Finishing an Era: Accelerated Decontamination and Decommissioning (D&D) at the K-25 Building, East Tennessee Technology Park, Oak Ridge, Tennessee – 14141

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ABSTRACT

In the fall of 1942, a 59,000-acre area in Oak Ridge, TN, became an integral part of what would be known as the Manhattan Project. Three methods of uranium separation would be pursued there: electromagnetic, thermal diffusion, and gaseous diffusion. Construction began on a 2 million ft^2 “great plant,” called K-25: “K” for the Kellex Corporation, the primary contractor, and “25,” a war code for uranium (U)-235.In April, 1945, construction started on a second gaseous diffusion plant, K-27, which was completed in January, 1946. Post-war uranium enriched in these facilities was used to fuel both reactors and submarines. Both buildings worked in tandem until they were shut down in 1964.

In 2002, the decommissioning of K-25 was begun and has presented several unique opportunities. The enormity of structure presented several challenges, with waste disposal strategy being preeminent. The technetium (Tc)-99 contaminated portion of the building structures and components was another significant concern that affected strategies in the deactivation, demolition, and waste disposal. The time that passed, between shutdown and decommissioning, coupled with the elements, caused significant structural degradation issues. Other challenges dealing with the approach to nuclear safety, criticality, and characterization were also experienced.

Several significant factors have contributed to the successful execution of the K-25 project, specifically the dedication of a safety-conscious workforce and the development of a true partnering relationship between the Department of Energy (DOE) and URS | CH2M Oak Ridge LLC (UCOR). The K-25 cleanup project is scheduled for completion in the first quarter 2014.

INTRODUCTION

In the fall of 1942, a 59,000-acre area, 18 miles west of Knoxville along the Clinch River, was purchased at a cost of $2,600,000. This was to become the Oak Ridge Reservation (ORR), but was known at the time as the Clinton Engineering Works (CEW). Three methods of uranium separation were to be pursued: electromagnetic, thermal diffusion, and gaseous diffusion. $1,000,000,000 would be spent over the next three years in pursuit of enough enriched uranium to create a new and different type of weapon, the atomic bomb. During this period the area would grow to a population of 70,000 inhabitants, but secrecy was of the utmost importance, and throughout the war effort, the area never showed on any map.

In the spring of 1943, design work for the gaseous diffusion plant was started by the Kellex Corporation, a subsidiary of the M.W. Kellog Corporation of New York. Construction was led by J.A. Jones of Charlotte, North Carolina. 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 (U)-235. The design and construction of K-25 would take a herculean effort. Engineering and planning alone required 20,000 pages of specifications, 12,000 drawings, and 10,000 pages of operating instructions.

Gaseous diffusion uses uranium hexafluoride (UF6) and multiple series of barriers to increase the enrichment by separating the heavier U-238 from the U-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.

The U-shaped structure would be four-stories high, over a half-mile-long and nearly a quarter mile in width. The building would enclose 2,000,000 square feet, making it the largest building in the world at the time. Due to the size of the structure and the urgency to begin construction, new methods would be employed to prepare the building footprint. The design required the floor elevations of all building segments to be maintained throughout the structure. The topography of the site required cuts of up to 46 feet and low areas up to 23 feet in depth to be filled. It was decided that fill would be spread in 6-inch layers, which would be compacted prior to addition of the next layer. This technique was similar to that employed in earthen dam construction during that period. This application of compacted fill was revolutionary in the field of building construction, at the time. The structure itself is reinforced concrete from the base to the main floor, with steel framing and transite siding utilized for the three additional levels. (Fig. 1.)

The first level housed all the auxiliary equipment such as transformers, switch gears, and heating, ventilating, and air-conditioning (HVAC) systems. The second floor housed the thousands of converters and compressors required for the gaseous diffusion process. The third floor was largely a pipe gallery, with the majority of piping enclosed in duct, manufactured from steel panels. The ducts were welded and enclosed a volume of 6,000,000 cubic feet. The fourth level was the operating floor. Hundreds of instrument panels and control devices were located on this level which aided in operation of the plant. In a central location on the operating floor a master control room was constructed that allowed operators to monitor and control the entire diffusion cascade.

Construction began in June, 1943, without the building design or the process theory/design being complete. Construction would require 12,000 workers and $512,000,000 (equivalent to $6.6 billion in today’s dollars) to complete.

Fig. 1. K-25 footings, April 6, 1944.

