DEMOLITION OF HANFORD'S 233-S PLUTONIUM CONCENTRATION FACILITY

G. T. Berlin, E. R. Lloyd, D. S. Mantooth, T. K. Orgill, J. G. Riddelle
Fluor Hanford, Inc.

ABSTRACT

This paper describes the technical approach being used to demolish a plutonium-contaminated processing facility at the Hanford Site. This project represents the first open-air demolition of a highly-contaminated plutonium facility at the Hanford Site. This project may also represent one of the first plutonium facilities in the DOE complex to be demolished without first decontaminating surfaces to near "free release" standards.

Demolition of plutonium contamination structures, if not properly managed, can subject cleanup personnel and the environment to significant risk. However, with proper sequencing and innovative use of commercially-available equipment, materials, and services, this project is demonstrating that a plutonium processing facility can be demolished while avoiding the need to perform extensive decontamination or construct large enclosures. The project is utilizing an excavator with purpose-built concrete shears, diamond circular saws, water misting and fogging equipment, specialized fixatives and dust suppressant mixtures, conventional mobile crane and rigging services, and near real-time modeling of meteorological and radiological conditions. Between the months of October and December 2003, approximately 85 percent of the footprint of the 233-S Facility had been demolished and properly disposed. Demolition of the remaining and more technically-challenging portion of the facility is expected to be completed by April 2004.

INTRODUCTION

Hanford's 233-S Plutonium Concentration Facility had been in a slow and continual state of deterioration since its deactivation in 1967. For nearly three decades, surveillance and maintenance was performed to ensure confinement of the building's significant levels of plutonium contamination. Severe winter conditions in 1996 accelerated the rate of building deterioration and heightened the potential of personnel exposure to contamination and environmental release. Based on the increase in risks and associated facility maintenance costs, decisions (under processes of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 [CERCLA]) were subsequently made by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) to remove/demolish the facility (DOE 1997b).

The purpose of the 233-S Demolition Project is to safely demolish the 233-S Facility and to package and properly dispose of all associated waste material. The scope of this project includes the 233-S Building, the 233-SA Exhaust Filter Building, and the MO-317 Mobile Office; a photo and schematic of the 233-S Facility are provided in Figs. 1 and 2, respectively. Upon project completion, the concrete floor slabs for the 233-S Building will remain in-place, capped with concrete, covered with clean fill, and posted as an underground contamination area (CA).

Fig. 1 233-S Facility (photo, looking south, taken before demolition began in October 2003). The 202-S REDOX facility is the large canyon building in background.

