

**CHANGING THE LANDSCAPE –  
LOW-TECH SOLUTIONS TO THE PADUCAH SCRAP METAL REMOVAL  
PROJECT ARE PROVIDING SAFE, COST-EFFECTIVE REMEDIATION OF  
CONTAMINATED SCRAP YARDS**

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**ABSTRACT**

Between 1974 and 1983, contaminated equipment was removed from the Paducah Gaseous Diffusion Plant (PGDP) process buildings as part of an enrichment process upgrade program. The upgrades consisted of the dismantlement, removal, and on-site storage of contaminated equipment, cell components, and scrap material (e.g., metal) from the cascade facilities. Scrap metal including other materials (e.g., drums, obsolete equipment) not related to this upgrade program have thus far accumulated in nine contiguous radiologically-contaminated and non-contaminated scrap yards covering 1.05E5 m<sup>2</sup> (26 acres) located in the northwestern portion of the PGDP. This paper presents the sequencing of field operations and methods used to achieve the safe removal and disposition of over 47,000 tonnes (53,000 tons) of metal and miscellaneous items contained in these yards. The methods of accomplishment consist of mobilization, performing nuclear criticality safety evaluations, moving scrap metal to ground level, inspection and segregation, sampling and characterization, scrap metal sizing, packaging and disposal, and finally demobilization. Preventing the intermingling of characteristically hazardous and non-hazardous wastes promotes waste minimization, allowing for the metal and materials to be segregated into 13 separate waste streams. Low-tech solutions such as using heavy equipment to retrieve, size, and package scrap materials in conjunction with thorough planning that integrates safe work practices, commitment to teamwork, and incorporating lessons learned ensures that field operations will be conducted efficiently and safely.

**INTRODUCTION**

The Paducah Gaseous Diffusion Plant (PGDP) in McCracken County near Paducah, Kentucky, is an active uranium enrichment facility. The uranium enrichment operation is located on land owned by the U.S. Department of Energy (DOE). PGDP is located approximately 6.4 km (4 miles) south of the Ohio River and approximately 16.1 km (10

miles) west of Paducah in western Kentucky. The DOE-owned property encompasses  $1.46\text{E}7 \text{ m}^2$  (3600 acres) of which  $3.04\text{E}6 \text{ m}^2$  (750 acres) are within a fenced security area that constitute the uranium enrichment facility. The plant began operations in the 1950s, supplying enriched uranium for both government and commercial needs.

Between 1974 and 1983, contaminated equipment was removed from the PGDP process buildings as part of an enrichment process upgrade program. The upgrades consisted of the dismantlement, removal, and on-site storage of contaminated equipment, cell components, and scrap material (e.g., metal) from the cascade facilities. Scrap metal including other materials (e.g., drums, obsolete equipment) not related to this upgrade program have thus far accumulated in nine contiguous radiologically-contaminated and non-contaminated scrap yard, covering  $1.05\text{E}5 \text{ m}^2$  (26 acres) located in the northwestern portion of the PGDP (1).

A walkdown of the scrap yards identified a number of different process components (e.g., pipe, valves, compressor blades, converters), as well as other items such as  $\text{UF}_6$  cylinders, piping, scaffolding, vehicles, and furniture. As shown in Figures 1a and 1b, the walkdown indicated that once inside the scrap yards, almost all of the equipment and items could be visually inspected. In addition, these walkthroughs have not revealed significant fissionable material buildup on component surfaces.



**Figure 1a. Accumulation of Equipment and Materials in the PGDP Scrap Yards**



**Figure 1b. Accumulation of Equipment and Materials in the PGDP Scrap Yards**

Although the amount of fissionable material, if encountered, is expected to be relatively small (e.g., thin films or stains), significant quantities may still exist in covered portions of the scrap yard piles. Therefore, due to the presence of a variety of Resource Conservation and Recovery Act (RCRA)-hazardous and radionuclide constituents that have been identified to date including suspected unknowns, the entire scrap yard area is designated as a hazardous waste site pursuant to Title 29 of the Code of the Federal Regulations, Part 1910.120 (29 CFR 1910.120) (2). Specifically, the radionuclides of concern dispersed throughout the scrap yards, although present in small quantities, include uranium, neptunium-237, and technetium-99. Other constituents requiring monitoring include asbestos, polychlorinated biphenyls (PCBs), and items containing aluminum, copper, iron, and stainless steel. Also, by virtue of the heavy equipment that will be required for the project, workers will be subjected to industrial hazards.