Since the site was 11 miles from town, a satellite community was constructed to house the workers and their families. Population eventually reached 15,000, and despite chronic shortages of food and other amenities, became know as “Happy Valley.” In addition to the camp, roads, bridges, bus terminals, a railroad, and a huge parking lot were constructed to accommodate the project. Work was scheduled as a 7-day workweek, with Monday through Friday being 10-hour days and Saturday and Sunday being 8-hour days. These workers were part of what would be later known as “the greatest generation.” The efforts that were put forth in this endeavor only served to reinforce this notion. As for their patriotism, workers voluntarily gave up their pay for two Sundays, to buy the U.S. Army Air Corp of Engineers a B-29 bomber. It would be named the “Sunday Punch,” and go on to fly missions in China, Burma, and India during World War II. (Figs. 2 and 3.)

Fig. 2. The Sunday Punch.

Fig. 3. Workers pouring monolith floor slab on operating floor, Feb. 5, 1945.

Speed was of the essence, as evidenced by area billboards reading, “Whose son will die in the last minute of the war?” (Fig. 4.) One J.A. Jones document states, “…the closest control had to be maintained over the flow of material, field coordination between all trades, engineering, planning, and design, installation of production equipment, and finally the testing and pre-operational runs. There was no ‘leeway’ in the construction schedules, and speed had to be maintained without any excuses.” [1]

Fig. 4. Billboard placed in the area.

Understanding the magnitude of the construction is a bit daunting in and of itself. By way of numbers, there were nearly 1,000 miles of air tight welding (Fig. 5.) which were completed by as many as 400 sheet metal workers at one time. There were 3,800 miles of electrical conductors and 825 miles of electrical conduits installed, requiring 90,000 separate tests of electrical connections. There were thousands of precision instruments using 3,000,000 feet of copper wire and 4,000,000 feet of copper tubing. There were 1,200,000 cubic feet of asbestos insulation installed. The gaseous diffusion cascade required 3,000 converters, 6,000 compressors paired with 6,000 motors and 340 miles of piping. There were 187,000 cubic yards of steel and 91,000 cubic yards of concrete.

Fig. 5. Worker performing air tight welding.

It is of little wonder that the K-25 Building was referred to at the time as “the great plant.” Remarkably, construction was completed in less than two years, and in early 1945, the great plant was operational, although portions of the plant were put into service prior to completion. (Fig. 6.)

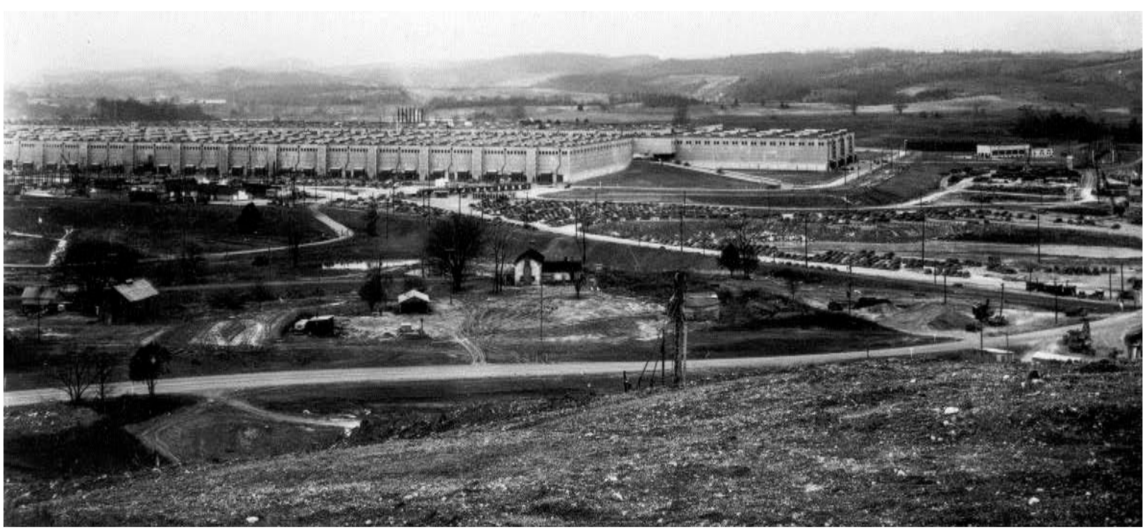

Fig. 6. Northwest view of K-25 with nearby farmhouse, 1945.

Operation of the plant was another monumental task. Although fully automated, 9,000 employees worked in three shifts to operate the plant. Under full operation, K-25 used one-seventh of the nation’s electrical power.

Uranium-235 from the ORR was used in the atomic bomb named “Little Boy,” which was dropped on Hiroshima, Japan, on August 6, 1945. Three days later, on August 9, a second bomb, named “Fat Man,” a plutonium bomb, was dropped on Nagasaki. On August 14, 1945, Japan surrendered, ending the world’s most costly war. (Fig. 7.)

