line management, supervisors, and workers. For example, hand monitoring equipment and radiation detectors were available, but their use was not mandatory or effectively monitored. A number of audits and appraisals conducted over the years highlights the lack of adherence to requirements, procedures, and guidelines such as use of protective clothing, hand monitoring, frisking, and boundary control. Areas of PORTS not believed to have a significant potential for contamination were often overlooked, such as the X-720 maintenance shops and X-750 garage, which were routinely used to repair potentially contaminated parts and vehicles. Limited health physics survey staffing resulted in low priority and infrequent surveys for these areas.

In the mid-1950s, Goodyear Atomic Corporation evaluated the seriousness of contamination in work areas by calculating a "contamination index" for each surveyed area. The contamination index was a weighted average based on a mathematical formula that considered both the contamination levels encountered and square footage. A three-tiered approach to contamination control was utilized based on the contamination index. Areas were categorized as red, orange, and clean. An index of greater than 75 was designated as a "Red Job Assignment," calling for company-issued undergarments, coveralls, head covers, and shoe covers or yellow-toe shoes. Showering was also a policy requirement for Red Job Assignments. An index of between 10 and 75 was classified as an "Orange Job Assignment" requiring somewhat less stringent protective clothing (no head covering) and no showering requirement. An index of less than 10 was considered clean for contamination control purposes. Despite these rather formal designations, inspection reports and appraisals indicated that adherence to protective clothing and contamination control requirements was inconsistent and was influenced primarily by the first line supervisor's philosophies and work ethic.

As early as 1955, permanent Red Job areas included portions of X-705, X-744G, X-342, X-344, and X-746. Classification of other areas was subject to change based on survey results. In some cases, classifications were not performed correctly. In 1980, surveys showed that portions of X-326 met the criteria for a Red Job area but were not categorized as such. A union grievance was filed and an investigation was performed to review the matter. Other problems with the classification system included the lack of formal restrictions on movement of personnel and equipment in and out of contaminated areas. In 1977, Industrial Hygiene and Health Physics noted that employees wearing contaminated clothing were permitted to enter clean areas such as the cafeteria, and individuals were allowed to eat and smoke in contaminated areas. A change in Goodyear Atomic Corporation standard practice procedure SPP H-8, "Health Protection Measures for Red Orange and Contaminated Job Assignments," was proposed at that time. In 1979, Goodyear Atomic Corporation established a Contamination Control Steering Committee to review the overall contamination control program at the Plant and make recommendations for implementation of a more effective and uniform policy. Contamination control problems continued to persist into the late 1980s.

Although Goodyear Atomic Corporation management and the Industrial Hygiene and Health Physics Department were concerned about the need to control contamination to levels as low as reasonably achievable (ALARA), contamination control policies and procedures were not fully effective, as evidenced by continuing radiological problem reports and PORTS emphasis on corrective actions that lasted into the 1990s. These deficiencies are likely to have resulted in additional exposures and spread of contamination over the Plant operating history.

3.1.9 Respiratory Protection

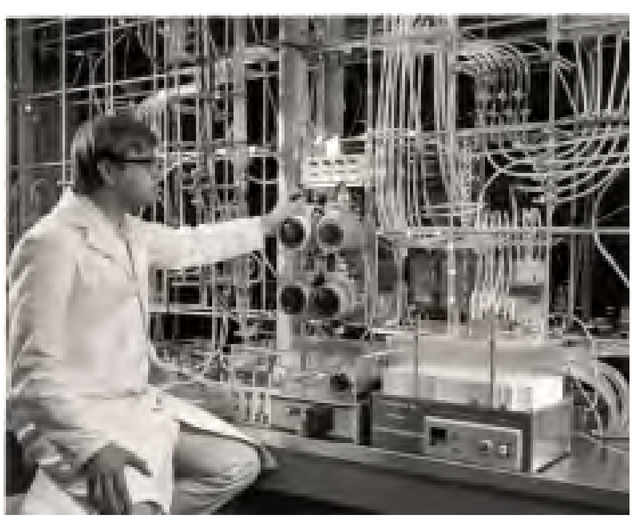
The PORTS Industrial Hygiene and Health Physics Department considered personnel exposures to low-enriched uranium compounds to constitute a chemical rather than radiological exposure. However, as discussed, site processes involved both soluble and insoluble forms and were designed to enrich uranium to over 97 percent, which complicated the respiratory protection issues at the site. Not only were the constituents of uranium compounds within the enrichment cycle hazardous (e.g., fluoride and acid compounds), but heavy metal poisoning could result from exposures to significant quantities of uranium. Consequently, respiratory protection programs of the time were instituted to minimize personnel exposures to these contaminants. Early in Plant life, the respiratory protection program principally utilized dust masks (paper masks) to minimize exposure to nuisance particulates (e.g., dusts and filings), and MSA masks with cartridges and the Army assault mask were used to minimize personnel exposures to chemical and radiological contaminants.

Many work activities at the site resulted in high airborne radioactive material concentrations in the work area. Based upon the results of air samples collected in those areas, Industrial Hygiene and Health Physics personnel routinely recommended using engineered controls (ventilation) or respiratory protection devices for specific tasks with identified high airborne radioactive material concentrations. Unfortunately, the Industrial Hygiene and Health Physics recommendations were made after high airborne radioactive material concentrations had been measured, and evidence indicates that although line management knew of those recommendations, they were not always implemented.

During 1973, the Industrial Hygiene and Health Physics group and Plant management took several initiatives to improve the level of respiratory protection for employees, which were driven by a 1972 safety and health appraisal. Industrial Hygiene and Health Physics developed and Plant management authorized a comprehensive program to upgrade respiratory protection practices at the site. Program elements included Plant surveys to identify respirator need and type; respirator procurement; employee training in respirator use, cleaning, and maintenance; fit testing; and procedure-controlled issuance. Plant management also identified and designated a number of Plant areas, particularly those where process gas might be present, as requiring respiratory use. These actions resulted, at least in part, from continuing problems with puffs. During this effort, 350 full-face and 150 half-face air purifying respirators (APRs) and air-supplied hood were purchased and placed into service. Purchased equipment was state-of-the-art for the period. However, deficiencies continued to occur, and it was not until 1982, during an OR assessment, that programmatic corrective actions were initiated for respiratory protection program deficiencies. The OR assessment resulted in a number of corrective actions designed to improve the program and implementation, including establishing a new respiratory fit testing facility in 1985; refitting and retraining all employees; developing a respiratory protection audit program; and reviewing and revising Goodyear Atomic Corporation procedures to include information required by the ANSI standard for respiratory protection.

Puffs, minor releases of UF_6 from process gas equipment, were a common occurrence despite efforts to minimize the amount of material available for release. Frequently, solid UF_6 deposits became isolated from the process gas stream in closed-end volumes, such as instrument lines, that developed blockage. Records from the 1960s and 1970s indicate that in some cases, puffs occurred numerous times per week. Evidence indicates that during this period, operators did not typically wear respirators while sampling cascade process gas, despite frequent puffs of UF_6. Puffs were also frequently experienced in product feed and withdrawal areas when UF_6 cylinder pigtails were disconnected. Although Plant procedures specifically required respirator use during these evolutions, they were not typically worn. This procedural violation repeatedly resulted in the development and issuance of radiological occurrence reports to document the adverse condition, but corrective actions were not effective. Interviews with process operators indicated the belief that the uranium materials at the site were relatively harmless, resulting in unwillingness to use appropriate personal protective equipment.

The Industrial Hygiene and Health Physics group always recommended the use of respiratory protection devices in areas with high potential for airborne and/or chemical contaminants. Records indicate that the Industrial Hygiene and Health Physics group routinely interacted with operations and maintenance management and workers to advise them on the use of respiratory protection equipment and provide counsel on the types of work that would normally require respiratory protection. However, records also indicate that despite the Industrial Hygiene and Health Physics group's concern with personnel protection, that group did not have the authority to direct the use of respiratory protection. Consequently, respiratory protection was not always utilized when high levels of airborne contaminants were present. For example, during 1972, Industrial Hygiene and Health Physics personnel assigned to X-705 reported approximately 300 radiological occurrences related to elevated airborne conditions in the oxide conversion facility. The reports indicate that as few as two and as many as 30 high airborne radioactive samples were identified during each incident, and in one case, a continuous air monitor alarm was ignored. Additionally, the reports indicated that respiratory protection was not used on many jobs for which the use of that equipment was specifically required by procedure, resulting in many special bioassay requests. Former-worker interviews and records indicated that failure to wear appropriate respiratory equipment was pervasive throughout the Plant.



Analyses Supporting the Industrial Hygiene Program

Both Industrial Hygiene and Health Physics and Plant management recognized the hazards associated with contamination from transuranic compounds, and actions were taken to limit receipt of those contaminants. Although records indicate that the oxide conversion facility and some cascade deposits contained significant levels of transuranics, PORTS considered technetium-99 to be more pervasive, and respiratory protection program recommendations were subsequently based upon transferable beta contamination levels in work areas. However, work was routinely conducted without the benefit of respirators on open cascade components in process buildings, maintenance, refurbishment work, and waste handling activities. Extrapolation of analytical data would have indicated that these areas could have contained transuranic compounds. Until the early 1990s, uranium and technetium compounds were the only radiological hazards mentioned in respiratory protection guidance, even though the Plant was aware that some transuranic contaminants existed in the recycled uranium being processed at the site.

Since the beginning of Plant operation, there were significant deficiencies in respiratory program implementation. The early lack of line management support for the program directly impacted the Industrial Hygiene and Health Physics group's ability to establish controls consistent with the hazards encountered by workers at PORTS. Worker acceptance of the respiratory protection program was hampered by lack of supervisory encouragement/enforcement, inadequate training regarding the hazards, and poor equipment fit, comfort, and visibility. In addition, there was a belief that uranium was relatively harmless and could even be ingested without ill effect. Because of these issues, unnecessary worker exposures to airborne radioactive materials occurred through PORTS history.

3.1.10 Medical Programs

In conjunction with the AEC, Goodyear Atomic Corporation established a formalized occupational medical program following the inception of the PORTS contract. Similar to the other uranium enrichment facilities, the medical program originally managed health physics, industrial hygiene, and environmental and workers compensation activities until expansion of these individual programs necessitated their own management structure. The PORTS safety and health system developed into the traditional environment, safety and health organization by the 1980s. Although the occupational medical program received management direction from Goodyear Atomic Corporation, Martin Marietta Utility Services, and finally Lockheed Martin Utility Services, it adhered to requirements established by AEC, ERDA, and ultimately DOE.

A review of medical records and Goodyear Atomic Corporation correspondence from the 1950s and 1960s indicated the existence of a sophisticated occupational health program. Individual medical records contained documented results from comprehensive medical examinations, including standard laboratory testing, audio examinations, vision testing, radiology reports, and physician history and physical examinations. The medical records also contained information concerning industrial injury records, some health physics urine bioassay records, employee work restriction information, and workers compensation records. In some early medical records, Goodyear Atomic Corporation physicians would write individual letters to employees discussing their medical examination results and offer suggestions to improve their health and general welfare. Little evidence of industrial hygiene exposure data and work area hazards was found in the medical records that were reviewed. Medical Division correspondence indicated that health physics, industrial hygiene, and safety personnel would follow up on accident and injury reports with local supervisors. Industrial hazards, such as heat, noise, metals and production chemicals, were of ongoing concern to the medical staff. Urine bioassays were routinely collected in the medical center because they had the facilities necessary to collect the specimens. Information published in Goodyear Atomic Corporation monthly and quarterly reports demonstrates tracking of medical program activity for occupational and non-occupational visits, Plant employee injury and illness statistics, compensation case rates, health physics data (urine and film badge), and industrial hygiene data.

Audits, appraisals, safety committee meetings, and bargaining agreement negotiations beginning in the 1970s mention weaknesses in the occupational health program. Shortages of medical staff, difficulty in locating and retaining physicians and nurses, and some issues regarding the quality of service were all mentioned in correspondence from the medical program archives. Unions wanted better medical care and more coverage from medical personnel on off-shifts and weekends. Several allegations found in the Goodyear Atomic Corporation archives from union employees, as well as letter from a former Medical Department contractor, identify instances where medical treatment and record-keeping practices were less than satisfactory. A DOE Headquarters medical program appraisal in 1978 mentioned "a lack of dynamic leadership and lackadaisical [Occupational Medicine] Program," resulting in management changes. Other appraisals recommended more involvement of medical personnel in Plant activities, the need to automate health records and health information, and the establishment of a more comprehensive approach to occupational medicine. Noted improvements were made in both the effectiveness and the scope of the medical program following the selection of an experienced occupational physician.

Although DOE orders in the late 1980s and early 1990s specified stronger occupational medical program requirements, staffing and integration of the medical personnel into site management activities were continuing issues that required resolution. With the assistance of the corporate Martin Marietta Utility Services Medical Director, comprehensive medical program procedures and protocols were developed and physicians with occupational experience were recruited. Although the DOE Portsmouth Site Office did not have the expertise to assess the PORTS medical program, both DOE Headquarters and Martin Marietta Utility Services personnel regularly performed program reviews. Medical services personnel were eventually transferred to USEC following the privatization agreement; however, DOE site office personnel and some contractor staff continued to utilize USEC medical services until 1999, when an offsite medical contractor was selected to provide medical services.

3.2 Operations and Maintenance

This section describes historical Plant operations and maintenance activities, related hazards, and the effectiveness of controls to protect workers, the public, and the environment from hazards. Appendix B summarizes the principal hazardous activities conducted at PORTS from 1952 through 1993 and identifies the hazards presented by these activities, the controls used to mitigate the hazards, and analysis of the effectiveness of these controls.

- *Feed Manufacturing Plant Operations (X-344)*
- *Oxide Conversion (X-705E)*
- *Cascade Operations*
- *Decontamination and Uranium Recovery (X-705)*
- *Smelting (X-744G)*
- *Maintenance*
- *Incineration of Waste (X-705A)*
- *Work for Others*

3.2.1 Feed Manufacturing Plant Operations (X-344)

From 1958 until 1962, PORTS generated some of its feed material in a feed manufacturing plant in X-344, which converted uranium tetrafluoride (UF_4), commonly known as "green salt," to uranium hexafluoride (UF_6) by reacting the green salt with fluorine at high temperatures (2000 F). The chemical reaction for this process is:

$$UF_4 + F_2\text{ (gas)} \rightarrow UF_6\text{ (gas)}$$

The feed manufacturing plant consisted of four fluorination towers for processing UF_4 to UF_6, two cleanup reactor towers for scavenging excess fluorine gas, compressors and cold traps to collect the UF_6, cylinder fill stations, a conveyer system to unload and transport the UF_4 powder, 40 fluorine generation cells (in adjoining X-342), and supporting equipment and powder storage areas. The UF_4 powder and fluorine gas were fed into the top of the towers, and the resulting UF_6 was passed through filters and into cold traps where the UF_6 solidified. Full cold traps were isolated from the process, connected to an empty cylinder, and reheated under pressure to allow the UF_6 to melt and drain to the cylinder for subsequent feeding to the cascade. Full ash receivers from the towers were removed to a storage area, allowed to decay for approximately two to six months, and then blended with the incoming UF_4 and re-fed to the towers. Liquids from decontamination of filters and system equipment were transferred to X-705 for uranium recovery. The recovered uranium was returned to X-344 as uranium oxide and blended with the UF_4 stream. When the plant closed in 1962, the ash remaining in X-344 was shipped to Paducah for processing and uranium recovery.

Operating records and personnel interviews indicate that the operating and maintenance practices utilized in the feed manufacturing plant were generally consistent with accepted commercial industrial practices at the time, although the work environment was harsh. Room temperatures in the tower areas were usually in excess of 100 F, noise levels were high, and leaks in all systems were common. Exposure to uranium dust was prevalent in both operations and maintenance activities. Mechanical problems with powder hoppers, conveyers, and towers resulted in a high level of maintenance throughout the four-year life of the plant. The green salt inside broken equipment had to be cleaned out by hand by the operators, and the maintenance workers were continuously working on highly contaminated equipment. Shift logs and interviews with workers indicated that powder spills were frequent, and green salt accumulated to several inches deep in some areas each shift. The green salt was routinely swept up by the operators and reintroduced to the process. Workers performing these activities wore company-issued overalls and work gloves. Health physics surveys routinely showed high-levels of alpha-emitting contamination, even after decontamination of the areas. X-344 processed nearly 12,000 metric tons of UF_4 during its lifetime, but is estimated to have lost over 400 kilograms of uranium each year to the atmosphere in the forms of dust and fumes.

Based on available records, UF_4 feed material to X-344 was all virgin uranium; no reactor recycle material was ever introduced as UF_4 into this facility. From August 1958 until October 1961, purge gas from the cascades was periodically processed in the feed manufacturing plant through the cleanup reactors to recover excess fluorine. Because of this flow from the cascade, technetium could have entered the feed manufacturing plant. Filter plugging in the cleanup reactor system increased dramatically following initiation of fluorine recovery operations using the purge gas, which could be indicative of technetium contamination. Also, X-344 could have been slightly contaminated with transuranics via cross-

Construction of X-344

contamination of X-344 waste liquid batches returning as uranium oxide from the X-705 uranium recovery system.

Radiation levels in the areas around the X-344 fluorination towers were generally less than 100 mrad/hour during normal operations. For example, health physics radiation surveys in 1961 indicated that radiation levels 12 inches from the fluorination towers during operation were usually 50 mrad/hr or less, and during one six-month period, these levels never exceeded 100 mrad/hr. Inside the fluorination towers and in the downstream ash receivers, uranium daughter products tended to concentrate and create high beta radiation fields, which were shielded during normal operation. Workers were exposed to these intense beta radiation fields when the towers were opened for maintenance or unplugging operations, and when the ash receivers were changed. The ash resulting from fluorination of UF_4 contained the most daughter products, which were in the form of small particulates or aggregates. When the towers were operating efficiently, the daughter products were highly concentrated in the ash. Several incidents of spilled clumps or piles of ashes in the tower pits are documented as emitting up to 6 rad/hour of beta-gamma radiation on contact, of which up to 700 mrad/hour was from gamma radiation. Operators were exposed to these intense radiation fields whenever they cleared out ash plugs in the towers or changed the ash receivers. In addition, the ash receivers were hot and fuming with UF_6 and HF gases when they were changed.

At least one full ash receiver usually needed changing each shift. Full ash receivers were stored in a separate area inside X-344 for at least a month to allow the fuming to subside and the shorter-lived daughter products to decay. The ashes were then processed through a grinder and returned to the green salt stream being fed to the towers. The ash grinder also experienced a high rate of mechanical failure, and leaks in the system produced considerable dust, resulting in extensive airborne contamination in the immediate area. Workers were frequently exposed to this environment during operations and maintenance.

Records indicate that procedural requirements for personal protective equipment, and especially respiratory protection, were developed and implemented at the feed manufacturing plant for jobs around towers, ash receivers, and the ash grinder. According to interviews with past employees, compliance with these requirements was generally good during the time of feed manufacturing plant operation. However, records of inspections indicate that respirator use was inconsistent. For example, some walkthroughs by PORTS industrial hygiene and radiation protection technicians indicated appropriate respirator use, while a May 1961 health protection program review by the AEC Oak Ridge office provided the following observations: "Operations observed in the feed plant were dusting noticeably but operators were not masked nor in possession of masks. The supervisor indicated operators did not normally mask in the area. A check of operating procedures indicated that anyone present in the area should have been masked."

3.2.2 Oxide Conversion (X-705E)

Over its entire period of operation (1957 to 1978), the oxide conversion process was probably one of the most hazardous radiological and chemical operations at PORTS. The X-705E oxide conversion facility was originally designed to recover oxides of uranium, primarily from decontamination solutions in X-705 and incinerator ash, into UF_6 for feed into the cascade. Between 1959 and 1961, uranium oxides from spent reactor fuel were also processed in the facility. The process was contained in two areas, "E" and "H," located in the northeast corner of the X-705 building. The E area, on the ground floor, contained the oxide weighing, storage, unloading, and sampling rooms; the flame tower room; and the cold trap room. The H area was located directly above the E area and contained the flame tower cleanout port, the upper section of the feed hopper, the magnesium fluoride traps, vacuum pumps, and various filters. The H area was also used to store uranium oxide canisters, contaminated waste, idle equipment, and wash solutions.

The general material flow consisted of initial receipt and weighing of oxide, sampling, grinding in preparation for feeding, and then feeding the oxide into a fluorination reactor (initially a stirred bed, then a flame tower). The resulting UF_6 was filtered through sintered metal filters and magnesium fluoride traps to remove heavy metal contaminants, and then captured in a "cold trap." When full, the cold traps were heated, and the liquefied UF_6 was drained into cylinders, depending on the assay. Initially, the process consisted of a stirred bed reactor, using a belt that moved the oxide through a pipe in a fluorine atmosphere. Later, a shaken bed reactor was used because of unreliable belt operations. Both methods had very low production capabilities. A demonstration facility with a 3-inch flame tower was built and operated from 1958 through 1965, but was shut down due to health physics concerns and uranium material balance problems. Problems identified by an Oak Ridge health protection review in 1965 included potential concentration of transuranics in the processes, internal uranium exposures from enriched insoluble oxides that were not detectable by urinalysis, and inadequate air monitoring capability. Although the need to study the transuranic contamination potential and the addition of a separate tower for re-feed of tower ash were identified by the Oak Ridge review, neither activity was implemented. The presence of transuranic contamination in feed material was not adequately considered in the design or operation of the oxide conversion process.

Although the tower room typically contained the highest radiation and contamination levels, most operations and maintenance exposures did not occur in the tower room. Primary activities resulting in exposures in excess of PALs included handling of oxide powders in preparation for feeding to the towers, changing the tower feed screw, connecting and disconnecting pigtails, and performing maintenance on cold traps plugged with foreign materials.

A handwritten report entitled "Oxide Conversion as Viewed by Development" was written by a member of the Development Department (circa 1966) in response to a significant error in the uranium mass balance in X-705E. The report explained that the oxide conversion process was originally established as a waste recovery process and not a production process. The subsequent introduction of reactor returns converted X-705E into a production facility, requiring a capacity that "it was ill equipped to handle." The report further explains that uranium inventory control and health physics concerns were secondary to production schedules and costs, until "eventually the inevitable happened." The author's reference to "the inevitable" was directed primarily at the uranium inventory problem, but also refers to health physics problems. This report provides evidence that the operating contractor was aware of safety problems in X-705E; however, production schedules were viewed as more important. The report also refers to the practice of "de-smoking ash pots through the building ventilation system" as a possibility for physical losses of small quantities of uranium. Since the building ventilation system was unfiltered and reactor return materials had been processed, transuranics from the ash pots likely entered the building ventilation system and were subsequently released to the environment but not monitored.

A 1968 paper entitled "Fluorination of All Enrichments of Uranium Oxides" by the Production Division - Chemical Operations Department, presented at the Rocky Flats fluoride volatility meeting on June 24, 1968, also describes 1964 health physics concerns that led to the decision to enclose the process in a glovebox. The paper cites several concerns, such as the average assay of reactor scrap being higher than that previously handled, the quantity of material processed contributing to problems, and mandatory respiratory protection while processing oxides. In July 1967, process modifications were completed, and operations resumed in mid-November 1967.