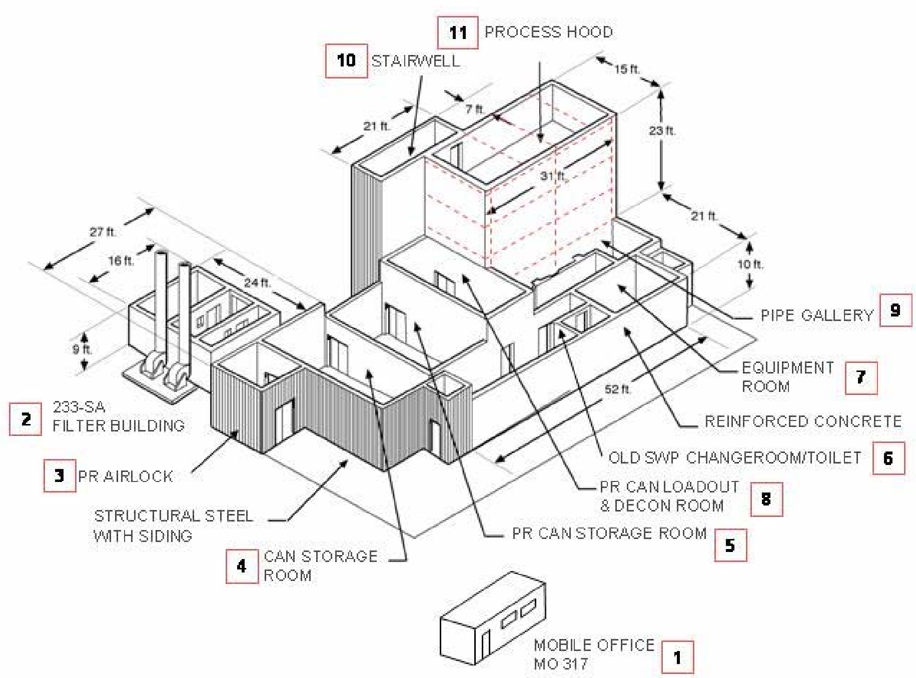

Fig. 2 Schematic of the 233-S Facility (view looking to southeast; numbers in boxes indicate demolition sequence)

The bulk of the building's materials have been designated as low-level waste (LLW) and are being disposed in Hanford's CERCLA landfill known as the Environmental Remediation Disposal Facility (ERDF). Less than 10 percent of the demolition debris has been designated as transuranic (TRU) waste; this waste is being packaged for temporary storage at Hanford's Central Waste Complex, and will eventually be shipped for ultimate storage/disposal at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.

Facility Description

The 233-S Facility is located in the southwest quadrant of Hanford's 200 West Area. Original construction of the facility began in 1953 and was completed in 1955. Several modifications (expansions) were made to the original structure over the following decade, resulting in an overall footprint of approximately 325 m^2 (3,500 sq ft).

The 233-S Facility was comprised of the 233-S Plutonium Concentration Building and the 233-SA Exhaust Filter Building. The 233-S Building was a reinforced concrete structure, with a footprint of 11.3 m (37 ft) x 25.7 m (86 ft), and roof elevations ranging from 3.7 m (12 ft) to 9.7 m (32 ft). Concrete wall thickness ranged from 23-cm (8 in.) to 30-cm (12 in.), and several exterior portions of the building were made of structural steel framing enclosed with corrugated metal exterior siding. The 233-SA Building, located northeast and just adjacent to 233-S, was a single story, reinforced concrete structure with 15-cm (6-in.) thick walls.

233-S Facility History

From 1957 to 1965, the 233-S Facility served a role in the process of developing weapons-grade plutonium. Hanford's plutonium production process began by irradiating uranium fuel at the Site's 100-Area production reactors. Spent reactor fuel was then transported to the 202-S Reduction Oxidation (REDOX) Plant where the aluminum cladding was stripped from the fuel elements and plutonium was extracted as a plutonium nitrate solution. This solution was piped from the neighboring REDOX Plant to the 233-S Facility for additional concentration and packaging. Concentration was performed in the 233-S Building's process cell by boiling and/or ion-exchange treatment. The concentrated plutonium solutions were then packaged in stainless steel, criticality-safe, product receiver (PR) cans (resembling 19 liter [5 gal] propane tanks), and the PR cans were placed into larger canisters for transport via roadway to Hanford's 231-Z Plutonium Isolation Building or the 234-5Z Plutonium Finishing Plant for further processing.

Several significant processing upsets took place during the facility's active operations. In 1956, failure of an air-activated diaphragm valve resulted in the release of approximately 32 grams of plutonium solution to the floor of the 233-S process hood, with subsequent spread of contamination to the REDOX Facility. Later, in 1963, chemical reactions within an anion-exchange concentrator resulted in a rapid pressure increase and the release of plutonium laden resin beads. This, in turn, ignited a fire that burned for 90 minutes, causing extensive damage to process equipment, damage to the ventilation system filter, a spread of gross alpha contamination within the process area, and distribution of radioactive contamination to other portions of the building's interior and the exterior roof surfaces. Between 1-3 kilograms of plutonium were lost as result of this fire. Following extensive cleanup, and construction of the 233-SA Exhaust Filter Building, the 233-S Facility resumed operations until 1967.