Fig. 7. Workers celebrate the end of the war.

In April, 1945, construction was started on a second gaseous diffusion plant, K-27, which was completed in January, 1946. (Fig. 8.) Post-war enriched uranium was used by power and research reactors, as well as U.S. nuclear submarines. These two buildings worked in tandem until they were shut down in 1964, after flawlessly operating for almost twenty years.

Fig. 8. K-25 Site in 1946. Southeast view of K-25 and K-27 (on left).

CHALLENGES

In 2004, the DOE and Bechtel Jacobs Company LLC (BJC) began the job of cleaning up K-25 and preparing it for final cleanup and demolition. (Fig. 9.) Since then, K-25 has seen two contractors, seven project managers, and four federal project directors, one of them twice. And while it took only two years to build, final cleanup and demolition will have taken almost a decade. In August, 2011, BJC officially turned over the K-25 Demolition and Decommission (D&D) Project to UCOR. The West Wing was demolished and disposed of. Deactivation of the North End and East Wing, minus the Technetium-99 (Tc-99) Area, had been completed, leaving the building and its components intact, less the high-risk equipment (HRE) that was removed to be mined. The North End vaults were filled with HRE components from the West, East and North Wings. The Tc-99 Area remained largely untouched.

Fig. 9. K-25 as of spring 2000.

Much insight can be gained by focusing on some of the larger challenges and solutions that were used to overcome them, sometimes having significant impacts on cost and schedule, both positively and negatively. Like most D&D projects, there was no magic pill, just hard work, coupled with innovation and a strong project management. There are five major areas worthy of examination. The first deals with the sheer size of the structure, which is closely coupled with the second, waste disposal. The third challenge deals with how to accommodate what has been deemed the Tc portion of the building and its associated components, which were heavily contaminated with Tc-99. The fourth challenge is related to the amount of time that passed between shutdown and decommissioning and its impact on the K-25 structure. Lastly, is a look at the fundamental approach that was taken in the nuclear safety, criticality control, and characterization arenas.

Size. The sheer size of K-25 presents unique challenges, not only with the demolition and waste hauling aspects of the job, but particularly with deactivation activities. Due to the repetitive nature of the process, identical deactivation activities are often done literally thousands of times. Whether it is separating compressors from their motors, cutting and capping converters, or a myriad of other deactivation activities, these tasks often occur thousands of times. Analyzing repetitive tasks is usually associated with manufacturing processes and not D&D. In most cases, D&D is anything but repetitive. However, in the case of K-25, repetition was, in fact, the predominant feature. Process improvements proved crucial in holding cost and accelerating schedule. Often process improvement teams would analyze a series of tasks and find ways to improve efficiency, saving an hour or two per activity set. At first, this doesn't appear significant, but if that activity set is repeated six thousand times, it results in a savings of 3 to 6 man-years. In addition to the repetitive nature of deactivation, the literal size of the work area provided its own logistical concerns. Everything from entry and exit points, to the location of fire extinguishers, to the distance that needed to be traversed to retrieve tools and equipment, needed to be carefully planned. The bicycles that were used during operation of “the great plant” have since been replaced with motorized mules, golf carts, and cargo vans. One thing is certain, when it comes to decommissioning gaseous diffusion plants, size really does matter!

Waste Volumes. Once demolition commences, it becomes readily apparent that efficient waste disposition is paramount. Fortunately, Oak Ridge has an on-site disposal cell; and even more fortuitously, it has a haul road that extends from the K-25 Site, located at the East Tennessee Technology Park (ETTP) to the Environmental Management Waste Management Facility (EMWMF), which is located at Y-12. Many highway safety studies were being conducted in the early 2000 time frame in an effort to determine the risks associated with transporting debris from ETTP to EMWMF. A leak of radioactive water in 2005 from a tank being transported to EMWMF for disposal and the subsequent road closure and repaving was all the catalyst needed to make the decision to build the haul road. The K-25 D&D Project has reaped huge benefits from being able to ship process gas equipment under controls and gram limits stipulated by a Transportation Safety Document (TSD) rather than under Department of Transportation (DOT) limits. Without the haul road, dump trucks of Process Gas Equipment (PGE) would have been limited to 15 grams of U-235, rather than the 350 grams currently allowed by the Transportation Safety Department (TSD) and EMWMF waste acceptance criteria (WAC). This likely would have forced the project to size reduce, box, and ship this material to the Nevada Nuclear Security Site (NNSS). On October 9, 2013, UCOR had hauled 20,000 loads of debris from K-25 to the EMWMF for ultimate disposal by UCOR, for a total of 38,000 loads overall.