This paper presents the sequencing of field operations and methods used to achieve the safe removal and disposition of over 47,000 tonnes (53,000 tons) of metal and miscellaneous items contained in these yards. The methods of accomplishment consist of mobilization, performing nuclear criticality safety evaluations, moving scrap metal to ground level, inspection and segregation, sampling and characterization, scrap metal sizing, packaging and disposal, and finally demobilization.

## **SEQUENCING OF FIELD OPERATIONS**

The sequencing of field remediation operations occurs in distinct stages controlled through Field Work Requests (FWRs). The FWRs provide direction for developing, planning, generation, approval and completion of the work package and activities. In addition to the FWRs, Activity Hazard Reviews (AHRs) and Activity Hazard Analyses

(AHAs) are prepared for each significant task conducted during this project. The AHRs/AHAs document the chemical, industrial and radiological hazards and necessary engineering, administrative and personal protective equipment (PPE) controls to mitigate identified and suspected hazards (3). FWRs, AHRs and AHAs have been prepared for the following work activities:

- Mobilization – Establishing Work Area Infrastructures and Controlled Areas
- Performing Nuclear Criticality Safety Evaluations
- Moving Scrap Metal to Ground Level
- Inspection and Segregation
- Sampling and Characterization
- Scrap Metal Sizing
- Packaging and Disposal
- Demobilization - Installation of Gravel Pads and Hydroseeding

The following sections provide specific details corresponding to the aforementioned FWRs, AHRs and AHAs.

### **Mobilization - Establishing the Work Area Infrastructures and Controlled Areas**

Before processing the scrap materials, all employees involved with the project were trained in accordance with the project's Health and Safety Plan, Quality Assurance Plan, procedures and related project documents. The comprehensive training requirements are identified in training matrices (e.g., classes and required reading) and site postings. Completion of classroom training and required reading is recorded on site access cards issued to employees, and in a computer database for easy access and verification.

The initial field activities consisted of establishing work area infrastructures (e.g., extending haul roads by using structurally sound media, installing break/changeout trailers, and utility hookups). As shown in Figure 2, posting access requirements, thereby establishing controlled access to the scrap yards, prevents interference from untrained or non-essential personnel.



**Figure 2. Postings and Fencing to Control Scrap Yard Access**

Therefore, nuclear criticality safety evaluations (e.g., visual confirmation), relocating scrap metal, inspection and segregation, sampling and characterization, sizing, and packaging can be performed safely in designated staging areas.

### **Performing Nuclear Criticality Safety Evaluations**

The scrap material was not considered fissile material. However, due to past waste storage practices and process knowledge, some of the material was removed from locations in which fissile material was present. Therefore, the material remains undisturbed until either a qualitative (e.g., inspection process) or quantitative (e.g., sampling) evaluation verifies that criticality is not an issue.

If significant quantities of material are found (i.e., more than a thin film or stain prohibiting a visual examination of the base metal), work will stop within a 4.6-m (15-foot) radius of the contaminated material. Unknown or suspect materials containing visible deposits or  $\geq 15$  g of uranium-235 and an assay  $\geq 1.0$  wt% shall not be moved or otherwise disturbed until approved. Therefore, the cumulative effect of these requirements is that the scrap piles will be “peeled back like an onion.” Although the likelihood of a criticality incident is very low, the impact of such an incident essentially mandates that such careful removal be incorporated into the work process.