Efforts to reduce health physics and contamination problems between 1967 and 1973 were ineffective, primarily because of poor practices by operators and supervisors. Training lecture notes from the late 1960s or very early 1970s, labeled "Health Physics in the Oxide Conversion Area," described problems with health physics practices after completion of those

Interior of X-705E

modifications. The notes indicated that it was common practice for operators to remove gloves from the gloveboxes to conduct some operations. It further discussed problems with deterioration of the gloves from the fluorine atmosphere inside the glovebox and indicated that oxide conversion was never intended to be a clean process. On January 30, 1970, an Industrial Hygiene and Health Physics internal memorandum discussed employee disregard for protective measures, lack of required protective measures in X-705E, problems in contamination control, and releases in the cold trap area from faulty cylinder valves and ruptured pigtails. It also noted that most of the exposures could be prevented with proper respiratory protection. Further, Industrial Hygiene and Health Physics found that many of the exposures could have been reduced and/or avoided by stricter adherence to operating procedures. A March 1973 OR appraisal cited ongoing poor health physics practices in X-705E, including a large number of radiological occurrences, ignored alarms, eating and drinking in the cold trap room, work performed without respiratory protection, and increasing lung burdens for some operators.

A 1976 memorandum (Memo GAT-922-76-184) identified transuranics as a problem at PORTS, especially in the oxide conversion process. PORTS had an existing inventory of transuranic-contaminated feed materials for oxide conversion and wanted to process that material. Based on recommendations from OR, Goodyear Atomic Corporation performed a variety of process improvements and test runs to model fluorination of transuranics and reduce system leaks and contamination. On September 13, 1978, Health Physics management determined that those efforts were not sufficient and recommended shutting down X-705E due to unacceptable health risks. On October 1, 1978, the oxide conversion facility was placed in a standby status; on December 14, 1978, Goodyear Atomic Corporation requested cancellation of the oxide conversion project.

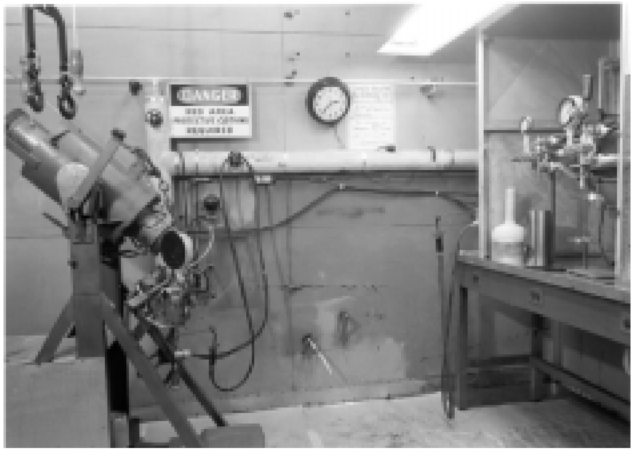
It appears that during its entire operation, the oxide conversion process placed Plant personnel working in the area, as well as security guards who may have been on patrol, at risk of exposure to chemicals and airborne radioactivity. Processing of transuranic-contaminated material was not adequately anticipated in the original or subsequent designs or operation. Samples obtained after shutdown showing the presence and level of transuranic contamination in the facility indicate that worker airborne exposures could have exceeded the acceptable standards, especially given the apparent lack of discipline in respirator use.

3.2.3 Cascade Operations

Feed/Product Withdrawal

Cascade piping was designed so that UF_6 could be fed to or withdrawn from any part of the cascade. The cascade generally operated below atmospheric pressure to prevent leaks from escaping outside the process, thereby limiting releases to process gas trapped in piping or equipment isolated from the cascade. High-assay product was withdrawn in the top product withdrawal area of X-326; this was also carried out at below-atmospheric conditions. The highly enriched product was withdrawn by passing UF_6 gas directly from the cascade at the appropriate enrichment through one of six 5-inch-diameter cylinders submerged in chilled TCE. At the lower temperature, the product froze to a solid inside the cylinders. The lower temperatures minimized TCE fumes in the area. Product was also withdrawn at various points in the cascade using a mobile side withdrawal facility consisting of a refrigeration unit and a TCE bath mounted on a scale. Each major cascade building had a mobile facility. A cylinder, submerged in the refrigerated TCE bath, was connected to the cascade through a heat traced flexible copper pigtail. The product froze to a solid inside the cylinder. Neither the top product withdrawal station nor the mobile side withdrawal facilities have been used since 1991 because of the lack of demand for high-enrichment product. During the highly enriched uranium refeed program begun in the mid-1990s, high-enrichment uranium was fed for downblending by connecting cylinders in the top product withdrawal area to the upper sections of the cascade. In all cases where feed and withdrawal operations were carried out below atmospheric pressure, the potential for process gas leaks during cylinder connection was limited to the contents of the connecting lines.

In addition, there are four permanent systems that operated above atmospheric pressure: the cylinder feed system, the extended range product withdrawal system, the low-assay withdrawal system, and the tails withdrawal system. Any leakage in these areas could have exposed workers to process gas. In the 1950s, UF_6 gas was fed to the cascades from cylinders placed in hot water baths. In the 1960s, the hot water baths were replaced with autoclaves to prevent a release in the event of a cylinder failure during feeding operations. Each autoclave serves as a containment boundary in case of a leak and is equipped with appropriate alarms, indicators, valves, and a remote



Product Sampling in X-326

cylinder valve closure device. Autoclaves are currently located in X-342A and X-343. Enriched and depleted UF_6 gas is withdrawn by pumps from the cascade and subsequently drains to cylinders in buildings X-326 (extended range product withdrawal), X-333 (low assay withdrawal), and X-330 (tails withdrawal).

Numerous releases resulted from connecting and disconnecting cylinders. At least one event occurred when a worker attempted to move a product cylinder with its pigtail still connected, resulting in a major UF_6 release. After a major release of UF_6 in X-342 in May 1973 and pressure from OR, a three-plant UF_6 handling committee and testing subcommittee performed extensive evaluations and implemented changes in the design, maintenance, testing, and operating procedures for pigtail connections. The changes were effective in reducing the number and severity of releases related to cylinder connection and disconnection. Interviews and Industrial Hygiene and Health Physics inspection reports indicate that respirator use was not always consistent during pigtail connections, and workers sometimes were exposed to releases without appropriate respiratory protection. Also, respirators became clogged or saturated at high concentrations, causing some workers to remove and not use their respirators.

Jetting/Venting

Before opening process equipment was opened for maintenance, trapped process gases in affected equipment had to be evacuated and the equipment purged to a UF_6 negative. The process for establishing a negative involved taking the cell off line, evacuating the cell to downstream cells, evacuating the remaining contents to surge drums, and then alternately purging and evacuating the cell at least three times with dry air or nitrogen to the surge drums. Once a UF_6 negative was established, the cell was raised to atmospheric pressure with dry air and released for maintenance.

To minimize UF_6 emissions to the environment, the resulting contents of the surge drums were either bled back to the cascade or passed through the cold recovery system, a refrigerated unit to trap the majority of UF_6 by freezing. The remaining light gases were then discharged to the environment using air-powered jets after passing through chemical traps to remove residual UF_6. A space recorder monitored the vent stream that exited the traps to record the amount and alert operators of excessive quantities of UF_6 getting through the traps. Procedures required operators to immediately investigate and attempt to reduce emissions in excess of 10 ppm UF_6; however, venting was allowed to continue as long as emissions did not exceed 20 ppm. In the mid-1980s, continuous sampling of jet emissions was initiated to allow periodic determination of the amounts of UF_6 released. The resulting composite samples were analyzed after the end of each sample period and did not provide a real-time control capability. Assuming that procedures were followed, generally less than a pound of UF_6 was available for release to the environment from a single cascade cell. The number and frequency of these authorized releases were not determined.

The process for preparing a cell for maintenance was tedious and sometimes time-consuming, particularly when cell isolation valves leaked or the cell contained significant uranium compound deposits. Because of the flexibility built into the design of the PORTS piping systems, alternative flow paths and practices to jet process gases to the environment were possible; some of these were not described in procedures. Reportedly, improper jetting increased during CIP/CUP due to management pressure to stay on schedule. One interviewee described a process he called "midnight rocket," which reportedly was used when operators needed to get rid of material fast. Operators would reportedly start a release, watch the space recorder indication increase, stop the release, wait for the indication to come down, and then open the valve all the way again. Depending on the pressure, temperature, and concentration of UF_6 in a cascade cell or surge drum when jetting was initiated, significant quantities of UF_6 could still have been available for release to the environment. The released UF_6 gas would hydrolyze with moist air to form a visible and pungent cloud of UO_2F_2 powder and hydrogen fluoride gas. The number and frequency of inappropriate releases were not determined.

In January 1986, a newly installed continuous vent sampler indicated that nearly 110 pounds of uranium had been released from a vent over a three-week period. An investigation concluded that: operators were not aware of the excessive emissions, despite multiple spikes on the space recorder charts; the space recorder indications were not always believed; venting continued in some cases despite elevated readings; venting was sometimes performed with the space recorders out of service; the chemical trap had not been surveyed as required, even though observations in September 1985 suggested that the trap was fully loaded; and procedures were not followed. The investigation report also documents numerous earlier examples of excessive uranium emissions, most of which were reportedly caused by valving errors or valve leaks. Because many of the events indicated ineffective use of the chemical traps, orifices were subsequently installed in jet suctions to limit flow through the traps, bypasses around traps and jets were removed, procedures were upgraded, and training was provided to assure that the staff understood management's expectation to prevent releases.

In response to these events and a later release in August 1986 due to a valving error with jets in operation, direction was given to not operate the jets without a functioning space recorder monitoring the vent, to secure the jet air supply and suction valves at all times except when venting operations were taking place, and to further modify piping and procedures to minimize the opportunity for mis-valving releases and to maximize the return of UF_6 to the cascade. Management guidance introduced in 1986, lab sampling, space recorder procedural requirements, and the existing practice of sending UF_6 back to the cascade provided strong incentives to use the jets as specified by procedures. As a result, UF_6 emissions were and have been significantly reduced.

3.2.4 Decontamination and Uranium Recovery (X-705)

Since the Plant began operation, equipment was decontaminated and uranium was recovered from decontamination solutions in X-705 (Decontamination Building). These activities were accomplished in areas that were physically separated from the oxide conversion areas. Hazards associated with decontamination and recovery included potential exposures to concentrated radioactive materials (technetium, uranium, and transuranics), acids (nitric, boric, acetic, and citric) and organic solvents (acetone, TCE, and methyl ethyl ketone). In addition, some of the components that were handled were contaminated with asbestos and/or PCBs. The most significant occupational hazard in X-705 was exposure from inhalation of airborne radioactive material. Radioactive materials in this building were often not contained, providing the opportunity for worker exposure. Spot checks by health physics personnel often found evidence of contaminated hands, shoes, and coveralls. Acceptable PALs for airborne radioactive material were exceeded more frequently in X-705 than in other buildings. Radiological hazards were particularly significant in X-705 because transuranic materials were concentrated by the uranium recovery and oxide conversion processes, and because insoluble forms of uranium were routinely handled. Transuranics and insoluble uranium were significantly more hazardous than the soluble uranium compounds that were the principal sources of radiation dose in other Plant areas. Prior to the mid-1970s, the health physics staff assumed that all detected radioactivity was uranium. This non-conservative assumption likely caused underestimation of the radiological hazards in X-705.

Radiological monitoring and controls were implemented to control the exposure of workers to uranium in X-705. Logs of inspections and sampling indicate that the level of attention to X-705 activities by the Industrial Hygiene and Health Physics Department was commensurate with the relatively high hazards in this building. Routine surveys were conducted to monitor the concentration of radioactivity on surfaces and in the air. Uranium recovery system operators wore coveralls, safety shoes, and neoprene or rubber gloves provided by the company. Respirators were available and were required by some procedures,

Exterior of X-705

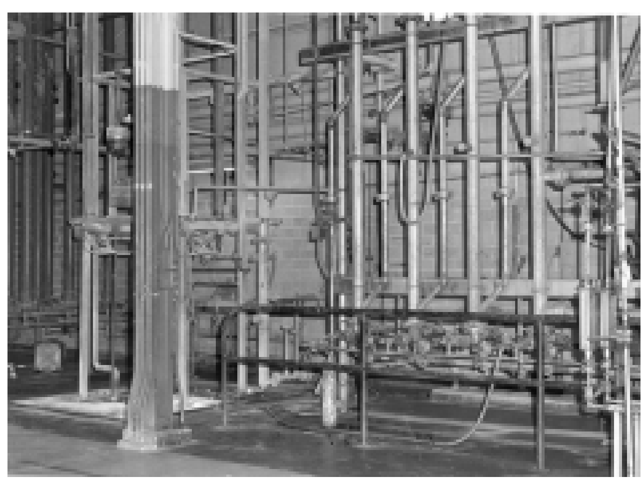
but respirator use was not strictly enforced. A clean lunchroom was provided in X-705 and was used by most workers, but smoking and eating snacks were common in process areas into the 1980s. Workers washed their hands but did not remove potentially contaminated clothing or shoe covers before entering the lunchroom. Spot checks by health physics personnel occasionally identified contamination on the coveralls and shoes of X-705 workers while in the lunchroom.

Decontamination

Large pieces of disassembled cascade equipment were cleaned in the X-705 decontamination tunnel, which consisted of a series of five spray booths through which large equipment was transported on dollies—much like a car wash. The equipment was sprayed with nitric, citric, or acetic acid solutions in the first three booths and rinsed with sanitary water in the fourth. The equipment was dried with hot air in the fifth booth. The acid solutions were collected for reuse in criticality-safe columns in the tunnel basement. When no longer effective, the solutions were processed for uranium recovery. Fans discharged air from the tunnel to the atmosphere through building roof vents. Interviews of workers and reviews of records indicate that the decontamination tunnel has functioned as designed and has caused few worker safety or health problems. A significant exception occurred in the late 1970s when a radioactively contaminated acid cleaning solution entered the plant process steam system through a leak in a heat exchanger that was being used to heat the solution. Radioactive contamination was transported to the steam plant and to steam piping across PORTS before the problem was identified and corrected. Today, many parts of the steam plant remain contaminated from this event. In the early 1980s, the South Annex to X-705 was constructed for disassembly and decontamination of large cascade equipment contaminated with high levels of technetium. The annex was maintained at a negative pressure relative to adjacent spaces in X-705 to control the spread of contamination. Operations included disassembly of compressors and converter tube bundles, and regeneration of alumina traps. Continuous air samplers indicate that this area had the highest average airborne contamination in the X-705 complex. Workers stated that air-supplied hoods were consistently worn inside the annex when work was in progress. Air was discharged through absolute filters to reduce airborne emissions to the environment.

Contaminated compressor seals and other small parts were disassembled and decontaminated in the X-705 seal disassembly room. Airborne radioactivity was consistently high in this room. Workers recalled that respirators were worn in this room when work was in progress. Army assault masks were worn until the mid-1970s, when they were replaced with air-supplied hoods. The room was maintained at a negative pressure relative to adjacent X-705 areas, and the room exhaust was filtered prior to discharge to the environment. Small parts with visible uranium contamination were decontaminated with nitric acid at the small parts hand table. The nitric acid was recycled until it was no longer effective, after which it was sent to the uranium recovery system. Samples in the 1970s indicated high transuranic contamination in the nitric acid decontamination solutions. Workers were protected with controlled airflow through a ventilation hood over the hand tables, and respirators were not normally worn. This process was effective in removing acid fumes and airborne radioactivity, as evidenced by continuous air samples collected through the early 1990s.

Empty UF_6 cylinders were cleaned in X-705 to remove “heels” of nonvolatile material remaining in the cylinders after UF_6 vaporization. All cylinder heels contained significant concentrations of uranium daughter products, and heels from reactor tails cylinders also contained transuranics. In the 1950s and 1960s, cylinders were washed with a hose in an open area in X-705, where wash water spilled onto the floor. After November 1970, a closed cleaning system was installed, in which cylinders were placed in a turning fixture and connected to piping through which boric acid and sodium carbonate cleaning solutions and rinse water were recirculated. The



Interior of X-705

cylinders were then moved to an enclosed drying booth where they were electrically heated and dried with forced air and inspected for cleanliness. Inspectors positioned their eyes over cylinder openings to inspect interior surfaces. Because workers did not always wear eyeglasses for these inspections, there was a potential for unmonitored beta radiation exposures to the lenses of their eyes. Cleaning and rinse solutions were processed through the uranium recovery system. Wastewater from the uranium recovery system containing concentrated uranium daughter products was discharged to the X-701B holding pond.

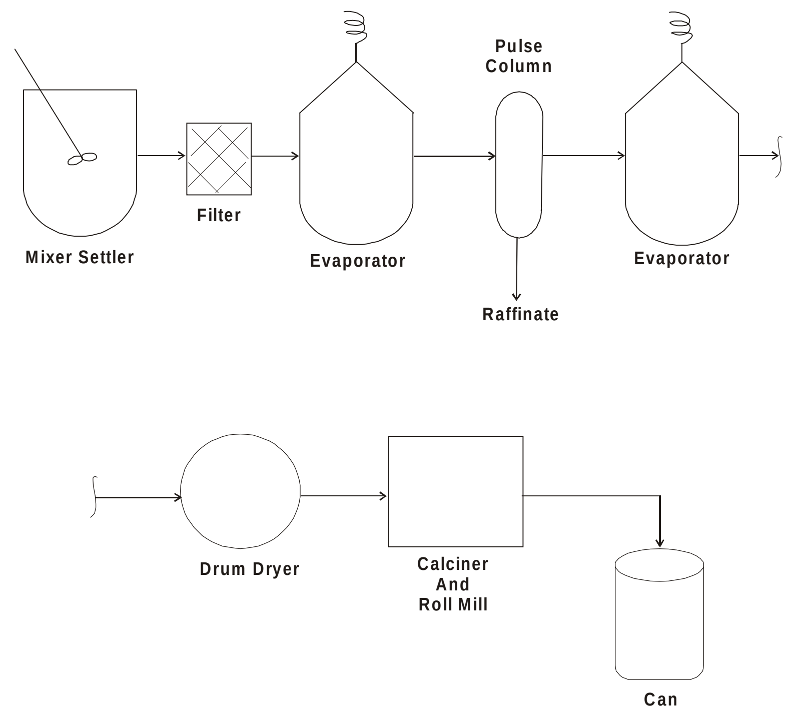
Uranium Recovery

Uranium recovery facilities in X-705 were used to chemically separate and recover uranium from a variety of liquid solutions and solid waste materials. Uranium in solid wastes was dissolved in nitric acid, and the resultant liquid solution was processed to produce U_3O_8. Sources of feed material for this process included fluorination tower ash, incinerator ash, UF_6 cylinder wash solutions, alumina and sodium fluoride pellets from traps in oxide conversion and the cascade, decontamination solutions, ventilation filters and vacuum cleaner particulates, uranyl nitrate hexahydrate from foreign sources containing transuranics, laboratory wastes, and materials from spills.

A solvent extraction process was used in X-705 to recover uranium from the above materials. Recovery steps included:

- Dissolving uranium oxides in nitric acid
- Removing insoluble solids in a mixer/settler and/or a filter
- Using an evaporator to reduce volume and concentrate uranium
- Separating uranium from contaminants in solvent extraction pulse columns
- Sampling the raffinate from the extraction columns, and recycling it through recovery if economically feasible or discharging it to the environment if not
- Using an evaporator to further concentrate uranyl nitrate from the extraction columns
- Drying the uranyl nitrate solution in a drum dryer (the drum dryer produced acid fumes and airborne radioactivity and was removed from service sometime before 1963)
- Oxidizing and roll milling uranium oxide in a calciner.

The calciner product, dry triuranium octoxide (U_3O_8) powder and associated contaminants, provided a potential for exposure of workers to insoluble uranium and transuranics. The hazards from this part of the recovery process were greatest when calcining material containing transuranics from the PORTS oxide conversion process and from foreign sources. Records indicate receipt of foreign recycled uranium compounds, in the form of uranyl nitrate hexahydrate in 1966, 1967, 1976, and 1977. This material was converted to U_3O_8 in the X-705 calciners. Lax procedural compliance and health physics practices during this period resulted in contamination of calciner work areas. Continuous air samples in the calcining area for the mid-1960s to the mid-1970s indicated annual average airborne radioactivity concentrations below the PALs for uranium applied at PORTS during this period; however, individual sample concentrations for this area exceeded the Plant limits for insoluble uranium . Actual concentrations were probably higher than recorded values because of the deficiencies in air



Uranium Recovery Process

sampling discussed previously in this report. In addition, although some of this airborne radioactivity was likely from transuranics, the contribution from transuranics was not measured and is unknown.

The aqueous raffinate from solvent extraction columns, which contained concentrated uranium daughter products and technetium, also posed a radiological hazard to system operators. Like most materials in the solution recovery system, these materials were processed wet and did not readily become airborne, although the uranium recovery system was not leaktight, and leaks were common. Most leaks were contained by drip pans placed under the equipment. Leakage of wet process materials that were dried by evaporation provided a potential for worker exposure to airborne radioactive materials.

Raffinate waste containing transuranics, uranium daughter products, and technetium was initially discharged to an onsite ditch that flowed to Little Beaver and Big Beaver Creeks, and then to the Scioto River. Subsequently, an onsite settling pond (X-701B) was added to reduce the amount of radioactive material released off site. In the early 1980s, an effluent treatment system was placed in service to remove technetium from X-705 effluents prior to discharge to X-701B.

3.2.5 Smelting (X-744G)

An aluminum smelter operated in X-744G from 1961 through 1983. This furnace was used to melt aluminum from used process equipment components. Disposition of the aluminum ingots is discussed in Section 4.2, “Management and Disposal of Scrap and Surplus Materials.” A 1960s Industrial Hygiene and Health Physics Department study indicated the potential for airborne concentrations of uranium to be generated during furnace loading, melting, unloading, and dross (the slag layer on top of molten aluminum) removal operations. Survey records during dross removal indicated general area contamination, implying periods of airborne activity; however, limited air samples taken with special high-volume air samplers detected no uranium or alpha activity during operations. Interviews conducted with a former health physics staff member noted that any uranium contaminants smelted with the aluminum tended to stay inside the aluminum. Although smelted materials were to have been previously decontaminated in X-705, radiological floor contamination surveys during the late 1970s in the smelter area indicated that alpha

Aluminum Smelter

contamination levels were routinely above PALs for both fixed and removable contamination.

3.2.6 Maintenance

Major Equipment Maintenance

Cascade equipment was subject to failures, as well as major upgrade and modification programs throughout the life of the Plant. Major components requiring maintenance and modification included compressors, converters, and block valves. These components were frequently cut out of the process system and transported to other buildings for repair. One of the significant hazards facing workers was residual process gas and deposits inside equipment and piping systems. Operators sometimes experienced difficulty in removing process gas due to these deposits or valve leakage. Testing in 1986 identified inaccuracies with the UF_6 negative test protocol and the strong possibility of false negatives. Consequently, when equipment was removed for maintenance, outgassing was common, despite an earlier determination of UF_6 negative. Respirators were required whenever process gas piping was initially breached; however, respirator availability was limited before the mid-1970s, and requirements for use were governed by the specific work being performed by an individual. As a result, some workers in the immediate vicinity of welders cutting out components were not wearing respirators when process gas releases were encountered. In 1987, an Operating Method required all personnel within the contamination control boundaries to wear full-face respirators when opening equipment to the atmosphere. Additional protection was required in those areas designated as containing technetium-99.