There were approximately 3,000 converters in K-25. These are large tank-like items for which available packaging, required for transport and final disposition, was limited. Through an intense inspection process and an evaluation of the internal workings of these components, UCOR (along with work being done in Portsmouth, Ohio) put together a position paper that showed that the converters themselves met low specific activity (LSA) and surface-contaminated object (SCO) type material. This designation, along with being fissile excepted, supported a more cost effective IP-1 “super sack” type packaging. Ultimately, UCOR has been able to ship 190 converters, with higher gram values than previously permitted under special permit, while utilizing a reasonably inexpensive package. This not only reduced the shipping and packaging costs, but also the cost and effort associated with mining material out of the converters prior to shipment.

Technetium-99. 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 the 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 NNSS. Characterization showed that all of the building structure and a portion of the process gas equipment could be dispositioned at the EMWMF. Approximately 88% of the overall volume of waste was able to be disposed of at EMWMF as a result. The next step in the process was to develop a demolition and waste removal strategy. Being just miles away from Knoxville, home of the Tennessee Volunteers, a “Go Orange” plan was developed.[1] The strategy includes instituting numerous administrative and engineering controls to: (1) significantly reduce the risk of a release to the environment; (2) ensure all waste is managed and dispositioned appropriately; and (3) prepare the on-site disposal facility, EMWMF, to receive and properly handle the waste. These controls included: foaming of process gas equipment; removal of "high-risk" items prior to demolition; pre-marking of Tc-contaminated components; 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; and a rigorous work control process. In addition, controls were implemented at EMWMF, which included placing the waste in the upper portion of the disposal cell to reduce the overall leachate that could percolate through the waste, and placing a daily cover over the debris that will divert water away from the waste.

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 project. The compressor volutes, once removed from the base, would not fit inside standard fissile containers that were previously certified. 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. Representatives from waste, transportation, environmental and engineering were assembled as a team to facilitate the process. An initial design was drafted and five vendors were identified to fabricate and test a new reusable container. A reusable container design was preferred because it would reduce container costs for the K-25 project and could also be utilized in the upcoming K-27 project as well. All five vendors fabricated and tested their containers, and all containers passed. A vendor was selected, design was finalized, and the first containers arrived two months later. This innovation would save the K-25 project alone over $1,000,000.

Timing. K-25 was shutdown in 1964 and decommissioning activities didn’t begin until 2002. The time span that elapsed, some 38 years, took its toll on the great structure. General failure of the roof allowed significant water intrusion, which continued throughout deactivation. Workers often joked that it rained inside K-25 for days after it stopped raining outside. This effected the general working environment, not only due to the presence of falling and standing water, but also the propagation of mold growth that would make respiratory protection mandatory for building entry. In addition, water

[1] Several colors of paint were tested to determine the highest visibility characteristics to enable identification of Tc-contaminated components in a debris pile. It was determined that orange looked too similar to rust. Blue was more visible, much to the delight of the Project Manager, a Penn State alumnus.

intrusion into the building complicated both contamination controls and criticality controls. Finally, and maybe more significantly, coupled with a multitude of freeze/thaw cycles, the confluence of these natural elements aided in the structural degradation of the building itself.

The first floor of K-25 was constructed of concrete, utilizing a column and beam configuration with the additions of corbels that provided additional support to the column/beam connection. It was in this area that structural failures were identified. In order to maintain the building’s structural integrity, numerous corbel and beam supports had to be augmented with engineered supports. In addition to the structural reinforcements required in the base of the structure, the fourth floor, the operating deck, was manufactured of pre-cast concrete floor panels.

By 2000, the number of defective precast floor panels had increased dramatically. Paths had to be marked with paint/barrier tape in order to provide safe passage to workers performing tasks for surveillance and maintenance on the operating floor. The condition ultimately caused a fall accident, with injury, to a worker in 2005. At that point, all access to the operating floor ceased. The degree of degradation was so significant by the time deactivation commenced that “nets and barriers” had to be installed into much of the building. Debris capturing nets were installed within a small number of withdrawal alleys on the west side of the K-25 building. These giant net systems had a large amount of installation/inspection costs, nearly $10,000,000, associated with them. Shortly after installation, the idea was abandoned in favor of metal barriers. These barriers were comprised of corrugated sheet metal panels that were installed directly underneath the degraded concrete operating floor panels. This installation amounted to tens of thousands of square feet with a significant impact to project cost and schedule.