Field inspectors, typically having  $\geq 10$  years of evaluation experience obtained at the PGDP, have inspected the scrap piles remotely and in close proximity using a man-lift. The inspectors approve removing materials from either the outer perimeter of a given scrap pile or an area within a scrap pile. Pieces that cannot be moved individually are marked for further evaluation consisting of collecting additional assay swipe samples or



performing visual examinations using a fiber-optic scope to examine interior sections of process equipment. Hold points, such as precluding movement in and around a suspect piece of scrap material until results have been obtained and accepted, ensure that nuclear criticality evaluations are being performed safely.

### **Moving Scrap Metal to Ground Level**

Following the nuclear criticality safety evaluations, the scrap metal piles will be reduced from top to bottom using various material handlers. As shown in Figures 3a and 3b, a Caterpillar material handler will be equipped with either a rotating grappler (i.e., “mechanical claw”) or a magnet, which originally was used to create the piles.



**Figure 3a. Caterpillar Material Handler with Rotating Grappler**



**Figure 3b. Magnet Attachment**

Another piece of heavy equipment available for use is the construction grapple, as shown in Figure 4.



**Figure 4. Construction Grapple**

These preferred methods will help mitigate an uncontrolled movement of metal (i.e., an avalanche). The potential for an avalanche is an occupational health and safety concern for team personnel and can negatively affect nuclear criticality safety evaluations.

## Inspection and Segregation

Once the scrap metal is placed on ground level, a “rough” decontamination may be performed to meet the intended treatment, storage, and disposal facility’s (TSDF’s) waste acceptance criteria (WAC). For example, a “rough” decontamination may consist of either brushing or scraping a localized deposit of material on the scrap metal to help meet the intended TSDF’s WAC. Furthermore, field inspectors and other appropriate team personnel inspect the scrap material for waste stream segregation. Currently, there are 12 primary waste streams and one secondary waste stream (WS 13) that have been identified for this project and are summarized in Table I.

**Table I. Anticipated Scrap Yard Waste Streams**

Waste Stream Number and Name	Waste Stream Description	Estimated Mass tonnes (U.S. tons)	Type of Container	No. of Cont.
WS 1: Scrap metal	Scrap metal in the nine scrap yards other than that defined by WSs 2, 4, 5, and 6	25,272 (28,080)	IM or ROB	1,664 <sup>a</sup>
WS 2: Nickel ingots	The nickel ingots from scrap yard C-746-H4	8,730 (9,700)	None	—
WS 3: Scrap wood	Cross ties, pallets, etc.	488 (542)	IM or ROB	40
WS 4: Mixed solid waste	Material that samplers/segregators characterize as RCRA- and PCB-contaminated	7.2 (8)	55-gal drum	53
WS 5: RCRA solid waste	Material that samplers/segregators characterize as RCRA-contaminated	1.8 (2)	55-gal drum	13
WS 6: PCB solid waste	Material that samplers/segregators characterize as PCB-contaminated	10.8 (12)	55-gal drum <sup>b</sup>	80 <sup>b</sup>
WS 7: Other solid primary waste	Solid waste not accounted for from WSs 1 through 6 (e.g., plastic pipe)	From WSs 1 through 7	55-gal drum, IM, or ROB (case by case)	None <sup>c</sup>
WS 8: RCRA/LLW waste	RCRA/LLW solid waste	13,104 (14,560)	IM- or TSDF WAC-approved container	Note <sup>d</sup>
WS 9: Liquid primary waste	Liquid segregated from primary solid waste including residual water, rain water, and dust control water	90 (100)	55-gal drum	500
WS 10: Decontamination water	Waste generated from decontaminating process equipment and sampling equipment	18 (20)	55-gal drum	100
WS 11: Decontamination sludge	Waste generated from decontaminating process equipment and sampling equipment	3.6 (4)	Initially placed in 55-gal drum	None <sup>c</sup>
WS 12: PPE and plastic sheeting	PPE and plastic sheeting generated during performance of work activities	11.7 (13)	Bagged and placed in with generating waste or in 55-gal drum	None <sup>c</sup>
WS 13: Other secondary waste	Other secondary wastes that include such items as geotextile sheeting, air filters, and contaminated disposable processing equipment	5.4 (6)	Bagged and placed in with IM or ROB, as appropriate, or in 55-gal drum	None <sup>c</sup>

<sup>a</sup>Material in IMs (for off-site disposal) will be more densely packaged than materials in ROB (for on-site disposal).