Compressors needed maintenance as a result of bearing or seal failures and compressor deblading. Bearing and seal failures could sometimes be repaired without removing the compressor from the cascade. However, compressor deblading evidenced serious internal damage, and the compressor had to be removed for repair. Workers would locate and retrieve the missing blade parts by crawling inside the piping with full personal protective equipment, including supplied-air respirators. These workers could have been exposed to uranium compound deposits, hydrogen fluoride, UO_2F_2, transuranics, uranium daughters, and fission products. Removed compressors were repaired in the X-720 compressor shop after disassembly and decontamination in X-705. Compressor disassembly presented significant inhalation hazards because of entrapped deposits. Although respirators were specifically recommended for this activity, use was inconsistent as reported by maintenance workers and Industrial Hygiene and Health Physics personnel. Compressor seals were disassembled in the X-705 seal dismantling room, which could be sealed and had fume exhaust hoods to minimize the spread of contamination. Workers would don air supplied respirators and gloves and close the room to disassemble the seals. Industrial Hygiene and Health Physics reports from 1974 and 1975 document contamination levels in the X-705 seal dismantling booth equal to or greater than any other found in X-705. These records also document the observed use of respirators while dismantling seals. Compressor mechanics were also exposed to TCE during vapor degreasing activities in preparation for compressor reassembly.

Converters needed maintenance as a result of cooler leaks or barrier plugging. Converters were repaired in the X-700 converter shop. In many cases, internal components were scrapped and replaced. The scrapping and disposal operations in X-705 presented a high potential for worker exposures to grinding dust, smoke, and airborne contamination. Occasionally, uranium compounds trapped within converter components were released during converter disassembly, presenting further inhalation hazards. Half-face respirators were required for the disassembly, although recollections of past employees suggest that this requirement was not strictly enforced. The shop was often filled with smoke, due to cutting and welding and an occasional asbestos blanket fire (the latter resulting from weld splatter igniting the blankets stuffed into converters to protect internal components). Converter components were cleaned in a large TCE vapor degreaser before final reassembly.

Process block valves needed maintenance for events such as seal or bellows failure or valve leakage. The valves were removed from the cascade and shipped to X-705 for initial teardown and decontamination. Each valve has a large valve-body space where process gases and deposits could be trapped. Occasionally, workers encountered significant outgassing when opening the valve bodies; however, survey records indicate minimal area and personnel contamination. Full-face respirators were recommended by health physics when working on or moving highly contaminated components. Decontaminated block valves were repaired, refurbished, degreased, and re-assembled in X-720.

In the early 1980s, instrument mechanics modified block valves in process buildings while the valves remained in service. The modification connected the block valve body to its associated downstream cascade piping through instrument tubing. The work involved drilling into and soldering on UF_6 filled systems. Workers sometimes experienced puffs of trapped gases from drilling into these systems. The released material would interact with the sweat on the workers' coveralls and create a snow-like dust that sometimes filled the room and obscured visibility. After some experience with the process, wooden plugs were manufactured and supplied to the mechanics to limit releases. Initially, the mechanics wore full-face respirators, coveralls, and cotton gloves. Subsequently, they also wore disposable paper coveralls over their cloth coveralls to limit contamination. Surveys in 1982

X-700 Converter Shop

identified instances of airborne alpha radioactivity exceeding PALs, but also noted that the personal protective equipment worn was more than adequate.

Starting in 1956, a series of "changeout" programs was initiated to modify production equipment and support facilities to increase capacity and improve performance, the most comprehensive and intensive of which was CIP/CUP. Congress authorized CIP in 1971 to increase uranium enrichment capacity through application of improved technology. Congress authorized CUP in 1974 to increase uranium enrichment capacity by enabling operations at higher power levels. CIP/CUP was implemented during 1972-1983 and involved the employment of many new workers at PORTS. New workers were teamed with experienced workers and learned their skills through on-the-job training.

CIP/CUP was implemented while cascade production continued, and it involved major modifications to compressors, converters, process gas piping, and support systems. All of the industrial, radiological, and chemical hazards associated with normal maintenance were present along with the additional challenge of a demanding schedule for completion of each task. Dedicated cell changeout teams were established to replace cell components on an almost continuous basis. Individual cells were isolated and prepared for turnover to maintenance; cell equipment was cut out, removed, and modified; new and refurbished equipment was installed; and the cell was returned to operations. Each cell typically took about three weeks to completely refurbish. In recognition of the hazards involved, the Maintenance Department assigned a foreman to monitor safety and ensure safe work practices during CIP/CUP, in addition to the normal Safety Department staff. Reportedly, most of the problems addressed were related to industrial safety deficiencies, such as use of hard hats, safety glasses, and safety shoes, rather than radiation safety or industrial hygiene. In addition, a 1973 response to an AEC representative's observation of cell changeout activities only addressed similar industrial safety concerns. However, Industrial Hygiene and Health Physics reports for the period demonstrate mixed performance with regard to radiological safety. A 1976 report notes continued problems, such as welding or grinding of surfaces with visible radioactive contamination without respiratory protection, transportation of grossly contaminated open components without proper covering or decontamination, and entering cell housings during air-arc scarfing without respiratory protection. Later Industrial Hygiene and Health Physics reports document improved use of personal protective equipment, improved requirements for their use, and enhanced compliance in the latter stages of CIP/CUP.

Industrial Hygiene and Health Physics surveillance reports for process gas system openings during CIP/CUP typically confirm the use of full-face respirators by welders and supporting mechanics. However, interviewees recall collocated workers, not assigned to support cutting into the system, frequently without respiratory protection and on occasion engulfed in a process gas release. Once the system was open, respirator use was normally not required except during grinding or some other dust-generating activity. Surveys of converter openings frequently confirmed worker complaints of excessive HF fumes, requiring continued respirator use or improved area ventilation. Early in the CIP/CUP campaign, efforts to prevent outgassing from equipment openings were not always implemented or effective. For instance, in 1977, 24 workers were sent for urine samples after a converter, which was suspended from a disabled crane, outgassed. In another 1977 event, workers refused to work in the area of an outgassing expansion joint that had breached its plastic flange covers until the pipe flanges were sealed by the Fire Department. Airborne alpha contamination in the immediate vicinity of the open joint was found to exceed PALs. As the CIP/CUP campaign progressed, shower caps, taped metal covers, and inflatable barriers were used over equipment openings to improve process gas containment and limit the spread of contamination.

Cell components were prepared for CIP/CUP modification in X-705 by disassembly, decontamination, and survey. Converter heads were cut off, coolers and barrier bundles were removed, the resulting parts were decontaminated and surveyed, and flanges were ground and prepped for re-welding. Subsequently, the barrier bundle was cut apart, parts were removed, the barrier was shredded, and the resulting unsalvageable scrap was placed in an old converter shell with tack welded top and bottom covers for disposal. Interviewees described converter internal fasteners as frequently covered with uranium compounds, which were the source of significant smoke, dust, and airborne contamination during component removal with air impact tools. Early in CIP/CUP, workers wore dust masks for this activity. Later, workers wore half-face respirators. One interviewee described a shortage of respirators amidst quantities of surface contamination in the X-705 high bay area during CIP/CUP while cutting and disassembling converters. The interviewee stated that he had to cut up converters without a respirator on some occasions. At the end of the shift, he would put his respirator, if he had one, in a pile of respirators, and at the beginning of the shift, he would get the best respirator he could from the pile. The shortage of respirators is confirmed by union safety meeting minutes in the 1973 to 1975 period.

Industrial Hygiene and Health Physics records for the period demonstrate frequent monitoring of CIP/CUP work activities and recommendations for improving worker protection, both as part of their routine activities and at the request of supervision. Industrial Hygiene and Health Physics reports emphasize the importance of respirator use during certain equipment disassembly steps and document inadequate respirator use when observed. However, supervisors and workers were not always receptive to these recommendations. For example, one record documents a worker's disregard of specific direction to don a respirator before entering an airborne contamination control area. As a result, contamination and exposure controls, as well as compliance with personal protective equipment requirements, were inconsistently applied and enforced. Many interviewees did not remember seeing Industrial Hygiene and Health Physics staff monitoring conditions or work activities. Workers involved in this phase of CIP/CUP were also sometimes subject to heat stress and exposure to asbestos and PCB contamination.

Transformer Maintenance

Many PORTS transformer dielectric oils contain PCBs. Early Material Safety Data Sheets (MSDSs) recommended avoiding prolonged skin contact with PCBs and the use of coveralls, gloves, goggles, shoe covers, and consideration of positive ventilation and respirators in confined spaces involving PCBs. Later MSDSs required chemical resistant suits with fresh air supplied masks.

During CUP, electricians sampled and tested the PCB-contaminated oil, drained PCB-contaminated oil from transformers, stored PCBs in tanks and drums, removed PCB oil from all outer surfaces with solvent, shipped transformers to offsite contractors for uprating, filtered PCBs for reuse, and refilled and topped off transformer tanks with recycled and new PCB oil. Contaminated personal protective equipment, filters, wipe rags, and oil absorbent were deposited in waste drums for subsequent disposal.

In the early 1980s, electricians drained and inspected other transformers not containing PCBs. Reportedly, they took five-gallon buckets of TCE inside the transformers for cleaning and did not wear respirators or gloves, even though the transformer tanks were recognized as confined spaces. Later, based on breathing zone air monitoring, electricians were required to wear respirators and limit TCE use to spray-bottle quantities while inside the transformers.

Contaminated Equipment from K-25

Recognizing the benefits of reuse of cascade equipment from the shutdown Oak Ridge K-25 facility, spare components and at least one complete upgraded cell were transferred to PORTS in the 1980s and early 1990s. The components included converters, compressors, motors, and valves; some were installed in the PORTS Gas Centrifuge Enrichment Plant cascade, while others were stored as spares. Workers in the X-700 converter shop complained about the high levels of hydrogen fluoride that emanated from these converters when opened, leading shop management to require additional purging before opening for rework. The resulting purge path used a makeshift purging apparatus in the X-700 converter shop instead of one of the dedicated purge stations. On September 29, 1987, a converter that was being purged blew off its welded steel nozzle cover plate, creating a very loud noise and damaging the building. Fortunately, no serious personnel injury resulted. An incident investigation board concluded that supervision did not understand the risks involved and did not prepare a procedure for the abnormal activity. Requirements to develop a procedure for this activity were not identified;

Converter Accident

therefore, no additional hazard review or analysis was conducted before the event, which might have prevented the incident.

A 1980 Industrial Hygiene and Health Physics report documents observation and radiological surveys of the disassembly of K-25 valves in X-705 prior to rework. Surface contamination ranged up to 400,000 dpm and exposure rates of 110 mrad/hour. The job was performed with full-face respirators, paper coveralls, gloves, caps, and booties, and adjacent to a vent hood to minimize the spread of contamination. Airborne contamination levels were maintained less than the PAL, and all parts were subsequently decontaminated. Worker surveys after removal of personal protective equipment showed no contamination greater than the PAL.

Instrument Maintenance

Instrument mechanics repaired instrument and control systems within the process buildings, the X-720 instrument shop, and various satellite locations. The principal instruments repaired were line and space recorders. Line recorders are mass spectrometers installed to measure the concentration of low molecular weight gases contaminating the process gas. Space recorders use large ionization chamber devices (sometimes referred to as space cans, because of their size and shape) for measuring radioactivity in gaseous vent streams. Excessive radioactivity might be present in gases vented or jetted from the cascade, if the equipment installed to remove UF_6 and technetium was overwhelmed or improperly used.

Because of the fragile nature and small size of many instrument parts, a separate cleaning and decontamination room was established in the X-720 instrument shop. The room had special ventilation to control the spread of contamination and facilitated the use of various cleaning agents, including nitric acid, hydrochloric acid, sulfuric acid, “brite dip,” acetone, and water to decontaminate and clean equipment. Equipment was scrubbed and flushed in the sink, and the resulting contaminated wash fluids were then drained to a covered pit just outside the instrument shop on the northeast side of X-720. TCE was also used to clean and degrease components and was reportedly disposed of by dumping out the back door until the 1980s. Mercury-contaminated equipment was also cleaned in this room, leading to several mercury spills. In the 1970s, mercury airborne levels in excess of PALs were identified. The room also contained electroplating equipment, which used cyanide salt solutions to plate fabricated instrument parts with nickel and silver for their use in refurbished or newly constructed instrument systems.

Before the 1980s, line recorder chemical traps reportedly were cleaned and refurbished by pouring contaminated mercury into other containers for recovery or disposal, and then flushing the traps of residual mercury with steam. This practice reportedly led to saturation of the ground with mercury and the need to post the area to prevent inadvertent entry. Maintenance practices were subsequently revised to discard and replace the mercury-filled traps, and multiple spent traps were transferred in drums to waste management for storage and disposal.

In the mid-1970s, the first evidence of technetium-99 began to appear in X-326 equipment. Some of the instruments became heavily contaminated with uranium compounds and technetium-99. Reportedly, the majority of space recorder background radiation came from technetium-99 that had plated out in the system. Instrument mechanics reported its frequent presence in instrument lines as a dark, gooey sludge having the appearance of black tobacco juice. The presence of technetium-99 resulted in significant clothing and personnel contamination and was difficult to remove. Discussion with instrument mechanics indicated that they were also concerned with the infestation of black widow spiders, since the spiders appeared to seek out the warmth of the cascade equipment cubicles and line recorders.

Industrial Hygiene and Health Physics reports generally document good use of personal protective equipment by the instrument mechanics. The instrument mechanics who were interviewed indicated that use of personal protective equipment was not always enforced, leaving it to the individual to ensure his or her protection. Reportedly, management allowed the instrument mechanics to select the personal protective equipment that they felt appropriate or to refuse jobs that they did not believe were safe. Half-face respirators were reportedly required when cutting into process instrument lines.

Cylinder Valve Replacement

Maintenance personnel removed and replaced defective cylinder valves and, in the 1970s, wore full-face respirators and neoprene gloves during cylinder valve replacement. Full cylinders with positive or unknown pressure, and with intact valves, were repaired in the X-705 South Annex. Full cylinders with sub-atmospheric pressure were usually repaired at the location where the problem was identified. Valves on empty cylinders were replaced in X-720 or outside in the cylinder yard. The principal hazards to workers engaged in cylinder valve replacement were radiological and chemical, involving the potential for inhalation of and exposure to UF_6 and its two hydrolyzed products, hydrogen fluoride and UO_2F_2, the "white smoke" frequently referred to in interviews of current and former staff.

In the event of a UF_6 release from an open or broken cylinder valve, 1960s procedures recommended using U.S. Army assault gas masks and carbon dioxide fire extinguishers and wooden plugs (the latter to slow and stop the leak). In the early 1970s, procedures required personnel entering the release area to wear neoprene-covered gloves and Army assault masks. When the UF_6 concentration was extensive, chemox masks or Scott air packs were specified. By the mid-1970s, emergency procedures required use of Scott air packs and impenetrable suits when entering UF_6 releases of unknown concentration. A Three-Plant UF_6 Cylinder Handling Committee, which convened in the mid-1970s, recommended a number of changes that impacted PORTS cylinder valve replacement activities. For example, subsequent procedures developed in the early 1980s provided additional guidance on equipment available to secure releases from cylinder valves, including valve cappers, wooden plugs, carbon dioxide fire extinguishers, wet rags with dry ice, and portable freeze-down devices.

3.2.7 Incineration of Waste (X-705A)

An oil-fired kiln-style incinerator located in X-705A operated from the mid-1950s until 1971. Although the incinerator was equipped with a cyclone separator to reduce emissions to the atmosphere, heavy black smoke and particulates were released from the stack. In 1971, a new incinerator was placed in service, which employees referred to by the manufacturer's model name, Radicator. The dual chamber Radicator operated until it too was shut down in 1986. Incinerators concentrated residual uranium by incinerating contaminated oil and burnable solids. Contaminated waste oil, paper, plastic shoe covers, cardboard, sweepings, wood, and rags were burned. Incinerator ash was shoveled and vacuumed from the combustion chambers and collected in five-inch-diameter containers to be recycled through the uranium recovery process. Measurable radioactive contamination was present on most surfaces inside

X-705A Incinerator

the 4,000 square foot building. The incinerators and building were demolished and removed in the 1990s. The principal hazard associated with operation of the incinerators was inhalation of airborne radioactive material. Uranium present in incinerator ash was likely in the form of insoluble oxides. Respirators were specified but not normally worn while handling incinerator ash.

3.2.8 Work for Others

Generally, PORTS employees did not perform work that did not directly support the enrichment of uranium. At the request of the AEC, Goodyear Atomic Corporation developed a capabilities brochure that was distributed by the AEC to solicit work for PORTS from other Federal government agencies, commonly referred to as "work for others." While hourly rates were developed for PORTS crafts shops and engineering personnel to perform work for others, during this investigation no evidence was found to indicate that such activities were conducted. However, information was obtained concerning two instances where PORTS performed activities to accommodate outside Federal government entities.

From 1955 until 1990, PORTS operated a disposal facility—referred to as X-749A—that accommodated the classified burial needs of PORTS and other DOE and non-DOE facilities. From November 1978 to April 1979, PORTS received a dismantled DOE nickel-working plant and associated equipment that was contaminated with nickel carbonyl and uranium for burial in X-749A. The plant, originally located in Huntington, W.Va., was built in 1952 and operated for DOE by International Nickel Company, Inc. (INCO).

It produced nickel to support PORTS, Paducah, and Oak Ridge. (See Section 4.1 for more information.)

In April 1987, PORTS received from Bettis Atomic Power Laboratory (West Mifflin, Pennsylvania) two boxes for burial at X-749A. The boxes contained specimens that had been developed for (and may have been subjected to) destructive examination, and were neither reactor fuel-related nor contaminated. The specimens were classified due to their design and chemical composition; they were metal shapes clad with either zirconium, a zirconium alloy, or hafnium.

During this investigation, no evidence was obtained indicating that PORTS performed work for others that was directly associated with nuclear weapons production (warhead or delivery system) or the burial of nuclear weapons components. Furthermore, no information was found demonstrating that classified material, such as computer tapes and records, from sources other than PORTS was buried in X-749A.

3.3 Operations Summary

A wide range of hazards existed at PORTS, including radioactive hazards, chemical hazards, and common industrial hazards. Radioactive hazards associated with the PORTS gaseous diffusion plant operations and supporting activities include uranium and its daughter products, transuranics, and fission products. The exposure of workers to radioactive materials was monitored, and with few exceptions, records of this monitoring indicate compliance with limits applicable at the time. However, monitoring deficiencies caused exposures to airborne radioactivity to be underestimated, and actual exposures were likely higher than indicated by PORTS monitoring records. This was the case when all radioactivity was assumed to be from uranium, even though airborne transuranic materials were present. This condition occurred in areas such as oxide conversion, uranium recovery, and the decontamination areas during the CIP/CUP programs. The failure to adequately monitor exposures of hands, feet, and eyes in high beta radiation fields, such as those in fluorination tower ash areas and during cylinder cleaning activities, caused exposures of these body parts to be underestimated and could have resulted in exposures exceeding limits.

Since the 1950s, there has been a conscientious effort by line management to identify and quantify worker hazards at PORTS, commensurate with the understanding of those hazards at the time. PORTS operations involved the use of a variety of chemicals and toxic metal hazardous materials. These included solvents (e.g., TCE, carbon tetrachloride, methylene chloride, and benzene), toxic materials (e.g., arsenic, mercury, lithium, chromium, nickel, and beryllium), toxic gases (e.g., fluorine, hydrogen fluoride, welding fumes, hydrogen cyanide, chlorine, chlorine trifluoride and its byproducts, and ammonia), acids (e.g., nitric acid and hydrochloric acid), and fungicides. The hazards and health effects of some of these substances were known from the early years of the Plant's history, such as mercury, fluorides, carbon tetrachloride, and TCE. Conversely, although asbestos and PCBs have been a significant hazard at the Plant since the Plant's construction, the hazards associated with asbestos and PCBs were initially not known, and efforts to sample and quantify airborne levels of asbestos were not initiated at PORTS until the 1970s.

Workers' failure to properly use personal protective equipment and supervisors' failure to enforce its use, especially respirators, contributed significantly to radiation and chemical exposures. Production needs in many aspects of operation and maintenance further contributed to worker exposures to radiation and chemicals. Examples include operating equipment with leaks, removing equipment without adequately venting the systems or removing deposits, and releasing uranium materials to the air without use of confinement systems.

4.0 Past Environmental Management Practices

PORTS operations have resulted in the release of a variety of contaminants into the environment through stack and diffuse air emissions; from discharges through sewers into lagoons, local ditches, and streams; through accidental releases; and from past waste disposal practices, such as the burial of low-level and hazardous waste.

Requirements governing the release of chemicals and radionuclides into the environment were limited in the early years of PORTS operations. The AEC established allowable limits for the release of radionuclides into the environment, but Federal and state agencies had few restrictions on discharge and disposal activities until the late 1960s. Releases from U.S. industrial operations during the 1950s and 1960s, including those at PORTS, were significant. Past PORTS operations and spills resulted in the release of radionuclides and chemicals in the vicinity of the Plant and the transport of these contaminants to local streams and groundwater. In 1989, DOE entered into legally binding agreements with EPA and the State of Ohio to remediate the site. Significant activities are still ongoing at Portsmouth to complete the actions governed by these agreements.

ENVIRONMENTAL MANAGEMENT PRACTICES

- ***Waste Management***
- ***Management and Disposal of Scrap and Surplus Materials***
- ***Liquid Effluents***
- ***Atmospheric Releases of Radioactivity and Fluorine/Fluorides***

4.1 Waste Management

- *Solid Waste Disposal*
- *Hazardous Waste Management*
- *Radioactive Waste Management*

During construction and subsequent operations at PORTS, various waste materials were generated that required storage, treatment, and disposal, either on site or at offsite disposal locations. Over the operating lifetime of the Plant, activities to manage these wastes evolved in response to internal and external requirements. The earliest of these requirements addressed controls for solid waste (trash), radioactively contaminated burnable and non-burnable waste, and highly contaminated radioactive waste. In the late 1970s and 1980s, requirements expanded to include hazardous waste (first PCBs, followed by RCRA-defined wastes), as well as tighter controls on contaminated radioactive waste. The organizational approach to performing these waste management functions also evolved from one in which several organizations managed the waste streams they each generated to an integrated approach that began in 1991 under the Waste Management Division.

A construction waste disposal area, operated by the PORTS construction contractor (Peter Kiewit), was the first of the site's disposal facilities and burial sites to be established. This was followed by development of ponds and pits, landfills, incinerators, classified waste burial grounds, and a waste oil biodegradation area. (Table 1 shows the facilities used for solid and containerized waste; ponds and pits are discussed in Section 4.3.) All these sites have been closed, and several are still being investigated and/or remediated under the RCRA closure process. However, interviews with current and former workers and review of historical documents indicated a number of additional locations where disposal or storage activities may have occurred. These locations, discussed in Volume 2, were referred to Plant management for further evaluation.

