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Revision 0

324 REC & SMF Hot Cell Disposition Radiological Options Analysis

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Hanford Field Office under Contract 89303320DEM000030

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Executive Summary

This document is prepared as a radiological assessment of various proposed demolition techniques for the 324 Facility located in the 300 area of the Hanford Nuclear Reservation. This document is intended to provide a basis of comparison for demolition techniques under consideration for areas with significant residual radioactive contamination in terms of airborne release fractions, internal and external exposure received by workers, and surface deposition of radioactive material.

Initially, four options were considered for evaluation to include diamond wire saw, universal processors, abrasive water jet, and expansive grout. Abrasive water jet and expansive grout were eliminated from consideration due to limitations; the abrasive water jet technique generates undesirable amounts of water, and the expansive grout technique requires extensive core drillings and lengthy set up times. As a result, demolition options analysis only includes diamond wire saw and universal processors techniques.

Analysis includes the calculation of respirable source term and the potential for the generation of airborne radioactivity, dose rates and shielding requirements.

The respirable source term and associated internal dosimetry hazard for universal processors removal of the hot cells is 455 times higher than for monolithic removal using diamond wire saws. Based solely on this criteria, monolithic hot cell removal is recommended.

Neither option alone provides the best fit demolition approach. A combination of the two for applicable scenarios including the use of an enclosure similar to that used for the Accelerated Retrieval Project (ARP) at the Idaho National Laboratory (INL) likely provides the optimum approach from both a radiological and demolition operations perspective. The following may be considered as plausible recommendations:

- For higher elevations, where radiological conditions do not prohibit occupancy, the use of diamond wire saw cutting with a wire and slurry confinement system is recommended.
- For lower elevations, near ground level and below ground surface (bgs), where radiological conditions prohibit occupancy, robotic universal processors and the use of soil for shielding purposes may be suitable.
- For occupied areas where derived air concentration (DAC) values may exceed prescribed respiratory protection factors, install breathing air for operator safety and comfort.
- Install a latex paint sprayer, or equivalent, near the end of universal processor end effectors to provide fixative for dust suppression, contamination, and airborne radioactivity control during processing.
- For elevated dose rates where universal processor cabs may be occupied, install telemetry dosimetry in the cab and near the end of the processor for operator safety.
- Determine threshold values for airborne radioactivity and dose rates where robotic universal processors should be used.

- Determine waste package design and shielding requirements where dose rates may exceed Hanford Transportation Safety and Environmental Restoration Disposal Facility (ERDF) waste acceptance criteria requirements.

- Consider the use of an enclosure with large air handling units to mitigate releases of contamination and airborne radioactivity to the environment once the above grade portion of the hot cells have been removed.

Additional analysis is required if the 324 Facility removal design approach deviates from that presented in this document.

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Acronyms

AED	Aerodynamic Equivalent Diameter
ARA	airborne radioactivity area
ARF	Airborne Release Fraction
ARP	Accelerated Retrieval Project
Ba	Barium
bgs	below ground surface
cm	centimeter
CMEL	Chemical Materials Engineering Laboratory
Cs	Cesium
DAC	Derived Air Concentration
DE-Ci	Dose Equivalent Curies
DOE	U.S. Department of Energy
DR	Damage Ratio
EF	Emission Factor
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FRPP	Fuel Recycle Pilot Plant
FSB	Fuel Storage Basin
Ft	feet
g	gram
HEPA	High Efficiency Particulate Air
HLV	High-Level Vault
hr	hour
in	inch
INL	Idaho National Laboratory
lb	pound
LLV	Low-Level Vault
LPF	Leakpath Factor
M	Moderate
MAR	Material-at-Risk
Mrem	millirem
μm	micrometer
PT	Pipe Trench
Pu	Plutonium
R	Roentgen
REC	Radiochemical Engineering Complex
RF	Respirable Fraction
RST	Respirable Source Term
SMF	Shielded Materials Facility
ST	Source Term
WTEL	Waste Technology Engineering Laboratory

1 Scope

This document is prepared as a radiological assessment of various proposed demolition techniques for the 324 Facility located in the 300 area of the Hanford Nuclear Reservation. This document is intended to provide a basis of comparison for demolition techniques under consideration for areas with significant residual radioactive contamination.

This document should not be used to provide absolute limits for allowable radioactive contamination.

2 Facility Description

The 324 Waste Technology Engineering Laboratory (WTEL) was constructed in the Hanford 300 Area from 1964 to 1966 as a Fuel Recycle Pilot Plant (FRPP). It was partially designed to support Plutonium Recycle Test Reactor (PRTR) operations by housing chemical processing and metallurgical examination of PRTR fuel elements. As such, it was built as a dual-purpose facility with both radiochemical and radiometallurgical hot cell facilities. Mission changes caused the facility to become known as the Chemical Materials Engineering Laboratory (CMEL) throughout most of its history.

The radiochemical hot cell facility is referred to as the Radiochemical Engineering Complex (REC). The radiometallurgical hot cell facility is referred to as the Shielded Materials Facility (SMF). Each is a monolithic structure constructed of thick reinforced concrete designed to provide protection from radiation sources on the order of 10^6 R/hr. The REC contains four hot cells (A-, B-, C-, and D-Cells), along with an Airlock Cell. The SMF contains two hot cells (East- and South-Cells) and has its own Airlock Cell.

Other monolithic support structures include the High-Level Vault (HLV), Low-Level Vault (LLV), Fuel Storage Basin (FSB), A-Frame Filter Pit, and REC Pipe Trench (PT).

Highly radioactive material is known to have leaked to the soil underlying the REC hot cells, with measured soil dose rates up to 13,000 R/hr. The highest dose rates are found below B-Cell. This area is designated as the 300-296 waste site.

Above-grade facilities and structures outside of the REC and SMF are assumed to have been demolished and are excluded from this analysis (above the 0’-0” elevation as shown on drawings).

3 Proposed Approaches

Suitable approaches for dismantling heavily reinforced massive concrete structures (biological shields, base mats, foundations, and walls >2 ft thick) are included in Table 1.[1]

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[1] DOE/EM-0142P *Decommissioning Handbook*, Table 10.2 *Summary of Application for Cutting and Demolition of Concrete*.

Table 1. Applications for Cutting and Demolition of Concrete

Technique	Remarks
Diamond Wire Saw	Thickness is virtually unlimited. However, access to both sides of material is required; high potential for spread of contamination. Metal aggregate may tear diamonds from wire and cause excess wire wear.
Universal Processors	Slow; can cut and separate rebar and embedded steel. Dust and contamination control with a fog spray. Interchangeable attachments for different applications.
Abrasive Water Jet	Depth of cut will be deeper where there is concrete only; therefore, multiple passes may be required. Generates large quantities of water and used grit.
Expansive Grout	Slow; rebar must be cut after fracture. Recommended where noise and vibration must be controlled or access is limited. Backhoe required to separate rubble.

3.1 Description of Techniques

3.1.1 Diamond Wire Saw

Diamond wire saw cutting involves a series of guide pulleys that draw a continuous loop of multistrand wire strung with a series of diamond beads and spacers through a cut. The length of wire required for a cut is obtained by assembling standard-length sections of wire end to end using screwed sleeves. A contact tension is kept on the wire. This force, in combination with the spinning wire, cuts a path through concrete and reinforcing rods. Linear wire speed and wire tension are adjustable. The wire is wrapped around the object to be cut and tension is applied. If an internal cut is required (e.g., doorway), core drilling is necessary, and the wire is fed through the holes. Almost any thickness can be cut with this technique.

One of the major benefits of the wire saw is the flexibility of its pulley system, which allows it to cut unusual configurations. This flexibility also allows easy and safe cutting in difficult to access areas without moving obstructions. The wire saw also lends itself to remote cutting in hazardous, radioactive, or underwater environments. Moreover, little noise and vibration are created, so the structural integrity of the surrounding structure is not affected. Water is used not only for cooling and lubricating purposes, but also for removing swarf from the kerf. This water can be treated and recycled, and the swarf, if contaminated, must be properly dispositioned.