<sup>b</sup>PCB waste may be placed in B-25 boxes. If so, approximately six B-25 boxes of waste would be generated. It is estimated that the scrap metal density in the IM’s will be 0.8 g/cm<sup>3</sup> (50 lb/ft<sup>3</sup>).



<sup>c</sup> Waste will typically be packaged with WS 1.

<sup>d</sup> Will be dependent on size of container.

IM = intermodal.

LLW = low-level waste.

PCB = polychlorinated biphenyl.

PPE = personal protective equipment.

RCRA = Resource Conservation and Recovery Act of 1976.

ROB = roll-off box.

TSDF = treatment, storage, and disposal facility.

WAC = waste acceptance criteria.

WS = waste stream.

The secondary waste stream (i.e., WS 13) encompasses WSs 10 through 12. These waste streams are segregated by waste type and potential contaminants. This segregation promotes waste minimization by preventing the intermingling of characteristically hazardous and non-hazardous wastes. This process also helps complying with storage and packaging requirements specified in the latest version of the PGDP WAC.

### **Sampling and Characterization**

Previous characterization data obtained from the existing equipment, scrap and other items placed in the scrap yards reported the following radiological constituents and their range of contamination levels:

- uranium: 6 - 336,000 ppm
- neptunium: <5 - 42 ppb
- technetium <5 - 48 ppb

These results support the historical process knowledge to the extent that the majority of scrap metal was decontaminated prior to being placed in the scrap yards.

Still, routine sampling performed by the waste samplers or Radiation Control Technicians consist of radiological surveys and swipe samples. Depending on the TSDF requirements, established plans, procedures and data quality objectives (DQOs), some of the scrap materials require extensive characterization analysis gained only through physical sampling (e.g., scoop samples or “coupons”).

In general, the scrap materials will be sampled and characterized to perform the following evaluations:

- Whether the waste is RCRA hazardous.
- Whether the waste meets the Land Disposal Restrictions.
- Whether WAC-prohibited items are in the waste.
- Whether radionuclides present are below the limits specified in the TSDF's radioactive materials license and the WAC.
- Provide information for nuclear material control and accountability, if needed.

- Provide information for those pieces considered surface-contaminated objects (SCOs) in order to demonstrate compliance with the U.S. Department of Transportation regulations.

Although process knowledge is used to characterize these parameters, confirmatory sampling will be collected as needed to provide definitive data according to the licenses and permits of the TSDF accepting the items for disposition. Still, there is no reason to expect volatile organic compounds (VOCs) to be present because: 1) the items placed in the scrap yards were either cleaned or “RCRA-emptied” and 2) extreme outside temperatures would drive off many VOCs. In addition, there is no reason to expect these items to contain cyanides, sulfides, herbicides or pesticides. Based on the nature of these wastes, initial baseline testing for ignitability (D001) and corrosivity (D002) characteristics has not been necessary, other than what is required to be reported to the TSDF. Possible “free liquid” content will be determined and contained using absorbents. Treatment and/or disposition of waste above action limit thresholds will be determined on a case-by-case basis after characterization is complete.

### **Scrap Metal Sizing**

Scrap metal sizing is needed to maximize transport density, meet transport container size limitations, and the TSDF’s WAC. Scrap metal sizing is performed by using heavy equipment to either shear or crush the scrap materials, which is preferred, or hot work (e.g., using an oxy-acetylene or plasma cutting torch). For example, process converter shells are sheared in the axial direction. Using mechanical tools for shearing and cutting metal or crushing light pipe and drums enhances worker field safety by eliminating direct contact with these materials, thereby preventing heat stress and hot-work air emissions (e.g., radiological constituents, arsenic). When hot work is performed using the oxy-acetylene or plasma cutting torch, the radiological and chemical emissions are controlled by high efficiency particulate air (HEPA)-filtered ventilation at the cutting zone with fire-watch personnel assigned to the work area.