Solid Waste Disposal

During Plant construction, the construction contractor used the construction waste disposal area south of the main Plant buildings for solid

Table 1. Solid Waste Management Treatment and Disposal Facilities

Facility Name	Operating Period	Material/Waste	Status
Peter Kiewit Landfill	1954 to 1968	Construction waste, sanitary waste	Solid waste closure
X-734 Spoils Area	1982 to 1985	Construction waste, plastic containers, waste drums, chemical product containers	Solid waste closure; inert capped according to State of Ohio solid waste regulations
X-735 Sanitary Landfill	1981 to 1997	Sanitary waste, sewage plant coarse screenings, asbestos, floor sweepings in southern portion; northern portion also received solvent-soaked rags	Northern portion of the landfill closed as a RCRA Subtitle C Unit; southern portion closed according to State of Ohio solid waste regulations
X-231A Oil Biodegradation Plot	1971 to 1977	Uranium-contaminated waste oil, solvent-contaminated waste oil, oil-soaked fuller's earth, chlorinated solvents	Temporarily capped in 1987 as part of an interim remedial measure
X-231B Oil Biodegradation Plot	1976 to1983	Uranium-contaminated waste oil, PCBs, solvents	Temporarily capped in 1987 as part of an interim remedial measure
X-749 Contaminated materials disposal facility	Northern portion operated 1955-1990; southern portion operated 1986-1990	Alumina-trap residue, sodium fluoride, incinerator ash with trace quantities of neptunium and plutonium, chemical trap material contaminated with technetium-99, metal hydroxide sludge from the X-705 raffinate, contaminated roofing	RCRA closure activities included installing slurry walls and groundwater collection trenches in 1991; a multi-layer cap placed over the entire Landfill in 1992; landfill received RCRA certification in 1993
X-749A Classified	1955 to 1993	Classified records; tube sheets; classified floor sweepings; compressor blades; other classified parts; nickel plant; metal shapes clad with either zirconium, a zirconium alloy, or hafnium	Unit capped according to State of Ohio solid waste regulations in 1994; being monitored
X-705B Incinerators	1950s to 1986	Contaminated solid burnable waste, classified waste, classified floor sweepings, plastic contaminated waste, used oils and solvents	Dismantled and removed
Smelter	1961 to 1983	Contaminated aluminum	Closed
X-705 Salamanders	1950s to 1970s	Contaminated-waste oils and solvents	Closed

waste disposal. This location, named after the construction contractor, was called the Peter Kiewit landfill. Following construction, this area became the site's landfill and was operated until 1968. Because of the continuing need for a construction spoils area, the X-734 landfill was established. In 1982, controls for the operation of X-734 were developed, specifying that no radioactive, toxic, or environmentally hazardous substances would be permitted. Although no metal or plastic containers were to be accepted for burial, a 1985 user questionnaire and an environmental audit discovered that the area was, in fact, receiving plastic, chemical product containers, and waste drums. As a result, this area was closed in 1985. Waste materials were then sent to the X-735 landfill, where tighter controls on waste receipt were in place.

General guidelines for generating, containerizing, handling, storing, and disposing of waste were in place even in the early days of the Plant, as indicated by the issuance of an operating method (SPP R-2, "Waste Management") in July 1955. Since a radioactively-contaminated landfill was also used from the early days of Plant operation, the sanitary landfills received only slightly contaminated material, including floor sweepings from the process buildings that were contaminated. In addition, waste was segregated based on the desire to recover enriched uranium, and there was no strict enforcement on many radioactive waste streams that had little recoverable uranium. In the earlier years, sanitary waste was generated from office and cafeteria locations, flooring sweepings, ash from the coal plant, and liquid industrial waste.

By 1968, the Plant had ceased open burning of combustible wastes and established the X-735 sanitary landfill. OR evaluations in the 1970s and early 1980s indicated that this landfill was operated effectively. In

X-752 Scrap Yard with X-734 Spoils Area Directly Behind

X-735 Landfill Area

1981, a specific maintenance method for operating the sanitary landfill was implemented, which prohibited burning of waste materials. This procedure allowed receipt of coarse screenings from the sewage treatment plant, but forbade sewage sludge. Conventional solid waste was disposed of in this landfill, as well as asbestos (in designated and segregated cells). Over time, tighter controls and limits were also adopted for receipt of radioactive material (e.g., the limit set for uranium and technetium was less than 3 ppm for disposal in the X-735 landfill).

As new requirements were enacted, additional items were restricted from the X-735 landfill, including hazardous waste. As part of these new requirements, the landfills were permitted by both the Pike County Health Department and the Ohio EPA in 1989. In addition, internal and external inspections evaluated the effectiveness of controls. These inspections identified numerous concerns about the disposal of non-permitted material, culminating in a 1990 OR surveillance that determined that rags used to remove solvents in the X-720 paint shop were disposed of in the X-735 landfill. As a result, shipment of waste from the PORTS shop areas to the landfill was banned, and part of the landfill had to undergo RCRA hazardous waste facility closure. In late 1991, the Martin Marietta Utility Services Waste Management Division established "Waste Management Information Notification Bulletins" to educate PORTS personnel regarding specific items that were prohibited from disposal in the landfill.

In the early 1990s, increased regulatory requirements mandated the need for a new landfill. However, after Plant operations were split between DOE and USEC, USEC opted to use an offsite vendor for disposal of solid waste. As a result, DOE elected not to construct a new landfill, and to close X-735 and ship solid waste to the Pike County landfill, beginning in 1998.

Hazardous Waste Management

In 1970, in response to increased waste management activities, the Power and Utilities superintendent recommended the establishment of a pollution coordinator and creation of a pollution control committee. Previously, the Chemical Operations Division had responsibility for hazardous and toxic material disposal. Liquid waste for most industrial operations was primarily discharged to wastewater treatment and recovery systems as discussed in Section 4.3. In some cases, waste solvents were deliberately dumped on the ground outside of some buildings by maintenance personnel. As a result, the amount of hazardous waste that was containerized for disposal was very limited. As new requirements placed restrictions on the use of these facilities and systems, the Health Protection organization expanded the scope of its responsibilities to include environmental compliance activities. Additional requirements resulted in the formation of a waste management organization within the Environmental Control Department, which worked with Chemical Operations. By 1986, the Environmental Control Department had the lead responsibility for waste management; as the program continued to expand, Waste Management became a separate division.

Contaminated oil was not treated in the liquid treatment systems. Waste oils were treated based on a biodegradable disposal process developed in Oak Ridge. At the request of the Environmental Control Department, maintenance services prepared the X-231A oil biodegradation plot south of Building X-600. This practice began in the 1970s and lasted into the 1980s. During this period, approximately 24,500 gallons of waste oil contaminated with solvent and radionuclides, 124,300 pounds of oil-soaked fuller's earth, 60 gallons of TCE, and 1,000 gallons of chlorinated solvents were applied at the X-231A oil biodegradation plot. The uranium concentration at the plot averaged 5,000 mg/L. Correspondence from this time indicates several problems in operating and controlling the waste, including the presence of drums, which increased the risk of an uncontrolled oil release. Resource limitations prevented the proper application of fertilizer and the required tilling and/or disking activities. Over time, controls were implemented to

Biodegradation Plots (Beyond Cooling Towers)

prevent regulated waste streams from being placed on the plots; however, a June 1982 OR appraisal indicated that these controls were not always effective. A second plot (X-231B) continued to be used after the X-231A plot was closed in 1977. A July 1984 State of Ohio EPA inspection of X-231B found that no records were kept on quantities of solvents applied, that monitoring was not occurring in the unsaturated zone, and that closure and post-closure requirements needed to be addressed. By 1988, the State of Ohio EPA sent a notice of intent to file suit for hazardous waste violations. These violations included: operating the X-231B oil degradation facility without a permit; failing to establish an unsaturated zone monitoring program for X-231B; and placing hazardous waste on the X-231B plot without establishing a land treatment program or demonstrating that the waste would be completely degraded. As a result, the plot was closed and monitored for the presence of volatile organic compounds, PCBs, metals, and radioactive constituents.

As concerns regarding the management and disposal of PCBs increased in the early 1970s, both Monsanto and the AEC provided safety-related information to the Plant. In 1979, the Plant provided guidance to workers on the disposal of PCB-contaminated items. Disposal limits were set, and potential sources were evaluated for the presence of PCBs, which led to the discovery that very large gaskets in the process building ventilation systems had been treated with PCBs. These gaskets had been dripping oil that was found to significantly exceed the regulatory limit for PCBs of 50 ppm. In 1983, the Environmental Control Department determined that Chemical Operations personnel were mixing the absorbent material used for cleaning the drips with the regular floor sweepings before this mixture was sent to the landfill for disposal. The drippings were also radioactive because the ventilation systems handled air from contaminated areas in the process building. The problems with management of PCBs required PORTS to work closely with EPA, and although some progress was made, a 1988 internal DOE memorandum stated that "the overall effort is entirely insufficient to meet the commitments made to EPA." The Tiger Team assessment also identified the absence of formal PORTS procedures to fully implement PCB cleanup standards, and as a result, a PCB implementation team was established.

Attempts were made to clean ventilation ducts to remove the collected contaminated oil; however, the extent of the problems indicated the need for a different approach involving a collection system consisting of troughs below each gasket and connected to drain lines. The collected liquids were managed as contaminated PCB waste that was later determined to have RCRA constituents. Criticality concerns dictated that the liquids be collected in polyurethane bottles to maintain configuration control until the radioactive content could be determined. Although USEC leases and operates the process buildings, this operation remains a DOE responsibility since PCBs are considered a DOE legacy waste.

In addition to PCB in the gaskets and electrical transformers, PCBs were also found in other locations and processes at the site. Historical review of records and transcribed interviews indicate that PCBs and uranium-contaminated oil were sprayed on gravel roads around PORTS as a means of dust suppression. The presence of PCB-contaminated sludge at the site's sewage treatment plant (the sludge had been used as fertilizer), drying beds, and concrete walls resulted in development of a 1983 *Operating Method for Handling Polychlorinated Biphenyl (PCB) Waste*. In the early 1990s, an incinerator at Oak Ridge was permitted to combust PCB waste that, due to radioactive contamination, could not be handled at commercially licensed TSCA disposal facilities. However, the limited capacity of the incinerator, combined with the large waste volumes from the sewage treatment plant, the gaskets, and personal protective equipment used during drip and spill cleanup, has resulted in the majority of this TSCA waste remaining in DOE Material Storage Areas in process buildings.

As RCRA regulations were being developed, PORTS identified resources and processes that would be necessary for compliance. A 1980 OR Environmental Management appraisal indicated progress in characterizing and handling hazardous waste. These actions began in early 1980 at the request of OR. As a generator, the Plant obtained EPA number OH890008983, which allowed hazardous waste to be sent to offsite disposal vendors. PORTS developed permit applications for those facilities that would be used to treat, store, and dispose of hazardous waste. Additional actions included identifying all waste streams and the current disposal path. Ultimately, the Plant did not submit permit applications because DOE determined in 1980 that all AEC authorized activities were exempt from RCRA, although DOE did finalize development of a system to manage hazardous waste. The Environment Control Department was the lead PORTS organization in implementing these actions, supported by numerous other departments. The Maintenance Division was tasked to operate the X-752 Warehouse as an "interim status" RCRA facility after the facility had been modified to meet interim standards. A Plant waste manifest system was developed to obtain information mandated by Federal regulations for processing offsite manifests.

Although actions were taken to identify and then control regulated waste, these actions were not always effective. As a result, regulated waste was discovered in several non-permitted facilities on the site, which then required a costly RCRA closure and the loss of a feasible disposal option. As an example, between August 1984 and June 1985, approximately 85,000 pounds of metal hydroxide sludge from the X-705 raffinate was incorrectly disposed of as non-hazardous waste based on an initial characterization; this material later failed the EP Toxicity (leachability) Test for cadmium. Since this sludge had been disposed of in the X-749 radioactive burial ground, the State of Ohio EPA required a RCRA closure.

After a June 1987 EPA and DOE agreement specifying that RCRA requirements did apply to DOE facilities, permit applications were submitted to both EPA and the State of Ohio EPA. These applications included the X-752 facility and later the X-744G storage facilities, as well as several liquid and solid disposal facilities that are discussed in other sections of this report. Although the X-744G facility had been used for several years to store spent chemical trap materials, miscellaneous dried sludges, and ash from the X-705 incinerator, it was not until the late 1980s that sampling identified the presence of RCRA wastes in several of these waste streams. Due to security requirements for storing specific levels of radioactively contaminated waste, the X-326 L Cage was also added to the permit application.

Numerous inspections by the State of Ohio EPA, DOE (e.g., Tiger Team assessment), OR, and internal organizational elements continued to identify performance problems in the treatment, storage, and disposal of hazardous waste. Primarily as a result of the Tiger Team assessment and the State of Ohio EPA inspection, the waste management function was centralized in 1990s under the newly created Waste Management Department. This Department implemented many improvements, including locating dedicated field services representatives in the major facilities to assist generators with waste packaging and characterization. A very conservative approach was adopted whereby waste was considered hazardous unless clearly shown to not meet regulatory thresholds. This conservative approach, combined with a DOE moratorium on shipping radioactively contaminated waste off site, required development of increased storage capacity for mixed and hazardous waste. Therefore, in 1990 PORTS requested that the State of Ohio EPA grant an exemption allowing storage of hazardous material in the X-7725 facility without a permit. Following this request, the X-7725 facility was upgraded as a compliant permitted RCRA facility. This facility currently stores all Plant mixed and hazardous waste, with the exception of the mixed hazardous waste that has special security requirements and remains in the X-326 L Cage.

Radioactive Waste Management

In the early days of Plant operations, the desire to recover uranium dictated controls for handling contaminated materials. Highly contaminated equipment and scrap metals were decontaminated for the recovery of enriched uranium before disposal, resulting in removal of loose contamination before the equipment or waste materials were buried or further processed on site. X-749 was the main disposal site for low-level radioactive waste (LLW). Additionally, key elements of the PORTS radioactive waste management strategy have been the burning of contaminated oils in trays, salamanders (a primitive device consisting of an upright tube mounted on a base), and incinerators and smelters.

Open burning of contaminated oils occurred from the 1950s into the 1970s. In 1959, a nuclear safety evaluation of criticality concerns in the X-705 area reported that unsampled hydrocarbon oils were being burned in three 18-inch diameter salamander oil burners. Several former workers involved in this operation stated that these oil burners were used on the west side of X-705 and that the residual ash was collected for reprocessing. A 1973 OR health protection appraisal revealed that the smoke from the salamanders (believed to contain phosgene gas) was introduced into the ventilation system and released into the X-705 high bay.

Starting in the mid-1950s, two oil-fired incinerators were installed and used to thermally decompose waste materials. One was used to destroy security burnables; the second was used for uranium - contaminated wastes generated from Plant operations. Several former employees stated that this second unit burned solid and liquid wastes and routinely produced heavy black smoke. Little documentation regarding the operation of these units was available; however, the 1962 OR health physics review stated that the incinerator was equipped with a cyclone-type filter and was not a significant contributor to environmental contamination. A 1970 internal Goodyear Atomic Corporation memorandum indicated that funds had been approved to replace the existing incinerators because they were inefficient, needed repair, and did not meet smoke and particulate emission standards.

In 1971, a pre-engineered incinerator was installed on the south side of Building X-705 at the same location as the previous waste incinerator. An air pollution source permit for operation of the incinerator was filed with the State of Ohio in 1976, and the incinerator was placed on the State registry. Several years later, an enclosure with support facilities was constructed. The Radicator (the manufacturer’s product name used by Plant employees) served an important role at PORTS in the destruction of burnable waste materials collected from approximately 100 Plant locations. Use of the Radicator allowed valuable space in the X-749 low-level waste landfill to serve other uses. Incinerator ash was sampled, and if economically beneficial, the ash was sent to the X-705 uranium recovery facility. Ash with lower levels of uranium was boxed and disposed of in the X-749 landfill. Operators indicated that during the CIP/CUP initiative in the 1970s, floor sweepings were collected from areas where classified components were managed and incinerated, and the resulting ash was disposed of in the X-749A classified landfill.

A number of problems were encountered with operation of the Radicator. A July 1972 memorandum noted that winds scattered contaminated burnables and caused fine-particulate incinerator ash to become airborne, presenting a health physics hazard to personnel in the area. Although the Radicator was to be smokeless, there were periods when smoke was observed by employees at the incinerator and by occupants of a nearby building. In 1984, the Radicator was smoking due to the heavy plastic disposal demand, which caused incomplete combustion. A Plant-wide notice directed operating organizations to deposit plastics in scrap barrels, not in burnable barrels. In 1986, two events occurred involving malfunction of the Radicator, causing the intake of smoke into the ventilation system of Building X-700, located only 200 feet from its stack. An incident report noted that the Radicator was improperly loaded with non-combustible items, that atmospheric inversion conditions prevented the vertical movement of stack gases, that deteriorating refractory lining caused heat loss and incomplete combustion, and that there was a lack of a preventive maintenance program.

Radicator operating limits were not clear to the operators, resulting in inappropriate introduction of oils and solvents to the incinerator. According to PORTS documents, between August 1984 and April 1986 the operators improperly introduced used oil and solvents into the incinerator to enhance combustion. In response to this discovery, on August 8, 1986, OR ordered that the Radicator be shut down pending development of specific procedures regarding receipt of acceptable wastes. The State of Ohio subsequently revoked the facility's registration status. Subsequent testing of the oils, solvents, and incinerator ash determined it to be hazardous waste pursuant to RCRA due to the presence of cadmium and barium. The facility never restarted and was closed under RCRA authorities in the 1990s. The termination of Radicator operations has contributed to the buildup of 1700 containers of legacy burnable waste materials that are currently stored on site. Additionally, the Plant continues to store residual incinerator ash. Analysis of this ash indicated that it contains enriched uranium and trace quantities of neptunium, plutonium, and hazardous metals. The operation of the incinerator also impacted the environment surrounding the facility, primarily through airborne particulates from the incinerator and through spills and runoff from the storage lot.

The X-749 landfill reportedly received alumina-trap residue, aluminum oxide, sodium fluoride, and incinerator ash totaling 134.2 cubic feet in 1961 when the AEC began requesting maintenance of disposal records for LLW burial. Throughout the 1960s and the early 1970s, annual disposal volumes remained in the hundreds of cubic feet, with a high of 468 cubic feet in 1965. In 1976, a report on LLW disposal at PORTS stated that much of the chemical trap material contained technetium-99, which is highly water-soluble. After that finding, this material was placed in sealed packages; however, this action followed nearly 20 years of disposal of chemical trap waste without the benefit of sealed containers. The report recommended no changes in the burial practices, since there was no evidence that solid radioactive wastes were leaching into the groundwater. In an apparent contradiction, the report recommended that percolation rates, infiltration rates, and porosity tests be conducted to determine the need for future changes in burial practices. Also recommended was the establishment of guidelines on the structure of burial containers, recognizing that using aluminum canisters for chemical trap material "obviously will confine fluorides and long-lived radionuclides for only a limited time."

Controls for disposal at X-749 were increased, and sealing of trap material continued. However, not until 1979 was action taken to develop a burial ground operating specification and provide training to address burial ground operations. In addition to the waste discussed above, contaminated roofing material, asbestos, concrete, light bulbs, and other non-burnable waste were disposed of in the trenches. Due to the inappropriate burial of waste that was determined to be regulated under RCRA, the landfill was closed at the direction of the State of Ohio EPA. Since the closure would significantly impact the site's disposal options, a concerted effort was made to place all waste that met regulatory limits in the landfill before it closed on May 15, 1990. This led to disposal of large volumes of waste that included contaminated vehicles, equipment, and the contents of large converter shells.

Burial of classified material and waste in X-749A began shortly after the Plant began operating. Early controls focused on meeting security requirements. Records show that very large amounts (250 to 300 tons) of material were disposed of, including tube sheets, and related hardware; classified floor sweepings; compressor blades; and other classified parts and records from the Plant. Extensive discussions with PORTS personnel indicate that, with one exception, only material used in or in support of the gaseous diffusion processes was buried in X-749A. This exception occurred in 1987, when two boxes of specimens from Bettis Atomic Power Laboratory were buried. Details on the contents of these two boxes are discussed under Work for Others in Section 3.2.8.

One of the largest items buried in X-749A was a nickel plant from Huntington, West Virginia. This plant, called the INCO (International Nickel Company) Nickel Plant, had been built in 1951, used until 1963, then maintained by INCO on backup status until the

AEC decided that the plant was no longer required. This plant had provided material to the Department's gaseous diffusion plants. Since the plant contained material and equipment that was still considered classified, a decision was made to bury the plant at PORTS. Investigations by a PORTS industrial hygienist identified several health and safety concerns, including asbestos and nickel carbonyl. Sampling of residual material and surfaces also indicated the presence of uranium. Special precautions were required for the asbestos, and National Emission Standards for Hazardous Air Pollutants were applied to the removal and burial activities. The demolition, transport, and burial involved personnel from OR, PORTS, the plant owner (INCO), and two subcontractors. INCO supervised the demolition activities that began in late 1978, resulting in over 50 truckloads of material being transported to PORTS for burial in the classified landfill.

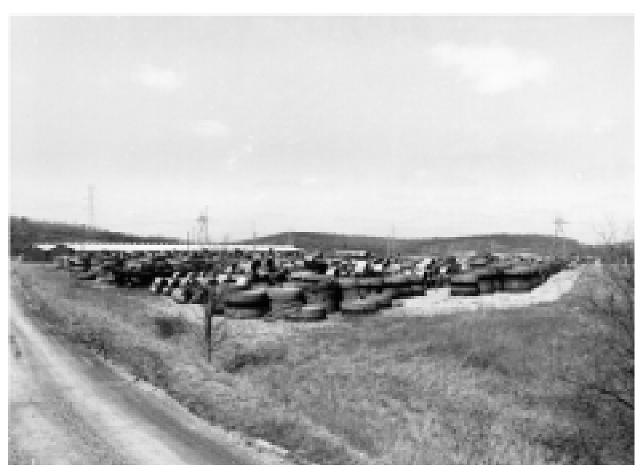
4.2 Management and Disposal of Scrap and Surplus Materials

Large volumes of scrap metal and surplus material were generated during construction, maintenance, repair, and facility upgrade activities at PORTS. These materials were either managed as waste or stored and managed as a commodity for resale. Much of the material was contaminated, and large volumes were disposed of on site. Additionally, large volumes of scrap remain in storage at the Plant pending future disposal or disposition.

Records indicate that Goodyear Atomic Corporation management was aware as early as the 1950s that contaminated surplus materials could only be shipped to properly licensed and authorized recipients, and that radiological monitoring of all potentially contaminated materials being offered for public sale was required. The handling and disposal of scrap materials were subject to a corporate waste management procedure that defined the manner of disposal and proper segregation for the different types of scrap and waste material generated. While contamination limits and specific categories changed somewhat over the years, scrap material was required to be segregated by contamination status. Drums or other containers were provided for each of the categories wherever significant quantities of scrap were generated. Containers were supposed to be marked to indicate the type of material that could be discarded in each. Line supervisors were responsible for ensuring that employees segregated all scrap materials appropriately; however, this requirement was not implemented consistently, resulting in the presence of contaminated items at designated clean locations. Many workers who were interviewed do not recall being required to segregate scrap materials and claim they simply placed all scrap materials into the same waste containers. Once containers were full, they would be removed by the Materials and Service Department and taken to the appropriate storage or disposition location. Material categorized as clean scrap was taken to the clean scrap yards for placement and preparation for public sale. Contaminated materials were managed as discussed in Section 4.1 or were sold to properly licensed recipients.

Contaminated aluminum presented unique challenges due to the large volume generated, and was often sent to the onsite smelter to be melted and cast into ingots for subsequent rework or reuse for Plant components or for public sale. These ingots were the subject of continuing concern due to the lack of requirements governing acceptable levels of volumetric contamination. Some ingots containing up to 75 ppm uranium and 1000 dpm/100 cm^2 of surface alpha activity were authorized by AEC for sale on the open market in the 1960s. A requirement to include the uranium content of the ingots was a condition of all such sales. AEC also urged disposition of aluminum ingots wherever possible by reworking into components for cascade use rather than public sale. Public sale of contaminated ingots was later discontinued due to the lack of definitive regulatory limits, which continues to present day.

