Management of Technetium Contaminated Demolition Debris from the Gaseous Diffusion Plants at the East Tennessee Technology Park – 15422

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ABSTRACT
The demolition of the final section of the gaseous diffusion plant (GDP) facility formerly known as K-25 at the East Tennessee Technology Park was completed in December of 2013, with the final shipment of waste completed only six months later in June 2014. While most of the radioactive waste shipments would be considered "routine" by today's standards (lower activity waste was disposed onsite at the Environmental Management Waste Management Facility [EMWMF] and at some offsite commercial disposal facilities with higher activity waste making its way across country to the Nevada National Security Site [NNSS] disposal facility) the final section of K-25, consisting of six cascade "units", presented some unique technical and stakeholder challenges. Portions of this final section of K-25 were presumed to be heavily contaminated with Technetium-99 (Tc-99) based on sampling and analysis activities conducted during facility deactivation. Tc-99 is known to be highly mobile under a variety of environmental conditions, and is suspected to be potentially mobile in unmitigated landfill conditions, resulting in the need to implement additional engineered controls during facility demolition as well as throughout the management of the resultant waste. A variety of controls were implemented to ensure Tc-99 mobility was controlled and possible consequences mitigated, including isolation and offsite shipment of highest Tc-99 concentration components, as well as construction of a "cell within a cell" at the EMWMF.

This paper will examine the process utilized to develop the controls for management of Tc-99 contaminated waste and will describe those controls. Additionally, it will describe the stakeholder involvement and approval process as well as examining and documenting the efficacy of the controls that were implemented. Finally, this paper will discuss lessons learned from this first of a kind demolition effort and how this experience can be utilized to further refine the Tc-99 waste management approach for the remaining GDPs at ETTP.

INTRODUCTION
At the time of the Manhattan Project, three methods of uranium separation were being pursued: electromagnetic, thermal diffusion, and gaseous diffusion. In the spring of 1943, design work for the gaseous diffusion plant began and by winter of 1943, construction was underway. The gaseous diffusion plant would be known as K-25, the “K” coming from the Kellex Corporation and the “25” from a World War II code designation for Uranium-235. At that time it was the world’s largest building under one roof. K-25 operated until 1964, producing enriched uranium utilizing the gaseous diffusion process. Gaseous diffusion uses uranium hexafluoride (UF_6) and multiple series of barriers to increase the enrichment by separating the heavier Uranium-238 from the Uranium-235 in a system known as a cascade. Due to the proportionally small quantity of the enriched product, numerous stages were required to achieve the necessary enrichment and quantity of material required. K-25 eventually housed over 5,000 enrichment stages, and enough barrier to stretch from New York to Tokyo.

There were many challenges associated with the demolition of K-25 including the sheer size of the structure (over 186,000 m^2 [2,000,000 ft^2]), the volume and types of waste requiring disposal, and demolition and disposal of an area of the facility that was heavily contaminated with Tc-99. Figure 1 shows a picture of K-25 in the spring of 2000, before demolition began.

Fig. 1. K-25 Prior to Demolition

Tc-99 is a low-energy beta emitter that is highly soluble in water. The final four units of the purge cascade in K-25 were contaminated with Tc-99 as well as uranium contamination that was encountered throughout the building. The highest areas of contamination were found within the process gas equipment, with the building structure being contaminated, though to a much lesser extent. The building structure and process gas equipment was originally believed to contain such high levels of Tc-99 that all waste generated from this section of the building would require disposal off-site at the NNSS. Fortunately following more detailed characterization, it was determined that all of the building structure and a portion of the process gas equipment could be dispositioned at the onsite CERCLA disposal facility known as the Environmental Management Waste Management Facility (EMWMF). Approximately 88% of the overall volume of waste was able to be disposed of at EMWMF as a result. Figure 2 shows K-25 at the start of the final demolition phase.