Between 1967 and 1987, limited efforts were made to perform initial characterization of the facility and removal of selected equipment and material from the building's load-out area. After 1987, the facility sat idle for nearly another decade.

As part of the CERCLA decision process, a report entitled *Engineering Evaluation/Cost Analysis for the 233-S Facility* (DOE-RL, 1997a) presented four optional approaches for further facility management, including the resulting levels of safety that could be anticipated. Decontamination and/or stabilization of the facility, followed by demolition and disposal, was selected as the most responsive approach to safety concerns, and most supportive of planned land remediation actions (DOE-RL, 1997b).

From 1997 to 2002, Bechtel Hanford, Inc. completed a significant amount of decommissioning scope including the removal of equipment from the process and non-process areas of the 233-S Building. In addition to installation of a portable exhauster, this scope included the removal of roof-mounted ventilation ducting, the process area viewing room support structure, 14 process vessels, nearly 1,500 meters (5,000 ft) of process piping, and other equipment from the equipment room, control room, and other areas of the facility.

In July 2002, responsibility for the 233-S Facility decommissioning was transferred from Bechtel Hanford, Inc., to Fluor Hanford, Inc.

DEMOLITION PREPARATIONS

After assuming contractual responsibility in 2003 for demolishing the 233-S Facility, Fluor Hanford focused the following 12 months on final removal of equipment, limited decontamination, pre-characterization of the building's structural materials, application of fixative coatings to "lock-down" potentially dispersible contamination, deactivation of the portable ventilation exhauster system, and the removal of temporary power and light services.

During the summer of 2003, Fluor Hanford issued requests-for-interest and proposals to provide technical support and a limited amount of equipment for the demolition of the 233-S Facility. A contract was subsequently issued by Fluor Hanford to cr/x environmental services^{SM}, inc. (hereafter referred as cr/x), of Coraopolus, Pennsylvania. The D&D consulting services and specialized heavy equipment hired from cr/x were supported by subcontracted engineering services from Burns & Roe of Oradell, New Jersey, and diamond concrete sawing expertise from Cutting Edge Services Corporation of Cincinnati, Ohio.

The following subsections describe the preparatory efforts prior to the start of demolition in October 2003.

Radiological Characterization

Extensive radiological surveys and nondestructive assay (NDA) measurements were performed during the various stages of equipment and material removal from the 233-S Facility in 2002 and early 2003. A final sampling plan was developed and implemented in mid-2003 to support 1) waste disposal planning for the purposes of minimizing the volume of TRU waste, and 2) evaluation of specific demolition techniques to minimize the release of radiological material during the demolition process. As noted in Table I, the total mass of TRU isotopes within the 233-S Building has been estimated at 13.4 grams (Mantooth, Barton, and Moder, 2003), with the majority of contamination located on the west and north walls of the 233-S process hood. This mass relates to contamination levels in the process areas in excess of 33.4 MBq/m^2 ($20x10^6$ $d/m/100\ cm^2$). The isotopic distribution of TRU within the 233-S Building is summarized in Table II.

Table I TRU mass estimates for 233-S Locations

Location	**TRU (grams)**
Can Storage Room	0.061
SWP Change Room	0.054
Pipe Gallery	0.141
PR Can Storage Room	0.039
PR Can Loadout	0.081
Stairwell – 1st Floor Wall	0.024
Stairwell – 2nd Floor Wall	0.055
Stairwell – 3rd Floor Wall	0.026
Stairwell – 4th Floor Wall	0.018
Stairwell – 1st Floor Landing	0.023
Stairwell – 1st Floor Landing	0.049
Stairwell – 1st Floor Landing	0.037
Stairwell – 1st Floor Landing	0.016
Stairwell – Ceiling	0.002
Process Hood – West Wall	5.682
Process Hood – North Wall	6.175
Process Hood – South Wall	0.038
Process Hood – East Wall	0.828
Process Hood – Ceiling	0.037
Total	13.39

