**WM'00 Conference, February 27 - March 2, 2000, Tucson, AZ**

# MANAGEMENT OF EXPENDED MATERIALS RELATING TO THE WEST VALLEY DEMONSTRATION PROJECT HIGH-LEVEL WASTE VITRIFICATION FACILITY

William F. Hamel, Jr., U. S. Department of Energy - West Valley Demonstration Project
Laurene Krieger - West Valley Nuclear Services Company
Robert DiBiase - West Valley Nuclear Services Company

## ABSTRACT

High-level waste (HLW) vitrification processing results in the generation of waste such as expended equipment and consumables. Previously, the expended materials were set aside in either the Vitrification Cell (VC) or the High-Level Waste Interim Storage Facility (HLWISF) for possible repair and reuse. The result of this practice was excessive accumulation of expended materials. The West Valley Demonstration Project (WVDP) is leading the U. S. Department of Energy (DOE) complex in the implementation of a proactive, fast-track approach to the management of these expended materials.

After a comprehensive technical and economic analysis, the WVDP chose a Vitrification Expended Material Processing (VEMP) Program that included size-reduction, segregation, characterization, and packaging of vitrification expended equipment (VEM) using remote tooling located in the VC. This packaged equipment is then removed from the VC and, to the extent possible, placed into on-site waste storage facilities destined for disposal as low-level waste (LLW). The remaining High-Level Waste (HLW) contaminated materials are packaged and placed into another shielded cell until a disposal facility is available.

This paper discusses the process development, systems engineering and design, regulatory analysis, and operational requirements for the VEMP Program, which is jointly funded by DOE-West Valley (DOE-WV) and DOE-Environmental Management's (EM-50) Office of Science and Technology through the accelerated Site Technology Deployment Program, and the New York State Energy Research and Development Authority (NYSERDA). In addition, this paper highlights key issues that are relevant to developing and implementing a safe, practical, and cost-effective strategy for the long-term goal of remote decontamination and decommissioning (D&D) of the Vitrification Facility (VF).

## BACKGROUND

In 1980, the U.S. Congress passed the West Valley Demonstration Project Act authorizing the DOE to conduct a high-level nuclear waste management demonstration project at the Western New York Nuclear Service Center. The WVDP is located in West Valley, NY approximately 30 miles south of Buffalo, at a former commercial nuclear fuel reprocessing plant.

The fuel reprocessing plant construction was completed in 1966 by Bechtel Corp. under contract to W. R. Grace Co. and was subsequently operated by Nuclear Fuel Services. Operations ceased in 1972 after approximately 700 tons of spent nuclear fuel was reprocessed. As a result of these reprocessing operations, approximately 600,000 gallons of high-level-liquid plutonium uranium extraction (PUREX) process waste were produced.

One of the objectives of the WVDP is to vitrify the HLW into a canistered waste form suitable for transportation and eventual disposal at a Federal repository. To date, approximately 95 percent of the HLW has been safely vitrified, resulting in 242 HLW glass canisters produced.

The WVDP is managed and funded by the DOE, in cooperation with the NYSERDA. West Valley Nuclear Services Company (WVNS), a subsidiary of Westinghouse Government Services Group, was chosen as the contractor to operate the facility.

This paper discusses the unique approach used to develop remote VEM process tooling, the technical and economic analysis performed to support the approach taken, the cost-effective waste classification approach, and how the information generated as a result of the Program is being used to design future remote tooling for longer-term D&D efforts. The VEMP Program is jointly funded by DOE-WV, DOE-EM-50's Office of Science and Technology, through the accelerated Site Technology Deployment Program, and NYSERDA.

## INTRODUCTION

During the course of vitrification operations, periodic maintenance, repair, and/or replacement of miscellaneous components, equipment, and hardware was necessary. An unavoidable by-product of these activities is the generation of expended material contaminated with residues of treated and untreated HLW that required shielded storage within the VF or the HLWISF. Historically, the expended materials were set aside for possible repair and reuse. This practice resulted in excessive accumulation of expended materials (see Figure 1). As a result, the need for a program to size-reduce, sort, characterize, package, and ultimately dispose of this material became necessary.