Fig. 2. K-25 During Start of Final Demolition (September 2013)

EMWMF was born out of a Record of Decision [1] as the selected remedy for the disposal of waste expected to be generated from the cleanup of the Oak Ridge Reservation. EMWMF consists of 6 disposal cells that were constructed in phases, with the final cell construction completion in 2011. Operations began in cells 1 and 2 in 2002, and progressed into cells 3, 4 and 5, with cell 6 remaining in stand by and ready to operate. The design capacity is 1.68 million cubic meters (2.2 million cubic yards), and to date, approximately 66% of this capacity has been consumed. Figure 3 shows a picture of EMWMF in May 2014.

Figure 3 – Aerial View of EMWMF

IDENTIFICATION OF TC-99 CONTROLS

In order to significantly reduce the risk of release to the environment and to ensure all waste was managed and dispositioned appropriately it was necessary to develop a demolition and waste removal strategy. The strategy included instituting numerous administrative and engineering controls including:

- foaming of process gas equipment to fix contamination and eliminate void space for disposal
- removal of "high-risk" items prior to demolition
- pre-marking (i.e., high visibility paint) of Tc-99 contaminated components so they could later be extracted from the demolition debris pile and managed separately
- an enhanced storm water pollution protection plan including engineered berms
- surgical demolition and segmentation of waste
- placement of fixatives on demolition debris piles
- environmental, radiological, and safety monitoring
- rigorous work control processes

Of all the Tc-contaminated process gas equipment that was removed during demolition and separated for disposition, the compressors provided a unique challenge to the demolition team. The compressor volutes, once removed from the base, would not fit inside a standard fissile shipping container. Size reduction of the volute was considered, but due to the thickness of the metal involved, and contamination control concerns, it was decided to pursue an alternate container. A new reusable container design was developed and fabricated by a commercial vendor. This innovation resulted in a savings of over

$1,000,000 to the K-25 project alone, and will continue to be utilized during the future demolition of the remaining GDPs at the ORR.

STAKEHOLDER INVOLVEMENT IN THE DEVELOPMENT OF CONTROLS AT EMWMF

In order to be acceptable for disposal at EMWMF, a waste stream must have a Waste Handling Plan (WHP) that is approved by the Environmental Protection Agency (EPA) and the Tennessee Department of Environment & Conservation (TDEC). The preparation of a WHP and the process for concurrence by the regulators is codified in the Federal Facility Agreement for the Oak Ridge Reservation [2] (FFA). The WHP is a “Primary Report”, as defined in the FFA, which is required to be submitted to the regulators for review and comment. If agreement on the content of a “Primary Report”, such as a WHP, cannot be reached, the parties may invoke the dispute resolution process whereby the disagreement is first addressed at the lowest possible decision making level, with provisions to elevate as necessary to ultimately resolve the dispute.

The K-25 Process Gas and Equipment WHP for the East Wing Purge Cascade was submitted to EPA and TDEC on February 14, 2013 and was approved by both agencies on September 15, 2013. An addendum to the WHP for the Demolition of Buildings K-25 and K-27 was submitted to the agencies on February 14, 2013 and approved on September 10, 2013.

The demolition of K-25 and K-27 are in the same CERCLA action memorandum. When the demolition project was started, a single WHP was prepared for the demolition of both structures. As demolition proceeded in stages (west wing, north end, east wing and purge cascade) an addendum to the original WHP was prepared for each stage. For process gas and equipment, a separate WHP was prepared for each phase of demolition.

Agreement on the WHP is documented via a Concurrence Form signed by EPA, TDEC, the U.S. Department of Energy (DOE) and UCOR. The Concurrence Form for the approval of the final waste lots from K-25 was drafted in July 2013. Under ordinary circumstances, the process would have proceeded as normal resulting in approval and start of demolition. In this case, however, due to the presence of Tc-99 contamination at much higher levels in the remaining sections of K-25 than in the balance of the facility that had already been demolished, in association with the additional radiological controls for the control of Tc-99 contamination, one of the regulator stakeholders raised concerns about the overall management approach of the demolition debris from these final sections, resulting in a minor dispute. Resolution negotiations began immediately as there was mounting pressure to complete the demolition of K-25.

