TPMC/PORTS-154

Environmental Management
& Enrichment Facilities

Purge and Evacuation Requirements During Decontamination and Decommissioning of Process Facilities at the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

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Henry Thomas 8/15/2007

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Theta Pro2Serve Management Company, LLC
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Purge and Evacuation Requirements During Decontamination and Decommissioning of Process Facilities at the Portsmouth Gaseous Diffusion Plant Piketon, Ohio

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managing the
Infrastructure Activities at the
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ACRONYMS

CSB	cold standby
CSD	cold shutdown
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
ETTP	East Tennessee Technology Park
PORTS	Portsmouth Gaseous Diffusion Plant
S&M	surveillance and maintenance
USEC	United States Enrichment Corporation

EXECUTIVE SUMMARY

Planning for the decontamination and decommissioning (D&D) of the Portsmouth Gaseous Diffusion Plant (PORTS) is currently underway, and D&D is expected to begin in a few years. D&D will involve removal and disposal of process equipment and auxiliary systems followed by demolishing the process buildings and removal of resulting debris. The U.S. Department of Energy (DOE) has invested several years of extensive chemical treatments and equipment purging operations to reduce the amount of uranium compounds and other volatile gases [i.e., uranium hexafluoride (UF_6), hydrogen fluoride (HF), etc.] that are hold-up in the internal components of the process equipment.

In order to ensure that airborne HF and UF_6 levels remain well below Occupational Safety and Health Administration/National Institute for Occupational Safety and Health standards during the PORTS D&D process equipment removal, the capability to evacuate and refill cells and process piping with air should be maintained. The air ejector system and the plant air system in the process buildings will effectively perform that function.

Since quantities of UF_6 that would require separation and recovery of the UF_6 from light gases are not expected to be encountered during D&D, process systems installed for the UF_6/light gases separation process should not be required. These systems include the purge cascade, evacuation booster stations, surge drums, and cold traps.

1. INTRODUCTION

The Portsmouth Gaseous Diffusion Plant (PORTS) was shut down in two phases; the X-326 Process Building, which was primarily used for production of highly enriched uranium, was shut down in 1992, except for operating cells in the Purge Cascade; and the remainder of the gaseous diffusion process, which continued to produce low enriched uranium after 1992, was shut down in 2001. The Purge Cascade has continued to operate after 2001 supporting ongoing programs of process equipment chemical deposit removal and a United States Enrichment Corporation (USEC)/U.S. Department of Energy (DOE) program to remove technetium from uranium feed material.

Planning for the decontamination and decommissioning (D&D) of PORTS is currently underway, and D&D is expected to begin in a few years. D&D will involve removal and disposal of process equipment and auxiliary systems followed by demolishing the process buildings and removal of resulting debris.

This report addresses the evaluation of evacuation approaches of the process equipment during the D&D process.

1.1 BACKGROUND

Both phases of the PORTS shutdown involved removal of uranium hexafluoride (UF_6) gas from process equipment followed by purging with dry air to a UF_6 "negative" of <10 ppm at 2 psia cell pressure. After purging, the cells were pressured to atmosphere with dry air. Extensive cell chemical treatments have been conducted following the X-326 Process Building shutdown and following the shutdown of the remainder of the gaseous diffusion process (X-330 and X-333 Process Buildings) to remove solid uranium deposits. Such chemical treatments result in the reaction of the chemicals with the solid uranium deposits forming gaseous UF_6 and other gaseous reaction products. Following chemical treatment, cells were again purged and refilled with dry air.

The PORTS operating gaseous diffusion plant includes a purge cascade designed to separate UF_6 from lighter molecular weight gases such as nitrogen, oxygen, and cell treatment chemicals and resulting reaction products. A general schematic diagram in Fig. 1 shows the location of the purge cascade within the X-326 Facility. Proper operation of the purge cascade provides pure UF_6 near the top of the isotopic cascade that can be liquefied and condensed into cylinders, and the light gases pass through the top cells of the purge cascade, through chemical traps, air ejectors, and to atmosphere through a stack regulated by an air permit. Since the ongoing cell treatments following the PORTS shutdown produced a mixture of gaseous UF_6, chemical treatment reaction products, and dry air (added as part of the treatment process), operation of the purge cascade has continued to be necessary throughout the cell treatment program.