**Figure 1**. **Vitrification Expended Material in the HLWISF**

The VEMP Program is an integrated, overall approach to volume reduction, segregation of HLW-contaminated materials from LLW, characterization, and packaging of spent hardware. Once packaged, the segregated LLW can then be removed from the VF and placed into on-site LLW storage facilities for eventual disposal. The remaining HLW-contaminated expended materials are transferred to another shielded cell, the HLWISF, until a disposal facility is available. In essence, this Program substantially reduces the amount of waste that must remain in a shielded cell and improves housekeeping during vitrification operations.

The VEMP Program is an example of a fast-track project that progressed from the conceptual design stage in early 1998 to a practical, functioning program with the commencement of size-reduction activities in July 1999.

The WVDP adopted an integrated systems approach to planning and implementation of the expended material. The planning effort for deployment focused on three areas: 1) engineering systems development, 2) regulatory analysis, and 3) operations.

## ENGINEERING SYSTEMS DEVELOPMENT

### Planning, Conceptual, and Preliminary Design

An initial Program Plan was developed in January 1998 and included conceptual designs for in-cell processing equipment for disposition of expended material. The Plan contains the Program’s overall goals, as well as the functional, operational, and design requirements. The Plan also addressed the benefits and drawbacks associated with the various size-reduction and decontamination technologies for processing the expended material.

The preliminary design phase introduced many of the initial conceptual alternatives identified in the Program Plan. These included a ball mill for dry mechanical removal of glass and dried slurry, a dissolver for chemical removal of glass and slurry, size-reduction equipment including plasma-arc technology for size reduction of the VEM into manageable sizes, remote material-handling equipment to interface with existing hot cell remote capability, and techniques and tools to sort the contents of the in-cell vacuum cleaner.

The preliminary design of VEM in-cell processing equipment was completed within three months. The output of that effort included: general arrangement drawings, process-flow diagrams, cutting and decontamination station plans, remote tooling and fixture drawings, size-reduction and decontamination equipment layouts, piping and instrument drawings, a draft system description, and equipment specifications. An internal, interactive-design review of the preliminary design was also completed.

In the period following completion of the preliminary design, a bench-scale laboratory testing program was initiated to determine the relative decontamination effectiveness of technologies utilized in the preliminary design. These tests were performed on nonradioactive surrogate contaminants representative of VEM. Removal rates of nonradioactive contaminants from VEM surrogate specimens were considered indicative of each technology’s relative effectiveness. Although the actual decontamination factor could not accurately be established with this mode of testing, the individual technologies could be evaluated relative to each other to confirm their ability to remove material from the surface of VEM.

Since the project timetable was relatively short, the final design of the VEMP system was required to begin prior to the completion of confirmatory testing. Hence, it was decided that the strategy for completion of the final design would include all preliminary design alternatives and, as data became available from the confirmatory-testing campaign, the design effort would become progressively more focused on the most promising alternative.

The final design and confirmatory testing were completed in four months. Project deliverables for this phase included: equipment fabrication drawings and specifications, a system description, engineering change documentation for modification of existing facilities and equipment to interface and provide services to the new VEMP equipment, a hazard analysis, waste-acceptance documentation, safety documentation, regulatory analysis, a cost estimate, a confirmatory-testing report, and a decision-analysis model. As the final design and confirmatory testing progressed, size-reduction and decontamination options were reevaluated and this resulted in the decision to continue forward with some alternatives and terminate others. The plasma-arc system was eliminated due to complexity and cost issues. Additionally, a glass-removal tool and waste-drum carrier were also eliminated based on further evaluation of Project need and feasibility, however these could be used later for future D&D applications. Size-reduction tools that were developed to completion included: a guillotine saw (power hack saw), band saw, circular saw with dual counter-rotating blades, and power gripper/shear. These tools were selected as a result of consultation with on-site experts in remote operations and size-reduction tooling, as well as experience in prior D&D campaigns. In addition, these tools were developed using commercially available subcomponents representing proven technology that could be adapted to meet the needs of the VEMP Program.