Potential concerns associated with wire saws include physical hazards caused by mechanical failure or contaminant transport. For example, a wire that breaks while it is being used can inflict injury upon the operator. It is just as important, however, that the same vigilance to ensure that the saw and drive unit are carefully maintained be extended to potential problems associated with contaminant transport. Contaminated swarf can be carried from the cutting area by the wire, contaminating the wire saw itself, the areas along the path of the wire, and the area where the drive unit is located.

3.1.2 Universal Processors

Universal processors demolition techniques refer to the use of various attachments mounted on an excavator or suspended by cable to disassemble a structure. Basic attachments, which operate off a hydraulic system, include such items as concrete pulverizers, shears, grapples, and rams. These attachments perform the following functions:

- Pulverizer – crushes concrete and separates rebar and encased steel beams
- Shears – sever concrete, metals, structural steel, wood, rubber, and plastic
- Grapple – serves as an all-purpose tool for demolition and materials handling
- Rams – demolish concrete structures (~6-ft. thick) using a moil or chisel point

Interchangeable jaws (concrete pulverizer jaws, shear jaws, and concrete cracking jaws) are also available. This line of equipment improves processing, reduces costs, and increases versatility.

3.1.3 Abrasive Water Jet

The abrasive water jet cutting technique involves the use of highly pressurized water. The water is pressurized by a hydraulically driven intensifier pump. The water flows through a chamber where it is mixed with an abrasive, the most common being crushed garnet. This mixture of water and abrasive is then forced through a wear-resistant nozzle with a small orifice, which focuses the abrasive jet stream at the component being cut. The pressurized jet stream exits the orifice at extremely high velocities, producing erosion that yields a clean cut with a minimal kerf. If this process is applied to contaminated surfaces, the resulting slurry consisting of cut particles of material (i.e., concrete, and reinforcing bar), abrasive, and water may require collection and treatment.

Abrasive water jet cutting generates large quantities of water and used grit. It is possible to recycle the water, but such a recycling effort requires an ultra-pure filtration system with sufficient capacity to support operations. Without an ultra-pure filter, the cylinders of the intensifier pump will become scored more quickly, making the generation of the necessary high pressure virtually impossible. Moreover, the abrasives may also wear away the recycling system piping components, which could lead to leakage of contaminants. The cost of the filtration system adds to the high cost of the intensifier, making the overall process fairly expensive.

3.1.4 Expansive Grout

Expansive grout is a material used to fracture concrete. The material, which is similar in property to portland cement, is mixed with water and poured into predrilled holes where it is allowed to cure. As it cures, it expands, cracking the workpiece so that it may be removed.

The process may be used to crack concrete of any size, reinforced or nonreinforced, provided it has a free face to which it may expand. The extent and direction of cracking is controlled by hole spacing, hole depth, and hole diameter. As the material hydrates, it expands, with the result that cracks are first initiated, propagated, and widened. The fractured burden may be removed by demolition hammer, jackhammer, paving breaker, or backhoe. If reinforcing rods are encountered, they must be cut separately. Dust control measures are required during the drilling and removal phases.

4 Suitable Approaches

Given that the abrasive water jet technique generates undesirable amounts of water and that the expansive grout technique requires extensive core drillings and lengthy set up times, these two approaches will not be discussed further. As a result, the remaining options analysis will only include diamond wire saw and universal processors techniques.

5 Definition of Terms

5.1 Source Term

The source term is the amount of radioactive material, in grams or curies, released into the air. The initial source term is the amount of radioactive material driven airborne at the source. The initial respirable source term, a subset of the initial source term, is the amount of radioactive material driven airborne at the source that is effectively inhalable. Lesser source terms are determined by applying filtration or deposition factors to the initial source term.

The airborne source term (ST) is typically estimated by the following five-component linear equation:

$$ST = MAR \times DR \times ARF \times RF \times LPF \quad \text{(Eq. 1)}$$

where:

MAR = Material-at-Risk (curies or grams),

DR = Damage Ratio,

ARF = Airborne Release Fraction (or Airborne Release Rate for continuous release),

RF = Respirable Fraction, and

LPF = Leakpath Factor.

The initial source term and initial respirable source term are products of the first three factors and first four factors, respectively. A depleted source term after a subsequent stage of deposition or filtration is a product of the initial source term multiplied by the leakpath factor of the specific stage.

<u>Material-at-Risk (MAR)</u>

The material-at-risk is the amount of radionuclides (in grams or curies of activity for each radionuclide) available to be acted on by a given physical stress. For facilities, processes, and activities, the MAR is a value representing some maximum quantity of radionuclides present or reasonably anticipated for the process or structure being analyzed. Different MARs may be assigned for different phases of demolition as it is only necessary to define the material in those discrete physical locations that are exposed to a given stress. For example, a spill may involve only the contents of a tank in one glovebox. Conversely, a seismic event may involve all the material in a building.

Damage Ratio (DR)

The damage ratio is the fraction of the MAR actually impacted by the demolition conditions. A degree of interdependence exists between the definitions of MAR and DR. If it is predetermined that certain types of material would not be affected by a given demolition technique, some analysts will exclude this material from the MAR.

Airborne Release Fraction (ARF)

Airborne Release Fraction is the coefficient used to estimate the fraction of MAR that can become airborne due to stresses created by the work activity. The ARF is based primarily on experimental values and is a function of particle properties such as size distribution, density, shape, and cohesiveness, and stress parameters that create the airborne release. When using experimental ARF values from DOE-HDBK-3010-94 [2], it is important to understand the particle properties, stress parameters, and limitations under which the measurements were made.

Respirable Fraction (RF)

The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-µm Aerodynamic Equivalent Diameter (AED) and less.

Leakpath Factor (LPF)

The LPF is the fraction of the radionuclides in the aerosol transported through some confinement deposition or filtration mechanism.

For this analysis, no confinement or filtration mechanism is assumed and LPF is conservatively assumed to equal 1. As such LPF is omitted in subsequent equations.

5.2 Respirable Source Term

The Respirable Source Term (RST) is the amount of Source Term that is subject to inhalation by the receptor. While inhalation is not the only pathway that must be considered, the RST is typically the dominant contributor to receptor dose. Calculated Respirable Source Terms are based on DOE-HDBK-3010-94 and estimated by the following equation:

$$\mathrm{RST} = \mathrm{ST} \times \mathrm{RF} \qquad \text{(Eq. 2)}$$

where:

ST = The initial Source Term, MAR × DR × ARF, as calculated above, and

RF = Respirable Fraction, as defined above.

6 Material at Risk

The material-at-risk (MAR) is assumed to be equal to the estimated radioactive material inventory

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[2] DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.

for each of the proposed monoliths in the 60% diamond wire saw cutting design from 0300X-CA-N0118 *Radioactive Material Inventory of 324 Building Hot Cell Disposition Monoliths*, Revision 1.[3]

To simplify airborne radioactivity estimates, radionuclide activities were converted to total dose equivalent curies (DE-Ci) relative to Type M Pu-239.