The USEC/DOE program to repackage existing DOE uranium material into compliant uranium feed cylinders and remove technetium from uranium feed material has also been supported by the operating purge cascade at PORTS. The technetium removal program required purging of lines containing UF_6, and the purging operation resulted in a mixture of gaseous UF_6 and dry air. This mixture was piped to the purge cascade where the UF_6 and dry air were separated, with the UF_6 being condensed and packaged in cylinders and the dry air discharged to atmosphere through chemical traps.

At PORTS there are actually two purge cascades—top purge and side purge and each consists of five cells (see Fig. 1). The purge cascades are specially designed cells to remove lights gases from UF_6 using

the gaseous diffusion process. Both top and side purge are in the X-25-7 unit in the X-326 Process Building. Since the X-326 contains 200 cells including the purge cascades, the purge accounts for 5% of the equipment in the X-326 Facility. Each cell contains six stages. Two of the cells in each purge cascade are low-speed cells and the other three cells contain speed increasers and special impellers that operate at higher speeds. The higher speeds are necessary at higher levels of light gases to maintain the compression ratios required to effect separation across the barrier.

Currently only the top purge is operating—the side purge is shut down. Four of the five cells in the top purge are operating to serve the deposit removal program and the uranium feed technetium removal program.

In addition to the four operating cells in the top purge, approximately 12 additional cells are operating in units X-25-7 and X-27-1 to support the purge cascade and to provide the process equipment necessary to allow removing the UF_6 liberated during the deposit removal program into product cylinders. UF_6 is removed and packaged into cylinders in the Extended Range Product Station at the northeast corner of the X-326 Process Building.

In order for the purge cascade to effectively separate UF_6 and light gases, at least two of the three higher speed cells and six to eight other low speed cascade cells must be operating.

If no separation is necessary, such as using the purge cascade to move air and/or HF from cells, no cells would be necessary. In that case, the flow could be taken directly to the top air ejectors, through chemical traps, and to atmosphere.

The process building cold traps located in the X-330 Building and X-333 Building will separate UF_6 from light gases, but the UF_6 remains in a solid phase, then it must be heated and returned to the cascade in the gas phase where the purge cascade further processes the material to allow packaging into cylinders. Significant modifications would be necessary to the cold trapping systems to allow UF_6 transfer directly to cylinders.

A cell monitoring program was conducted throughout cold standby (CSB) and cold shutdown (CSD) at PORTS. The cell monitoring program has periodically sampled cells for UF_6, HF, and moisture. This data verifies that after the cells have been purged and evacuated to a UF_6 negative (< 10 ppm UF_6), no significant volatile UF_6 is generated over time. In fact, during FY 2006, 100 of 101 cell samples that were taken continued to meet the UF_6 negative criteria. As of May 2007, 58 of 59 cell samples taken in FY 2007 were found to meet the UF_6 negative criteria. This data provides a sound basis to assume that only very low amounts of UF_6 in cell equipment is expected at D&D.

The CSB and CSD cell monitoring program does show modest increases in the HF for shutdown cells. Since January 2006, HF concentrations have been found in cells to range from 2 to 874 ppm. The continued evolution of HF is, in large part, due to the slow desorption of HF from the internal equipment surfaces. Therefore, it is prudent to maintain a configuration of equipment and systems from the PORTS facilities capable of purging the HF to a low as reasonably achievable level prior to removal and disposition of the equipment.

Both the cell chemical treatment program and the USEC/DOE program to remove technetium from uranium feed material are expected to be completed prior to the initiation of the process equipment removal phase of D&D at PORTS.