With regard to decontamination of expended material, confirmatory testing of a wet system (chemical dissolver) and a dry system (ball mill) resulted in a recommendation to further evaluate the dissolver. The ball-mill design effort was discontinued when confirmatory testing did not support its efficacy for removal of surface contaminants.

### Decision-Analysis Model

A decision-analysis model was developed to aid in the selection of decontamination alternatives. This was done in conjunction with the final design as the design and cost details were acquired. The model was a detailed cost-benefit study that was the basis for determining what part of the VEMP Program would be deployed in 1999. The deployment recommendation was the culmination of an intensive seven-month effort that incorporated operations, transportation, disposal, and capital costs. In addition, the time-to-implement and technology effectiveness were also incorporated.

Based upon the quantity of VEM waste to be managed, the use of a decision-analysis model resulted in the conclusion that the small tank dissolver and the associated dissolution process were technically feasible but economically impractical at the WVDP. In short, the analysis determined that, due to the capital costs associated with deployment of the dissolution process using a new dissolver vessel, any economic benefit obtained by the reduction in the amount of VEM contaminated with HLW would be consumed by the cost of deployment. The model indicated that the most economically favorable option was the baseline option of size-reduce, segregate, and package the HLW-contaminated material from the LLW for staging or disposal as appropriate. By implementing this approach, WVDP expects to reduce by >80% the amount of contaminated expended materials that traditionally would be managed as HLW. In a sensitivity analysis, it was determined that the parameter the model was most sensitive to was disposal costs. It was assumed that the cost of disposal for HLW would be similar to the cost for disposal of HLW canisters.

The decision-analysis model conclusions resulted in additional evaluation of a previously rejected option to use the existing vitrification process vessel, the canister decontamination station (CDS), as a VEM dissolution vessel. The CDS would also continue to serve as the HLW canister decontamination vessel. The option was previously dismissed because of operational inefficiencies associated with the back-and-forth preparation of the vessel to perform the different functions and the potential for cross-contamination of the HLW canisters. In addition to the CDS reevaluation, radioactive confirmatory testing was initiated to evaluate the performance of the various decontamination reagents that could be used in the dissolution process and dissolver vessel.

The results of the CDS re-evaluation and radioactive testing were:

1) Nitric acid dissolution is a viable process for HLW-contaminated materials to achieve a LLW classification.
2) It is technically possible to convert and use the CDS as a dissolver.
3) The CDS conversion is economically more attractive than constructing a small tank dissolver.
4) The "size-reduction and segregate-only" baseline alternative continues to be economically more attractive than the CDS conversion or the installation of a small tank dissolver.
5) It is not technically or economically practical to implement a dissolver option for removal of HLW from VEM without the option of vitrifying the decontamination solution in the melter.

Ultimately, based on this evaluation, no further development work was conducted on the dissolver option with respect to HLW removal from VEM. However, lessons learned from this study may be incorporated into future WVDP D&D activities.

The primary purpose of the decision-analysis model was to ascertain whether the selected process equipment should be deployed in 1999. The model demonstrated to the stakeholders that it was economically favorable to implement the program and also served as documentation that the WVDP was doing what was technically and economically practical with regard to management of HLW-contaminated equipment as required by DOE Order 435.1, "Radioactive Waste Management."