Table 2. Monolith MAR (DE-Ci)

Monolith ID	Description	MAR (DE-Ci)
M1	Airlock Roof (North)	1.79E-03
M2	Airlock Roof (South)	1.79E-03
M3	Airlock Door	2.05E-04
M4	D-Cell	7.76E-01
M5	C-Cell	6.80E-03
M6	A-Cell Top	6.47E-03
M7	A-Cell Bottom	6.52E+00
M8	B-Cell Top	1.65E+00
M9	B-Cell Middle	2.21E+00
M10	B-Cell Bottom	2.00E+01
M11	A-Frame Filter Pit	9.39E-02
M12	Airlock Floor Slab	6.81E-03
M13	Low Level Vault	1.58E+00
M14	High Level Vault	3.50E+01
M15	SMF Lid (South)	2.89E-04
M16	SMF Lid (North)	2.17E-04
M17	SMF Bottom (South)	1.51E-01
M18	SMF Bottom (Mid)	1.08E-04
M19	SMF Bottom (North)	7.89E-02
	Total	**6.81E+01**

7 Analysis of Demolition Techniques

Two demolition methods are considered in this analysis: Diamond Wire Saw and Universal Processors. Each method has a unique Damage Ratio, Airborne Release Fraction, and Respirable Fraction due to individual characteristics each technique exhibits. These parameters allow the calculation of a specific Respirable Source Term for each technique. The Respirable Source Term for each technique is determined using consequence analysis and data found in DOE HDBK-3010-94.

7.1 Diamond Wire Saw

Monolithic removal by diamond wire saw cutting was the selected dismantling method prior to discovery of the 300-296 waste site. Sixty percent (60%) Engineering design documents segmented the REC and SMF into nineteen (19) total monoliths.

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[3] 0300X-CA-N0118, *Radioactive Material Inventory of 324 Building Hot Cell Disposition Monoliths*, Revision 1.