TDEC EXPECTATIONS

The dispute was finally resolved following some intense negotiation between DOE and TDEC. As part of the settlement of the dispute, TDEC requested, and it was eventually agreed that several expectations associated with the management of the waste from the final sections of K-25 would be implemented. These expectations included:

1) The waste lots must be placed in a cell that DOE assures is long term stable (this condition resulted from recent elevated ground water readings from a piezometer located beneath Cell 3 that called into question the overall stability of the landfill, although subsequent engineering evaluation concluded the landfill was stable)
2) The waste lots are to be placed “high and dry” and there is sufficient water management to minimize the generation of contact water (this condition resulted from the known solubility of Tc-99 in water and the potential mobility of the Tc-99 into the contact water)

3) Approval of this approach does not set a precedent for additional future material disposal
4) EMWMF contact water release criteria associated with these waste lots will be negotiated between DOE & TDEC and as a result, is not captured in this K-25 project specific concurrence (this condition resulted from a separate, but related, dispute regarding water discharge standards)
5) DOE shall provide a separate area for collection and storage of any potentially impacted contact water so that if technetium-99 is mobilized in water, water from the cell may be segregated and treated to minimize the volume of water requiring treatment. Once the waste is covered and mobilizing technetium-99 is no longer a possibility DOE may return to authorized EMWMF water management practices (similar to expectation 2 above).

As the EMWMF operations team began to develop the approach to implement these controls, they found implementation of expectation 5) somewhat more challenging than initially anticipated. Because there was no effective way to segregate the water from the Tc-99 waste, the team had to come up with another plan. Ultimately it was decided to create a cell within a cell, known as the “Tc Bowl” for its bowl shaped appearance within the cell (see Figure 4). In addition, a cover of 0.15 – 0.3 meters (6 – 12 inches) of machine compacted clay was placed daily to minimize the contact of precipitation with the waste. Finally, it was decided that waste receipt would be suspended during periods of precipitation for the same reason. By creating the “Tc Bowl” it was thought any water that contacted the waste would be driven by gravity into the leachate collection system as opposed to being collected as contact water. The approach is shown graphically in Figure 5. Since all leachate collected is required to be treated anyway, there would be no additional burden resulting from management of the Tc-99 water. Table I summarizes the approach utilized to satisfy each one of the stakeholder expectations.