## Application of Value Engineering

In an effort to further reduce the VEMP Program deployment costs and simplify the operational aspects of the size-reduction portion of the system, the final design was reviewed in the beginning of fiscal year 1999. This review utilized value-engineering principles to streamline the design complexity. One example of this was with regard to the power and control aspects of the size-reduction tooling. Whereas the final design of the system provided power and control through hot cell penetrations via an umbilical to the size-reduction equipment, the reassessment resulted in the decision to convert the equipment to utilize an existing in-cell power source. Specifically, the in-cell power source was the 480 V crane power supply and the forward/reverse control switch that is presently used for control of the hot cells remote impact wrench. Although the level of control and data acquisition to and from the size-reduction equipment was reduced, the review of the Program forced a focus on actual needs and resulted in the reduction in system complexity and associated cost. Overall, this was a major change that required development of unique control packages integrally mounted for each specific piece of equipment. Some examples are:

- Mounting step-down transformers on various pieces of equipment when multiple voltages were required.
- Adding variable-speed feed motors, timing circuits, and switching relays so that a sequence of operations could be performed by the piece of size-reduction equipment with minimal control input.

### Fabrication and Deployment

The approach taken for implementation and deployment of the system was to fabricate and procure tooling and in conjunction with the operators, test the tooling then make enhancements and retest again. This approach ensured that the final unit would accomplish the functional requirements and also provided a platform for early involvement and training of operational personnel. By the time the final, completed units were delivered to the WVDP, familiarity, buy-in, and ownership of the equipment by operational personnel was achieved, making final deployment much smoother.

## REGULATORY ANALYSIS

The regulatory analysis process included evaluating those regulatory issues that impact the design, operation, and implementation of VEMP. Of particular importance, were the waste management concerns and how the classification/characterization of the waste may dictate operation, packaging, transportation, and disposal requirements.

Although all of the expended material was generated during the vitrification of HLW, it is not all directly contaminated with HLW. Five separate types of contamination were identified based on expected differences in their radionuclide profile and Resource Conservation and Recovery Act (RCRA) characteristics. These five contaminant types include: HLW slurry (untreated HLW), HLW glass (treated HLW), submerged bed scrubber (SBS) solution, airborne contamination, and off-gas contamination. Because two of the waste types were directly in contact with the HLW, an incidental waste process pursuant to DOE Order 435.1, "Radioactive Waste Management," was employed to reclassify some or all of these wastes as LLW or transuranic. The remaining three waste types that did not come into direct contact with HLW were classified based on their levels of contamination.

There are two ways to meet the incidental waste criteria: process "by citation" or "by evaluation." The citation process is used to classify job wastes; (e.g., personal protective equipment, sampling wastes, decontamination solutions, laboratory clothing, tools, equipment, etc.) that have become contaminated with HLW. These materials are excluded from the definition of HLW and can be classified based on the radioactivity of the waste.

The second way to make waste incidental to reprocessing determinations is through the evaluation process. The evaluation process can be used for the expended equipment that is contaminated with HLW. In order to meet the criteria to classify the equipment contaminated with HLW as transuranic or LLW, the site must demonstrate that the wastes meet the following criteria:

- Have been processed or will be processed to remove the key radionuclides to the maximum extent that is technically and economically practical;
- Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C, "Performance Objectives," and either:

1. "Are to be managed, pursuant to DOE's authority under the Atomic Energy Act, as amended, and in accordance with the provisions of Chapter IV of this Manual, (DOE O 435.1, "Radioactive Waste Management") provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 CFR 61.55, "Waste Classification"; or
2. Will meet alternative requirements for waste classification and characteristics, as DOE may authorize. Such waste shall be managed pursuant to DOE's authority under the Atomic Energy Act, as amended, in accordance with the provisions of Chapter III or Chapter IV of this Manual (DOE Order 435.1), as appropriate."

Since the incidental waste determination "by criteria" was not applicable to the wastes that are being handled in the VEM process, the second option, "by evaluation," was the selected process for classifying the segregated expended material as LLW or transuranic. The cost-benefit analysis was used to support the "technical and economically practical" criteria of the incidental waste determination. The other criteria required to meet the incidental waste determination are met by complying with the waste-acceptance criteria of the off-site disposal facility.