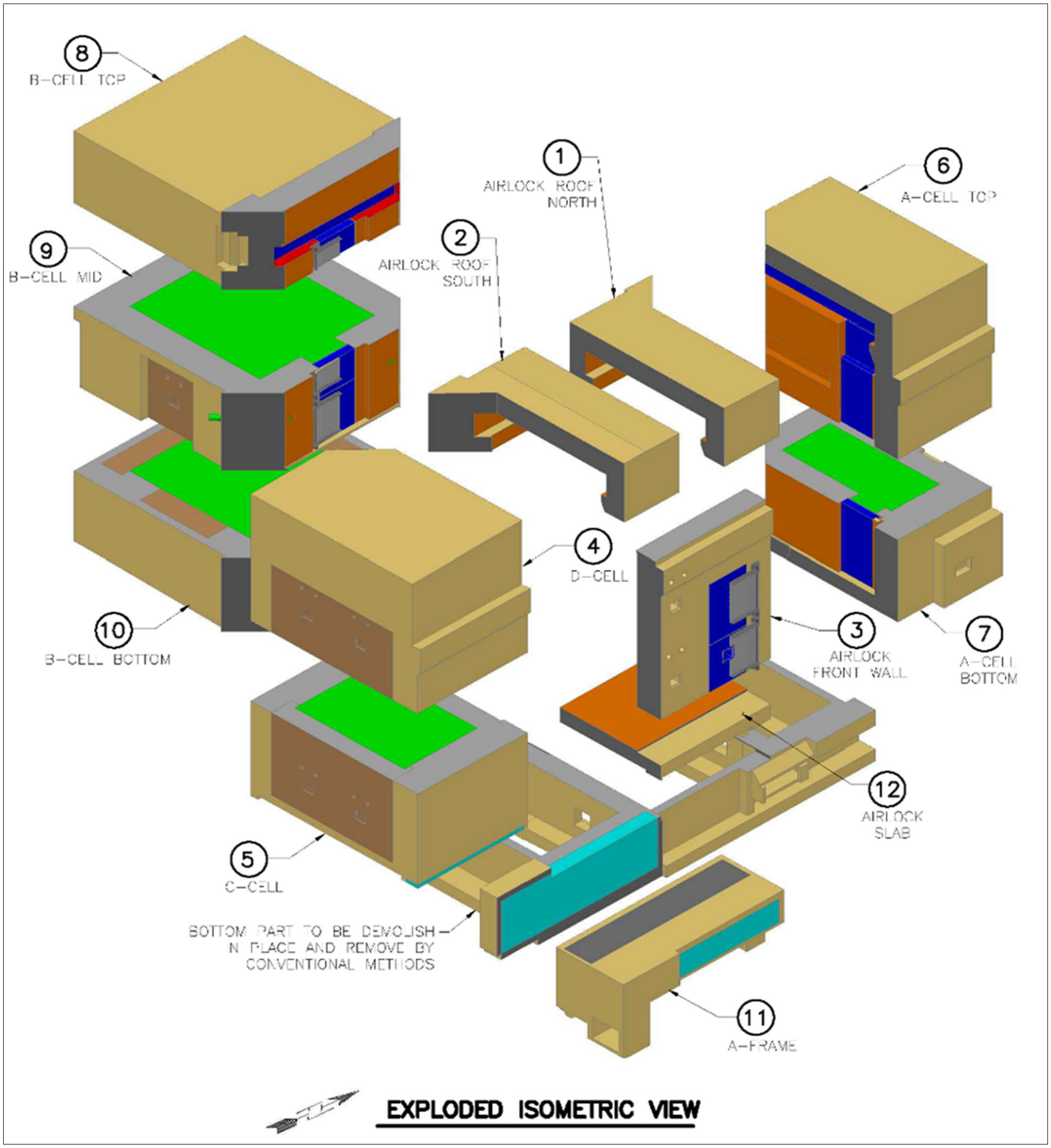

Figure 1. REC Monolith Segmentation Plan

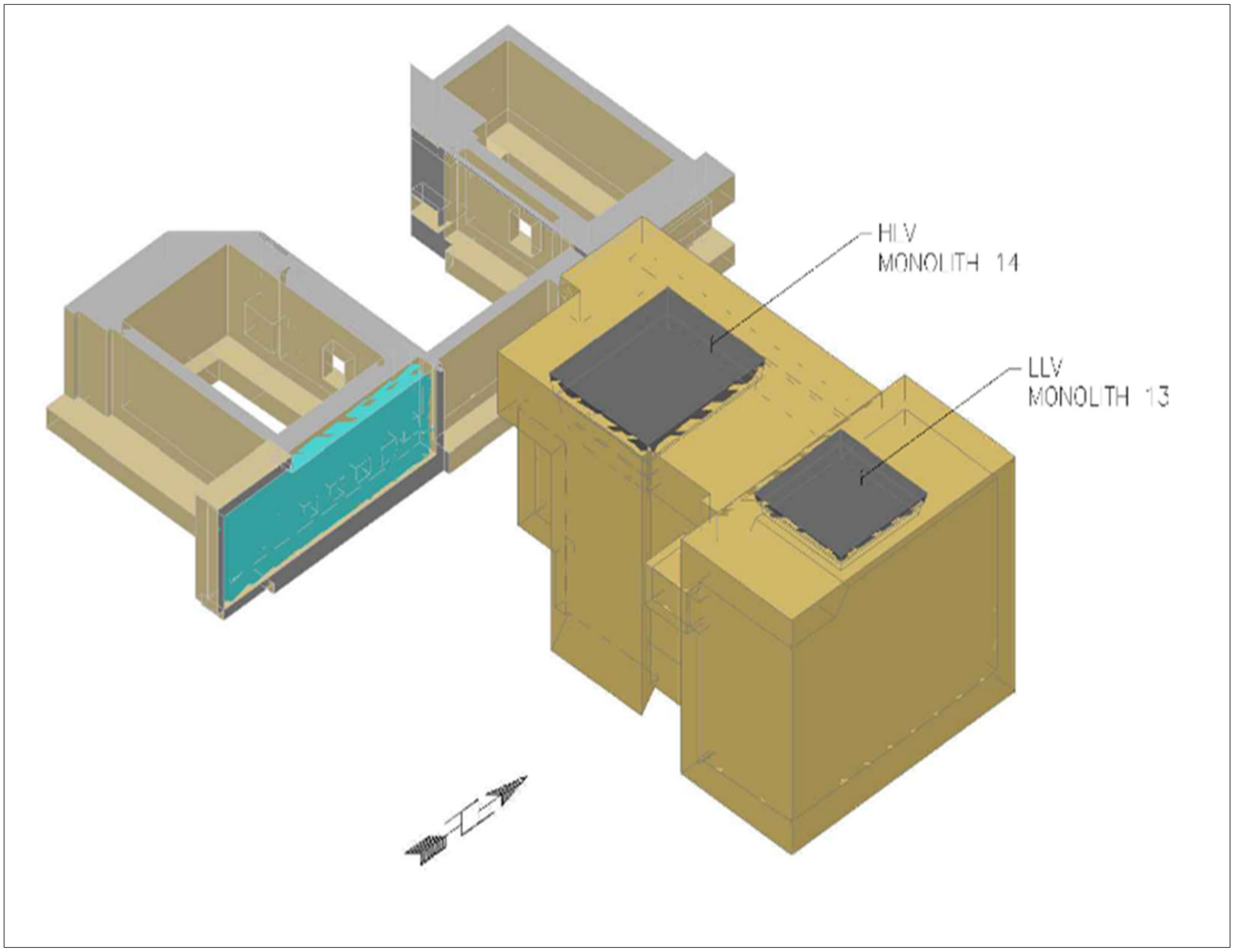

Figure 2. HLV & LLV Segmentation Plan

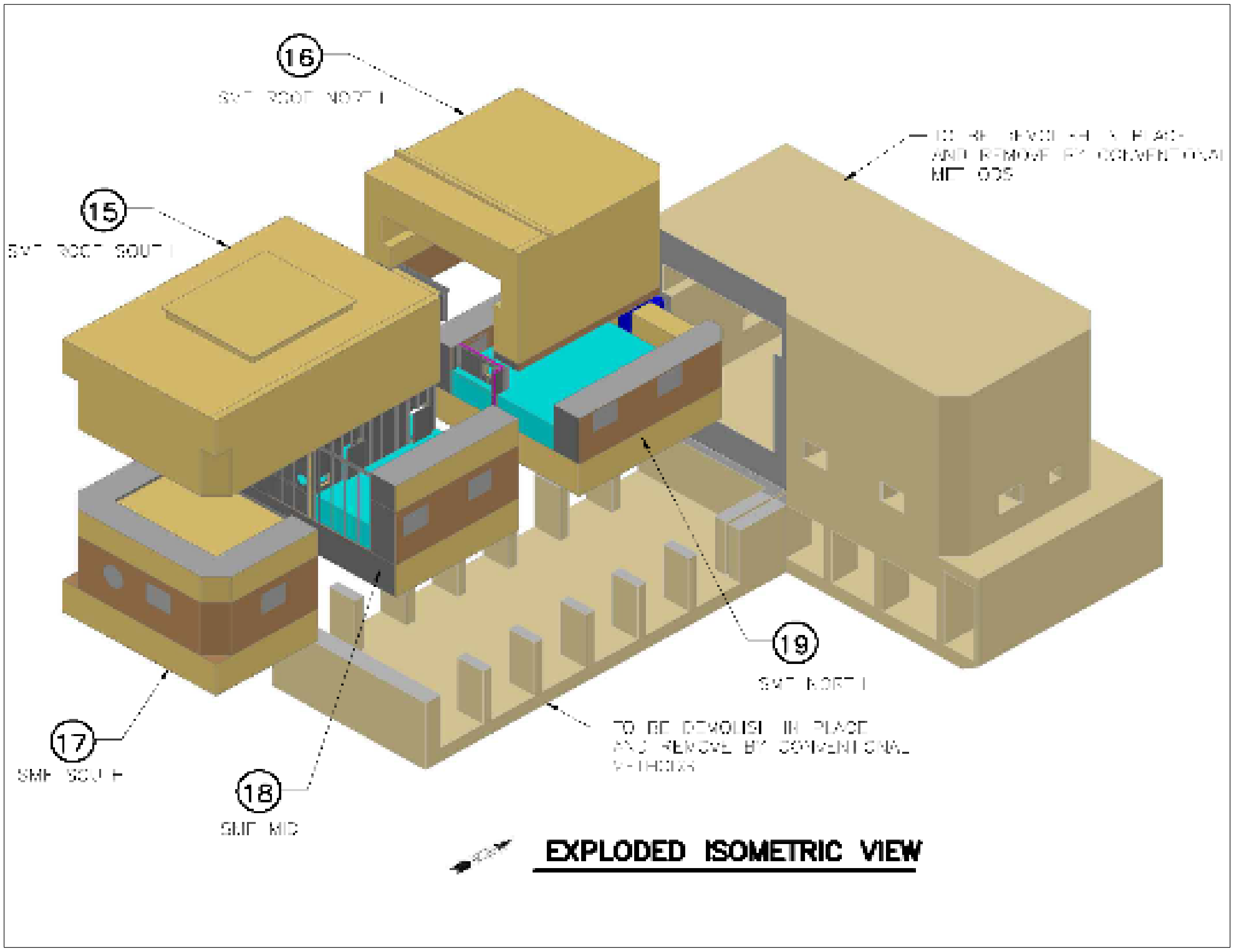

Figure 3. SMF Monolith Segmentation Plan

7.1.1 Damage Ratio

For diamond wire saw demolition, the DR represents the efficiency of a cut by comparing the volume of material lost, the kerf, to the total volume of material, the monolith. Using a 2.5 cm (1 in) kerf, the following equation is used to calculate the damage ratio:

$$\mathrm{DR} = \frac{\text{kerf (cm)} \times \text{Cutting Area (cm}^2\text{)}}{\text{Total Volume (cm}^3\text{)}} \qquad \text{(Eq. 3)}$$

Assumption: Diamond wire saw DR is represented by a 2.5 cm wide kerf.

Calculation 0300X-CA-N0139[4] states diamond wire saw cutting widths of 0.394 in. (1 cm) and 0.512 in. (1.3 cm) were originally planned for hot cell removal. As such, assuming a 1 in (2.5 cm) kerf is conservative.

The formula represents the fraction of the structure turned into dust or slurry during the cutting process. For example, given a monolith of dimensions 50 cm width × 50 cm depth × 50 cm height, the cutting area is 50 cm × 50 cm = 2,500 cm^2 and the total volume is 50 cm × 50 cm × 50 cm = 125,000 cm^3. The DR is then:

$$\mathrm{DR} = \frac{2.5\ \text{(cm)} \times 2{,}500\ \text{(cm}^2\text{)}}{125{,}000\ \text{(cm}^3\text{)}}$$

$$\mathrm{DR} = 0.05$$

Note that this example is for an arbitrarily small monolith. Increasing the size, or total volume of the monolith will tend to decrease the DR. This low ratio is why diamond wire saw cutting is a preferred method for controlled building demolition because it minimizes the generation of airborne radioactivity and structural vibration.

Assumption: Diamond wire saw DR = 0.05.

7.1.2 Airborne Release Fraction

The diamond wire saw airborne release fraction results from the suspension of contaminants into an aqueous solution. Abrasion of the surface is assumed to occur throughout the entire cross section of wire contact. The actual percentage dislodged or released is a function of the abrasion and suspension of all fixed and removable contaminates into a slurry and is assumed to fall within the median value of 5E-05.[5]

Assumption: Diamond wire saw ARF = 5E-05.

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[4] Calculation 0300X-CA-N0139, *Radioactive Contamination Estimates for 324 Hot Cell Monolith Disposition,* page. 10 of 17.

[5] DOE-HDBK-3010-94, Reaffirmed 2013. *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities, Section 3.2.3.2, Slurries*

7.1.3 Calculation of Airborne Source Term

ST = MAR × DR × ARF

ST = MAR (see Table 2) × 0.05 × 5E-05

7.1.4 Respirable Fraction

No data is available regarding the respirable fractions generated as the result of wire saw operations. Experimental results of slurries falling from a 3-meter height indicate a bounding RF of 0.8.