Fig. 4. The "Tc Bowl" at EMWMF

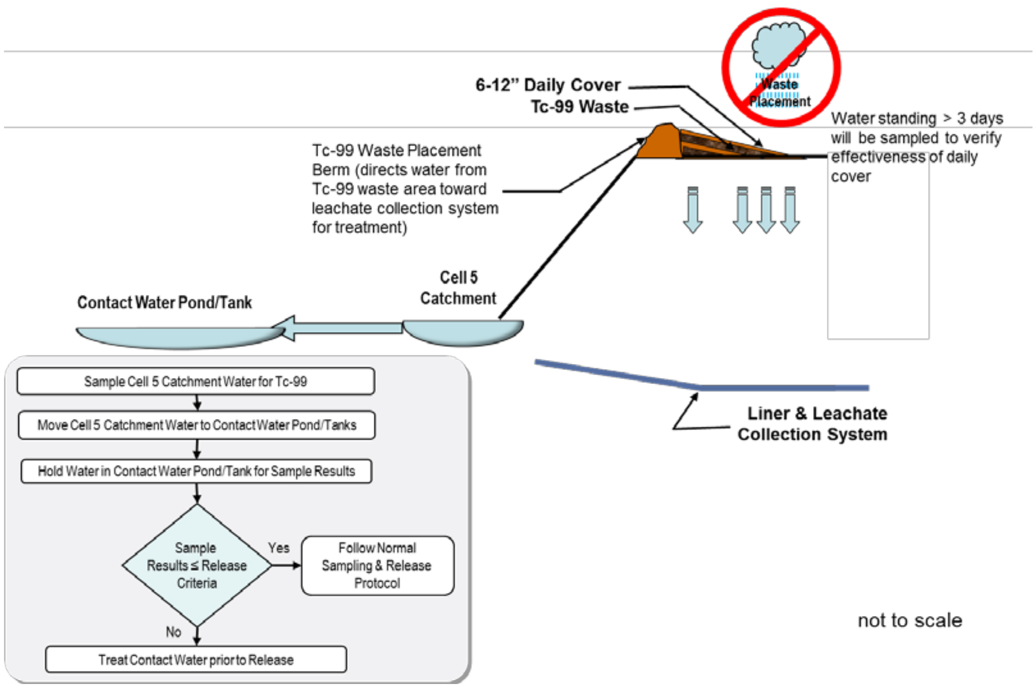

Fig. 5. Tc-99 Water Management Approach

TABLE I. Summary and approach to satisfy stakeholder expectations

EXPECTATION	EMWMF APPROACH
1	Engineering stability evaluation was completed indicating that EMWMF was stable under all static conditions and catastrophic failure was unlikely during a seismic event; weekly inspections continue to be performed showing no movement
2	"High and Dry" - Tc-99 waste will be placed in the upper portion of Cells 3/4 in areas near the final waste grade which minimizes the time for placement of the enhanced operational cover and reduces the amount of leachate percolating through the waste (see Figure 6) Water Management – area was isolated from precipitation by not receiving waste during precipitation events in which runoff is imminent or occurring; berms and daily cover (0.15 – 0.3 meters [6 – 12 inches] of compacted clay) directed water away from the contact water catchment and into the leachate collection system
3	Agreement with the regulator that this approach would not set future precedent
4	The EMWMF approach was designed to eliminate contact water generation, which eliminated the need for separate release criteria
5	In addition to not placing waste during precipitation events and placement of daily cover, water that accumulated within the "Tc Bowl" area for 3 days would be sampled to confirm effectiveness of the daily cover, and water in the contact water catchment would be sampled for Tc-99 prior to pumping to contact water ponds/tanks for release

Fig. 6. **View of "High and Dry" Placement Area**

OPERATING EXPERIENCE IN THE DEVELOPMENT OF ADDITIONAL CONTROLS

As demolition proceeds, water is used for dust suppression purposes. Additionally, the climate in East Tennessee is such that routine precipitation is a common occurrence (average annual rainfall for Tennessee is approximately 1.35 meters (53 inches) which is significantly more than the national average). As a result, the waste sent for disposal is moist. Moist waste helps prevent the spread of airborne contamination as the waste is loaded in the trucks at the site of demolition and also as it is dumped from the trucks at EMWMF. Dump trucks with hinged tailgates and double walled beds are used to haul the demolition debris from the demolition field to EMWMF. Contamination is contained within the truck bed through the use of a rubber gasket between the bed and the tailgate (see Figure 7). The demolition of the remaining portion of K-25 was well underway in November 2013 when shipments to EMWMF had to be temporarily suspended due to an increase in contamination found on and around the area of the gasket. The concern was that increasing levels of contamination could result in increased opportunity for personnel contamination as well as the potential to contaminate the dedicated haul road used to transport the waste from the demolition field to the EMWMF. As a result, additional operational controls were established at EMWMF to significantly reduce the potential for contamination spread including:

- A decontamination/survey station was established to allow for more thorough examination and decontamination (if necessary) of the gasket and tailgate area (see Figure 8) prior to moving to the final survey area for release
- Sorbent "pigs" were placed in the empty truck bed prior to its return back to the demolition field (see Figure 9) to aid in moisture control of the waste load

Following implementation of these additional controls, shipments resumed, however, a week and a half later a significant contamination event occurred at EMWMF. Thirteen trucks arrived at EMWMF on the morning of November 23, 2013. The first two trucks dumped without incident. The third truck dumped and proceeded to the decontamination/survey station where contamination was found that exceeded 4,000,000 disintegrations per minute (dpm), which significantly exceeded the Radiological Work Permit levels of 100,000 dpm. Subsequent investigation determined the bed of the truck was covered with a black, milky, tar-like substance thought to be pertechnetic acid. Ultimately, because of the pace of dumping that day, 8 of the 13 trucks drove through the contamination and they too became contaminated. Fortunately the contamination was confined to the dump area within EMWMF and no personnel contamination occurred; however, a significant decontamination effort had to be completed before the trucks could be returned to service. As a result of this event, it was decided that each truck would now be lined with a plastic liner to significantly improve the ability of wet debris, mud, grit, and fines to discharge without contacting the tailgate area.