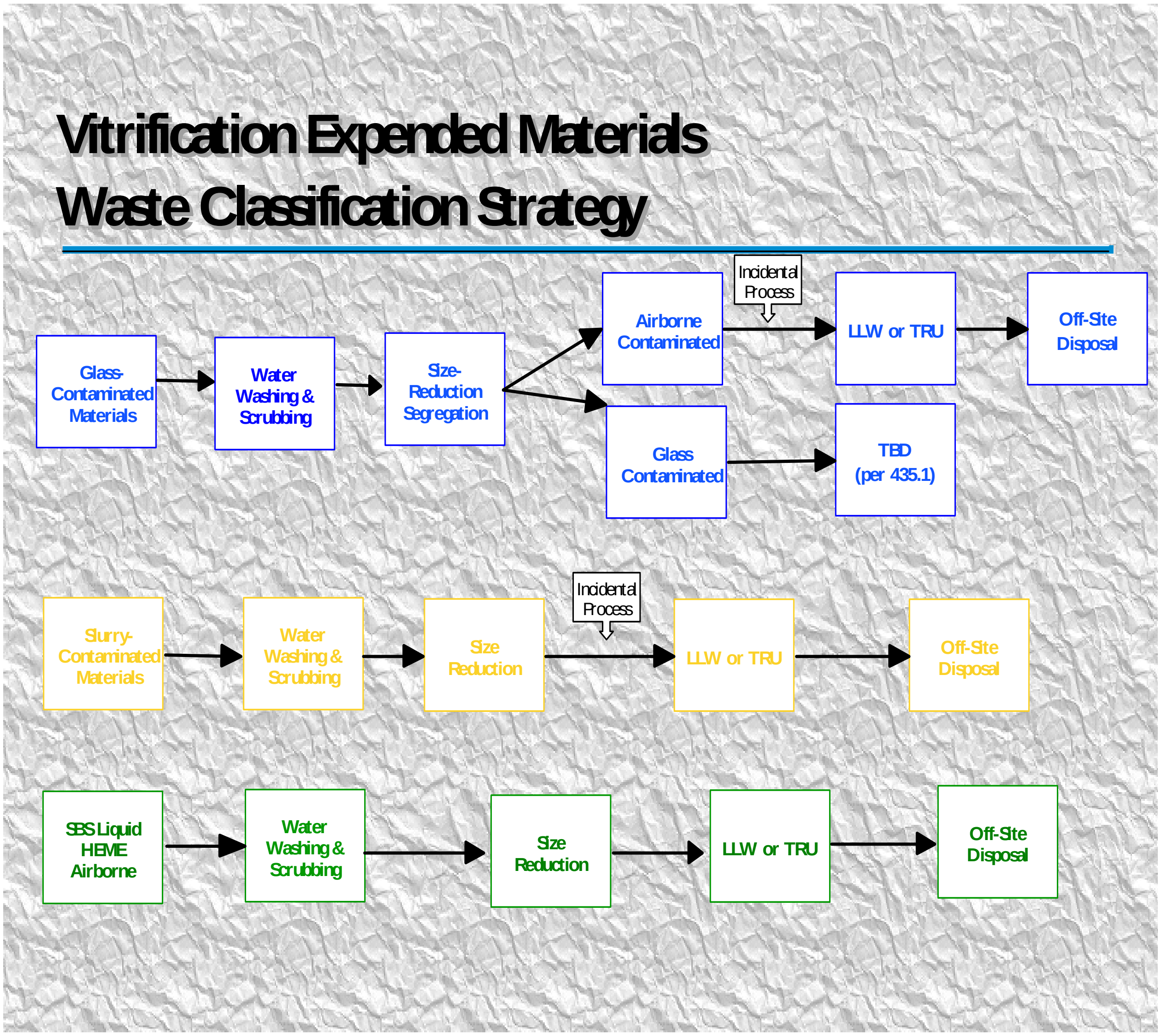


**Figure 2. Waste Classification Strategy**

Once it was determined that the wastes could meet the incidental waste criteria, the radiological classification was performed using dose-to-curie conversions based upon radionuclide profiles. The radionuclide profiles are generated for each of the different waste types based on analytical data collected. Once the ratios of the radionuclides are established for a particular waste stream, the measured dose from a package can be used to establish the classification of the waste. This classification approach represents a significant cost savings to the Project since classification could be accomplished using a nonintrusive dose measurement rather than a sample. Figure 2 depicts the overall waste classification strategy for the VEMP wastes.