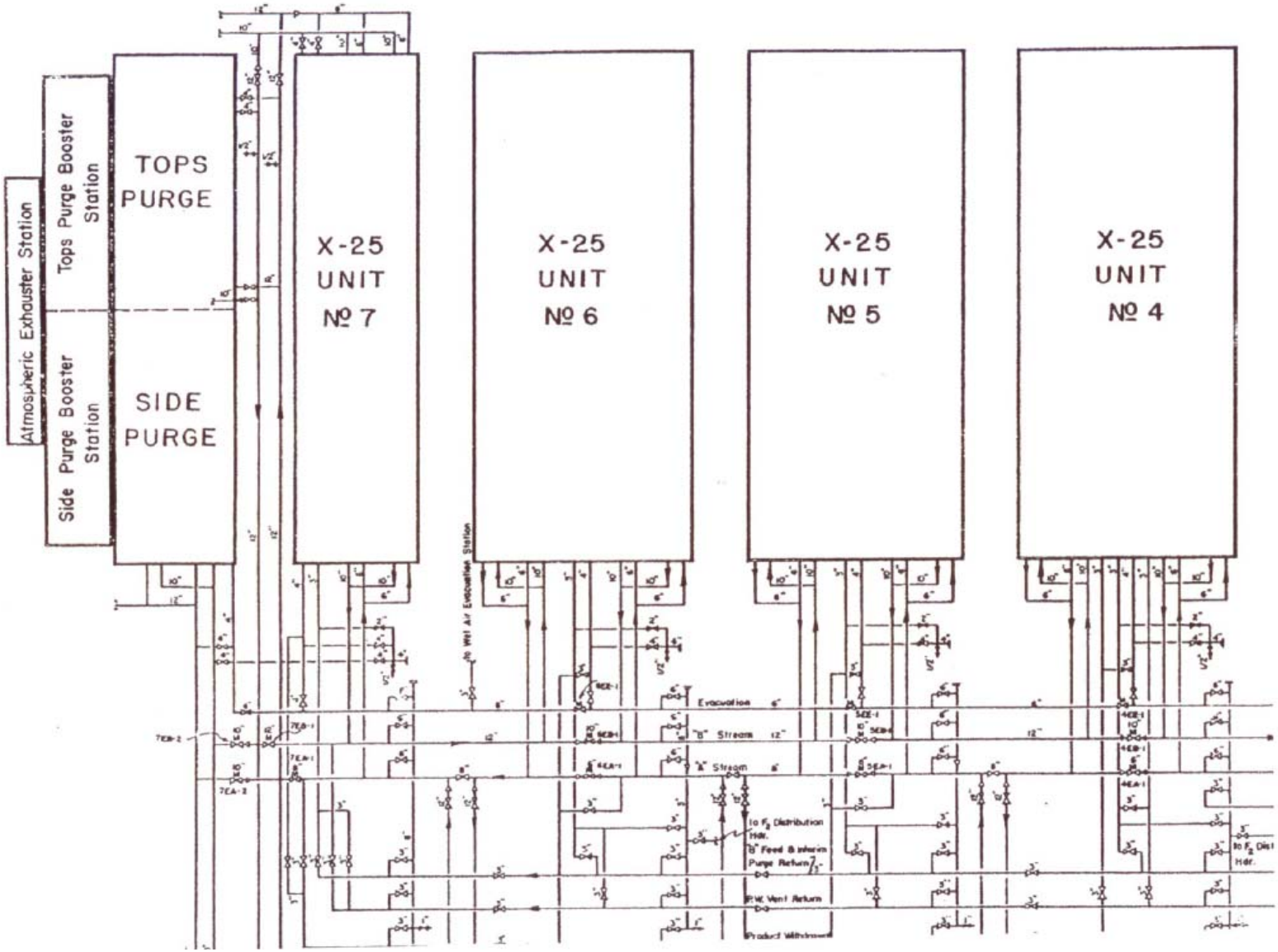

Fig. 1. Purge Cascade schematic diagram.