Monthly Industrial Hygiene and Health Physics reports document that Goodyear Atomic Corporation conducted radiological surveys for other types of scrap



X-752 Scrap Yard

and surplus materials released from the Plant via public sale. A 1958 report lists a total of 28 sales, with the monitoring of an estimated 1,346 gross tons of scrap metals. In addition, surplus items, such as 84 vehicles and electrical, plumbing, chemical, and fire fighting equipment, were surveyed for contamination prior to release. A number of similar records and reports addressing radiological monitoring of scrap materials were reviewed during the investigation.

Despite the knowledge and proper corporate health and safety procedures instituted by Goodyear Atomic Corporation for scrap sales, the program encountered a number of problems, highlighted in internal memoranda and documents that began appearing in the mid-1970s. A September 1976 memorandum from Industrial Hygiene and Health Physics advised that insufficient manpower had resulted in an inability to survey each load of scrap unloaded at the concrete pad near Warehouse 15 and that recent surveys had identified a number of contaminated items. The problem escalated to a point that in September 1979, Industrial Hygiene and Health Physics recommended discontinuing the sale of scrap materials, based on concerns identified during an internal audit of the clean scrap yard. The problems included equipment directly associated with process gas, including blades, instrument lines, and peanut valves, present in material being loaded by a buyer. Surveys of these items indicated they were " highly contaminated." The buyer also stated that he had previously purchased similar items; no evidence was provided to indicate that the Plant conducted any follow-up actions. Other concerns included observing unmonitored scrap and debris being dumped into the yard and handled by the buyer without the use of gloves. In addition, process housings with visible contamination were observed in the yard. In 1980, Goodyear Atomic Corporation issued a revised plan for control of scrap and trash material, along with a revised waste disposal procedure. Despite these changes, additional problems were noted in 1981 and 1982 during follow-up inspections at the clean scrap yard.

It is clear that the Industrial Hygiene and Health Physics Department was aware of problems and made significant efforts to properly segregate contaminated materials from clean materials intended for sale to the public. However, given that the responsibility for proper scrap handling rested with line management and that only a small number of qualified health physics personnel was available to perform radiological surveys, it is evident that material exceeding appropriate radiological release guidelines was released from the Plant periodically from the 1950s through the 1980s.

4.3 Liquid Effluents

- *Regulated Outfalls*
- *Routine Historical Discharges*
- *Accidental Spills*

Liquid effluents have been routinely discharged from the Plant and from accidental spills and releases. Effluents were historically released in a number of ways, including via the sanitary sewage and storm water drainage systems. Effluent material that was not otherwise held up or recovered through wastewater treatment facilities and recovery systems flowed to the various Plant outfalls and ditches and ultimately into the Scioto River. Little Beaver Creek, which received effluent from the east and north sides of the Plant, received the vast majority of Plant effluents and discharged into Big Beaver Creek. Big Beaver Creek flows into the Scioto River.

The environmental monitoring program at Goodyear Atomic Corporation was initiated in 1955. Since that time, effluents have been analyzed for radioactive contaminants from the Plant's east and west drainage ditches and the south holding pond. Additionally, cooling water blowdown was monitored for chromium prior to being piped directly to the Scioto River. The Ohio Pollution Control Board adopted standards to govern public water supplies in April 1970. Goodyear Atomic Corporation established an Environmental Control Committee during April 1971 to determine the most effective program to ensure compliance with the new regulations. The Goodyear Atomic Corporation Environmental Control Department was created on June 1, 1971, to be responsible for compliance with the new regulatory activity. This department expanded as additional regulations were established.

Regulated Outfalls

In the early 1970s, the Clean Water Act established the National Pollutant Discharge Elimination System (NPDES), which administered effluent limitations and water quality requirements for chemical releases. In 1973, sampling began in support of the NPDES permitting process whose requirements were finalized in 1975. In 1976, a chromium reduction facility for treating cooling water blowdown before it was piped to the Scioto River was built to meet the requirement of the NPDES permit. Liquid discharge locations were maintained and monitored by the DOE and regulated by the State of Ohio.

Over the years, monitoring data from the Plant outfalls have been distributed as part of the annual site environmental report. The number of regulated outfalls has varied with Plant expansions and improvements. In the mid-1980s, there were as many as 18 NPDES outfalls, including the east drainage effluent, the X-701B holding pond, the south holding pond, the sewage treatment plants, the recirculating cooling water blowdown, X-611 sludge lagoon outfalls, and the three former Gas Centrifuge Enrichment Plant outfalls. Chemical parameters routinely monitored at the outfalls included total dissolved solids, biochemical oxygen demand, total suspended solids, oil and grease, total residual chloride, trace metals, nitrate, and ammonia. Liquid effluent discharge limits for radionuclides were not specifically promulgated by EPA but were always required and published under the AEC and ERDA regulations and later documented in DOE orders as maximum permissible concentrations or radioactive concentration guides in water. Despite the discharge restrictions, it is clear that enough radionuclides and chemicals have been released to create legacy environmental contamination. The existence of legacy contamination has been confirmed through environmental sampling data.

The X-615 sewage treatment facility was built in 1953 as part of the original infrastructure during Plant construction. The facility was intended to receive conventional sanitary waste from the process and support buildings, from such sources as sinks and floor drains. The facility was designed as a secondary treatment system using a primary clarifier, a high rated trickling filter, and a secondary clarifier with provisions for recirculation through the trickling filter. In the 1970s, a post-chlorination process was added to treat the effluent before discharge to the Scioto River. The influent to X-615 contained radionuclides, resulting in the generation of digested sludge that contained LLW. The sludge was either spread on the land adjacent to X-615 or used as fertilizer at PORTS. In the 1980s, PCBs were found in the sludge, resulting in the sludge being boxed and stored. The X-615 sewage treatment facility was replaced with X-6619 during the construction of Gas Centrifuge Enrichment Plant facilities in the mid-1980s. The X-6619 sewage treatment facility is an activated-sludge facility utilizing the plug flow process, aerobic digestion, secondary clarification, and granular-media filtration for effluent polishing (tertiary treatment). This plant received sewage and non-conventional wastewater, such as the X-705 laundry effluent, mobile equipment maintenance shop discharge, and developer and fixer used in x-ray and microfiche development. In addition to receiving sanitary effluent from the process and support buildings, the new sewage treatment plant received effluents from the three DOE remediation pump and treat facilities. In these DOE facilities, groundwater is treated for VOCs and then the effluents containing uranium, thorium, technetium and trace transuranics are released to X-6619. The sludges from X-6619, contaminated with radionuclides and PCBs, are boxed and stored as mixed TSCA and radioactive waste. The facility effluent is discharged into Outfall 003, the upper end of a subsurface pipeline to the Scioto River.

The NPDES outfall that contained the recirculating cooling water (RCW) normally had the highest flow rate and volume. Over the years, the treatment of the RCW has been improved in order to remain in compliance with NPDES standards. At the onset of Plant operations, hexavalent chromium had been used as a corrosion inhibitor in the eight cooling towers at the Plant. In 1976, hexavalent chromium was reduced to the less toxic, trivalent form in the X-616 chromate reduction facility, thereby eliminating the more toxic, hexavalent chromium from the discharge stream. In 1991, PORTS converted the RCW treatment from a chromium-based corrosion inhibitor to a non-hazardous phosphate-based inhibitor. Currently, the RCW is discharged to the Scioto River through a separate pipeline.

Routine Historical Discharges

Historically, the most significant liquid radiological effluent source was from the X-705 Decontamination Building, which has been used since 1955 for decontaminating and monitoring equipment exposed to uranium compounds and for recovering uranium from decontamination solutions. Operations within the X-705 Building, described in Section 3.2.4, include equipment decontamination, uranium recovery, uranium hexafluoride cylinder decontamination, a laundry service, and a chemical laboratory. The operation of this facility resulted in the release of significant quantities of chemicals, uranium, technetium, and smaller amounts of plutonium and neptunium into the environment through the X-701B holding ponds.

Most X-705 process effluents have historically been discharged to the X-701B holding pond. The last rinse booth of the large equipment decontamination tunnel was converted to a recirculating system upon the deactivation of X-701B in 1988. In 1977, interdepartmental correspondence documents that effluents from the cleaning facilities were found to be bypassing the X-701B holding pond and discharged directly to the east drainage ditch leading to Little Beaver Creek. A contract was let to divert the effluent to the X-701B holding pond after this condition was discovered.

Uranium recovery for the entire Plant was accomplished at a solution recovery facility located within X-705. Feed solutions were digested with nitric acid, then concentrated, extracted, and calcined to produce uranium oxide. Effluents were discharged to the X-701B holding ponds. Solutions from this process were subsequently treated by a microfiltration system that was installed in 1988. This system uses microfiltration and pressure filtration technology to treat all process waters produced in the X-705 Building. Nevertheless, in the past, uranium has been the principal radioactive constituent released to the X-701 holding pond, comprising 92 percent (76.5 kg) of the total radioactivity in 1969 and 90 percent (117.0 kg) of the total in 1970.

The X-705 facility also provided laundry services for protective clothing and operated a chemical analysis laboratory. Dilute chemical solutions were discharged to X-701B during its operation. Various other sources of discharge from X-705 are known to have occurred. Some floor drains in X-705 discharged to X-701B prior to 1988. This discharge was estimated to be about 400 gallons per month. Foundation drains, roof drains, steam condensate, and cooling water were discharged via two basement sumps, each averaging 8,800 gallons per day. One of the sumps discharged into X-701B prior to 1988. Currently, the basement sump effluent is piped to the X-622T treatment facility, where it is treated through carbon filtration.

X-701B Holding Pond

Starting in 1975, Plant records reveal that elevated technetium and transuranic contamination was unexpectedly discovered in liquid process effluents from the X-705. Before then, radiological effluent monitoring was only conducted for uranium and indicator parameters. The PORTS environmental monitoring program did not include these contaminants, which were known by Plant management to have been introduced into PORTS industrial facilities from the processing of reactor returns and from Paducah production feed material. Based on the information collected, it does not appear that personnel responsible for environmental monitoring were aware of the presence of these contaminants at PORTS.

In September 1975, the beta-gamma activity in the east drainage ditch sharply increased, judging by samples from the east drainage ditch immediately before it joined Little Beaver Creek. The Chemical Analysis Department identified the major source of this activity as beta radiation from technetium-99. The weekly sample collected on September 29, 1975, showed a technetium-99 concentration of slightly in excess of the discharge concentration guideline for uncontrolled areas. Studies by the Process Technology Department indicated that all of the technetium in the drainage ditch originated at X-705. Major radioactive effluents at X-705 were temporarily curtailed until a remedy could be put in place. By December 1980, technetium-99 levels in the discharge from the east drainage ditch had increased by approximately 350 percent over previously reported levels. Mass balances performed based on technetium-99 discharged from X-701B and Outfall 001 showed that the technetium-99 from Outfall 001 was being discharged from the X-705 Building through the X-701B holding pond. Uranium recovery raffinate discharges accounted for approximately 25 percent of total discharges of technetium-99. Other operations that had resulted in elevated technetium-99 discharges in the past were investigated and cleared. It was determined that most of the technetium was associated with rinse water from the equipment decontamination tunnel, which bypassed the uranium recovery system. The increase in technetium-99 discharges occurred shortly after the initiation of equipment changeout in the X-330/X-326 process buildings. A technetium treatment system was proposed in the late 1970s and installed in the early 1980s to reduce the levels being discharged into the environment.

By 1976, transuranics had also been identified in raffinates generated by the recovery of uranium from contaminated equipment and materials processed in X-705. These raffinates were discharged to the X-701B pond. Subsequent monitoring detected transuranics at significant levels in sludges from this pond and in the effluents from the pond to the east drainage ditch. Transuranics in the effluent originated primarily in reactor-return materials processed in the X-705 Building. As an outcome of these findings, a committee was formed in December 1976 to study Plant-wide aspects of the transuranic contamination. Developing more sensitive analyses for transuranics was among the top priorities. At the time, the Goodyear Atomic Corporation analytical procedures had a limit of detection that was equal to about 7 percent of the ERDA recommended concentration guide for neptunium-237. The committee determined that the detection limits would have to be lowered to increase the effectiveness of the environmental monitoring program. In 1977, Goodyear Atomic Corporation investigated transuranic contamination in sediments in Little and Big Beaver Creeks and identified low levels of plutonium and neptunium contaminants at some of the locations sampled. Sampling for transuranics in environmental media was terminated in the mid-1980s and until recently has not been a priority of the site.

The X-701B holding pond was a major effluent source to Little Beaver Creek. It was an unlined pond used for the neutralization and settling of metal-bearing waste water, solvent-contaminated solutions, and acidic waste water. Most of the waste discharged to the pond originated at the X-700 Chemical Cleaning Facility and the X-705 Decontamination Building, which was described previously. The X-700 Chemical Cleaning Facility contained, among other cleaning processes, two vapor degreasers, one of which had been in operation since 1955; the other had been used from 1955 until the early 1980s, when it was deactivated and removed from the building. TCE was used for degreasing until 1987; 1,1,1-trichloroethane has been used since. Floor drains in the basement of X-700 previously emptied into a ceramic pipe that discharged into a sump in the basement of X-700. The sump contents were then discharged to the X-701C pit, prior to entering the X-701B holding pond, until the pit was closed in 1988. This was a major source of TCE in X-701B and the entire east drainage ditch area.

From 1974 until 1988, slaked lime was added to the X-701B influent to neutralize the low pH and induce precipitation of uranium and trace quantities of transuranics. This precipitation caused a large amount of sludge to accumulate in the pond and necessitated annual dredging of the sludge. The X-701B holding pond was constructed early in Plant operations and received process discharges until November 1988.

Accidental Spills

In addition to the continuous discharge of process waste to primarily Little Beaver Creek, there have been numerous spill events throughout the history of the site. A variety of historical spill events and accusations of spills were reviewed as part of this investigation. The Ohio EPA emergency response records from 1978 to 1988 contained 23 reported spills at the Plant. Six of the reported spills affected watercourses adjacent to the Plant. Site records indicate dozens of other spills that were identified and investigated by Plant management. Materials commonly spilled were UF_6, PCB oil, and sodium hydroxide. Other materials spilled include road binder, chlorine wash water, ferric sulfate, gasoline, mercury, Freon, sulfuric acid, TCE, uranium, and lubrication oil.

Several fish kills in surrounding creeks have resulted from spills at the Plant. Ohio Department of Natural Resources fish kill records from 1970 to 1986 contained eight fish kill investigations. Over the years, most kills were due to oxygen depletion in the stream water rather than toxic conditions caused by hazardous chemicals. Instances of fish kills include:

- In 1955, a fish kill occurred in Little Beaver Creek as the result of the oxygen balance being temporarily upset by lignins washing from the X-633 cooling tower, causing a noticeable dark brown color in Little Beaver Creek.

- On April 17, 1978, several hundred dead fish were discovered in Little Beaver Creek, downstream from the confluence of the east drainage ditch. After a site investigation, the only anomalous condition discovered was the presence of elevated metal (aluminum, nickel, copper, and zinc) concentrations in the fish and creek sediments. The source of these metals was determined to be the X-701B holding pond.

- On January 24, 1980, Environmental Control Department surveyors discovered a high pH discharge at the east drainage ditch outfall. Further investigation revealed the presence of sodium hydroxide (caustic soda) from the X-330 Nitrogen Plant in Little Beaver Creek and a number of dead minnows.

- On October 31, 1983, a fish kill due to a sodium hydroxide spill killed approximately 5,800 fish in Big Run Creek and resulted in restitution to the Division of Wildlife.

On occasion, nearby property owners have filed complaints of cattle kills with the Plant. PORTS personnel conducted a number of investigations; however, Plant emissions were not identified as a contributing cause in these investigations. One such case occurred in January 1955, when six dairy cows died on a dairy farm near the town of Wakefield. The farm was adjacent to Big Run Creek, and the owner associated the deaths in the herd with activities at the Plant. Onsite and offsite sampling of the creek was performed directly above the farmer's property. Autopsy findings and the stream water analytical results did not link the deaths of the animals to Plant discharges. This conclusion was reinforced when the results of experiments with white rats were reviewed. Creek water from the drainage near the farm was given to the rats for a period of two weeks, and they developed no clinical signs of illness.

4.4 Atmospheric Releases of Radioactivity and Fluorine/ Fluorides

- ➢ *Stack Emissions*
- ➢ *Accidental Releases*
- ➢ *Diffuse and Fugitive Emissions*
- ➢ *Planned or Unauthorized Releases*

Radioactive and fluorine/fluoride air emissions to the atmosphere began with Plant startup in 1954 and have continued to the present from USEC operations that are regulated by NRC. The sources of air emissions were process stacks (which included routine releases), diffuse and fugitive emissions, accidental releases, and some likely planned or unauthorized releases. During the early years of Plant operation, environmental monitoring activities focused primarily on characterizing liquid effluents to ditches and streams. Air sampling at various onsite and offsite locations was not initiated until the mid-1960s in an effort to better characterize and analyze the potential impact of radiological and non-radiological contaminants (e.g., fluorides) on the public and the environment.

PORTS has estimated that approximately 10,545 kg of uranium, comprising approximately 8 Ci, and 27 Ci of technetium-99 have been released to the atmosphere from 1955 to 1993. These emissions and the potential resulting population dose were reported by OR as the lowest of the three gaseous diffusion plants. This may be attributable in part to the increased costs, tighter limits, and related economic factors associated with production of higher assay enriched uranium.

Nearly half of all the estimated uranium released to air at PORTS was attributable to one accidental release from a 14-ton cylinder in 1978. Another 30 percent of the total uranium released is estimated to have been released during the first eight years of Plant operation, during the time that the Feed Production Plant was operational. Uranium releases dropped significantly in 1963, coinciding with the shutdown of the Feed Production Plant. Approximately 19 of the 27 estimated curies of technetium-99 were released in 1982 and 1993, corresponding to increased cleaning and maintenance of contaminated cascade equipment during those periods. While technetium-99 was known to be present in feed materials as early as the mid-1960s, it should be noted that Goodyear Atomic Corporation did not believe that any significant amounts of technetium-99 were released prior to 1975 because of relatively low beta-gamma radiation that had been measured in effluents before then. A marked increase in beta-gamma activity was discovered in 1975, well above that which could be attributed to uranium daughter activity. This led to further analysis and the conclusion that technetium-99 contamination was a potentially significant contributor to radionuclide emissions. While technetium-99 was likely introduced into the cascade feed long before 1975, the expected time period for significant accumulation and its ultimate release from the cascade was never established. The calculations and methods for evaluating radionuclide discharges were not located during this investigation.

The release of fluorides is often closely correlated with releases of uranium, because airborne releases of UF_6 hydrolyze with the water vapor in air to form hydrogen fluoride. However at PORTS, due to Plant design characteristics, fluorine and fluoride compounds were used in significant quantities and were required to be vented directly as waste gases. The baseline quantity of fluorides released annually at PORTS from routine operations has been estimated to be on the order

Roof Vent from X-330

of 20 to 30 tons. Concern over the need to vent fluorine and the associated environmental and human liability problems was expressed in an August 30, 1954, memorandum from the Goodyear Atomic Corporation Portsmouth General Manager to the Goodyear Atomic Corporation corporate legal department in Akron, Ohio. In the memorandum, fluorine was described as an extremely toxic and highly reactive chemical. Potential damage to foliage, crops, and livestock is discussed, as are concerns with exceeding recommended standards for air concentrations to humans. The memorandum also indicated that it was the intention of PORTS to modify Plant design within 6 to 12 months to preclude the need for venting fluorine to the atmosphere under conditions other than an emergency. Follow-up correspondence to this memorandum was not located during the investigation. Venting of fluorine has continued since the initial operation of the Plant.

Stack Emissions

PORTS did not perform continuous vent monitoring of radionuclides or fluorides until the mid-1980s. However, the collection of grab samples and the use of space recorders provided a means of calculating the quantity of fluorides and uranium released through process stacks before then. While space recorders provided a monitoring capability for uranium, this method was far from ideal, and numerous limitations associated with the use of this instrument in emission calculations have been noted over the years, including calibration, maintenance, and procedural problems. For example, a January 1979 memorandum indicated that the X-326 top purge space recorder had been out of service for over one year. There were also recurring contamination problems associated with space recorders that rendered the data from these units unreliable for release estimation. Grab sampling techniques, which could also be used, were considered unacceptably prone to error. A Vent Committee was formed in the early 1980s to study the atmospheric vents, and a report was issued in 1985 recommending that continuous samplers be installed on a number of process vents.

Before 1984, the main source of radionuclide and fluorine releases from routine diffusion operations was the X-326 top and side purge cascade vent streams. Operational changes in 1983 reduced purge cascade radionuclide emissions to within an order of magnitude of the next two largest sources of gaseous emissions—the X-330/X-333 cold recovery and wet air evacuation system vents. Other smaller emission points included the X-345 and X-744G sampling facilities. The Feed Production Plant contributed approximately 407 kg of uranium (0.22 Ci) per year to total sitewide radionuclide emissions from 1958 until its closure in 1962. No estimates of routine releases from the oxide conversion facility were identified, since this facility did not contain process stacks. However, as discussed below, this facility was also a likely source of some radionuclide releases during its operation from 1961 to 1967. In addition to process buildings, the X-342A Fluorine Plant was a source of fluorine emissions.

It is likely that emission estimates have been made in good faith; however, these estimates do not reflect all the potential releases that were possible, including some that could have been significant. While the estimates were generally concerned with radionuclide quantities, similar concerns exist for fluorides. The potential for human error and unmonitored or unauthorized venting of contaminants has always existed at PORTS, partly because of Plant design. The vast piping and valving flexibility associated with the cascade buildings offers many configuration possibilities, including relatively simple means of rerouting both uranium and fluorine release paths to alternative locations, such as those that may be unmonitored. By simply mispositioning or adjusting a few valves, effluent streams can be rerouted to discharge locations other than that specified by the design basis. For example, the Building X-326 Evacuation Header can still be connected to the "D" Jet, which vents at roof level without going through a trap, by unlocking and repositioning valves, thereby bypassing any monitoring systems.

Accidental Releases

A number of accidental releases have occurred at PORTS, most of which were relatively minor from the standpoint of environmental impacts. Not all documented accidental releases involved atmospheric releases. During the investigation, several lists of accidents were reviewed. One list identified approximately 515 material releases from September 24, 1954, to November 26, 1993. The most significant release occurred in March 1978, when a 14-ton cylinder fell from its carrier and cracked open. An estimated 4,820 kg of uranium escaped into the atmosphere. Total activity was estimated at slightly less than 3 Ci, as the uranium was present at low (natural) assay. Other major releases involved a valve failure on a tails cylinder in October 1978 (releasing 560 kg of uranium and 0.125 Ci), a similar valve failure in 1969 (releasing 460 kg of uranium and 0.102 Ci), and a process malfunction in the side purge cascade in December 1983 (releasing 50 kg of uranium and 0.69 Ci). In addition, a string of accidental releases of mostly depleted uranium during the first five years of Plant operation accounted for essentially all of the known or reported uranium lost to the atmosphere from 1955 to 1958, and 20 percent of the losses in 1959 (the remaining losses came from the Feed Production Plant).