The hazardous components associated with the HLW stream include: barium, cadmium, chromium, mercury, selenium, and silver. Once vitrified, the waste is no longer characterized as RCRA hazardous waste since vitrification is the required treatment standard. RCRA requires that waste be characterized at the point of generation and is also important in determining short- and long-term waste-handling requirements. Only two types of contamination were identified that could potentially result in the generation of RCRA hazardous waste: untreated HLW slurry and SBS liquid. Since the HLW slurry is hazardous for RCRA metals, the contaminated equipment is characterized based on the quantity of slurry still remaining on the equipment when it is declared a waste. Using a worse-case scenario, a bounding calculation was prepared to successfully verify that none of the slurry-contaminated expended material would be RCRA hazardous waste. The SBS liquid has not yet been sampled for RCRA characterization, however the liquid may contain sufficient concentrations of mercury to result in a RCRA hazardous waste characterization. The SBS liquid will be sampled prior to the generation of any equipment contaminated with this material. If determined to be RCRA hazardous, the equipment will be managed as mixed waste pursuant to the site treatment plan.

## OPERATIONS

Approximately 18 months after the expended-equipment-system need was identified, size-reduction and segregation activities of HLW-contaminated materials were initiated using remote in-cell tooling. In order to accomplish a smooth transition from engineering to operations, the WVDP developed a process flow plan. The process-flow-sheet development consisted of a series of meetings and included functional departments across the organization. The VEM process was flowcharted and the requirements for each step defined, including load-in equipment, container movement, size reduction, packaging, interim storage, and load-out from the VF. A standard operating procedure (SOP) was drafted (at the same time as completion of the flowcharting process) to ensure consistent understanding by both the Engineering and the Operations organizations. Once a draft procedure was prepared, the organization proceeded to perform extensive mock-ups and conduct operator training exercises.

### Operator Training

Testing of the VEMP tools and training of the operators began with visits to the tool fabricator's shop. Two WVDP operators examined the tools and observed their operation during these visits. They also took the opportunity to make suggestions regarding the design and operation of the tools.

During these visits, the operators observed testing of a guillotine saw, a port-a-band saw, an electric grabber, an electric shear, a large Adamant™ saw, and a portable work bench. A number of design improvements, such as those involving bail design, V-notches in the workbench, weights to hold pieces of equipment down on the workbench, the handle design for remote manipulator operation, the base design for free-standing stability, guides to keep the shear square-to-the-work, and work-holding clamps on the tools, were derived from these early demonstrations.

Once the tooling was delivered, Operations conducted full-scale mock-ups in the Vitrification Test Facility (VTF). During the course of this training activity, the operators contributed many ideas that led to tooling and process refinements that ultimately, along with Engineering, defined the cutting plan to be used on the first item to be size-reduced remotely in-cell (a thermowell).

### Operational Readiness

The immediate objectives during this phase of the Project were two-fold: 1) ensure that the equipment was physically and functionally ready to perform its design task, and 2) deploy the necessary equipment into the VC just prior to initiating VEMP size-reduction operations. In this sense, "necessary equipment" meant only the equipment that would be required to complete the specific task of size-reducing the initial item, including minimal contingency equipment. In order to minimize the generation of additional

contaminated equipment, the tooling deployed in the cell was restricted to that required to complete the specific task. Since the VEMP Program was not a major modification to the facility, operational readiness was established using Project-specific checklists and existing site procedures in a graded approach as specified by the facility manager.
Once the required level of readiness evaluation was established, an evaluation plan was prepared during the developmental phase of the Project (approximately 45 to 60 days prior to the targeted start-up date). This not only ensured that sufficient time was available to accomplish the readiness evaluation, but also allowed time for discussion and agreement with all stakeholders on the level of evaluation to be performed.