Assumption: Diamond wire saw RF = 0.8.

7.1.5 Calculation of Respirable Source Term

RST = ST × RF

RST = ST × 0.8

Table 3 provides a summary of Monolith RSTs to include derived values for DR, ARF, ST, and RF.

Table 3. Monolith RST (DE-Ci)

Monolith ID	Description	MAR (DE-Ci)	DR	ARF	ST (DE-Ci)	RF	RST (DE-Ci)
M1	Airlock Roof (North)	1.79E-03	0.05	5.00E-05	4.48E-09	0.8	3.58E-09
M2	Airlock Roof (South)	1.79E-03	0.05	5.00E-05	4.48E-09	0.8	3.58E-09
M3	Airlock Door	2.05E-04	0.05	5.00E-05	5.14E-10	0.8	4.11E-10
M4	D-Cell	7.76E-01	0.05	5.00E-05	1.94E-06	0.8	1.55E-06
M5	C-Cell	6.80E-03	0.05	5.00E-05	1.70E-08	0.8	1.36E-08
M6	A-Cell Top	6.47E-03	0.05	5.00E-05	1.62E-08	0.8	1.29E-08
M7	A-Cell Bottom	6.52E+00	0.05	5.00E-05	1.63E-05	0.8	1.30E-05
M8	B-Cell Top	1.65E+00	0.05	5.00E-05	4.13E-06	0.8	3.30E-06
M9	B-Cell Middle	2.21E+00	0.05	5.00E-05	5.52E-06	0.8	4.42E-06
M10	B-Cell Bottom	2.00E+01	0.05	5.00E-05	5.01E-05	0.8	4.01E-05
M11	A-Frame Filter Pit	9.39E-02	0.05	5.00E-05	2.35E-07	0.8	1.88E-07
M12	Airlock Floor Slab	6.81E-03	0.05	5.00E-05	1.70E-08	0.8	1.36E-08
M13	Low Level Vault	1.58E+00	0.05	5.00E-05	3.96E-06	0.8	3.17E-06
M14	High Level Vault	3.50E+01	0.05	5.00E-05	8.76E-05	0.8	7.01E-05
M15	SMF Lid (South)	2.89E-04	0.05	5.00E-05	7.22E-10	0.8	5.77E-10
M16	SMF Lid (North)	2.17E-04	0.05	5.00E-05	5.43E-10	0.8	4.34E-10
M17	SMF Bottom (South)	1.51E-01	0.05	5.00E-05	3.78E-07	0.8	3.02E-07
M18	SMF Bottom (Mid)	1.08E-04	0.05	5.00E-05	2.69E-10	0.8	2.15E-10
M19	SMF Bottom (North)	7.89E-02	0.05	5.00E-05	1.97E-07	0.8	1.58E-07
	Total	**6.81E+01**			**1.70E-04**		**1.36E-04**

7.1.6 Airborne Radioactivity Potential

The respirable source term was used to estimate airborne radioactivity concentration from the point of release during demolition using methods described in 1307-CDMP-0127.[6] Key airborne radioactivity parameters affecting demolition method decisions include locations where the average concentrations may exceed respiratory protection factors (>200 DAC), locations where monitoring needs to be considered (e.g., air sampling, bioassay) (>0.02 DAC), and if concentrations at demolition boundaries can be maintained below airborne radioactivity area (ARA) posting criteria (>0.2 DAC), and are summarized in Table 4.

Table 4. Diamond Wire Saw Airborne Radioactivity Concentration

Monolith ID	Description	>200 DAC Within Demo Boundary[a, b]	>0.02 DAC at Demo Boundary[c]	ARA Boundary Distance (ft)[d]
M1	Airlock Roof (North)	No	No	5
M2	Airlock Roof (South)	No	No	5
M3	Airlock Door	No	No	5
M4	D-Cell	Yes	No	33
M5	C-Cell	No	No	5
M6	A-Cell Top	No	No	5
M7	A-Cell Bottom	Yes	Yes	30
M8	B-Cell Top	Yes	No	33
M9	B-Cell Middle	Yes	Yes	30
M10	B-Cell Bottom	Yes	Yes	100
M11	A-Frame Filter Pit	No	No	15
M12	Airlock Floor Slab	No	No	5
M13	Low Level Vault	Yes	Yes	33
M14	High Level Vault	Yes	Yes	600
M15	SMF Lid (South)	No	No	5
M16	SMF Lid (North)	No	No	5
M17	SMF Bottom (South)	No	No	25
M18	SMF Bottom (Mid)	No	No	5
M19	SMF Bottom (North)	No	No	20

a. 100-foot demolition boundary assumed.
b. 200 DAC exceeds protection factor of powered air purifying respirator (PAPR).
c. >0.02 DAC requires air monitoring. Consider bioassay.
d. Distance to estimated airborne radioactivity area (ARA) boundary, assuming 0.2 DAC posting criteria.

Additional controls are required in locations >200 DAC within the demo boundary and >0.2 DAC at the demo boundary, respectively, such as:

- Strategically locate cut locations to avoid locations with high material-at-risk (e.g., floors, sumps, trenches, tanks).

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[6] 1307-CDMP-0127 *Radiological Engineering Methods Technical Basis Document*, Revision 2, Section 8.3.6.

- Reduce the RST release rate by limiting the MAR allowed to be affected in a given day (slow down the demolition process). For example, increasing the time to complete demolition of a given area by a factor of two will reduce the airborne activity release rate by a factor of two and airborne concentration estimates will be reduced accordingly.

- Remove or prevent the RST from entering the air stream before individuals are exposed, e.g.:
  - Use high efficiency particulate air (HEPA) filtered ventilation
  - Install a confinement barrier

7.2 Universal Processors

For this analysis, each of the 60% design monoliths is assumed to be removed using universal processing equipment. Universal processors, or multi-processors include, but are not limited to interchangeable jaws, concrete and steel shears, pulverizers, crushers, and rotating scrap and demolition processors.

Table 5, Summary of Source Term Factors are excerpted from Table A.2-5 in PNNL-27456, *Air Dispersion Modeling of Radioactive Releases During Proposed 234-5Z Building Demolition Activities*.[7] These factors can be readily applied to the 324 Facility demolition activities. It can be observed that shearing of walls and ceilings when surface contamination is in removable form provides the most limiting activity with an emission factor (EF) of 9×10^{-5}. It is assumed that if desired conditions are met for the most limiting demolition activity, then all other demolition activities would also meet desired conditions. For simplicity and consistency with section 7.1, DR, ARF and RF will be evaluated. A brief description of the rationale for selected source term factors is provided following Table 5.

Table 5. Summary of Source Term Factors

Demolition Activity	Impacted Structures	Type	DR	ARF	LPF	RF	EF
Shearing	Walls and Ceilings	Removable	0.90	$1\text{x}10^{-3}$	0.10	1.00	$9.0\text{x}10^{-5}$
		Fixed	0.10	$1\text{x}10^{-4}$	0.10	1.00	$1.0\text{x}10^{-6}$
Dropping of Rubble	Rubble	Removable and Fixed	0.10	$2.6\text{x}10^{-6}$	0.366	1.00	$9.52\text{x}10^{-8}$
Surgical Removal	Gloveboxes	Contents	0.01	$1\text{x}10^{-6}$	0.10	1.00	$1.0\text{x}10^{-9}$
Removal	Stubs, ducts	Fixed	0.10	$1\text{x}10^{-4}$	0.10	1.00	$1.0\text{x}10^{-6}$
Sorting, Sizing, Re-loading	Rubble	Removable and Fixed	1.00	$2.6\text{x}10^{-6}$	1.00	1.00	$2.6\text{x}10^{-6}$
Resuspension Between Shifts	Rubble	Removable	0.10	$3.6\text{x}10^{-5}$/hr	0.10	1.00	$3.6\text{x}10^{-7}$/hr

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[7] PNNL-27456, *Air Dispersion Modeling of Radioactive Releases During Proposed 234-5Z Building Demolition Activities*

7.2.1 Damage Ratio

Mechanical shears or mechanical hammer may be used for demolition activities (ceilings, walls, and floors). This will result in various sized pieces of rubble. Unless otherwise specified, the material at risk (MAR) is the inventory assumed to be evenly distributed over the entire contaminated area being worked on (wall segment, etc.). The damage ratio (DR) is that portion or percentage of the contaminated area acted on by the shear force. For concrete and plaster-on-lathe structures it is assumed to be 90%; for metal panels it is assumed to be 10%. Shears or mechanical hammer are assumed to fracture, crush, spall, or otherwise impact the surface being sheared.