There is evidence that PORTS consistently assessed the potential public dose impact from environmental releases. Dose estimates are provided in annual site environmental reports that summarize all releases for each calendar year starting from the early 1970s. Prior to this time, heavy reliance was placed on ambient air samples for assessing impacts on the public. However, ambient air samples were not always available, and they only measured plumes that were at ground level. Lofted plumes may not have been measured depending on meteorological conditions. For example, plume lofting can occur during accidental releases of UF_6, since an exothermic reaction occurs between the UF_6 and water vapor.

In addition to accidental releases of uranium, a number of releases involving fluorine and/or fluorides have occurred. A July 5, 1973, memorandum from Industrial Hygiene notes a call from the Shift

Cylinder Rupture

Superintendent on July 4, 1973, advising that hydrogen fluoride was being released in copious amounts from the X-342 vent stack. An estimated 30- to 40-foot high column of hydrogen fluoride vapor was observed coming out the vent stack. Other accidental releases of fluorides have occurred; however, because of the need to vent fluorine from the cascade buildings, such planned releases would not be classified as accidental. Despite authorization requirements and standards for the controlled venting of fluorine from the cascade buildings, the system has weaknesses. Personnel at the Plant have made recurring reports of offensive fluorine fumes, breathing difficulty, and in some cases permanent respiratory tract damage. Offsite residents and farmers have complained of odors and damage to crops. Investigations of these complaints generally conclude that the evidence is insufficient to support a causal relationship to Plant venting. For acute cases, there is often no trace of contaminant that remains by the time a response team has arrived to investigate the alleged incident. While ambient fluoride samplers have been used for many years to measure the levels of fluorides in the environment, these samplers average the ambient concentration over a period of several days and may not be sufficient to capture a potential acute fluoride release that could result in health effects over a short duration. Notwithstanding this limitation, a number of results from the ambient samplers have shown actual fluoride concentrations that exceed guidelines established by various states for monthly maximum concentrations.

Diffuse and Fugitive Emissions

Diffuse and fugitive emissions were generally not calculated for the Plant from 1952 through 1993. Workplace air samplers, as well as evidence of contamination on roofs and grounds, point to unmonitored releases. For example, very high airborne concentrations of radioactive material were prevalent in the oxide conversion facility, which could have been vented to the atmosphere through penetrations, ventilation systems, doors, and windows. A February 1978 AEC memorandum referencing an investigation of the X-705 oxide conversion facility concluded that the area had unfiltered exhaust that draws air away from the high bay area, through the oxide conversion area, and through a roof stack, thereby allowing venting of releases from inside the oxide conversion facility directly to the atmosphere. As discussed in Section 3.2.2, since the facility processed reactor returns, the unmonitored releases from this location could have contained transuranics. No estimates of releases from this facility have been incorporated into sitewide release estimates or dose calculations reviewed during the investigation. After the mid-1960s, the ambient air samplers could reflect some air concentration contributions from diffuse and fugitive sources. Unfortunately, no modeling studies were performed to evaluate the relationship between these samples and emissions. Also, only low-volume samples were taken. This investigation found no information documenting how the low-volume, ambient air sampler performed for a variety of wind and weather conditions.

Planned or Unauthorized Releases

As described in Section 3.2.3, there is evidence that planned releases may have occurred during preparation of the cascade cells for maintenance. Cell jetting may have been performed to reach a desired low concentration of uranium in the cells. These releases would occur from the roofs of the process building or possibly unauthorized locations that bypass monitoring systems. The frequency and amounts of the releases are unknown; however, significant quantities of uranium would normally be available to be released during a single jetting event. While economic considerations would provide a strong incentive to avoid jetting of higher-assay material, for some lower-assay material in the cascade this constraint would have been less significant. Because of the possibly significant quantity of uranium involved, jetting of the cascades could be an undocumented contributor to the estimated quantity of uranium released from 1955 through 1993.

4.5 Environmental Management Summary

Over the operating lifetime of the Plant, activities to manage wastes and liquid and air process effluents evolved in response to internal and external requirements. PORTS personnel monitored emerging regulations and established plans and strategies in response to new requirements. However, implementation of necessary changes and new compliance programs often required an extended period of time and were not always fully effective.

The generation of waste and scrap materials began with Plant construction in 1954, and general guidelines for handling, storing, and disposing of waste existed in the early days of Plant operations. Onsite sanitary landfills likely received some contaminated material, since waste segregation practices were not fully understood or effective. As new requirements were enacted, additional waste streams, such as hazardous wastes, were restricted from disposal in onsite landfills. PCB- and uranium-contaminated oils were spread on roads, disposed of in oil biodegradation plots, burned in open containers, and incinerated.

Implementation of waste management regulations and internal controls was not always effective. The State of Ohio EPA, DOE, and Goodyear Atomic Corporation conducted numerous inspections and identified performance problems in the treatment, storage, and disposal of hazardous waste. By 1988, the State of Ohio EPA sent DOE and the Plant a notice of intent to file suit for hazardous waste violations.

Several important disposal options for the site, such as the X-735 sanitary landfill, the X-749 radioactive waste landfill, and the X-705A incinerator, were lost in the late 1980s and early 1990s because of inappropriate disposal of regulated wastes.

Large volumes of contaminated metal and surplus matter were generated during construction, maintenance, repair, and facility upgrade activities. It is clear that significant efforts were taken to properly segregate contaminated materials from clean materials intended for sale to the public. However, given the known problems in contaminated scrap segregation and the limited number of qualified health physics personnel available to perform radiological surveys, it is evident that material exceeding appropriate radiological release guidelines has been released from the Plant periodically from the 1950s through the 1980s.

Liquid effluents have been routinely discharged from the Plant and from accidental spills and releases. The environmental monitoring program at Goodyear Atomic Corporation was initiated in 1955. Significant changes in liquid effluent discharge practices were required upon the establishment of Federal and state regulations in the 1970s. Several new wastewater treatment systems were constructed to meet new permit requirements and to significantly reduce the levels of radionuclide emissions. Despite the discharge restrictions imposed by the AEC and subsequently the State of Ohio, it is clear that, over the years, enough radionuclides and chemicals have been released into ponds, local ditches, and streams to create legacy environmental contamination. The existence of legacy contamination has been confirmed through environmental sampling data. In addition to the continuous discharge of process waste to local creeks, there have been numerous spill events throughout the history of the site. Spills at the Plant have resulted in several fish kills in surrounding creeks.

Starting in 1975, Plant records reveal that technetium and transuranic contamination was unexpectedly discovered in liquid process effluents from X-705. The Plant environmental monitoring program did not include these contaminants, which were known by Plant management to have been introduced into PORTS industrial facilities from the processing of reactor returns and from Paducah feed materials. Based on the information collected, it does not appear that personnel responsible for environmental monitoring were aware of the presence of these contaminants at PORTS. These discoveries triggered significant efforts by Plant personnel to isolate sources of technetium and transuranic contamination, develop or improve control methods, and establish appropriate monitoring protocols.

Radioactive and fluorine/fluoride air emissions to the atmosphere began with Plant startup and have continued to the present. The sources of air emissions were process stacks, diffuse and fugitive emissions, accidental releases, and some planned releases. Air sampling for radiological contaminants and fluorides at various onsite and offsite locations was not initiated until the mid-1960s. The principal radionuclides released to the air from PORTS operations were isotopes of uranium and technetium-99. PORTS records indicate that nearly half of all the uranium released to the air at PORTS was attributable to one accidental release from a 14-ton cylinder in 1978. Another 30 percent of the total uranium released is estimated to have been from the Feed Production Plant when it was operated during the early years of Plant production.

PORTS was proactive in assessing the potential public dose impact from environmental releases. Dose estimates and release summaries are provided in annual reports starting from the early 1970s. While it is likely that air emission estimates made by PORTS were done in good faith, these estimates do not reflect all the potential historical releases, including some that could have been significant. Diffuse and fugitive emissions were generally not calculated for the Plant from 1952 through 1993. Workplace air samplers, as well as evidence of contamination on roofs and grounds, point to unmonitored releases, including potentially significant releases from the oxide conversion facility. The Plant did not perform continuous vent monitoring of radionuclides or fluorides until the mid-1980s, relying on less precise methods to calculate releases. Evidence also exists that planned releases may have occurred through jetting of process gases from unmonitored vents in preparation for cascade cell maintenance.

Fluorine and fluoride compounds were used in significant quantities at PORTS and were required by Plant design to be vented directly as waste gases. In August 1954, concern over the need to vent fluorine and the associated environmental and human liability problems was expressed by the Goodyear Atomic Corporation Portsmouth General Manager. There have been recurring reports by Plant personnel of offensive fluorine fumes, breathing difficulty, and, in some cases, permanent respiratory tract damage. Offsite residents and farmers have complained of odors and damage to crops. Investigations of these complaints generally conclude that the evidence is insufficient to support a causal relationship to Plant venting. For possible acute cases, a timing problem is evident, in that often no trace of contaminant remains when a response team arrives to investigate the alleged incident. For chronic exposures, environmental monitoring for fluorides has been conducted for many years, and ambient samplers sometimes indicated fluoride concentrations that exceeded guidelines for acceptable concentrations.

5.0 Past Management and Oversight Practices and Employee Relations

5.1 Oversight

The AEC, ERDA, or DOE have had a nearly continuous site presence at PORTS. The AEC had a local Portsmouth Area Manager performing contractor oversight. Records reflect some indirect ES&H-related oversight activities by the Area Manager, including communication of new or revised regulations and standards, transmittal of appraisals performed by OR, and communication of concerns related to events and reporting of off-normal conditions. Records reflect limited direct Federal ES&H oversight of Plant activities in the early years. OR appraisals of ES&H, called "contractor health protection program reviews," were performed as early as 1957, and the AEC manual required annual ES&H assessments starting in 1961. These assessments were generally performed by two persons over three days and addressed radiation protection, criticality safety, industrial hygiene, environmental programs (scrap metal and effluent discharges), and corrective actions in response to recommendations from prior reviews. Goodyear Atomic Corporation appears to have been responsive to AEC recommendations. Although important deficiencies and issues were identified by these reviews, the size and complexity of Plant operations and the nature of the industrial hazards and environmental concerns present warranted longer and more frequent assessments using more than two assessors. These reviews consistently concluded that the PORTS health protection program (including environmental controls) was satisfactory. A more in-depth, two-week assessment conducted in 1973 by OR included field observations of Plant conditions, work performance, and interviews with workers and first-line supervisors; it concluded that the health protection program at PORTS was inadequate. However, there was no further evidence of more rigorous assessments, and the limited annual appraisals resumed until the 1980s. Starting in 1975, OR performed annual OSHA inspections of PORTS. In the 1980s, OR conducted annual environmental assessments that evaluated air emission and water discharge control programs. These assessments were expanded to include hazardous waste management programs as regulations for TSCA and RCRA were promulgated. These assessments, combined with special reviews by OR environmental personnel, identified several significant environmental concerns, as discussed in Section 4.1. The annual environmental assessments were discontinued in the late 1980s.

The AEC performed detailed investigations of the more significant events (releases and accidents), and OR or Portsmouth Site Office personnel participated in many Goodyear Atomic Corporation investigations of less serious incidents. Generally, these investigations were thorough, and many included identification of ES&H issues and specification of detailed corrective actions to address root causes. However, the continuing problems over the first 25 years with process gas and fluorine releases and with contamination control indicate that the thresholds for acceptable performance were too low and implementation of corrective actions was ineffective.

The AEC and its successor organizations also investigated worker allegations of unsafe conditions and practices, but with inconsistent rigor and results. Many of these allegations surfaced at times of contention between Goodyear Atomic Corporation and unions. For example, worker complaints to DOE during an October-November 1977 investigation and in May 1978 regarding respirator usage and related training resulted in nine recommendations concerning safety meetings, electrical work permits, hazardous work permits, heat stress, eating in contaminated areas, training, operator certification, and personal protective equipment usage. From 1979 through 1982, another major DOE investigation of worker complaints, conducted at the direction of Congress, identified performance problems in a variety of ES&H areas.

Historical weaknesses in DOE investigation of worker allegations have continued to the present program. One case in particular, raised during the transition from DOE to NRC oversight of USEC, still remains unresolved. That case involves allegations by a Plant guard who maintains that, in 1994, he was exposed to fluorine, and that his radiation exposure records were falsified. Internal investigations by Lockheed Martin Utility Services found some merit to the allegation, and the allegation was forwarded to the Oak Ridge Operations Office Inspector General in 1996. That case remains inadequately investigated and unresolved by DOE.

In 1980, the General Accounting Office (GAO) performed a review of the DOE program for ensuring the safety and health of workers at the three uranium enrichment plants. GAO determined that program implementation was inadequate. This report acknowledged that safety statistics and radiation exposures were low compared to similar industries, but stated that ES&H oversight "is not approaching the coverage required by the program" and cited a shortage of safety and health staff at OR. Also cited were delayed and inadequate corrective actions for known contamination control problems that were not addressed until the union issued formal complaints. The DOE disputed the significance of GAO's concerns.

In the 1970s and 1980s, the DOE Headquarters Environment, Safety and Health organization performed technical safety appraisals of functional areas at approximately five-year intervals. In the 1990s, OR increased ES&H oversight appraisal activities by performing more detailed functional area appraisals and providing input to ES&H elements of the award fee contracting process. The current DOE Portsmouth Site Office was formed about 1988 with approximately eight technical staff members in various disciplines to oversee production activities and ES&H performance. The 1989 DOE Tiger Team assessment identified numerous health, safety, and environmental deficiencies; ES&H program weaknesses; and management issues. OR and the DOE Headquarters Office of Nuclear Energy performed increased functional area assessments until USEC assumed operation of the Plant in 1993. As discussed in Volume 2, DOE oversight of ES&H from 1994 through 1999 was limited to Portsmouth Site Office activities.

In summary, AEC-ERDA-DOE oversight of ES&H performance was not rigorous or proactive for much of PORTS history. Although this oversight was sometimes effective when vigorously exercised, such as event investigations or the Tiger Team assessment, consistency and follow-through on corrective actions were often lacking.

5.2 Labor Relations

Established in 1954, the Oil, Chemical, and Atomic Workers Union (OCAW) was aggressive in its efforts to protect and improve employee welfare. This aggressiveness sometimes caused friction between Plant management and labor. On numerous occasions, the positions of management and labor differed widely, and resolution was accompanied by extreme measures, as evidenced by one unauthorized and six authorized strikes that occurred from 1954 to 1993. Furthermore, the severity of management and labor disagreements appears to have increased beginning in 1974, as suggested by the frequency and duration of strikes. While economic issues were common to most strikes, safety and health were an important element in three of these seven actions, as summarized in Table 2.

Collectively, the number of grievances filed, worker compensation claims submitted, and alleged acts of retaliation committed provide further support that management and labor relations were strained. From 1954 through1993, it is estimated that more than 17,000 union worker grievances were filed addressing a variety of issues in addition to safety and health, including work jurisdiction, discipline, overtime, work rules, and benefits. A review of selected ES&H-related grievances filed during this period reveals that sometimes labor took issue with company actions that may not have been clearly defined by policy, and management responded to the aggrieved employees with ambiguous statements, thereby exacerbating what

1976 OCAW Strike

Table 2. Portsmouth Gaseous Diffusion Plant Oil, Chemical and Atomic Workers Strike History: 1954-1993

Strike Period	Duration	Type	Principal Reason(s)
October 3 - 4, 1956	1 day	Unauthorized	Responsibilities and Safety[a]
May 10 – 16, 1957	6 days	Authorized	Wages and Safety[b]
May 2 – May 20, 1969	18 days	Authorized	Wages[c]
May 2 – August 8, 1974	98 days	Authorized	Wages[d]
August 28 – December 13, 1976	106 days	Authorized	Wages[e]
May 3 – December 15, 1979	228 days	Authorized	Wages and Health[f]
June 11, 1991 – April 6, 1992	299 days	Authorized	Overtime and Requirements[g]

[a] Reason for the strike involved ten issues associated with work jurisdiction, employee responsibilities, treatment of grievances, showering time and facilities, seniority, overtime, safety, and uniform treatment between hourly and salaried employees.

[b] Reason for the strike involved 19 issues associated with employee fringe benefits, employee responsibilities, union contract language, safety and health program, and overtime.

[c] Reason for the strike involved issues associated with wages and contract language.

[d] Reason for the strike involved issues associated with wages and worker classification.

[e] Reason for the strike involved issues associated with wages, and medical and pension fringe benefits

[f] Reason for the strike involved eight issues associated with overtime, work responsibilities, contract language, wages, physical examinations, and fringe benefits.

[g] Reason for the strike involved issues associated with overtime administration, seniority, contract language, and following Department of Energy orders.

was already a strained relationship. For example, in February 1958, X-700 maintenance mechanics filed a grievance because they were denied cold weather outer garment contamination clothing (parkas) to control the spread of contamination when commuting to and from their assigned building or working outside. Management did not dispute the furnishing of parkas "to the extent they are available to control the spread of uranium contamination when employees on red job assignments are required to perform outside work." However, management stated that "beyond this basis for issuance, parkas are not within the scope of the clothing which the Company requires employees to wear for their own protection." Additionally, management stated that the "Company has not established either the policy or practice of furnishing parkas to all maintenance mechanics in the X-700 building when leaving or working outside that building." There are other instances in which communication between management and labor was ineffective. For example, a 1979 grievance was filed by an employee who received a memo from management for "coming into work [in the X-700 Building] without wearing safety glasses." Records indicate that there was a misunderstanding between union members and management on the wearing of eye protection in Buildings X-700 versus X-720. Safety glasses were required at all times in X-700, while this was not true for X-720.

In contrast to the previous examples, there are records suggesting that labor grievances were filed to be confrontational, as management appeared to have been acting appropriately and in the interest of its employees' safety and health. For instance, in 1976 an employee filed a grievance protesting being admonished formally by the company for failure to follow certain operating and safety procedures, including wearing required respiratory protection equipment. This grievance was denied, as the company considered its actions "extremely liberal in view of

[its] strong position on insisting that operational and safety procedures be complied with explicitly."

Worker compensation claims, which began to appear in the early 1950s shortly after Plant startup, also reveal discord between management and labor. Interviews with past and present employees and review of records indicate that there were allegations by employees that management would go to great lengths to deny or avoid compensation claims, including being untruthful and pursuing legal loopholes to avoid accountability. For example, workers claimed that Plant management would use sampling data taken from surveys performed hours or days after an alleged exposure to disprove safety and health injuries purported to have resulted from Plant operations. Additionally, there is evidence suggesting union distrust of Plant medical opinions, leading workers to obtain the services of certain community physicians to address their medical concerns. Consequently, disagreements between management and workers concerning exposure levels for radiation, metals, and chemicals were harsh and were often heatedly debated in correspondence and during compensation testimony. In many cases, it appears that the company started from an assumption that the exposure could not have resulted from work at the Plant, and then set out to prove its premise.

Records indicate that some employees, who had contracted illnesses like leukemia or other forms of cancer, filed compensation claims to request monetary compensation for their illnesses; in the case of death, their families filed lawsuits. Some of the claims lacked technical basis, such as a case of liver cancer developed by a Goodyear Atomic Corporation employee after a brief work history at the Plant and a long history of health problems. Correspondence between the Plant medical director, a family physician, and lawyers working on this case appeared to successfully explain the lack of any relationship between Plant exposure and the disease. Other cases were not resolved so easily, and some were "showcased" on the radio, television, and in newspapers. Some employees sought damages amounting to several million dollars, claiming loss of income and punitive damage; in cases where the employee died prior to settlement, surviving relatives continued the case.

The time, money, and expertise necessary to respond to worker compensation claims prompted the program to move from the medical department to the direct control of human resources management. External legal counsel was frequently added to defend difficult or complicated compensation cases. Discussions with a longstanding worker compensation program employee suggested that Goodyear Atomic Corporation, Martin Marietta Utility Services, and Lockheed Martin Utility Services were conscientious in following the State of Ohio workers compensation regulations.

The perceptions of some past and present employees indicate that raising safety and health issues, either by simple verbal complaints, filing formal grievances, or submitting worker compensation claims, was sometimes accompanied by management and peer retaliation. For example, an hourly worker filed a grievance in December 1978 maintaining that he was unjustly suspended for insubordination for failing to enter an area that he believed was contaminated despite the opinion of his foreman, who maintained that the area was uncontaminated. The union protested the suspension, and the grievance was sustained by an independent arbitrator.

The impact of management and labor discord on the Plant-wide safety and health program is two-fold. While alleged efforts by management to deny culpability in certain personal injury cases and authorized strikes by the union workforce may have heightened mutual distrust, the sheer number of grievances and workers compensation claims compelled the company to react and be more conservative in its approach to protecting its employees. The discord also created a heightened awareness among various stakeholders (e.g., the public and the Federal government), thereby prompting independent investigations into the safety of Portsmouth operations.

The other major union at the Plant, the United Plant Guard Workers of America (UPGWA), has had no strikes since its formation in 1955. Generally, protective force personnel appeared to be considered outside the Plant mainstream, despite the fact that they were integral to maintaining its security and were collocated with Plant operations. Interviews with some protective force personnel, combined with a lack of formal records, suggest that information on Plant hazards and associated safety precautions was insufficient, and this, combined with other factors, fostered the blind obedience exercised by the guard force in maintaining the security of PORTS. Interviews with various PORTS workers, in addition to historical photographs, provide some evidence suggesting that from Plant startup until the early 1990s, guard force personnel were generally unprotected from the hazards associated with the operations and products they were responsible for securing. Often guard posts were in close proximity to Plant workers who were wearing respirators while protective force personnel were not, or guards were at the scene of accidental releases without appropriate respiratory protection. Even as the balance of the Plant responded to new information on hazardous materials and EPA and OSHA safety regulations, protective force training lagged. Guards continued to conduct drills and practice in spaces and amongst equipment and products they were responsible for protecting that were sometimes radiologically and chemically contaminated. As the protective force received better information and training on Plant hazards and safety precautions in the mid- to late 1990s, they focused attention on obtaining answers and compensation from management for past and present personnel who had possibly been subjected to harm.

APPENDIX A
HISTORICAL HAZARDS

This appendix discusses the radiological, chemical, and physical hazards present at PORTS, and the potential effects of exposure to these hazards.

Radiological Hazards

The radioactive hazards associated with PORTS operations and supporting activities include uranium and its daughter products, transuranics, and fission products. From 1957 into the mid-1960s, numerous studies of the radiological effects of neptunium, plutonium, technetium, and other fission products and transuranic elements found low concentrations of these impurities in incoming reactor tails. However, the impurities tended to concentrate in certain areas of the oxide conversion plant, cascade, equipment, and process piping.

The policies in place at PORTS to protect personnel from the inherent hazards of handling radioactive materials were based upon preventing personnel exposures from exceeding the Radiation Protection Guides (RPGs) established by the Federal Radiation Council, the requirements of AEC manual chapters (subsequently ERDA and DOE orders), those established by the National Committee on Radiation Protection and Measurement (NCRP), and the National Bureau of Standards Handbook 69. The AEC policies in place at the time further encouraged the maintenance of radiation doses as far below applicable standards as was practical. The application of these policies from 1954 to 1990 and the expectation that employees would adhere to procedures and guidelines were essential factors in hazard identification and control at PORTS.