Only those elements specific to the VEMP Project were included in the readiness evaluation. WVNS site programs, for example, the Quality Assurance Program and the Industrial Hygiene and Safety Program which had been previously verified through internal assessments, were not included. This resulted in a scope consistent with the scope of the Project and eliminated unnecessary and repetitive review.

The method of planning and performing the VEMP Readiness Review resulted in an evaluation of sufficient scope and rigor to ensure safe operations without becoming an administrative roadblock to achieving operational status of the system.

**Deployment**

In cell operations of the VEMP Program were initiated in July 1999, with the size reduction of a HLW-glass-contaminated thermowell. A diagram of the facility layout is provided in Figure 3. The expended material is staged in both the VF and the HLWISF   The first thermowell was transported from the HLWISF to the VC and was brought to the sample station using the transfer cart and the VC crane. The thermowell was washed down with a high-pressure water-spray wand and a manipulator-held, nylon-bristle brush before making the first cut. The expended material was then placed on the maintenance station (east wall of the VC) for size reduction.

Size reduction was initiated using the guillotine saw. Based on the contaminant properties and potential disposal options, size-reduced material was segregated into the following four categories:
Category 1 - Expended material consisting only of glass-contaminated Inconel and stainless steel.
Category 2 - Expended material that is all other glass-contaminated material.
Category 3 - Expended material contaminated with slurry, including nonseparable glass and slurry.
Category 4 - Expended material that has no glass or slurry contaminants.

Each of the four categories is placed into uniquely identified 30-gallon white drums that are positioned next to the maintenance station until they are full.

In support of the field operations, a cognizant engineer prepares a cut-and-segregate plan for each piece of equipment to be size-reduced based on visual inspection and process knowledge. A series of cut plans is kept for each 30-gallon waste container that contains pieces of the size-reduced equipment. This allows the site to maintain a complete inventory of all the size-reduced equipment and a record of how it was dispositioned.

The size-reduced pieces of equipment are washed a second time and placed in the appropriate waste cans that hang from the maintenance station. Once a container is full, it will be overpacked and transferred from the VC on the transfer cart. The container is surveyed in the Equipment Decontamination Room (EDR). If the container is surveyed at <100 mR/hr, the drum is transferred to on-site LLW storage. If the drum surveys at >100 mR/hr, it will be transferred to the HLWISF, where the insert will be removed from the overpack and staged until additional shielding arrangements are developed. Figure 3 is a general layout of the VEMP process.