2. PORTS D&D PROGRAM

The PORTS D&D program will involve the removal of process equipment in all three process buildings and disposal of the equipment in approved disposal facilities. Although this equipment has been chemically treated extensively to remove solid uranium deposits, and the cells have been purged of the gaseous reaction products and pressured to atmosphere with dry air, some residual uranium deposits remain. Since HF is a primary reaction product of UF_6 and moisture, some residual HF should be anticipated to be encountered as process equipment is opened and removed. In order to minimize the potential for HF outgassing and employee exposures, equipment and procedures should be in place to ensure that any potential HF that has accumulated in the process equipment during shutdown is removed prior to opening the system during D&D.

During operation of the gaseous diffusion plants, cells that were purged to a UF_6 "negative" awaiting maintenance and were placed in a backlog for several weeks until the maintenance could be performed have been known to "lose the negative" and require re-purging in order to get the UF_6 and/or HF levels down to acceptable levels prior to cutting the equipment in preparation for removal. The maximum levels of HF contained inside cells and process equipment that have been shut down for extended periods can be expected to reach the immediately dangerous to life or health level of 30 ppm at 1 atmosphere pressure (NIOSH 2005). Removal of this HF through wet air evacuation systems should remove much of the HF in chemical traps and dilute the remainder through air ejectors before exhausting to atmosphere.

Removing the HF from the cells and process equipment and refilling the cells and equipment with air should reduce levels to the <10 ppm range prior to cutting into the cell.

Based on cell monitoring data collected during CSB and CSD, similar situations should be anticipated during D&D since the cells have been shut down for a significant time following chemical treatment and purging.

The air ejector at the purge cascade can be operated and used to remove HF and air from cells prior to opening for D&D. The HF will pass through the purge cascade along with oxygen and nitrogen and be exhausted through chemical traps and air ejectors through a stack at the south end of X-326 Process Building to atmosphere. The air ejector would dilute the HF as it is exhausted to atmosphere.

Since no separation of UF_6 and light gases is necessary, if it is desired to use the purge cascade air ejector to move air and/or HF from cells, no purge cascade cells would be necessary. In that case, the flow could be taken directly to the top air ejectors, through chemical traps, and to atmosphere.

The PORTS process buildings each contain "air evacuation" systems consisting of chemical traps and air ejectors. In addition to the X-326 top purge air ejector described earlier, there is an air ejector system in both the X-330 and X-333 Cold Recovery Areas. A line diagram of the X-330 air ejector system is shown in Fig. 2. The air ejector system in these facilities would bypass the area surge drums, evacuation booster station, and cold traps. With the air ejectors and evacuation system piping, each cell and each section of process piping can be evacuated to a low pressure, removing any excess HF or UF_6. Cells and process piping can be evacuated and refilled with dry air just prior to cutting out and removing equipment to ensure that HF and UF_6 levels are at or below "negative." Cells and process piping can be sampled after evacuating and refilling with dry air to assure HF and UF_6 levels are below those needed for worker and environmental protection.