Fig. 7. Dump Truck Showing Gasket Used for Contamination Control

Fig. 8. Dump Truck Being Surveyed at Decontamination/Survey Station

EFFICACY OF CONTROLS

By the time the demolition of K-25 was complete, EMWMF had received nearly 30,500 m^3 (40,000 yd^3) of Tc-99 contaminated debris with minimal increases in Tc-99 levels in the contact water and leachate. This is shown in Figures 10 and 11. The stakeholder expectations were met.

Additionally, there were no personnel contamination events at EMWMF, there was no spread of contamination beyond the dump face at EMWMF, and there were no additional contamination events for the remainder of K-25 demolition. As a result, these controls contributed to the completion of the demolition of K-25 and disposition of all associated waste over one year ahead of schedule and $225 million under the federal baseline budget.

Fig. 9. **Workers Prepare to Place Sorbent "Pigs" in Truck Bed**

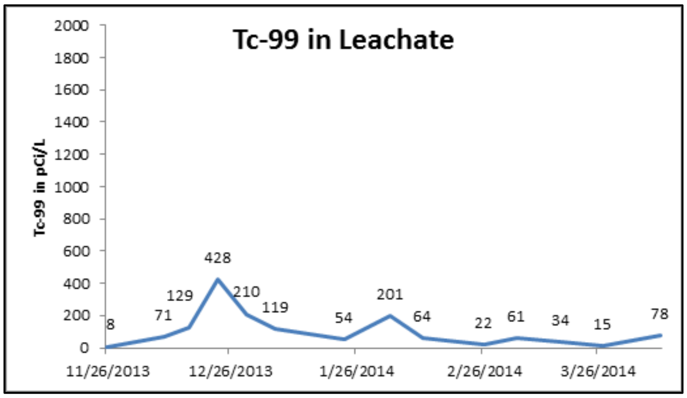

Fig. 10. **Tc-99 Contamination Levels in Leachate at EMWMF**

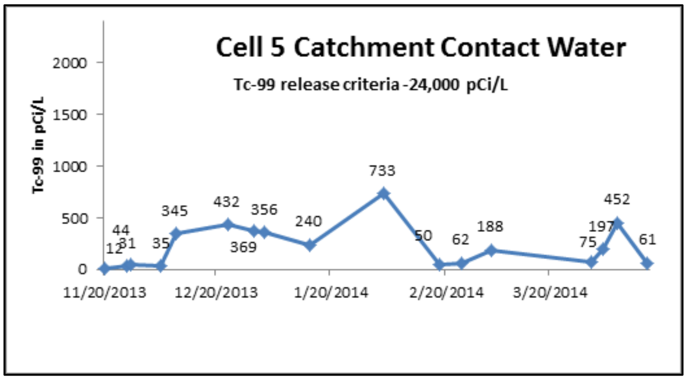

Fig. 11. **Tc-99 Contamination Levels in Contact Water at EMWMF**

CONCLUSIONS AND LESSONS LEARNED

UCOR believes in the process of continuous improvement. There were many lessons learned during the demolition of K-25 that will be applied to future demolition activities. There are two Gaseous Diffusion Plant buildings remaining to be demolished – K-31 and K-27. K-31 had previously been deactivated and decommissioned and completely emptied of its contents, and remained in stand-by awaiting demolition. Demolition of K-31 was approved to proceed in 2014 and is currently ongoing with expected completion by the summer of 2015. It does not present any of the Tc-99 challenges posed by K-25. K-27 is currently undergoing deactivation and is nearly 50% complete. It does present Tc-99 challenges similar to K-25.