Table II Isotopic weight distribution as determined through sampling and analysis data

Isotope	Weight Fraction (w_i/w_T)
Pu-238	0.0007
Pu-239	0.8405
Pu-240	0.1046
Pu-241	0.0074
Pu-242	0.0059
Am-241	0.0108
Np-237	0.0301
	w_{TRU}/w_T=0.9926

Radiological Analysis of Demolition Techniques

Characterization data (as referenced above) were utilized for purposes of waste designation, and for performing radiological analysis of demolition techniques. The Hotspot 2.01 (Hotspot, 2002) atmospheric dispersion computer code was utilized to estimate the downwind personnel committed dose and surface contamination levels that would result from four different demolition techniques (Knight and Mantooth, 2003). These techniques included demolition via the use of 1) a wrecking ball, 2) mechanical shear, 3) circular blade diamond wall sawing, and 4) continuous diamond wire sawing. Hanford Site averages for wind speed and stability class were used for the model. The wrecking ball method demonstrated the greatest potential for generating airborne contamination, followed in order by mechanical shearing, circular diamond blade wall sawing, and continuous diamond wire sawing.

As reflected in Table III, for a given quantity of radioactive material at risk, use of the diamond circular blade or wire saws would result in a level of downwind contamination two-to-three orders of magnitude less than the more aggressive techniques. Values for use of a wrecking ball are not noted below, nor considered for further evaluation because the method was not approved for use under the facility's safety basis.

Table III Evaluation of demolition methods

Demolition Method	Maximum CEDE* (rem)	Maximum Alpha Contamination (d/m/100cm2)	Distance to Max. (km)
Mechanical Shears	2.1	1.8E+05	<0.01
Circular Diamond Blade Wall Sawing	0.56	460	<0.01
Continuous Diamond Wire Sawing	0.046	500	<0.01

*CEDE = Committed effective dose equivalent

The values noted in the above table compare unmitigated releases resulting from each demolition method. Mitigation techniques such as pre-decontamination, water misting/fogging, fixative applications or other engineered methods would further reduce the potential for release of radioactive material.

Demolition Method Selection

Based on a value-engineering session (Parker, 2003) involving input from all levels of 233-S Facility staff, a proposed plan from cr/x, and other planning efforts, an acceptable demolition approach evolved for the 233-S Facility. The selected approach involved using a Caterpillar excavator equipped with a concrete-shear attachment to size-reduce the single-story and less-contaminated portions of the 233-S and 233-SA Buildings. The selected approach also involves use of circular diamond blade wall saws for cutting the taller and more contaminated portions of the 233-S Facility (i.e., process hood) into large, rectangular blocks that would then be lowered via crane.

After the combined shearing and sawing approach was selected for 233-S Facility demolition, a decision was made to perform additional and more detailed atmospheric dispersion modeling to confirm that the work could be performed without releasing alpha contamination beyond the CA boundary in excess of 33.4 Bq/m^2 (20 $d/m/cm^2$). The dispersion modeling was performed by AlphaTrac of Westminster, Colorado, using ISC-PRIME (an EPA-developed program that uses actual weather conditions). The ISC-PRIME code was considered more applicable for modeling potential atmospheric releases from 233-S than the previously used HotSpot 2.01 code, for the following reasons: 1) it uses actual site weather conditions reported hourly; 2) it has algorithms that account for the building "downwash" generated by the 202-S REDOX Plant; and 3) releases to the atmosphere from demolition activities could be matched to time of release and actual weather conditions, providing a more accurate picture of where potential contamination will occur.

The ISC-PRIME dispersion modeling results indicated that all areas with contamination levels exceeding 33.4 Bq/m^2 (20 $d/m/100\ cm^2$) would lie within a 40 meter-radius CA boundary as measured from the center of the 233-S process hood. These analyses helped to reaffirm that this "first-of-its-kind" open-air demolition project should proceed as planned.