Fixatives serve to fix contamination to the surfaces. In most instances, the particulate contamination becomes integral with the fixative as opposed to merely being shielded or covered. Fixatives are extremely effective in preventing the migration of contamination from surfaces experiencing little or no impact. When used during demolition, however, one must consider the impact of the demolition method on the fixative surface structure (e.g., the propensity of the demolition method to produce airborne particulates of the fixative surface containing radioactive contaminants). In this analysis, fixatives are assumed to reduce the production of airborne particulates on surfaces not directly involved with the shearing or cutting processes; however, the shearing process breaks up the material so severely that fixatives are assumed to be only 10% effective for concrete shears or mechanical hammer.

The effectiveness of the fixative on the rubblized material (approximately 90% of the sheared concrete/plaster material; 10% of metal panels) will conservatively be considered totally lost (i.e., all of the contamination on these pieces is considered removable). The fixative covering the larger pieces (approximately 10% of the sheared material, essentially all of the cut material) will be considered largely intact and remain effective. All of the material cut by shears or mechanical hammer will be piled on the ground until placed in waste containers.

Thus, the DR is differentiated between removable and fixed contamination as following:

- DR = 0.9 (removable contamination)
- DR = 0.1 (fixed contamination)

7.2.2 Airborne Release Fraction

DOE's factors for impaction stress due to vibration shock were selected as the most representative release fractions for the crushing processes. The ARF factors selected were 1×10^{-3} for removable contamination and one-tenth that (1×10^{-4}) for fixed contamination (DOE 1994, Section 5.3.3.2.2).

Surfaces not directly impacted by cutting will be disturbed from a variety of sources, including the cutting process (especially for shear cutting), movement and placement of material, general shaking of the building surface, vibrations from heavy equipment, and vibration from fall of rubble to the floor surface. Releases from these surfaces will be controlled by existing fixative, periodic application of fresh fixative, continually wetting of surfaces, and water spray/mist in the air. These controls are assumed to be sufficient to prevent any emissions from vibration of noncontact surfaces.

The EPA's (EPA 1995)[8] compilation of airborne release fractions includes a range of uncontrolled release fractions for crushing of ores and rocks that range from 0.012 to 6 pounds per ton of ore, which relates to an ARF of 6×10^{-6} to 3×10^{-3} – these ranges overlap, supporting the selection of the DOE value for Shearing:

- ARF = 1×10^{-3} (removable contamination)
- ARF = 1×10^{-4} (fixed contamination)

7.2.3 Calculation of Airborne Source Term

$$ST = MAR \times DR \times ARF$$

Removable Contamination

$$ST = MAR \text{ (see Table 2)} \times 0.9 \times 1E\text{-}03$$

Fixed Contamination

$$ST = MAR \text{ (see Table 2)} \times 0.1 \times 1E\text{-}04$$

7.2.4 Respirable Fraction

The respirable fraction refers to the fraction of the material that has become airborne that is in a respirable size (i.e., maximum diameter of 10 µm). The respirable fraction is conservatively assumed to equal 100% (RF = 1.0) for all processes in calculating the ground surface contamination level.

The RF is the fraction of airborne radionuclides as particulate that can be transported through air and inhaled into the human respiratory system. The RF is assumed to include particles 10 µm AED and less. In this study, all of the suspendable material is addressed (not just the respirable portion) although it is estimated that most radioactive particles in the contamination are respirable in size.

In this evaluation, the radioactive particulate is assumed to be bound to dust particles from the rubble and transported in a size distribution representative of construction dust. These particles are removed from the plume and placed on the ground through dry deposition, a process that removes non-respirable particles much more effectively than respirable particles. The result of these considerations is that transport of radioactive particulate is modeled as a mixture of particle sizes representative of dust from the rubble. A respirable fraction of 1.0 is applied in the Source Term equation.

7.2.5 Calculation of Respirable Source Term

$$RST = ST \times RF$$

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[8] *Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources*, AP-42, Fifth Edition. U.S. Environmental Protection Agency.

Removable Contamination

$$RST = ST \times 1.0$$

Fixed Contamination

$$RST = ST \times 1.0$$

Table 6 provides a summary of Universal Processors – Removable Contamination RSTs to include derived values for DR, ARF, ST, and RF. Table 7 provides a summary of Universal Processors – Fixed Contamination RSTs to include derived values for DR, ARF, ST, and RF.

Table 6. Universal Processors – Removable Contamination RST (DE-Ci)

Monolith ID	Description	MAR (DE-Ci)	DR	ARF	ST (DE-Ci)	RF	RST (DE-Ci)
M1	Airlock Roof (North)	1.79E-03	0.9	1E-03	1.61E-06	1.0	1.61E-06
M2	Airlock Roof (South)	1.79E-03	0.9	1E-03	1.61E-06	1.0	1.61E-06
M3	Airlock Door	2.05E-04	0.9	1E-03	1.85E-07	1.0	1.85E-07
M4	D-Cell	7.76E-01	0.9	1E-03	6.98E-04	1.0	6.98E-04
M5	C-Cell	6.80E-03	0.9	1E-03	6.12E-06	1.0	6.12E-06
M6	A-Cell Top	6.47E-03	0.9	1E-03	5.82E-06	1.0	5.82E-06
M7	A-Cell Bottom	6.52E+00	0.9	1E-03	5.87E-03	1.0	5.87E-03
M8	B-Cell Top	1.65E+00	0.9	1E-03	1.49E-03	1.0	1.49E-03
M9	B-Cell Middle	2.21E+00	0.9	1E-03	1.99E-03	1.0	1.99E-03
M10	B-Cell Bottom	2.00E+01	0.9	1E-03	1.80E-02	1.0	1.80E-02
M11	A-Frame Filter Pit	9.39E-02	0.9	1E-03	8.45E-05	1.0	8.45E-05
M12	Airlock Floor Slab	6.81E-03	0.9	1E-03	6.13E-06	1.0	6.13E-06
M13	Low Level Vault	1.58E+00	0.9	1E-03	1.42E-03	1.0	1.42E-03
M14	High Level Vault	3.50E+01	0.9	1E-03	3.15E-02	1.0	3.15E-02
M15	SMF Lid (South)	2.89E-04	0.9	1E-03	2.60E-07	1.0	2.60E-07
M16	SMF Lid (North)	2.17E-04	0.9	1E-03	1.95E-07	1.0	1.95E-07
M17	SMF Bottom (South)	1.51E-01	0.9	1E-03	1.36E-04	1.0	1.36E-04
M18	SMF Bottom (Mid)	1.08E-04	0.9	1E-03	9.72E-08	1.0	9.72E-08
M19	SMF Bottom (North)	7.89E-02	0.9	1E-03	7.10E-05	1.0	7.10E-05
	Total	**6.81E+01**			**6.13E-02**		**6.13E-02**

Table 7. Universal Processors – Fixed Contamination RST (DE-Ci)