Deactivation and Demolition Lessons Learned

The first of many lessons learned at the demolition location involves implementation of a more robust evaluation of potential migration pathways including all mechanical extrusions and building slab penetrations, as well as other utilities (e.g., electrical, water, sewer) located near the facility that were previously isolated. Additional emphasis will be placed on ensuring these potential migration pathways are sufficiently plugged, sealed and isolated. Additional monitoring of these systems will be done to ensure the integrity of these engineered controls is maintained throughout demolition.

Another lesson learned was the need for an enhanced storm water management approach to ensure that migration of contaminants from the waste pile created by demolition could be more effectively mitigated or eliminated. Specific approaches to be implemented include more robust water containment berms at the demolition location, evaluation of methods to protect the structure slab to minimize potential for cracking, and a review of dust suppression techniques to minimize the amount of water that is collected inside the demolition area.

Third, significantly more of the process equipment in K-27 will be removed than was possible in K-25 because the K-25 facility was in such disrepair that equipment removals created an industrial hazard for the workforce. By removing more of the process equipment, the source term will be contained by not having to size reduce this equipment in the demolition field thereby exposing the source term to unpredictable environmental conditions.

Finally, the demolition of K-25 focused on the demolition of the structure itself, with less focus on size reduction and shipment of the debris to EMWMF for disposal. As a result, while size reduction and disposal were occurring, the waste pile grew at a rate faster than the rate of disposal. Because of this, the contaminants contained within the waste pile were exposed to environmental conditions for longer periods of time than would have occurred had the size reduction and disposal rate been higher. During demolition of K-27, a more focused coordination will be employed to balance demolition activities to match size reduction and disposal rates and minimize the size of the waste pile, rather than to maximize the demolition rate.

Waste Management Lessons Learned

The reusable fissile shipping container will continue to pay dividends in the ongoing deactivation and demolition of K-27.

Several lessons learned from the successful approach for controlling water contamination during the K-25 Tc-99 waste disposal at the EMWMF are recommended for future Tc-99 waste disposal campaigns. Placing waste within a bowl surrounded on all sides by clean fill or non-Tc-99 contaminated waste minimizes the amount of run-off from surrounding areas, limiting mobilization of the Tc-99. The sides of the bowl direct precipitation falling within the bowl to the leachate system for treatment. Pre-planning for the next Tc-99 waste placement by placing other waste to form a bowl during placement rather than construction of the bowl after placement will save time, reduce cost, and reduce wear and tear on equipment.

The Tc-99 waste was neither placed when heavy precipitation was occurring or forecast to occur, nor placed when conditions within the excavated bowl were muddy. The active waste area was kept small and was sloped towards the bottom of the bowl to prevent collection of water at the active disposal face. A shorter push path was maintained to limit the amount of exposed waste.

Because of the rainfall that East Tennessee regularly experiences, a daily cover was initially placed over the waste. However, the daily cover used significant airspace, was not a key factor in Tc-99 control, and contributed significantly to the creation of muddy conditions during precipitation events that negatively impacted efficient operations. The recommendation for future campaigns is to place a clay cover over the waste prior to longer periods of inactivity such as holiday weekends, and when significant storms are predicted.

Additional lessons learned and recommendations for future Tc-99 campaigns include lining the dump truck beds with plastic to minimize Tc-99 mobilization to the truck bed and tail gates during dumping, and immediate radiological survey of trucks after dumping to identify and decontaminate truck beds prior to leaving the immediate dumping area.

Implementation of these key factors resulted in controlling discharged water to approximately 4% of the 24,000 pCi/L discharge criterion and are highly recommended for future projects.

REFERENCES

1. Record of Decision for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste, Oak Ridge, Tennessee (DOE/OR/01-1791&D3)
2. Federal Facility Agreement for the Oak Ridge Reservation, 1991 FEDERAL FACILITY AGREEMENT UNDER SECTION 120 OF CERCLA AND SECTIONS 3008(h) AND 6001 OF RCRA, Docket No. 89-04-FF