DEMOLITION OPERATIONS -- PROGRESS TO DATE

Demolition operations at the 233-S Facility began in mid-October 2003. At the time of this writing, MO-317, the 233-SA Building and the single-story portions of the 233-S Building have been safely demolished, packaged, and buried in the ERDF landfill. This scope was accomplished without any release of contamination outside of the controlled area boundary.

The following subsections describe a number of the controls established to accomplish this work, the general approach employed, and lessons learned that have been acquired thus far.

Radiological Controls

A variety of radiological controls were established to protect the decontamination and decommissioning (D&D) workers, and to prevent the spread of contamination outside of the CA

(Mantooth, 2003). As noted earlier, the CA boundary was established at a 40-meter (131-ft) radius from the center of the 233-S process hood. A radiological buffer area was also established 10 meters (30.5 ft) beyond the CA boundary to allow for staging of supervisory personnel, waste containers, and a variety of support equipment.

Fugitive dust emissions from the breaking and/or packaging of concrete rubble were controlled by use of water-efficient misters and foggers. MARTIN® FOG CANNONS™ were positioned on two sides of the demolition activity to provide light and general-area misting; each unit delivered approximately 53 liters/min (14 gal/min). A low-flow, 9.5 liters/min (2.5 gal/min) misting system head was designed by cr/x and installed directly into the excavator arm, with nozzles positioned at the throat of the shear. The design, which localized a concentrated mist directly into the cutting action of the shears, proved to be extremely effective. Dust suppressants (i.e., Soil-Sement® solutions) were also applied prior to shut-down periods and prior to any anticipated high-wind conditions.

Specialized controls were established for capturing the potentially-contaminated water that will be generated while cooling/lubricating the circular diamond saw blades as they dissect the highly-contaminated process hood into large blocks. Prior to the start of shear demolition operations, the predetermined saw-cut pattern lines were marked on the interior wall and ceiling surfaces of the process hood. A network of metal gutters were then installed via powder-actuated fasteners to cover each of the saw cut lines on the inner wall and ceiling surfaces; the gutters are positioned to drain to a common manifold for water collection and disposal. To address the need to capture the potentially-contaminated saw cooling/lubrication waters on the exterior of the process hood, cr/x developed a uniquely-designed shroud that attaches directly to the saw as it cuts along the concrete surfaces. A set of saw receiver shrouds were also created for attachment directly to the ends of the saw track to capture concrete slurry as the saw blade travels beyond the corners, openings, or ends of the structure as it completes the saw cuts.

Wind conditions are continually monitored via windsock, a nearby weather station, and hand-held anemometers. All workers and support equipment are to be located upwind of the demolition activity and at a distance sufficient to prevent inadvertent contamination should the wind direction change. The maximum allowable wind speed for demolition operations was 12 miles per hour.

Personal protective equipment (PPE) requirements for all demolition and support personnel within the CA include a single set of special work permit (SWP) clothing, waterproof rain gear, and a Power Air Purifying Respirator (PAPR) with hood. A Hanford standard dosimeter and a lapel air sampling pump are also required for radiation monitoring of personnel. Contamination surveys and air monitoring are also routinely required via three grab-air samplers, five continuous air monitors, 18 fixed plate survey stations, and exit surveys of personnel and equipment.

Concrete Shearing Operations

As of late December 2003, MO-317, the 233-SA Building, the single-story portion of the 233-S Building, and the four-story stairwell (connected to the 233-S process hood) have been completely and safely demolished; segmentation of the process hood using concrete saws began in January 2004.

All of the demolition effort to date has been accomplished using a 45,000 kg (100,000 lb) CAT® hydraulic excavator equipped with $12x10^6$ newton (1,300 ton) rotating mechanical shear. The demolition sequence began with the Mobile Office (MO-317), as previously noted in Fig. 2. Demolition and waste packaging/disposal of this relatively benign structure demonstrated that all equipment, personnel, dust suppression systems, and waste loading procedures were indeed prepared and ready to proceed immediately to the more contaminated 233-SA Building.