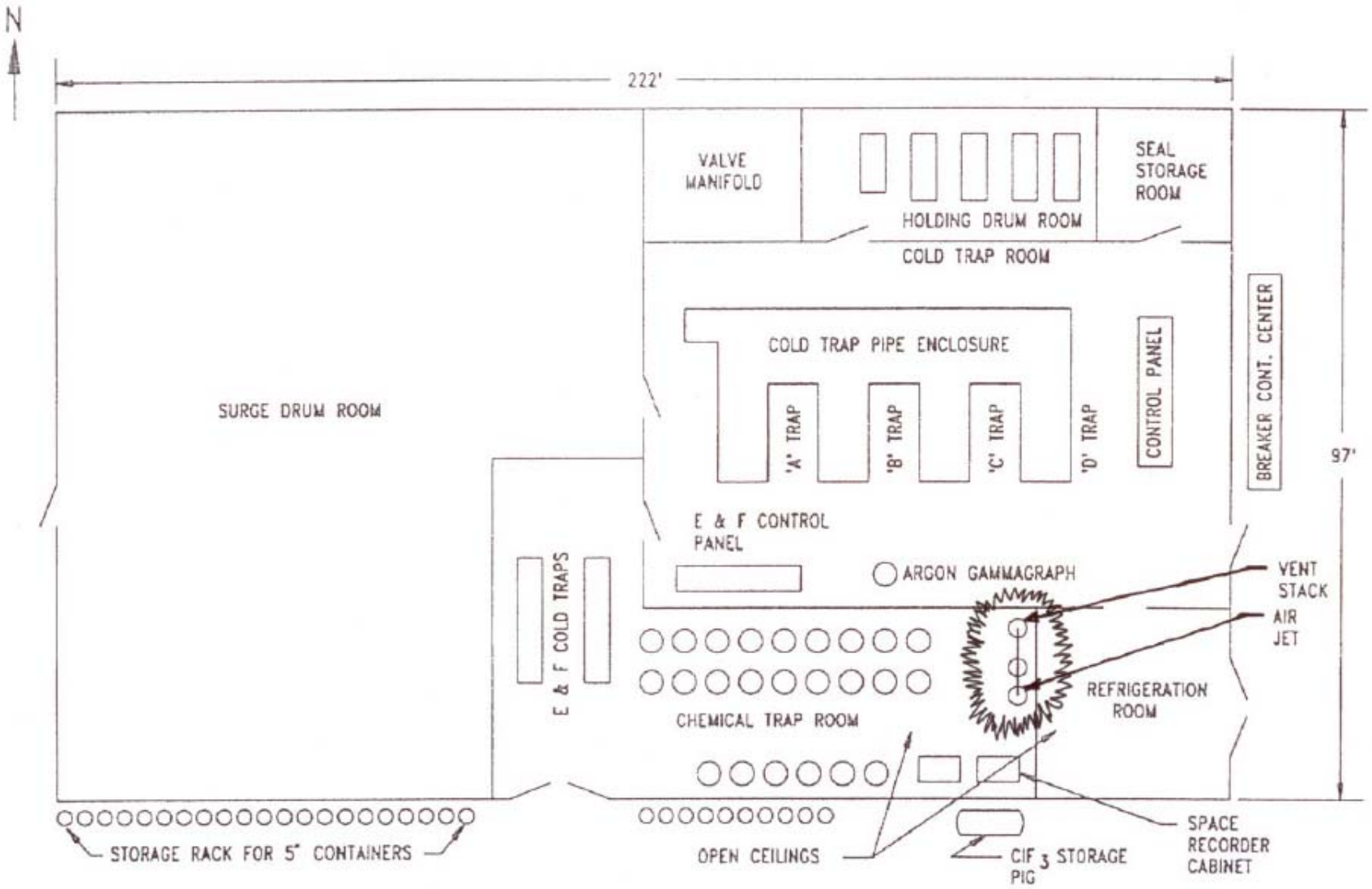

Fig. 2. X-330 Air Ejector System.

Since the only constituents expected to be encountered are HF, low levels of chemical treatment reaction products, and low levels of UF_6 in dry air, processing through chemical traps prior to atmospheric discharge will be the only cleanup required for evacuating and refilling cells and process piping during D&D. Consequently, there is no need for purge cells, evacuation booster stations, surge drums, and cold traps during D&D. The purge cascade can be shut down as soon as the chemical deposit removal program and technetium removal programs are complete and subjected to D&D along with the remainder of the gaseous diffusion equipment. Using the air ejector systems during D&D will require that D&D sequencing place process equipment removal ahead of removal of the air ejector systems.