Uranium is a naturally occurring element in the earth and is mined for commercial purposes. Natural uranium is 99.3 percent uranium-238 (U-238) and 0.7 percent 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 (the period for material to decay to half of its initial radioactivity) of 4.47 billion years. Once in the body, uranium may concentrate in the kidneys, bones, or lungs, depending on its solubility. For insoluble forms, radiation dose to the lung is a predominant concern. The principal sources of internal uranium exposures at PORTS relate to the inhalation or ingestion of primarily soluble forms but include insoluble compounds in some areas, such as the oxide conversion (X-705E) and feed production (X-344) facilities. The maximum enrichment for PORTS until July 1964 was 97 percent. From July 1964 to 1991, the maximum enrichment for PORTS was 93 percent U-235. In the mid-1990s highly enriched foreign (French) fuel was down-blended (that is, its enrichment was reduced). UF_6 exists at PORTS as a gas, liquid, and solid. Other compounds of uranium, such as UF_4, UO_3, and U_3O_8, have been present in significant quantities in the feed manufacturing plant and the oxide conversion plant. There is evidence that workers were exposed to uranium in forms that could cause adverse health effects.

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 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. Exposure to daughter products from transfer to clothing, tools, or other items is likely to result in unanticipated beta radiation doses to workers. Protactinium-234m emits a high-energy beta particle, which contributes most of the beta dose from the uranium-238 daughter products.

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

- **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. The low concentration of neptunium found in reactor tails feed material was not a significant radiological hazard, and at such levels the controls for uranium would protect personnel from exposure to neptunium. However, neptunium concentrated at certain points in the uranium conversion, enrichment, and recovery processes. The highest concentrations were associated with oxide conversion and the waste streams associated with that process (X-705E and X-701B).

- **Plutonium-239** is significantly more radioactive than neptunium but is less a hazard at PORTS because it was present in much lower concentrations. It has a radioactive half-life of 24,065 years. Once plutonium reaches the bloodstream, 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 carried to other organs where the radiation can cause cell damage and increase the likelihood of biological effects. Recent estimates indicate that there was only a small amount of plutonium in the uranium fed into the PORTS cascade; plutonium concentrated in the oxide conversion facility. Because it remained in the ash material, most was removed with the ash residues and particulate filters in the conversion of uranium oxides to UF_6. 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 exposures during CIP/CUP activities.

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 PORTS was technetium.

- **Technetium-99** is a weak beta emitter with a radioactive half-life of 213,000 years and was introduced at PORTS in recycled reactor feed. The primary exposure pathways are ingestion or inhalation. Protective clothing would adequately shield the low-energy beta particles emitted by technetium. Technetium passed through the Paducah cascade as a volatile compound of fluorine, depositing on internal surfaces of the cascade and contaminating the uranium product. Similarly, technetium at PORTS contaminated many areas, including cascade equipment. The AEC did not specify a limit for technetium in UF_6 feed but controlled the concentration of technetium indirectly to about 10 ppm by limiting gross beta due to fission products. In addition, some customers established a 10 ppb limit on technetium in product cylinders. There was evidence that workers had some exposure to technetium.

Chemical and Toxic Metal Hazards

The PORTS operations exposed workers to a wide variety of chemical and toxic metal hazards. Some of these hazards and their health effects were known from the early years of the Plant's history, such as mercury, fluorides, carbon tetrachloride, and TCE. However, the hazards of some substances, such as PCBs and asbestos, were not recognized until the 1970s. As knowledge of the health effects of hazardous chemicals increased, permissible exposure levels have generally decreased. Accordingly, many of the limits established in the 1950s would not be acceptable today. The issuance of the OSHA hazard communication standard in 1983 drove improvements in chemical hazard identification at PORTS. The hazard communication standard required identifying chemical hazards, labeling chemicals, documenting a chemical hazard program, training workers, and most importantly requiring that manufacturers develop and disseminate Material Safety Data Sheets (MSDSs) to chemical purchasers. The following paragraphs summarize the principal hazards of toxic metals, gases, and solvents that PORTS workers were exposed to during the period of 1952 until 1997.

Uranium radiation hazards are discussed above. As a heavy metal, uranium is toxic and can damage the kidney. Both the solubility and enrichment determine the toxic chemical effects. In 1987, the National Institute of Occupational Safety and Health (NIOSH) completed a study to assess the risk of cancer mortality associated with exposure to uranium compounds at the Plant, particularly uranyl fluoride, the most prevalent compound of exposure interest. The study concluded that the workers at PORTS had experienced excess stomach cancer and excess cancer of the hematopoietic system, which included leukemia. However, the study also concluded that these excesses were not statistically significant, because they occurred in a group of workers who demonstrated less overall mortality than the U.S. population in general. (NIOSH is updating this study, and results are expected before the end of calendar year 2000.) Uranium chemical exposures have been monitored at PORTS since Plant startup. Routine bioassays were conducted as early as the 1950s, and air sampling was performed throughout the history of the Plant.

Beryllium is a silver-gray metallic element used as pure metal, as beryllium-copper and other alloys, and as beryllium oxide. Beryllium is useful in manufacturing due to its strength, light weight, machinability, and relatively high melting point. The severity of health hazards resulting from even minimal contact with beryllium is only now being fully understood. 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, which occurs in one to six percent of exposed workers, has a latency period of up to 20 years and has no known cure. There was limited evidence of incidental use of beryllium at PORTS. Besides the use and/or disposal of sealed plutonium-beryllium neutron sources, one stores department worker indicated that he had stocked beryllium bars, which were sent to the X-720 machine shop. Another worker and a supervisor believed they might have machined small quantities of beryllium in the same shop in the mid-1970s. Beryllium at PORTS may have included incidental machining of beryllium copper-alloy process piping components, such as valves. Some tools plated with beryllium were also used. Other beryllium use may have included use and disposal of fluorescent light bulbs containing beryllium oxide and use of beryllium-containing welding rods until the mid-1990s. The site routinely sampled for beryllium in the environment in the early 1990s, and detectable beryllium concentrations above background were identified in several areas at PORTS.

Arsenic exists in organic or inorganic forms, and all are toxic. Non-occupational exposure to arsenic can also occur from drinking water, food, polluted air, and cigarettes. Symptoms of chronic arsenic poisoning include illness and fatigue, with stomach and intestinal distress. Arsenic is a carcinogen, causing increased risk of skin, liver, and lung cancer. Arsenic has been identified in several areas in the Plant, including the X-342 fluorine generators, X-326 process gas, converter maintenance in X-700, wood preservatives in the cooling towers, and coal and coal byproducts in the steam plant. In 1993, arsenic was first discovered in X-326 process gas that resulted from arsenic-contaminated UF_6 feed material. A March 1994 NIOSH evaluation of worker exposures to arsenic in the process system concluded that concentrations were generally below detectable limits. Only one of the 600 air samples taken during this study was above the OSHA limit. Arsenic also naturally occurs in coal and accumulated in the boilers of the PORTS steam plant. Utility personnel, who routinely removed scale from boilers, were unaware of an arsenic hazard until the potential for it was identified in a notice from OR in the late 1980s. Subsequent sampling indicated that arsenic concentrations exceeded limits by factors of 10 to 100. Consequently, workers shifted from dust masks to air-supplied respirators for descaling. Arsenic was also present in fly ash, but the concentration was much lower than the concentration in firebox scale. Ash was routinely buried in an onsite landfill, used on site roads, and placed on a track at a local high school. Use of fly ash for this purpose is a common industrial practice, and not unique to PORTS. Toxicity tests of the fly ash in the early 1990s demonstrated that it did not meet RCRA criteria for hazardous waste. Since that time, however, fly ash and scale material have been returned to the coal mine by the coal contractor. The health effects for workers exposed to arsenic, especially in the process system, are indeterminate. General exposure levels were low, but in some cases the presence of arsenic was not recognized. In the steam plant, exposures could have exceeded limits, as is the case in all industrial coal-fired steam plants.

Mercury exists as an element (metallic) with inorganic and organic forms. 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. Chronic elemental mercury symptoms are slow to develop and difficult to diagnose. Inorganic mercury salts, such as mercuric chloride, often cause skin problems and can result in extensive kidney damage. Organic mercurials, such as methyl mercury, can cause severe birth defects or mental retardation. Health effects of mercury were known as early as the 1950s. As early as 1955, PORTS bulletins contained precautions for avoiding mercury poisoning.

The principal uses of mercury at PORTS included thermometers, manometers, chemical traps, vacuum pumps, switches, and fluorescent lights. Manometers were used to measure differential pressures, flows, and absolute pressure. Line recorders (spectrometers) used mercury in chemical traps to remove UF_6 from sample streams to allow detection of low molecular weight gas contaminants contained in the process gas. Diffusion vacuum pumps were used to sustain vacuums necessary for proper operation of assay and line recorder spectrometers. Mercoid switches that contained mercury and large manometers (reported to contain pounds of mercury) were initially filled and refurbished in the X-710 and the X-720 Instrument Shop. One interviewee remembered having to reclaim several hundred pounds of mercury stored in a hood. In the 1950s and 1960s, recovery operations involved mercury distillation in the X-705 recovery area. In those years, cleanup reportedly involved brushes and dustpans for retrieval by workers wearing Army assault masks and rubber gloves. However, some former workers who were interviewed reported experience with mercury spills inside and outside buildings and handling open containers of mercury without any type of personal protective equipment. In the 1960s and 1970s, airborne mercury levels greater than PALs were identified in the instrument shop cleaning room after a spill. Chemical trap cleaning before the 1980s reportedly involved flushing, resulting in saturating a small ground area with mercury. Later, mercury vacuum cleaners and Mercury-X (a specialized cleanup product) were utilized for cleanup. In the 1980s, efforts were made to reduce mercury on site, and recovery in X-705 ceased. 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 for the month. Overall, mercury was handled extensively, sometimes without adequate personal protective equipment, and could have had adverse health effects on workers.

Lithium is intensely corrosive and may produce burns on the skin from the formation of the hydroxides. Like most toxic metals, 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) were stored at PORTS in five warehouses. The LiOH was transferred from OR for storage at PORTS. The LiOH stored at PORTS also contains 2-15 ppm mercury. Originally, lithium was in 55-gallon fiberboard drums, which corroded over time, spilling some of the contents on warehouse floors. During the late 1970s, a significant Plant project involved the cleanup and relocation of the lithium, moving the drums, and dismantling and moving the warehouses to provide space for the construction of the gas centrifuge plant. According to some workers interviewed, the LiOH dust during drum relocation was sometimes so thick that the lights of the forklifts were hard to see. Although dust masks were worn by some, respirators were not required. Several workers who participated in this project complained of ill effects, including high blood pressure and increased occurrence of cardiovascular ailments.

During the mid-1980s, a significant Plant project involved the overpacking of the LiOH because the warehouses in which it was stored were leaking from rain events, causing deterioration of the fiberboard drums. The 55-gallon fiberboard drums were overpacked into 85-gallon drums, and the roofs on the five warehouses were repaired. Use of the 85-gallon drums required additional warehouse space; therefore, two additional warehouses were constructed on the hill on the west side of the reservation, overlooking the perimeter road, to handle the overflow. Today, the inventory is less than half of the original amount. A commercial contractor is gradually removing the product off site.

Chromium salts are irritating and destructive to tissue. Mists from electrolysis baths and plating baths cause dermatitis and damage to nasal membranes. Problems extend to the respiratory tract when dusts, fumes, or mists are inhaled. Because of the toxic nature of plating bath contents, disposal must be done carefully to preclude serious environmental damage. Chromium and chromium compounds were used throughout the Plant's history in electroplating operations and as an anti-corrosion inhibitor in recirculating water systems.

In the mid-1950s and later, sodium dichromate was added in considerable quantities to the recirculating water system, primarily as an anti-corrosive agent. For example, during one week in 1956 three trailer loads of sodium dichromate were received at Stores, totaling 160,000 pounds. Sodium dichromate typically came in 100-pound paper bags, some of which ruptured during transport. On one occasion, a worker filed a written complaint alleging that several workers had been treated in the hospital for overexposure to sodium dichromate. Industrial hygiene personnel concluded that three workers had been overexposed, as evidenced by nasal irritation experienced by the workers, and that the protective clothing at the beginning of the job was less than adequate. The Safety and Industrial Hygiene Department issued a Safety Letter, advising workers of the hazards of sodium dichromate and chromic acid and indicating the appropriate personal protective equipment. While the long-term health effects are not well known, some workers have been exposed to chromium compounds from plating operations, transport, addition of dichromates to water systems, and during maintenance of those systems.

Nickel metal is a hard, silvery solid with a high melting point. 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. Nickel compounds also can cause chronic eczema. Some individuals are susceptible to becoming sensitized to nickel, and once sensitized, they respond even 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.

At PORTS, nickel-related operations were performed in several areas of the Plant. Worker exposure to nickel was possible during welding, cutting, or grinding on nickel-containing components, and during nickel spraying operations in X-720. Nickel sulfate crystals and nickel chloride were used in nickel plating operations in X-720 during the mid-1950s and later. 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 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. One of the more hazardous operations involved nickel spraying. A 1982 industrial hygiene survey of nickel spraying in X-720 identified airborne nickel concentration up to 15 times the limits. Consequently, personal protective equipment was improved to require supplied-air respirators, company-supplied welder's coveralls, leather gloves, and face shields or welder's glasses. In 1980, a feasibility study to reduce airborne nickel was performed, resulting in improved ventilation systems. In 1991, NIOSH expanded a previous 1987 NIOSH study on worker exposures at PORTS by considering worker exposures to fluorides and nickel. The results of this study are to be published by the end of calendar year 2000. In general, although many workers were exposed to nickel fumes/mist (some of which exceeded permissible exposure limits), most workers were informed and usually wore personal protective equipment to mitigate the hazard,

Fluorine is a pale-yellow to greenish gas with a pungent, irritating odor. **Hydrogen fluoride**, or hydrofluoric acid (HF), is a colorless gas or fuming liquid with a strong, irritating odor. Exposure routes include inhalation, skin absorption (liquid), and skin and/or eye contact. Exposures can result in a variety of symptoms, ranging from irritation of mucous membranes to severe burns. The primary sources of exposure to HF at PORTS involve the opening of normally closed systems that are used to process UF_6 or generate fluorine gas, leaks, or process upset events. Fluorine was used in the oxide conversion and feed manufacturing processes and was generated in X-342. Fluoride hazards were identified early in the Plant's history.

Although the potential for exposure to fluorides at PORTS is widespread and involves many workers, documented overexposures have been infrequent. For decades, the industrial hygiene and safety group has maintained airborne and biological monitoring programs for fluorides. The biological monitoring program consisted of routine and special urinalysis to determine fluoride content. Routine urine samples were submitted on a frequency consistent with expected exposure frequency and concentrations, but typically on a monthly basis. In case of a probable exposure, special samples were obtained within a few hours after the event. Short-term air grab samples, area air samples, and personal breathing zone samples have been used to determine HF concentrations during work activities and to determine respiratory protection requirements. Workers at PORTS seldom exhibited urinary fluoride levels above limits. The highest recorded fluoride exposure level at PORTS was 45 mg/liter from the urine of a supervisor who had entered a fluoride release cloud without proper respiratory protection. Another worker was diagnosed with fluoride poisoning following exposure to UF_6 in 1984 at the high-assay sampling station. Before and after the X-326 stack extension in 1981, numerous workers complained of high fluorine levels causing nausea and nasal, throat, and eye irritation. Industrial hygiene sampling seldom identified concentrations above permissible limits; however, the gas dispersed rapidly, and samples may not have been representative of what workers were exposed to. A 1969 report identified HF concentrations of 3 ppm or greater outside X-705. Additionally, former worker interviews indicated that there were many releases where samples may not have been taken and where workers did not report to the Medical Department. In the early years of operation, there were a number of HF burns, and workers experienced symptoms similar to those described above.

Chlorine, at atmospheric conditions, is a greenish-yellow, non-combustible gas having a density about 2.5 times that of air. Its disagreeable and suffocating odor, as well as the irritation it causes to the nose and throat, generally warns even unwary persons, thus enabling them to escape substantial exposure. Chlorine was used in water and sewage treatment systems as a disinfectant. Industrial hygiene records indicate routine sampling for chlorine, such as the Chlorine Room in X-633. **Chlorine trifluoride** is a powerful oxidizing agent, igniting many organic compounds on contact, and it reacts violently with water. At room temperature and pressure, chlorine trifluoride is a colorless gas having a density of 3.14 times that of air. Chlorine trifluoride is extremely corrosive to tissue, and any contact with skin or eyes will typically result in severe damage. Its reactivity led to its use as a fluorinating agent in Portsmouth processes. Chlorinated compounds and chlorinated reaction byproducts were produced from the cascade process. The potential exposure of X-326 security guards to chlorinated compounds, among other factors, led to a NIOSH health hazard evaluation.

Welding has always been a common and continuing work activity at PORTS over the years, and there is a wide degree of variation in the degree of hazard that workers experienced on the job. The hazards to the eyes and skin due to sparks and fragments of hot metal were well recognized, and welders were usually well protected with face masks, gloves, and other protective clothing, including flame retardant coveralls in later years. However, the dangers from chemical exposure were not as well recognized. The type of fumes from welding depends on the metal being welded and the type of welding rod. Arc welding and plasma cutting produce irritating and oxidizing ozone gas. Degreasing fluids can remain on the metal, resulting in additional vapors. In addition, paints, grease, and other coatings may be burned and volatilized.

PORTS industrial hygienists have analyzed welding fumes since the 1950s. For example, a 1954 inspection of the machine and welding shops in X-720 identified a variety of welding fumes from welding on metals coated with cadmium, lead, mercury, and zinc. The welding included the use of fluoride welding fluxes that produced nitrogen oxides as well. One record dated in May 1957 identified significant levels of nickel and ozone in fumes from inert gas welding and heliarc welding in X-700. In 1959, elevated levels of phosgene were detected in the breathing zone of welders in X-720. In all of these early cases, ventilation requirements were evaluated, and respirators were recommended to control the hazard. A review of welding areas by Industrial Hygiene in 1973 identified nickel, uranium, copper, and iron oxide contaminants in steel metal inert gas welding in the X-720 welding shop. A Plant inspection in 1973 identified the use of cadmium and lead solders, without prior testing of local exhaust systems or without air samples to assess worker exposures. Union safety meeting minutes between 1972 and 1975 identified numerous complaints of shortages of company clothing and respiratory equipment, especially for welders.

Welders also fabricated, modified, joined, cut open, and repaired leaks on Freon systems, both within the process buildings and in X-700. The systems and components were usually drained and evacuated before cutting or welding; however, these controls were not always effective. One former worker described getting severe headaches while welding in high concentrations of Freon fumes without a respirator in the late 1970s. An Industrial Hygiene and Health Physics report addressing workers' complaints about cutting out

Freon piping in 1980 documents the exposure of eight workers to phosgene, hydrogen chloride, hydrogen fluoride, and Freon at levels exceeding safe limits. The workers had complained of a blue flash and irritating fumes. The problem appeared to result from a leaking hydrostatic test boundary valve in an adjacent cell. Welding fumes presented a variety of potential health hazards to workers from the 1950s through the 1980s. Most welding hazards were recognized and evaluated by industrial hygiene personnel, and respirators were prescribed. Some workers, however, were most likely exposed for short periods to fume concentrations greater than permissible limits, with potential for health effects.

Hydrogen cyanide gas, when inhaled, or the ingestion of cyanide salts, leads to cyanide poisoning. Cyanide has a characteristic "bitter almonds" odor that can aid in diagnosis. However, a significant percent of the population is genetically incapable of detecting this odor. Therapeutic treatment must be initiated immediately to be life-saving. At PORTS, both cyanide salts and solutions have been used by instrument mechanics engaged in copper and silver cyanide plating. Cyanide salt solutions and cyanide waste solutions were stored in toxic lockers in the instrument decontamination area of X-720. In 1982, Industrial Hygiene investigated the feasibility of installing a cyanide monitor to continuously sample cyanide fumes from silver plating operations. A 1980 memorandum from Industrial Hygiene stressed the importance of minimizing the onsite inventory of cyanide, and that large-scale plating operations should be avoided. Industrial hygiene personnel also required gloves, aprons, and face shields when working with cyanide waste solutions. A cyanide medical kit and a safety shower were required to be in the vicinity of any work involving cyanide solutions, waste, or salts. In most cases, cyanide storage and use appeared to be well monitored and controlled throughout the Plant's life.

Trichloroethene is a colorless liquid with a chloroform-like odor 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 concentrates in the respiratory system, heart, liver, kidneys, central nervous system, and skin. At PORTS, TCE became the solvent of choice in the 1970s and early 1980s. Large components were frequently cleaned in one of several vapor degreasers located in X-705, X-700, and X-720. Leaking vapor degreaser lids causing vapors and high TCE concentrations prompted a ventilation project for the building in the mid-1990s.

In the 1950s and later, bulk TCE and carbon tetrachloride were available at several locations at PORTS for dispensing to smaller containers for transport and use in hand-cleaning parts and surfaces, both in the shops and in the field. At least one interviewee remembered others using TCE to clean PCB-contaminated oil from their skin. Instrument mechanics remembered using TCE to clean control valves in the X-720 Instrument Shop and disposing of waste TCE by dumping it out the back door. The Instrument Shop also had an ultrasonic cleaner in their standards room that used TCE for degreasing. However, in response to complaints about the vapor, the unit was later removed.

A 1976 Industrial Hygiene and Health Physics report summarizing the hazards of TCE in welding areas described an incident near the X-720 Compressor Shop where airborne concentrations of TCE exceeded 700 ppm (maximum permissible concentration is 150 ppm). This occurred when an operator sprayed a suspended part with TCE over a vapor degreaser. This practice was reportedly in violation of previous recommendations. The report noted that if a welding unit had been operating in the area, which was often the case, dangerous and even fatal concentrations of phosgene could have been produced; ultraviolet rays from the welding arc can react with the chlorinated solvent vapor to produce phosgene gas. A 1980 Industrial Hygiene and Health Physics report documents the investigation of worker complaints of noxious odors while welding in the X-700 converter shop. Sampling identified TCE and phosgene in the immediate vicinity of the welders. A subsequent investigation determined that the ventilation system was not operating properly and did not provide sufficient exhaust from the chemical cleaning area to prevent TCE vapors from flowing into the converter shop.

Former workers remembered being taught not to breathe in or smoke around TCE vapors and to wear a respirator when degreasing. X-700 vapor degreaser procedures from the period 1958-1988 do not mention the use of respirators. A 1980 Industrial Hygiene and Health Physics report documents monitoring TCE concentrations during the hand-cleaning of small parts with TCE in the X-700. Based on continued problems with TCE vapor in the degreaser area, a project was funded to upgrade the ventilation. Historical evidence indicates a significant exposure to a large number of workers using TCE in several facilities, some without appropriate protection. In the late 1980s and early 1990s, as efforts were made to improve environmental programs, the use of bulk TCE was phased out and the vapor degreasers were emptied.

Other **chlorinated hydrocarbon solvents**, such as carbon tetrachloride and methylene chloride, have been used as degreasing solvents. Chlorinated hydrocarbons cause skin irritation 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 on continued exposure. Methylene chloride is a central nervous system depressant, and when metabolized in the lungs produces carbon monoxide, which readily combines with blood hemoglobin and restricts the body's uptake of oxygen. In 1980, a worker complained of lightheadedness while degreasing a compressor with a solution containing 20 percent methylene chloride. Several former workers described using carbon tetrachloride to clean the insides of equipment before initial operations, and subsequently cleaning up dust and deposits inside converter shells with a bucket of carbon tetrachloride and a sponge. Interviewees also asserted that they did not understand the hazards of these chemicals, used no respirators or gloves, and would frequently wash their hands in these cleaning agents.