Since nearly all of the structures demolished during the shearing phase of the project (with exception of the four-story stairwell) were less than 3.6 m (12 ft) from grade level, all building material removed by the excavator were generally directed onto the interior slab surface. Protection of adjacent building and structures (e.g., an electrical transformer on the east side of 233-S, and an underground pipe trench located on the west side of 233-S) from falling rubble was established via chain-link barriers and other materials prior to the start of demolition.

After the 233-SA Building was demolished and its waste was loaded, demolition of the 233-S Building proceeded from northeast to southwest. Photographs in Fig. 3 depict the field settings during demolition of the 233-SA Building, and weeks later when the excavator was demolishing the four story stairwell on the east side of the 233-S process hood.

Fig. 3 Images during demolition – left photo depicts demolition of the 233-SA Building (note the FOG CANNON™ in lower left of the image and the ERDF waste container in center); right photo depicts subsequent demolition of the 233-S process hood stairwell.

Loading of concrete into the lined ERDF waste containers, each 2.4-m wide x 6.1-m long x 1.8-m high (8 ft wide x 20 ft long x 6 ft high), was performed whenever a sufficient quantity of rubble was generated. The rubble piles were kept wet at all times. The concrete rubble was loaded into the ERDF containers using a front-end loader, and the structural steel and metal siding associated with the process hood stairwell were primarily loaded into the ERDF containers via the grappling capability of the shear jaw. A total of 65 ERDF containers were used to package and dispose of all debris generated during demolition of MO-317, the 233-SA Building, the lower portions of the 233-S Building, and the stairwell attached to the 233-S process hood.

Lessons Learned from Shearing Operations

As of January 2004, approximately 85 percent of the 233-S Facility footprint has been safely demolished, packaged and properly disposed. While only 15 percent of the footprint remains to be demolished, this final task is expected to account for about 40 percent of the total project effort due to the higher levels of contamination within the process hood.

Lessons learned from this demolition project are extremely important, as additional plutonium facilities are scheduled for demolition at Hanford and at other DOE sites over the next several years. The facility operations staff is continuing to gather lessons learned from the field operations; specific documentation on this subject will be prepared upon project completion. A sampling of lessons learned from the past several months of 233-S Facility demolition operations is provided below.

- *Fixative Applications Proving to be Very Effective* – Both paint, Polymeric Barrier System™ (PBS) and other fixatives were extensively applied to the buildings interior surfaces over the past several years. Contamination levels as high as 28.4 Bq/m^2 (17x10^6 d/m/100 cm^2) were recorded in the stairwell before fixatives were applied to this area. While some paint chips from the stairwell were found on the ground surrounding the general area of demolition, the contamination was "captured" within the paint volume, and not found to be smearable.

- *FOG CANNON™ and Misting Devices Proved to be Very Effective* – The use of the MARTIN® FOG CANNON™ was new to the Hanford Site, and proved to be extremely effective for capturing and "knocking down" dust generated during the demolition process. Also, the misting device designed and installed by cr/x for applying a more localized mist near the end of the excavator arm appeared to be extremely effective.

- *Front-End-Loader Was Most Efficient for Waste-Container Loading* – In addition to deploying the concrete shear, original plans called for the hydraulic excavator to also perform most of the waste loading. The grappling capability of excavator's shearing attachment was effective for handling the structural steel and metal siding materials. However, use of a dedicated front-end loader for placing concrete debris into the large ERDF waste containers was found to be more time efficient than switching-out attachments on the hydraulic excavator (i.e., switching the mechanical shears and a companion 5-yard bucket).