### **Packaging and Disposal**

Once the sample results from the laboratory have been verified and validated, and are within the waste profile of the intended TSDF, the waste containers (e.g., intermodals) will be loaded and shipped for disposition. The majority of the scrap metal packaging is accomplished using intermodal containers, as shown in Figure 5, that are approved for low specific activity (LSA) and SCO wastes and are located in the work area for continuous loading.



**Figure 5. Intermodal Container**

These containers have a capacity of 18 tonnes (40,000 pounds), a volume of 19.1 m<sup>3</sup> (675 ft<sup>3</sup>), and are loaded according to the TSDF's WAC. A Hyster intermodal loader, as shown in Figure 6, is used to maneuver the containers around the scrap yards in preparation for off-site shipment.



**Figure 6. Hyster Intermodal Loader**

All containers and other types of approved packaging (e.g., B-25 boxes) used for off-site transportation and disposal are loaded to prevent punctures by the scrap metal. The packaging is selected based on compliance with stringent quality assurance standards (e.g., 10 CFR 830.120), including a manufacturer assessment and an individual inspection of each container upon receipt at the PGDP. Much of the non-process scrap metal and non-metal wastes are candidates for disposal in the PGDP's landfill thus reducing disposal costs. These types of wastes meeting the landfill's WAC and disposal package requirements will be placed in roll-off bins that will be covered to prevent accumulation of rainwater. Whether shipping to a designated TSDF or the PGDP's landfill, a waste compliance specialist provides oversight through visual inspection and verification to ensure that the container integrity and its contents meet all TSDF WAC requirements prior to leaving the site.

### **Demobilization - Installation of Gravel Pads and Hydroseeding**

Following removal of the scrap metal, the scrap yard areas will be covered by a layer of gravel. Hydroseeding will be conducted in all other areas requiring cover. Areas will be sloped, to the extent practical, to manage storm water and minimize erosion.

### **LESSONS LEARNED**

Implementation of numerous lessons learned from this and previous projects have thus far consisted of:

- Acquiring several equipment checklists from other sites and various manufacturers to perform heavy equipment inspections.
- Reviewing the regulations, developing calculations, and establishing protocols to ship industrial hygiene (IH) breathing zone (BZ) samples directly to the designated laboratory for analyses. This new process reduces reporting time to personnel, reduces handling costs, and establishes direct communication between the lab and personnel collecting the BZ samples.
- Initial processing of the low-hazard materials allows personnel to obtain additional on-the-job training, thus optimizing field activities prior to processing suspect, high hazard materials.
- Conducting crew briefings to emphasize attention to work activity techniques and contamination control issues.
- Establishing hold points or issuing "STOP work" notifications immediately when personnel encounter issues outside the defined scope of work.
- Working in multiple locations with adequate safety coverage to minimize workforce downtime.
- Subject matter experts (SMEs) from supporting organizations (e.g., nuclear criticality safety) are required to attend and participate in the daily safety meetings to address questions from field personnel. This enhances communication and feedback where employees can ask the SME questions directly and obtain answers immediately.

- Although the majority of the scrap yard activities are being performed in a radiological area, processing low-hazard materials first allows these materials to be candidates for being disposed at the PGDP's landfill.
- The intermodals and other waste containers are staged in a buffer area for radiological survey prior to leaving the site to minimize the spread of radioactive contamination and expedite off-site shipment.

## CONCLUSION

The ongoing success of the scrap metal project has been attributable to the quality work of every individual involved. The existing project philosophy encourages ownership of safety from the highest level of management through entry-level positions. This project continues to demonstrate that faithful execution of the principles and practices of the Integrated Safety Management System to plan the work, analyze and mitigate hazards, perform the work within established controls, obtain employee feedback and utilize lessons learned only enhances the opportunity for success. In addition, low-tech solutions such as using heavy equipment to retrieve, size and package scrap materials in conjunction with thorough planning that integrates safe work practices, commitment to teamwork, and incorporating lessons learned ensures that field operations will be conducted efficiently and safely.

## REFERENCES

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