The consequence of maintaining only the air ejector systems during D&D is a large cost savings over operating the purge cascade as shown in Table 1. During periods of no cell evacuations, the air ejector system requires essentially no maintenance. Prior to operation, the air ejector system will require calibrations of the space recorder and continuous flow analyzer as well as adequate absorption capacity of the chemical traps associated with the vent emission. In addition, during venting operations, the alumina traps associated with the continuous flow analyzer must be changed and analyzed weekly to adequately monitor the uranium and fluoride regulated emission levels. The estimate for operating the air ejector system is based on maintenance records over the past two years and is detailed in Appendix A.

In contrast to the minimal cost of maintaining and operating the air ejector system, the current cost of maintaining and operating the purge cascade is very significant. Based on actual direct costs incurred in May 2007, the cost to currently operate the purge cascade is approximately $9,700,000 per year (see Appendix B for details). Just as in the case of the air ejector system, during periods of no purge and evacuate operations [surveillance and maintenance (S&M) only], the purge cascade could be shutdown and all maintenance activities deferred until operations resumed. However, in the case of the purge cascade, a very significant start-up cost will be incurred to restart the cell equipment and re-establish appropriate calibrations, settings and preventive maintenance requirements. As recently as 2003, the purge cascade operations in the X-326 Building were shutdown and then restarted after only a few months of inactivity. Maintenance records for reactivating the purge cascade are summarized in Appendix C. In total, over 13,600 maintenance hours were expended at a cost of approximately $1,500,000 to restart the operations in this facility. It is reasonable to expect that the restart cost will increase as the period of inactivity increases.

The cost estimates presented in Table 1 for both the operation of the air ejectors and purge cascade are incremental to the cost of the source of air. Since the cost of air is the same in both cases, it is neglected for comparison purposes.

Table 1. Cost comparison of air ejector vs. purge cascade

System	S&M annual cost	Operating annual cost
Purge cascade	$0	$9,700,000
Air ejector	$0	$144,000

Clearly, there is a large cost advantage to using the air ejector system for purge and evacuation needs during D&D. There are two alternative modes to operate the air ejector system. Further evaluations must be done to determine whether it would be more economical to run the PORTS dry air system for the air ejectors and cell refilling or more economical to purchase package compressors that may be able to produce the needed pressure and flow of air. Since the process equipment will be removed and disposed of, if criticality safety requirements allow, compressed air that has not been through a dryer may be acceptable for evacuating and purging cells and process piping during D&D.

Finally, another alternative for purge operations during D&D has been implemented at the East Tennessee Technology Park (ETTP) for the K-25/27 D&D project. At ETTP, openings are cut into the equipment and ambient air is drawn through a high-efficiency particulate air filter to purge the system of hazardous volatile materials. This system should effectively purge the equipment and the system is likely to be very cost effective. However, there are three significant considerations that must be investigated before implementation at PORTS. First, the portable system requires that the process equipment must be breeched before the purging operation. Since the K-25/27 process equipment has been breeched for various reasons over the years, this is not an issue at that site. However, PORTS facilities have been maintained in standby and higher levels of HF have been identified during CSB and CSD. The safety risk for exposure to hazardous materials is therefore increased over the air ejector or purge cascade alternatives. The extent of this risk must be evaluated further in detail. Second, the gaseous emissions from the process facilities are regulated and reported through the National Emission Standards for Hazardous Air Pollutants program. Implementing the portable purge system involves a significant change to that regulatory agreement and must be evaluated further in detail. Third, the ETTP model of the portable purge system pulls only ambient air through the process equipment. It is not designed to dry the air purge. A nuclear criticality safety evaluation must be performed to ensure the safety of this operation.

3. CONCLUSIONS AND RECOMMENDATIONS

A system to evacuate and re-fill cells with air during PORTS D&D should be maintained in order to ensure that airborne HF and UF_6 levels are maintained well below required limits for worker protection. This capability can be realized by maintaining the air ejector systems in the process buildings operational during D&D. Based on current information, maintaining the air ejector systems provides a clear cost savings over using the purge cascade for this purpose. Additional savings may be possible compared to the installed air ejector systems by using portable compressors and evacuation systems. Analysis of the costs and effectiveness of using the installed air ejector systems versus portable systems should be performed before the decision on purge and evacuation capability is made.