- *More Waste Shipments Needed than Originally Planned* – The number of waste container shipments for disposal of the demolition debris turned out to be greater than originally planned; this was mostly due to the bulk of the materials and the desire to minimize the amount of "on-ground" processing/size reduction of debris and sheet metal.

- *Flexibility and Patience Needed to Accommodate Weather* – Average wind and temperature patterns were considered during the initial project planning and scheduling. However, Hanford's weather during the months of November and December 2003 proved to be unseasonably windy and much colder than anticipated. Snow accumulations were also been much greater than usual. Consequently, periods of downtime were greater than expected. While nearly all equipment was well protected for subfreezing conditions, small-diameter water lines were a challenge. Also, with the use of PAPR hoods (which blow ambient temperature air into the hood), and the potential for frost bite and slippery conditions, elevated concern for personnel comfort and safety has been essential.

UPCOMING DEMOLITION OF PROCESS HOOD

Removal of the highly-contaminated 233-S Building process hood began in January 2004 and will continue for several months. This task will be accomplished by segmenting the structure into pre-engineered panels using track-mounted, diamond-blade wall saws. Recent photos of the saw cuts made on the roof of the 233-S process hood are shown in Fig. 4. After each rectangular panel is cut, it will be lowered via crane, and then prepared for disposal. Most panels will be wrapped in plastic and polypropylene bags (supplied by MHF Logistical Solutions) and transported for disposal as LLW at the ERDF site. Designated panels from the lower northwest portion of the process hood are classified as TRU waste and will be further size- reduced, packaged, and transported to Hanford's Central Waste Complex. The TRU waste will eventually be disposed at the WIPP Site in Carlsbad, New Mexico.

A detailed cutting plan has been prepared to ensure that integrity of the roof and wall structures is maintained during the segmentation and crane/rigging evolutions. The reinforced concrete wall and roof sections are 30.5 cm (12-in.) thick; the largest of panels will be cut to 2.4 m x 4.6 m (8 ft x 15 ft), weighing approximately 9,000 metric tons (20,000 lb). Over 80 lineal cuts will be necessary to fully segment and remove the process hood structure. The total length of cutting is in excess of 275 m (900 ft).

Fig. 4 Images during segmentation – left photo depicts shrouded concrete saw at the beginning of a horizontal roof cut; right photo depicts the shrouded wall saw at the end of a horizontal roof cut. (*Notice saw receiver -- designed to capture slurry released by the exposed saw blade as it begins or completes the cut).*

Before demolition operations began in October 2003, a core-boring drill was used to create a number of through-holes in predetermined location to install lifting hardware. These holes were installed in the roof and on all accessible/exposed locations on the walls of the process hood. After the stairwell and single story portions of 233-S Building were demolished, the remaining holes were installed. As discussed earlier, some of the additional preparations for saw cutting included the installation of gutters on the interior walls of the process hood to capture the cooling/lubrications waters that will spray-off from the rotating saw blades during the final break-through cuts. Expertise on the saw cutting operations is being provided by Cutting Edge Services Corporation. Representatives from Cutting Edge staff are providing the services of equipment operations, training of Hanford's D&D workers, and technical support.

SUMMARY AND CONCLUSIONS

This project represents the first open-air demolition of a highly-contaminated plutonium facility at the Hanford Site. This project may also represent one of the first plutonium facilities in the DOE complex to be demolished without first decontaminating surfaces to near "free release" standards. The decision to perform or not perform extensive decontamination of wall, floor, and ceiling surfaces prior to demolition of radioactively contaminated facilities presents significant trade-offs in cost, schedule, and risk. While this project is expected to be completed several months ahead of the contracted date of June 2004, significant challenges still lie ahead as the process hood is cut and disassembled via saw cutting techniques.

Nearly 85 percent of the 233-S Facility footprint has been successfully removed without release to the environment and without personnel injury. Upon completion of this project, the acquired skills and lessons learned will be shared to benefit future demolition projects at Hanford and other DOE sites.

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