Monolith ID	Description	MAR (DE-Ci)	DR	ARF	ST (DE-Ci)	RF	RST (DE-Ci)
M1	Airlock Roof (North)	1.79E-03	0.1	1E-04	1.79E-08	1.0	1.79E-08
M2	Airlock Roof (South)	1.79E-03	0.1	1E-04	1.79E-08	1.0	1.79E-08
M3	Airlock Door	2.05E-04	0.1	1E-04	2.05E-09	1.0	2.05E-09
M4	D-Cell	7.76E-01	0.1	1E-04	7.76E-06	1.0	7.76E-06
M5	C-Cell	6.80E-03	0.1	1E-04	6.80E-08	1.0	6.80E-08
M6	A-Cell Top	6.47E-03	0.1	1E-04	6.47E-08	1.0	6.47E-08
M7	A-Cell Bottom	6.52E+00	0.1	1E-04	6.52E-05	1.0	6.52E-05
M8	B-Cell Top	1.65E+00	0.1	1E-04	1.65E-05	1.0	1.65E-05
M9	B-Cell Middle	2.21E+00	0.1	1E-04	2.21E-05	1.0	2.21E-05
M10	B-Cell Bottom	2.00E+01	0.1	1E-04	2.00E-04	1.0	2.00E-04
M11	A-Frame Filter Pit	9.39E-02	0.1	1E-04	9.39E-07	1.0	9.39E-07
M12	Airlock Floor Slab	6.81E-03	0.1	1E-04	6.81E-08	1.0	6.81E-08
M13	Low Level Vault	1.58E+00	0.1	1E-04	1.58E-05	1.0	1.58E-05
M14	High Level Vault	3.50E+01	0.1	1E-04	3.50E-04	1.0	3.50E-04
M15	SMF Lid (South)	2.89E-04	0.1	1E-04	2.89E-09	1.0	2.89E-09
M16	SMF Lid (North)	2.17E-04	0.1	1E-04	2.17E-09	1.0	2.17E-09
M17	SMF Bottom (South)	1.51E-01	0.1	1E-04	1.51E-06	1.0	1.51E-06
M18	SMF Bottom (Mid)	1.08E-04	0.1	1E-04	1.08E-09	1.0	1.08E-09
M19	SMF Bottom (North)	7.89E-02	0.1	1E-04	7.89E-07	1.0	7.89E-07
	Total	**6.81E+01**			**6.81E-04**		**6.81E-04**

7.2.6 Airborne Radioactivity Potential

The respirable source term was used to estimate airborne radioactivity concentration from the point of release during demolition using methods described in 1307-CDMP-0127. Key airborne radioactivity parameters affecting demolition method decisions include locations where the average concentrations may exceed respiratory protection factors (>200 DAC), locations where monitoring needs to be considered (e.g., air sampling, bioassay) (>0.02 DAC), and if concentrations at demolition boundaries can be maintained below ARA posting criteria (>0.2 DAC), and are summarized in Table 8.

Table 8. Universal Processors Airborne Radioactivity Concentration

Monolith ID	Description	>200 DAC Within Demo Boundary[a, b]	>0.02 DAC at Demo Boundary[c]	ARA Boundary Distance (ft)[d]
M1	Airlock Roof (North)	Yes	No	33
M2	Airlock Roof (South)	Yes	No	33
M3	Airlock Door	No	No	15
M4	D-Cell	Yes	Yes	>1,000
M5	C-Cell	Yes	Yes	33
M6	A-Cell Top	Yes	Yes	33
M7	A-Cell Bottom	Yes	Yes	>1,000
M8	B-Cell Top	Yes	Yes	>1,000
M9	B-Cell Middle	Yes	Yes	>1,000
M10	B-Cell Bottom	Yes	Yes	>1,000
M11	A-Frame Filter Pit	Yes	Yes	1,000
M12	Airlock Floor Slab	Yes	Yes	33
M13	Low Level Vault	Yes	Yes	>1,000
M14	High Level Vault	Yes	Yes	>1,000
M15	SMF Lid (South)	No	No	25
M16	SMF Lid (North)	No	No	20
M17	SMF Bottom (South)	Yes	Yes	>1,000
M18	SMF Bottom (Mid)	No	No	15
M19	SMF Bottom (North)	Yes	Yes	>1,000

a. 100-foot demolition boundary assumed.
b. 200 DAC exceeds protection factor of powered air purifying respirator (PAPR).
c. >0.02 DAC requires air monitoring. Consider bioassay.
d. Distance to estimated airborne radioactivity area (ARA) boundary, assuming 0.2 DAC posting criteria.

Additional controls are required in locations >200 DAC within the demo boundary and >0.2 DAC at the demo boundary, respectively, such as:

- Reduce the RST release rate by limiting the MAR allowed to be affected in a given day (slow down the demolition process). For example, increasing the time to complete demolition of a given area by a factor of two will reduce the airborne activity release rate by a factor of two and airborne concentration estimates will be reduced accordingly.

- Remove or prevent the RST from entering the air stream before individuals are exposed, e.g.:

  - Use HEPA filtered ventilation

  - Install a confinement barrier

8 Dose Rates

Experience has shown that penetrating dose rates at the 324 Facility are predominantly from Cs-137 in equilibrium with Ba-137m. As such, Cs-137/Ba-137m is assumed for penetrating dose estimates.

8.1 Diamond Wire Saw

Dose rate estimates were performed to support the 60% Engineering design effort for monolithic removal of the REC and SMF hot cells. Estimates focused on determining if allowable dose rates for non-exclusive use shipments of 200 mrem/hr on contact and 10 mrem/hr at 1 meter from the surface of the waste package could be met without additional shielding and, if not, the amount of shielding required.[9] Estimates provide an indication of conditions that may be encountered during diamond wire saw monolith removal activities.

Maximum and average contact and 1-meter dose rates are summarized in Table 9. Bold italicized values indicate grout filling of monolith voids and/or additional shielding is required to meet non-exclusive-use shipment criteria.

Table 9. Diamond Wire Saw Monolith Dose Rate Estimates (mrem/hr)

Monolith ID	Description	Maximum		Average	
		Contact	1 m	Contact	1 m
M1	Airlock Roof (North)	82	***18***	39	***14***
M2	Airlock Roof (South)	82	***18***	39	***14***
M3	Airlock Door	13	4	--	--
M4	D-Cell	191	***61***	27	9
M5	C-Cell	***204***	***58***	***107***	***40***
M6	A-Cell Top	92	***40***	77	***28***
M7	A-Cell Bottom	***11,800***	***7,950***	***2,683***	***2,137***
M8	B-Cell Top	***28,100***	***14,800***	***22,541***	***9,735***
M9	B-Cell Middle	***27,800***	***14,800***	***22,300***	***9,538***
M10	B-Cell Bottom	***38,100***	***21,100***	***29,263***	***13,321***
M11	A-Frame Filter Pit	***520***	***68***	***205***	***53***
M12	Airlock Floor Slab	***707***	***170***	--	--
M13	Low Level Vault	86	***37***	28	***16***
M14	High Level Vault	***1,230***	***769***	***538***	***380***
M15	SMF Lid (South) (a)	***29,000***	***966***	***6,023***	***327***
M16	SMF Lid (North)	***3,754***	***66***	***495***	***21***
M17	SMF Bottom (South) (b)	***4,579***	***2,112***	***3,361***	***1,707***
M18	SMF Bottom (Mid) (c)	35	***12***	15	5
M19	SMF Bottom (North) (c)	***2,980***	***588***	***527***	***291***

a. M15 dose rates are dominated by inventory in HEPA filter above Compartment 1.
b. M17 dose rates assume Compartment 1 portion of monolith is filled with grout to top of viewing windows.
c. M18 & M19 dose rates assume monoliths are filled with grout to bottom of viewing windows.