There is no benefit to maintain the capability to separate UF_6 from light gases and recover the UF_6 since significant quantities of UF_6 are not expected to be encountered during D&D. This conclusion is based on the assumption that the current inventory of recoverable UF_6 in the cascade is very low, and use of the purge cascade and product withdrawal system would result in the recovery of a limited amount of UF_6 (in the range of a few kilograms). This is based on review of operational observations, cell monitoring data, and non-destructive assay (NDA) data during the deposit removal program, the technetium removal program, and the CSB and CSD programs. Chemical treatments and the technetium removal program are expected to be completed prior to initiation of D&D process equipment removal. Any small residual amounts of UF_6 remaining after the conclusion of these programs can be adequately removed by the chemical traps preceding the air ejector system. The purge cascade, evacuation booster stations, surge drums, and cold traps can be removed during the D&D program without need for maintaining these capabilities.

Prior to shutting down the PORTS purge cascade, DOE should review potential new programs that may need the capability to separate UF_6 and light gases. An analysis and evaluation of the separation alternatives including maintaining the PORTS purge cascade should be considered.

4. REFERENCES

NIOSH (National Institute for Occupational Safety and Health) 2005. *NIOSH Pocket Guide to Chemical Hazards*, NIOSH Publication No. 2005-149, September 2005.

APPENDIX A

COST ESTIMATE CALCULATIONS FOR THE AIR EJECTOR SYSTEM

Cost Estimate for the X-330 Cold Recovery Air Ejector System Operations and Maintenance

Costs for X-330 Cold Recovery Air Ejector System 07/01/05 thru 06/30/07				
WBS	**Task description**	**RCC**	**Hours charged**	**Cost @ $110/hr**
CSMA0101	Measure air-flow at Cold Recovery	6635 - Shops	2.00	$220.00
CSMA0101	PM Exhaust Ventilation	6801 - Cascade Mechanical	15.40	$1,694.00
CMSA0217	Calibrate Space Recorder	4742 - Cascade I & C	13.40	$1,474.00
DRMA0129	Calibrate Space Recorder	4742 - Cascade I & C	15.40	$1,694.00
DRMA0129	Calibrate Space Recorder	4742 - Cascade I & C	12.00	$1,320.00
DRMA0129	Calibrate Space Recorder	4742 - Cascade I & C	11.10	$1,221.00
DRMA0229	Change NaF Trap Media	3850 - Mechanics/Welders	34.20	$3,762.00
DRMA0229	Change NaF Trap Media	6801 - Cascade Mechanical	3.70	$407.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	29.80	$3,278.00
DRMA0229	Set up scaffolding for NaF Change Out	6615 - Painters/Carpenters	11.70	$1,287.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	8.40	$924.00
DRMA0229	Repair Cold Recovery Roof Vent Fan	6801 - Cascade Mechanical	7.70	$847.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	14.00	$1,540.00
DRMA0229	Repair Space Recorder	3851 - Instruments	3.70	$407.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	11.10	$1,221.00
DRMA0229	Move Air Pals for NaF Change Out	3851 - Instruments	4.00	$440.00
DRMA0229	Repair Cold Recovery Roof Vent Fan	6801 - Cascade Mechanical	4.00	$440.00
DRMA0229	Repair Cold Recovery Roof Vent Fan	6801 - Cascade Mechanical	11.70	$1,287.00
DRMA0229	Repair Cold Recovery Roof Vent Fan	6801 - Cascade Mechanical	11.00	$1,210.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	6.00	$660.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	13.10	$1,441.00
DRMA0229	Repair Space Recorder	3851 - Instruments	7.70	$847.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	18.40	$2,024.00
DRMA0229	Repair Space Recorder	4742 - Cascade I & C	20.50	$2,255.00
DRMA0229	Repair Valve	6801 - Cascade Mechanical	60.50	$6,655.00