Despite the hazard that the operating floor presented to workers on the project, access to certain areas was still necessary in order to help achieve “criticality incredibility” prior to building demolition. Areas requiring access in order to perform non-destructive assay (NDA) measurements, sampling, and component removals were denoted and an access platform system was designed. The Modular Work Platform (MWP) system was designed, tested and approved by April, 2008. MWPs were utilized throughout K-25, as required for access, at a cost of well over $1,000,000.

Approach to Nuclear Safety. The challenges associated with the nuclear safety, criticality control, and characterization arenas are the last to be discussed. While these are worthy of their own discussion, they are included in this paper only in order to acknowledge that the sheer impact that they have on the project. It is evident that at the start of the project, the approach taken in addressing these areas was focused on “what was needed to begin.” This approach continued throughout the early and middle stages of the project, and still exists currently. The continuing piecemeal approach driven by “what was required to accomplish the next task” resulted in layer upon layer of component-specific controls, rather than a bounding control set. These controls trickled down through a litany of procedures, postings, and work documents. At some point the layers became so tangled and interdependent, that escape from the “piecemeal” approach to a more comprehensive, bounding approach becomes impractical. The sheer number of controls, coupled with the component specificity, increased the complexity of an inordinate number of tasks. With the advantage of hindsight, this was fundamentally the wrong approach.

Similarly, the characterization of the K-25 systems and structure was divided into 38 waste lots, each bounded by the section of building or equipment that needed to be dispositioned next. If K-25 had been viewed as a whole, the characterization could have been broken into just nine (9) waste lots. This would have resulted in far less sampling, analysis, and waste streams. During the K-25 characterization process, over 2,500 samples were taken. If this approach had been employed, 80% of those samples could have been avoided. The fundamentals of this approach were utilized by UCOR, for the remaining portions of the K-25 building, which reduced sampling cost by roughly $1,500,000.

CONCLUSION

Since UCOR took over the project in August, 2011, the East Wing, non-Tc Area, and the North Wing have been completed. Recently, four of the six remaining units in the East Wing, Tc Area have also been completed.

UCOR plans to complete the demolition of the K-25 structure in late 2013. The size reduction and disposal of building rubble is scheduled to be complete in the first quarter of 2014. Final pad decontamination and closure paperwork is scheduled to finish in the summer of 2014. (Fig. 10.)

Physical Factors. As a project, K-25 has certainly faced its share of challenges, but it also has had some significant advantages. From a purely pragmatic standpoint, the haul road was an essential element in the waste disposition strategy.

Fig. 10. Northwest view of Bldgs. K-25 and K-27, September 2013.

Workforce. When discussing success factors related to the K-25 demolition project, as with the original construction, not to mention the quality of the work force would be inexcusable. The decommissioning of K-25 would not have been successful without the dedication and hard work of the building trades. Laborers, pipe fitters, teamsters, operators, iron workers, electricians, mechanics, and carpenters made up a truly remarkable work force. In addition, the Atomic Trades & Labor Council (ATLC) workers at EMWMF received 80% of all waste generated for ultimate disposal, over 38,000 trucks. The work ethic and safety culture of both groups were and are exemplary. Labor relations are outstanding, and the success of the project largely rests on the shoulders of the work force.

Partnering Relationships. Lastly, during contract transition, both DOE and UCOR committed to generating and sustaining a teaming relationship. This partnership is apparent across the contract, but nowhere more so than the K-25 project. As just one example, there are weekly Integrated Project Team (IPT) meetings that are truly integrated. While this type of meeting is often held, the atmosphere, content, and freedom of discussion found at this particular meeting goes beyond what is normally experienced at a joint client/contractor meeting. This meeting is indicative of the partnering relationship that has been developed. Frank and open discussions dealing with issues across the board are conducted. Discussions are less centered on compromising and more centered on what best serves the project. This free exchange of information alleviates frustrations, moves the project forward, and virtually eliminates surprises on both sides. With the partnership of DOE and UCOR as a foundation, both labor and security also serve as essential members of the team. Together the team works to resolve issues and satisfy the stakeholders: the Environmental Protection Agency (EPA); the Tennessee Department of Environment and Conservation (TDEC), as well as the National Historic Preservation (NHP); Community Reuse Organization of East Tennessee (CROET); Oak Ridge Site Specific Advisory Board (ORSSAB); and various other interested parties. Working together, the K-25 D&D Project is nearing completion, but even before the last load of debris is dispositioned, plans are being put into place to preserve the legacy of “the great plant,” along with the men and women that made it great.

REFERENCES

1. An Engineering News Record Reprint, December 13, 1945.