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[9] DOE/RL-2001-36, *Hanford Sitewide Transportation Safety Document*.

8.2 Universal Processors

Dose rate estimates for hot cell waste generated using universal processors assume hot cells are demolished in phased increments coinciding with the 60% monolith diamond wire saw removal design, and all waste is rubblized and loaded into Environmental Restoration Disposal Facility roll-on/roll-off containers (ERDF RO/RO) for transportation and disposal.

Contact and 1-meter dose rate estimates are summarized in Table 10. Bold italicized values indicate blending with clean soil, container stand-offs, additional shielding, or a different transportation container design is required to meet non-exclusive use shipment criteria. Values assume the respective MAR is evenly distributed throughout the waste and that processing of waste results in a homogenous mixture of concrete and air with a density of 1.76 g/cm^3.

Table 10. Universal Processors ERDF RO/RO Container Dose Rate Estimates

Monolith ID	Description	Weight (tons)	No. ERDF Cans	Total Cs-137 (Ci)	Cs-137 per ERDF Can (Ci)	mR/hr	
						Contact	1 m
M1	Airlock Roof (North)	142	9	3.81E-01	4.37E-02	1.8	0.8
M2	Airlock Roof (South)	150	9	3.81E-01	4.14E-02	1.7	0.8
M3	Airlock Door	215	13	4.37E-02	3.31E-03	0.1	0.1
M4	D-Cell	830	51	2.00E+02	3.94E+00	161	***74***
M5	C-Cell	628	39	1.45E+00	3.75E-02	1.5	0.7
M6	A-Cell Top	731	45	1.38E+00	3.07E-02	1.3	0.6
M7	A-Cell Bottom	540	33	1.34E+03	4.03E+01	***1,652***	***759***
M8	B-Cell Top	844	52	3.51E+02	6.78E+00	***278***	***128***
M9	B-Cell Middle	869	53	4.70E+02	8.82E+00	***361***	***166***
M10	B-Cell Bottom	869	53	4.26E+03	8.00E+01	***3,276***	***1,504***
M11	A-Frame Filter Pit	340	21	2.01E+01	9.63E-01	39	***18***
M12	Airlock Floor Slab	109	7	1.45E+00	2.16E-01	9	4
M13	Low Level Vault	817	50	3.37E+02	6.72E+00	***275***	***126***
M14	High Level Vault	932	57	7.43E+03	1.30E+02	***5,327***	***2,446***
M15	SMF Lid (South)	476	29	6.22E-01	2.13E-02	0.9	0.4
M16	SMF Lid (North)	470	29	4.68E-01	1.62E-02	0.7	0.3
M17	SMF Bottom (South)	490	30	3.26E+02	1.08E+01	***444***	***204***
M18	SMF Bottom (Mid)	490	30	2.32E-01	7.70E-03	0.3	0.1
M19	SMF Bottom (North)	493	30	2.97E+02	9.83E+00	***403***	***185***
	Totals	**10,435**	**640**	**1.50E+04**			

9 Shielding Estimates

Shielding estimates for diamond wire saw cutting and universal processors are summarized in the following sections.

9.1 Diamond Wire Saw

Shielding estimates were performed to support the 60% Engineering design effort for monolithic removal of the REC and SMF hot cells. Estimates focused on reducing dose rates for non-exclusive-use shipments of 200 mrem/hr on contact and 10 mrem/hr at 2 meters from the surface of the waste package. Results are summarized in Table 11. Except for REC Airlock door and floor slab monoliths (M3 & M12, respectively), estimates assume monolith voids are filled with low-density cellular grout [30 lb/ft^3 (0.48 g/cm^3)] to aid the diamond wire saw cutting process and to meet ERDF waste acceptance criteria. Listed values are maximums and assume grout with a density of [120 lb/ft^3 (1.92 g/cm^3)] is used for shielding.

Table 11. Diamond Wire Saw Monolith Shielding Estimates

Monolith ID	Description	Grout Filled	Max Shielding Thickness (in.)	Max Shielding Location
M1	Airlock Roof (North)	Yes	0	--
M2	Airlock Roof (South)	Yes	0	--
M3	Airlock Door	No	0	--
M4	D-Cell	Yes	6	Airlock side of monolith
M5	C-Cell	Yes	6	Airlock side of monolith
M6	A-Cell Top	Yes	6	Airlock side of monolith
M7	A-Cell Bottom	Yes	6	Monolith bottom & Airlock side
M8	B-Cell Top	Yes	16	Monolith bottom
M9	B-Cell Middle	Yes	14	Monolith top & bottom
M10	B-Cell Bottom	Yes	14	Monolith top, N & S faces of pipe trench
M11	A-Frame Filter Pit	Yes	8	West face of monolith
M12	Airlock Floor Slab	No	10	Top of slab
M13	Low Level Vault	Yes	4	Monolith bottom
M14	High Level Vault	Yes	12	Monolith bottom, including below TK-106 & TK-107 shelf
M15	SMF Lid (South)	Yes	18	Below HEPA filter above compartment 1
M16	SMF Lid (North)	Yes	8	Monolith bottom
M17	SMF Bottom (South)	Yes	14	Monolith north face
M18	SMF Bottom (Mid)	Yes	0	--
M19	SMF Bottom (North)	Yes	12	Monolith top

9.2 Universal Processors

Shielding estimates for waste generated using a universal processors assume a waste geometry consistent with a half-filled ERDF RO/RO container with a maximum Cs-137 inventory from Table 10 of 1.30E+02 curies per container. Hanford dry concrete with a density of 136 lb/ft^3 (2.18 g/cm^3) is assumed as the shielding material.[10]

Given these assumptions, up to 15-inches of concrete shielding may be required to reduce dose rates for non-exclusive-use shipments to less than 200 mrem/hr on contact and less than 10 mrem/hr at 2 meters from the surface of the waste package.

10 Summary/Recommendations

The sum of the total removable and fixed RSTs from Table 6 and Table 7 for universal processor demolition, divided by the total RST from Table 3 for diamond wire saw demolition is 455. As such, the associated internal dosimetry hazard for universal processors removal of the hot cells is 455 times higher than for monolithic removal using diamond wire saws. Based solely on this criteria, exclusive of any additional controls (i.e., confinement, HEPA filtration, etc.) monolithic hot cell removal is recommended.

Neither option alone provides the best fit demolition approach. A combination of the two for applicable scenarios including the use of an enclosure similar to that used for the Accelerated Retrieval Project at the Idaho National Laboratory likely provides the optimum approach from both a radiological and demolition operations perspective. The following may be considered as plausible recommendations:

- For higher elevations, where radiological conditions do not prohibit occupancy, the use of diamond wire saw cutting with a wire and slurry confinement system is recommended.
- For lower elevations, near ground level and below ground surface (bgs), where radiological conditions prohibit occupancy, robotic universal processors and the use of soil for shielding purposes may be suitable.
- For occupied areas where DAC values may exceed prescribed respirator protection factors, install breathing air for operator safety and comfort.
- Install a latex paint sprayer, or equivalent, near the end of universal processor end effectors to provide fixative for dust suppression, contamination, and airborne radioactivity control during processing.
- For elevated dose rates where universal processor cabs may be occupied, install telemetry dosimetry in the cab and near the end of the processor for operator safety.
- Determine threshold values for airborne radioactivity and dose rates where robotic universal processors may be used.

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[10] PNNL-15870, *Compendium of Material Composition Data for Radiation Transport Modeling*, Revision 2, Material 92.

- Determine waste package design and shielding requirements where dose rates may exceed Hanford Transportation Safety and ERDF waste acceptance criteria requirements.
- Consider the use of a structure/enclosure with large air handling units to mitigate releases of contamination and airborne radioactivity to the environment once the above grade portion of the hot cells have been removed.

Additional analysis is required if the 324 Facility removal design approach deviates from that presented in this document.

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