Costs for X-330 Cold Recovery Air Ejector System 07/01/05 thru 06/30/07 (continued)

WBS	Task description	RCC	Hours charged	Cost @ $110/hr
DRMA0229	Repair Valve	6812 - Cascade Electrical	22.40	$2,464.00
DRMA0229	Repair Space Recorder	3851 - Instruments	5.40	$594.00
		Two-year Maintenance Cost	378.30	$41,613.00
		Annual Maintenance Cost	**189.15**	**$20,806.50**
Lab Personnel	Continuous Vent Monitor Operation and Maintenance	Annual Cost @ 8 hours/week/vent	416.00	$45,760.00
Lab Analysis	Vent Monitor Trap Analysis	Annual Cost based on May 2007 - 58.6 hours	703.20	$77,352.00
		Grand Total Annual Cost	**1,308.35**	**$143,918.50**

APPENDIX B

COST ESTIMATE CALCULATIONS FOR THE PURGE CASCADE

Cost Estimate for Purge Cascade Operations and Maintenance

May 2007 Costs for Purge Cascade Operation			
WBS 1t	**Task Description**	**RCC**	**April Invoiced Dollars**
DRMA0023	Cell Restart Support - PORTS	4742 - Cascade I & C 6801 - Cascade Mechanical 6812 - Cascade Electrical	3,412.63 69,363.13 4,005.30
DRMA0025	Lube Oil System	all	46,752.96
DROPS002	Production Process Operators	3685 X-326 Building 8814 X-300 Building	6,549.56 52,005.96
DRPS0109	1.2.5.09.1 DR Lab Ser.- Level of Effort	all	8,744.41
DRPS0113	1.2.5.13.1 DR Process Ser. - Level of Effort	5610 - ES&H Analytical Services 5816 - Uranium Sampling/Analysis	9,017.59 489.97
DRPS0209	1.2.5.09.2 DR Lab Ser. - Vent TC Analysis	5815 - Uranium Sampling & Analysis	5,785.83
DRPS0309	1.2.5.09.3 DR Lab Ser. - Vent U & Assay Analysis	5815 - Uranium Sampling & Analysis 5815 - Uranium Sampling & Analysis	8,583.51 805.63
DRPS0513	1.2.5.13.5 DR Process Serv. - U-Tube Dumping	5816 - Uranium Sampling/Analysis	1,093.87
DRPS0613	1.2.5.13.6 DR Process Serv. - Vent Composite Analysis	5815 - Uranium Sampling & Analysis 5816 - Uranium Sampling/Analysis	2,211.79 227.90
		Subtotal from DR Invoices	**$219,050.04**
CONTFEED	Contfeed (Operations Non-compliant Cylinder Project)	3685 - X-326 Building 8814 - X-300 Building	403,601.90 67,506.61
TC000026	TC DOE Non-Compliant Cylinders - Maintenance	4742 - Cascade I & C 6812 - Cascade Electrical	15,658.38 5,727.36
		Subtotal from Tc Invoices	**$492,494.25**
TC999999	Power Operations - Tc Power Operations - CSD OVEC Power - Purge Cascade	-- -- 0.816 MW or 606.8 MWH	42,474.77 19,640.19 34,205.00
		Subtotal Power	**$96,319.96**
		Grand Total	**$807,864.25**

Estimated Annual Purge Cascade Cost **$9,694,371.00**

APPENDIX C

COST ESTIMATE DATA FOR RESTARTING THE PURGE CASCADE FROM 6/15/03 THROUGH 6/15/04

Restarting X-326 Operations Following Shutdown
9/01/03 - 6/15/04

	PM	CM	Total
Total hours	5237.8	9643.3	14881.1
CAAS			801.0
Battery Room			226.7
NCSA			106.7
Fire Protection			81.0
L-Cage			30.7
***Subtotal CSD hours**			**1246.1**
Total X-326 Purge Cascade Startup hours			**13635.0**
Total Cost @$110/hr			**$1,499,850**

*work performed independent of purge cascade startup