Aromatic hydrocarbons were in frequent use at PORTS, but generally in lesser quantities than the chlorinated hydrocarbons. Benzene, for example, was a common industrial solvent used in the X-720 electrical and instrument maintenance shops in the mid-1950s. 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. A 1955 internal memo notes that "the use of benzene should be avoided whenever possible by substitution of a less toxic solvent." Benzene was also a common component of paints in the 1950s, and painters in the sign painting shop were cautioned on its use. It was evident that many workers were exposed to these solvents, and some had little knowledge of or regard for the short-term or long-term health effects.

Physical, Biological, and Common Industrial Hazards

Since the 1950s, line management has made a conscientious effort to identify and quantify worker hazards at PORTS, commensurate with the understanding of those hazards at the time. Asbestos has been a significant hazard at the Plant since construction. However, the hazards associated with asbestos were unknown, and efforts to sample and quantify airborne levels of asbestos were not initiated at PORTS until the 1970s. Throughout the decades, hazard identification resulted in changes in PORTS facilities, processes, and procedures to reduce or eliminate the hazard. However, there are numerous documented cases of inadequate procedures and procedural non-compliance by workers and supervisors, including monitoring, which show that these practices were common.

Polychlorinated biphenyl (PCB) is a colorless to lightly colored, viscous liquid with a mild odor. The critical pathways of exposure are inhalation, ingestion, and absorption. When humans are exposed, PCBs can affect the skin, liver, central nervous system, and respiratory system.

PCB-based oils were used at PORTS, for their stability, fire resistance and dielectric properties, in many power transformers and industrial capacitors. Until the early 1970s, these oils were periodically filtered and de-sludged, with the resulting filtrate and contaminated filter material disposed of on site. PCB oils were also used in pole-mounted transformers, synchronous condenser grounding transformers, fluorescent light ballasts, and certain oil-filled capacitors. PCB contamination was also determined to be present in cascade lubricating oil and hydraulic systems as early as 1980. During 1983, workers were informed that PCB oil contamination had been identified in the black caulking on cascade cell and unit bypass housings. PCB contamination from oil leaks was subsequently identified on other equipment, such as electrical cabling and local control center gaskets. Procedures for handling, storage, and disposal of PCB-contaminated oils were in place as early as 1977, specifying use of neoprene gloves and aprons, safety glasses, and disposable coveralls worn over regular fabric coveralls. Full-face respiratory protection was recommended when splashing was possible. Respirators were not deemed necessary, except in confined areas with large spills or when the PCBs were heated above 55 C. Because of the hazards, additional controls were placed on handling, cleaning, and disposal of spills, leaks, and waste oils.

In 1982, PCB was discovered in the gaskets in process building ventilation duct joints. The PCB contamination from ventilation ducts was carried by oil droplets from process motors to the floor of the process buildings. Therefore, management initiated a cleanup in 1983. In the late 1980s and early 1990s, PORTS installed troughs on leaking ventilation duct joints and connecting manifolds to collect PCB-contaminated oil, prevent the spread of contamination, and assure appropriate disposal. Results of limited blood sampling of workers potentially exposed to these PCBs found only two workers with measurable levels, both reportedly less than permissible exposure limits. However, it is likely that exposures were higher based on the extensive handling of PCB-contaminated oil and the lack of precautions early in Plant life. In 1990, PORTS established and began implementing a comprehensive PCB Program Management Plan. Many components previously containing PCB-contaminated oils have since been replaced or flushed to remove PCBs. Exposure to PCBs was pervasive for some work groups. Throughout industry, including PORTS, the hazards and controls for working with PCBs were not known until the 1970s. Some workers most likely were overexposed, with unknown long-term health effects.

Asbestos, as airborne fibers, can be inhaled or swallowed, and these fibers can become embedded in the tissues of the lung and digestive system. Once the fibers become trapped in the lung's alveoli (air sacs), they cannot be removed. In industry and construction, years of exposure to asbestos has caused a number of disabling and fatal diseases, including asbestosis, an emphysema–like condition; lung cancer; mesothelioma, a cancerous tumor that spreads rapidly in the cells of membranes covering the lungs and body organs; and gastrointestinal cancer, caused by ingesting asbestos-contaminated food. Like PCBs, identification of asbestos as a hazard did not emerge nationally or at PORTS until the 1970s or later. Before the 1970s, asbestos was widely used at PORTS because of its resistance to heat and corrosive chemicals. Asbestos was used extensively for construction, welding, and insulation since Plant construction. Asbestos was also used in 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. To work in hot areas or on hot pipes, workers would lie on asbestos blankets with large fans blowing air across the freshly cut asbestos blankets. This occurred in the late 1970s in X-333 and X-330. A number of PORTS workers in the 1950s to the 1970s were exposed to asbestos without knowledge of the hazards. The first asbestos control procedure was issued at PORTS in 1980. During 1980, divisional asbestos control managers were also assigned. Few controls were in place during the early decades, and the full extent of the long-term health effects is unknown.

Dust, noise, and illumination pose industrial hazards at PORTS. Many workers were exposed to high nuisance particulate (dust) concentrations and excessive noise from machinery; in some cases, work was performed in areas with poor illumination. These hazards were well recognized in the early years of the Plant. Monitoring by Industrial Hygiene often resulted in modifications to facilities and equipment. For example, in 1955 Plant industrial hygienists evaluated the impact of proposed modifications to the cascade buildings on the available lightning. A 1974 appraisal by OR identified that workers were exposed to more noise than was previously recognized, and that administrative controls (i.e., restricting workers' time in high noise areas) was not an adequate policy in lieu of issuing hearing protection devices to workers. Despite improving controls, historical documents indicate that many practices led to excess worker exposure to dust, noise, and other common industrial hazards.

Fungicides and biocides have also used been used at PORTS. Fungicides were used as an organic material preservative. Fungicides and pesticides can enter the body through ingestion, inhalation, and absorption pathways, with inhalation and skin absorption being the primary concerns. Health effects vary from minor headaches and nausea to debilitating conditions of the central nervous system.

The water for PORTS cooling towers was originally treated with sodium dichromate, sulfuric acid, and chlorine. Safer chemicals, such as phosphate and bromine-based dry chemical additives, were later substituted for the chromates and gaseous chlorine, to reduce environmental impact and enhance worker safety. Utility operators sprayed fungicide by climbing within the cooling tower structure on ladders and work platforms while dressed in protective clothing and breathing apparatus. The interior surfaces were coated with the dilute fungicide-water mixture. Steam sterilization in combination with several fungicides was utilized in 1962 and 1963 to rid the cooling towers of fungal colonies. Procedures from as early as 1961 specified protective equipment of Graylite (plastic suits) or equivalent, Graylite hoods, and neoprene gloves and boots. The 1982 version of the procedure allowed mixing with neoprene gloves and a dust respirator, but required full respiratory and outer garment protection for rinsing. Reportedly, one operator on the tower acted as a safety observer, a second operator on the tower did the spraying, and a third operator on the ground mixed the chemicals. Interviewees remembered that the safety observer and the ground person wore paper dust masks before the mid-1970s, and respirators thereafter.

Reviews of Industrial Hygiene and Health Physics records and discussions with long-time employees did not identify evidence of chemical exposure monitoring while spraying fungicides and algaecides in the cooling towers. Former carpenters interviewed expressed concern for the green dust generated during cooling tower repairs and the rotted and ice-damaged wood during the early period when they did not wear respirators. They assumed that the dust contained chromates, but the inspection team identified no monitoring data to reflect the materials and concentrations to which the carpenters might have been exposed. An industrial hygiene survey in November 1976, addressing the mist of an operating cooling tower, determined that all chemicals for which they analyzed were below established limits. However, this sampling may have no correlation to concentrations possibly encountered during spraying or cutting cooling tower wood with power saws.

Cooling tower operating procedures from as early as 1984 required respiratory protection against the possible presence of bacteria while working on top of an operating tower and within heavy mist. The principal concern is Legionnaire's Disease bacteria (LDB), a naturally-occurring bacterium that has been monitored in PORTS cooling towers since 1979 and has on occasion reached potentially infectious levels. Control of LDB was implemented with halogen shock treatments, and with a control level well below assumed infectious levels. Earlier versions of the procedure also referenced concern for asbestos fibers, first detected in the cooling towers in 1975 and derived from asbestos-bearing fill material. Following asbestos abatement in the late 1980s and early 1990s, cooling tower fiber levels have dropped and are no longer a concern. Interviewees remember not wearing respirators on the towers in the early years and saw the change in requirements as an improvement in safety. The hazards associated with fungicides and biocides were identified, monitored, and controlled for some workers (e.g. cooling tower sprayers), but not for all workers (e.g., carpenters).

APPENDIX B
PRINCIPAL ACTIVITY EVALUATION SUMMARY

Table B-1 outlines the principal activities conducted at PORTS between 1952 and 1997, and provides an assessment of the hazards that may have been encountered by these activities, the controls available and generally used to mitigate the hazards, and the effectiveness of the controls when implemented. Acronyms are defined at the end of the table.

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Ash handling	X-344, X-705E	RAD, exposure to UF_6 gas, and inhalation of dust containing uranium and concentrated daughter products; TRU and fission products at X-705 only	Film badge or TLD, PPE, stay time, worker rotation, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Buffer modification of G-17 valve	Process buildings	RAD, UF_6, HF, UO_2F_2, uranium daughters, fission products, TRU, and heat stress	Film badge or TLD, PPE, wood plugs, ventilation, bioassay	Effective when used correctly	1982-1983
Building access (to perform various duties, such as deliveries)	All Plant facilities	See full range of hazards described for all Plant facilities	Film badge or TLD, PPE, bioassay, housekeeping, postings	Minimally effective when used correctly prior to 1988 Effective when used correctly after 1988	1953-1987 1988-1997
Burial of classified and contaminated materials	X-749, X-749A	RAD, UF_6 gas, nickel carbonyl, asbestos	Film badge or TLD, PPE, stay time, bioassay	Effective when used correctly	1953-1997
Can and drum crushing	Process buildings, X-705, X-720, X-740	RAD, UO_3, TRU, technetium	Film badge or TLD, PPE, bioassay	Effective when used correctly	1997
Carpentry	Cooling towers	Asbestos, arsenic, fungicides, sulfuric acid, chromates, noise, STF, Legionnaire's Disease	PPE	Effective when used correctly.	1952-1997
Collection of uranium oxide powder from calciner	X-705	Inhalation of insoluble airborne uranium, TRU	PPE, bioassay	Moderately effective when used correctly	1954-1997

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Crane operation	Process buildings	RAD, PG, heat stress	PPE, bioassay	Effective when used correctly	1953-1997
Cross connection of sanitary water and contaminated condensate systems	Steam plant	RAD, ingestion or inhalation of particulates	Removal of cross-connection in early 1990s	Effective when used correctly	1979-1997
Cutting or welding Freon pipe	Process buildings, X-700	Phosgene, hydrogen chloride, burns	PPE, ventilation, Freon evacuation procedures	Effective when used correctly	1954-1997
Cylinder heel cleaning	X-705	RAD, UF_6 gas, TRU, NC, chemical burns, concentrated fission and daughter products	Film badge or TLD, PPE, bioassay, ambient air flow, cylinder net weight determination, enclosed cleaning system	Moderately effective when used correctly; beta dose to eyes not measured	1954-1997
De-blading of compressor rotor and stator	X-705	RAD, UF_6, HF, UO_2F_2, TRU, technetium, fission and uranium daughter products, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, ventilation	Moderately effective when used correctly	1954-1997
Decontamination of equipment	Process buildings, X-705, X-720 instrument room	RAD, UF_6, HF, UO_2F_2, TRU, NC, PCBs, acids, solvents, uranium daughter and fission products, asbestos, chemical burns	Film badge or TLD, PPE, stay time, bioassay, ventilation, geometry, sampling, uranium mass determination	Moderately effective when used correctly	1954-1997
De-smoking ash pots through building ventilation	X-705E	RAD, TRU, HF, UF_6, UO_2F_2 contamination at building vents and release to environment	None	Ineffective	1958-1966
Disassembly of stuck shut G-17 cell block valves	X-705	RAD, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products, noise, burns, NC	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, disassembly procedure, shop evacuation, ventilation, geometry, sampling, uranium mass determination	Effective when used correctly	1955-1997
Draining cold traps	X-705E	RAD, UF_6, UO_2F_2, HF, TRU, NC	Film badge or TLD, PPE, bioassay, geometry and sampling	Effective when used correctly	1958-1978

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Duct maintenance	All buildings	RAD, UF_6, PCBs, fluorine, strychnine from pigeon feces due to poisoning	Film badge or TLD, PPE, bioassay	Effective when used correctly	1954-1997
Dumping uranium from vacuum collector to drums and returning uranium to process	X-344, X-705	RAD and inhalation of uranium dust	Film badge or TLD, PPE, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Electrical maintenance	All	PCBs, solvents, electrocution, noise	PPE, work permits	Effective when used correctly	1953-1997
Fire box cleaning at steam plant (annual)	Steam Plant	Airborne arsenic from coal combustion	PPE, air monitoring after discovery of hazard in late 1989; only paper mask worn prior to 1989	Effective when used correctly Ineffective before 1989	1953-1997
Flange grinding	Process buildings, X-700, X-720, X-705	RAD, UF_6, HF, UO_2F_2, TRU and uranium daughter products, noise, heat, asbestos, cadmium, nickel fumes	Film badge or TLD, PPE, bioassay, decontamination, ventilation	Effective when used correctly	1954-1997
Groundskeeping	All	RAD, PCBs, asbestos, arsenic, fungicides, radioactive dust	Film badge or TLD, PPE, bioassay	Moderately effective when used correctly	1952-1997
Guard patrolling	All facilities and roads	See full range of hazards described for all Plant facilities	Film badge or TLD, PPE, contamination surveys, bioassay	Moderately effective when used correctly	1953-1997
Guard drills	All facilities and roads	See full range of hazards described for all Plant facilities	Film badge or TLD, contamination surveys, bioassay	Ineffective	1983-1995
Incinerator operations	X-705 Incinerator (New and Old)	RAD, PCB, barium, cadmium, radioactive dusts	Film badge or TLD, PPE, bioassay	Effective when used correctly	1959-1985
Industrial photography	All buildings	RAD, PG, UF_6, STF	Film badge or TLD, bioassay	Effective when used correctly	1952-1997
Instrument maintenance	X-720, X-770, and satellite instrument shops	RAD, HF, UF_6, TRU, uranium daughters and fission products, acids, mercury, solvents, burns, cyanide	Film badge or TLD, PPE, bioassay, decontamination, ventilation	Effective when used correctly	1954-1997

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Jetting/Venting	Process buildings	RAD, UF_6, HF, UO_2F_2, TRU and uranium daughters released to environment	Film badge or TLD, bioassay, procedures specified limiting venting to only purging cells with < 20 ppm UF_6	Effective when used correctly	1953-1997
Landfill operations	Peter Kiewit, X-734, X-735	Asbestos and ash from coal-fired plant, dust from contaminated building rubble	Administrative controls on disposal items; in early 1980s added controls on asbestos and building rubble disposal	Effective when used correctly	1955-1997
Lithium repackaging	X-740 warehouses	Lithium hydroxide monohydrate (LiOH) exposure	Respirator	Effective when used correctly	Mid-1980s
Lithium relocation	X-740 warehouses	LiOH exposure	Dust masks	Minimally effective when used correctly	1977-1980
Lubrication	All	PCBs, solvents	PPE, decontamination	Effective when used correctly	1987-1990
Machining	X-710, X-720	Lead, PG, solvents, uranium, beryllium	PPE	Effective when used correctly	1953-1997
Mercury handling	Laboratory, X-705 recovery room, X-720, process buildings	Spills, mercury vapor and contamination	PPE, containment, decontamination, ventilation	Effective when used correctly	1953-1997
Operation and maintenance of uranium recovery system (by solvent extraction and other uranium solution processing and storage)	X-705	RAD, TRU, technetium, airborne uranium, radioactive effluents, NC	Film badge or TLD, bioassay, PPE, effluents were sampled and release limits were applied, geometry and sampling	Moderately effective when used correctly	1954-1997
Plating	X-720	Cyanide, halide, ammonia, hydrogen cyanide, acids	PPE, ventilation	Effective when used correctly	1954-1997
Product withdrawal during normal operations	X-326, X-330, X-333	RAD, UF_6, TCE	Film badge or TLD, PPE, stay time, worker rotation, bioassay, ambient air flow	Effective when used correctly	1954-1997
Pulverizer operations and maintenance	X-705E, X-344	RAD and inhalation of dust containing uranium, fission products; thorium, TRU (including Np and Pu) at X-705 only	PPE, film badges or TLD, bioassay, ambient air flow	Moderately effective when used correctly	1957-1978 (X-705E) 1958-1962 (X-344)

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Receiving and using K-25 equipment	X-15, X-705, process buildings	RAD, UF_6, NC, HF, uranium compound deposits, TRU, technetium	Film badge or TLD, PPE, bioassay, purging, ventilation, decontamination, evacuation	Moderately effective when used correctly	1980-1997
Release response	Process and support buildings	RAD, inhalation of radioactive materials, skin contamination, chemical burns	Film badge or TLD, PPE, bioassay, ventilation, decontamination procedures, response kit	Effective when used correctly; ventilation systems were frequently inoperable	1954-1997
Removal of “000” compressors stub shaft	X-705	RAD, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products, NC, burns, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, ventilation, pit evacuation, sampling, uranium mass determination	Effective when used correctly	1957-1978
Removal of compressor seals	Process buildings, X-705	RAD, HF, UO_2F_2, TRU, fission and uranium daughter products, burns, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, ventilation, evacuation	Effective when used correctly	1954-1997
Removal of converter shell internal fixtures	X-705	RAD, uranium compound deposits, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products, burns, noise	Film badge or TLD, PPE, bioassay, UF_6 Negative procedure, additional purge in cell, evacuation	Effective when used correctly	1957-1993
Replacement of full UF_6 cylinder valve	X-343 X-344 X-705	RAD, UF_6, HF, UO_2F_2, TRU, fission and uranium daughter products	Film badge or TLD, PPE, bioassay, repair procedure, cooling cylinder to sub-atmospheric, and emergency response procedures	Effective when used correctly	1954-1997
Reproduction	X-100 reproduction facility	Naphtha; hydrochloric, sulfuric, phosphoric, citric, and acetic acids; ammonia; methyl alcohol; skin burns from carbon arc lamps; TCE	PPE	Effective when used correctly	1952-1997
Roof access	Various buildings	Venting HF, uranium, and other chemicals to roof	Bioassay; roof access controls implemented in X-710 in 1963	Ineffective Effective when used correctly	1954-1991 1992-1997
Sand blasting	X-744G	Silicon dioxide	PPE	Effective when used correctly	1954-1997

Table B-1. Portsmouth Gaseous Diffusion Plant Principal Hazardous Activity Evaluation Summary: 1952-1997 (Continued)

Activity Description	Plant Location(s)	Potential Hazard(s)	Hazard Control(s)	Hazard Control Effectiveness and Use	Time Period
Smelting	X-744G	RAD, HF, PG, airborne uranium, TRU, process heavy metals	Film badge or TLD, PPE, air samples, bioassay	Moderately effective when used correctly	1961-1983
Spraying cooling towers with fungicide and corrosion inhibitors	Cooling towers	Fungicides, sulfuric acid, arsenic, chromates, Legionnaire's Disease, asbestos, noise, STF	PPE	Effective when used correctly	1953-1997
Transformer maintenance	All	Electrocution, PCBs, asbestos, confined space, solvents	PPE, work permits, ventilation	Effective when used correctly	1950s-1997
Unplugging feed plant transfer lines, hoppers, and conveyers using sledge hammers and rods during normal operation	X-344	RAD, UF_6, inhalation of uranium dust, noise	Film badge or TLD, PPE, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962
Unplugging fluorination towers	X-344, X-705	RAD, TRU (in X-705 only), NC, exposure to UF_6 gas, inhalation of dust containing uranium and fission products (X-705 only)	Film badge or TLD, PPE, stay time, bioassay, ambient air flow, geometry, and sampling	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Uranium powder conveyer, hopper, and other equipment maintenance and replacements	X-344, X-705	RAD and inhalation of uranium dust	Film badge or TLD, PPE, bioassay, ambient air flow	Moderately effective when used correctly	1958-1962 (X-344) 1957-1978 (X-705)
Welding	Process buildings, X-700, X-720	RAD, UF_6, PG, HF, UO_2F_2, acids, uranium and fission products, asbestos, heat stress, thermal burns, phosgene, nickel fumes	Film badge or TLD, PPE, bioassay	Effective when used correctly	1954-1997

Key:

CIP Cascade Improvement Program
CUP Cascade Upgrade (or Uprating) Program
HF Hydrogen Fluoride
NC Risk of nuclear criticality
NDA Nondestructive Analysis
Np Neptunium
PCB Polychlorinated Biphenyl
PG Process gas
PPE Personal Protective Equipment (includes one or more of: respirator, shoes, gloves, caps, eye protection, ear plugs, and contamination clothing)
Pu Plutonium
RAD Includes one or more of alpha, beta, or gamma radiation
STF Slips, trips, and falls (common industrial accidents)
TCE Trichloroethene
Th Thorium
TLD Thermoluminescent Dosimeter
TRU Transuranic
Note: Bioassay includes urinalysis and/or in-vivo lung counting.

WEMS
Wastren-EnergX Mission Support, LLC

Portsmouth Information Release Approval Request

I. Document / Information Description
(To be filled out by Requestor)

ID Number: ~~DOE 2000~~ N/A

Originated Date: ~~10-01-12~~ 05/2000

Document Title or Identification: Office of Oversight, Environment, Safety and Health, Independent Investigation of the Portsmouth Gaseous Diffusion Plant, Volume 1

Original Author(s) / Organization: U.S. Department of Energy

Technical Editor(s) /Organization: U.S. Department of Energy

Format: ☒ Document: 99 Total # Pgs ☐ Transparencies / Presentations
☐ Photos: ____ # Prints ☐ Electronic Media: Type ____

Audience: ☐ Public Meeting ☐ Private Meeting ☐ Presentation to Congress
☒ Distribution List ☐ Internet Publication ☐ Publication/Press Release

Justification: For inclusion in Waste Disposition Administrative Record

Requestor: Sue Chabot-Mack Date: 10-01-12
Legible Signature or Print Name & Signature

II. Patent, Classification and Protected Information Review
(To be completed by the PORTS Classification Office)

	Yes	No	
Patent/Proprietary Review:	☐	☑	Contains Patentable or Proprietary and/or has clearance patent information
Classification Review:	☑	☐	Document is Unclassified
	☐	☑	Document is Classified
Sensitive Information Review:	☐	☑	Contains Official Use Only (OUO)
	☐	☑	Contains Export Controlled Information (ECI)
	☐	☑	Contains Unclassified Controlled Nuclear Information (UCNI)
	☐	☑	Contains Personal Identifiable Information (PII)
	☐	☑	Contains other Protected Information, describe:

III. Information Release Approved or Denied
(To be completed by the PORTS Classification Officer)

☑ Approved for Public Meetings, Widespread Distribution, or Presentation to Congress
☑ Approved for Publication, Media Broadcast, and/or Public Website
☐ Approved for Internal Distribution Only
☐ Approved for Publication on the Internal Network only (access restricted to network users only)
☐ Not Approved for Release
☐ Approved with restrictions (describe): ____

H A Thomas 10/2/12
Classification Officer/Technical Information Officer Signature / Date

Send to OSTI? ☐ Yes ☒ No

Note: Requestor must retain a record copy of all requests (approved or rejected) and material being released. Classification Officer send a copy of this form to TPMC Records Management and Document Control.

FSSF-4101 (3-10)