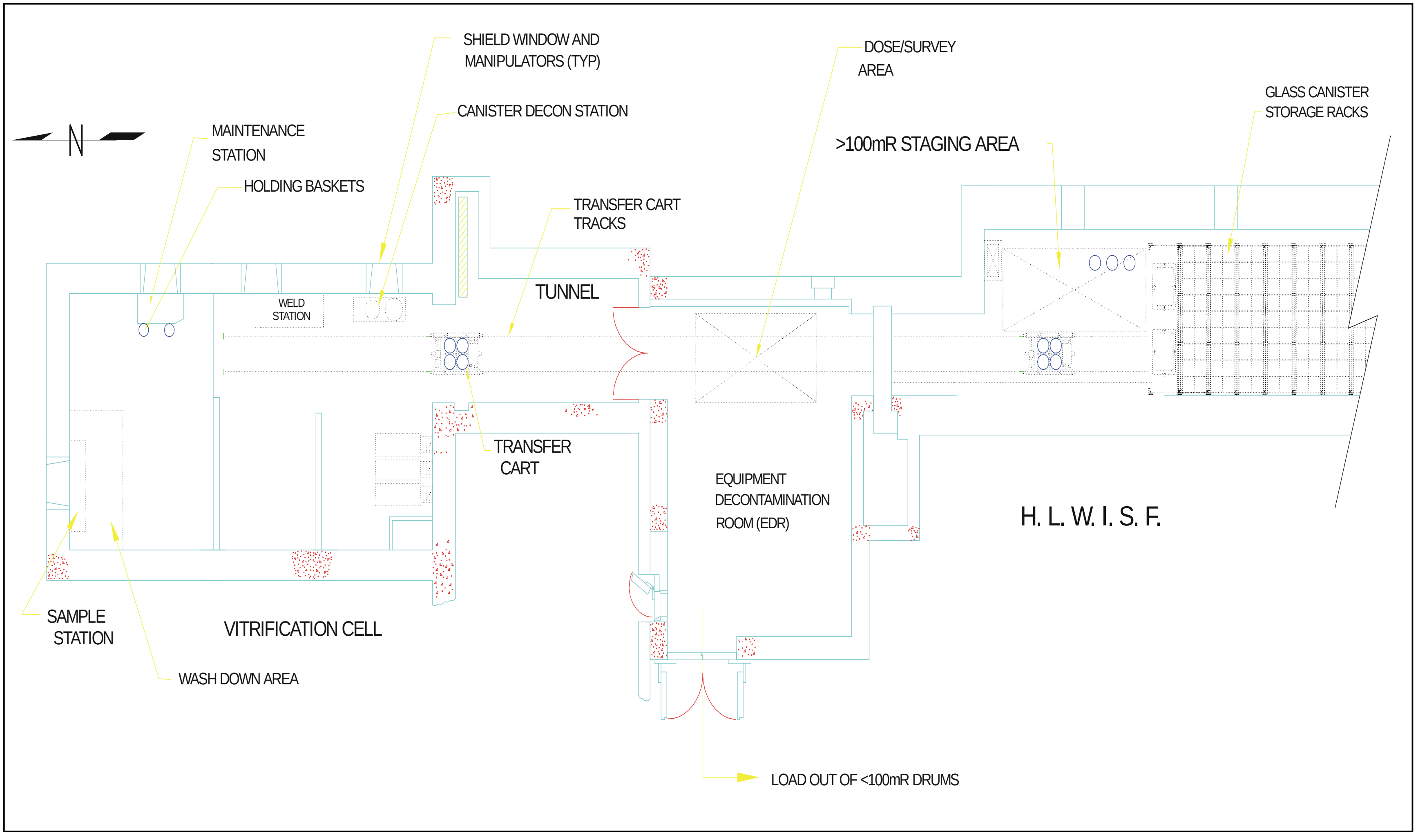


**Figure 3**. Vitrification Expended Materials Processing Facility Layout

## TOOLING DEPLOYED

In order to minimize the rate of increase in the amount of VEM being added to the cell environment the equipment deployed in the cell was restricted only to that required to complete the specific task. The VEMP Program was prepared with a number of tools to deploy based on need. Judging from the initial cutting scope, it was determined that only those tools that were necessary to size-reduce and segregate the thermowell were loaded in-cell. Table I lists the equipment deployed.

**Table I. In-Cell Equipment Deployed**

| Quantity | Equipment Deployed |
|---|---|
| 1 | Guillotine Saw |
| 1 | Electric Assembly Grabber |
| 2 | Waste Handling Can Holder Assembly |
| 4 | Vitrification Waste Handling Cans |
| 1 | Chain Vise Adapter |
| 1 | Thermowell Lift Yoke |
| 2 | Clamping Jaw Adapters |
| 1 | Dynamometer (1000 #) and Stand |
| 4 | Strainer Baskets |
| 2 | VEMP Work Support Fixtures (V-Block Stands) |
| 1 | Wash Basket |
| 2 | L-Clamps |
| 2 | Jack Stands |

Figure 4 provides an example of the equipment that was remotely deployed.

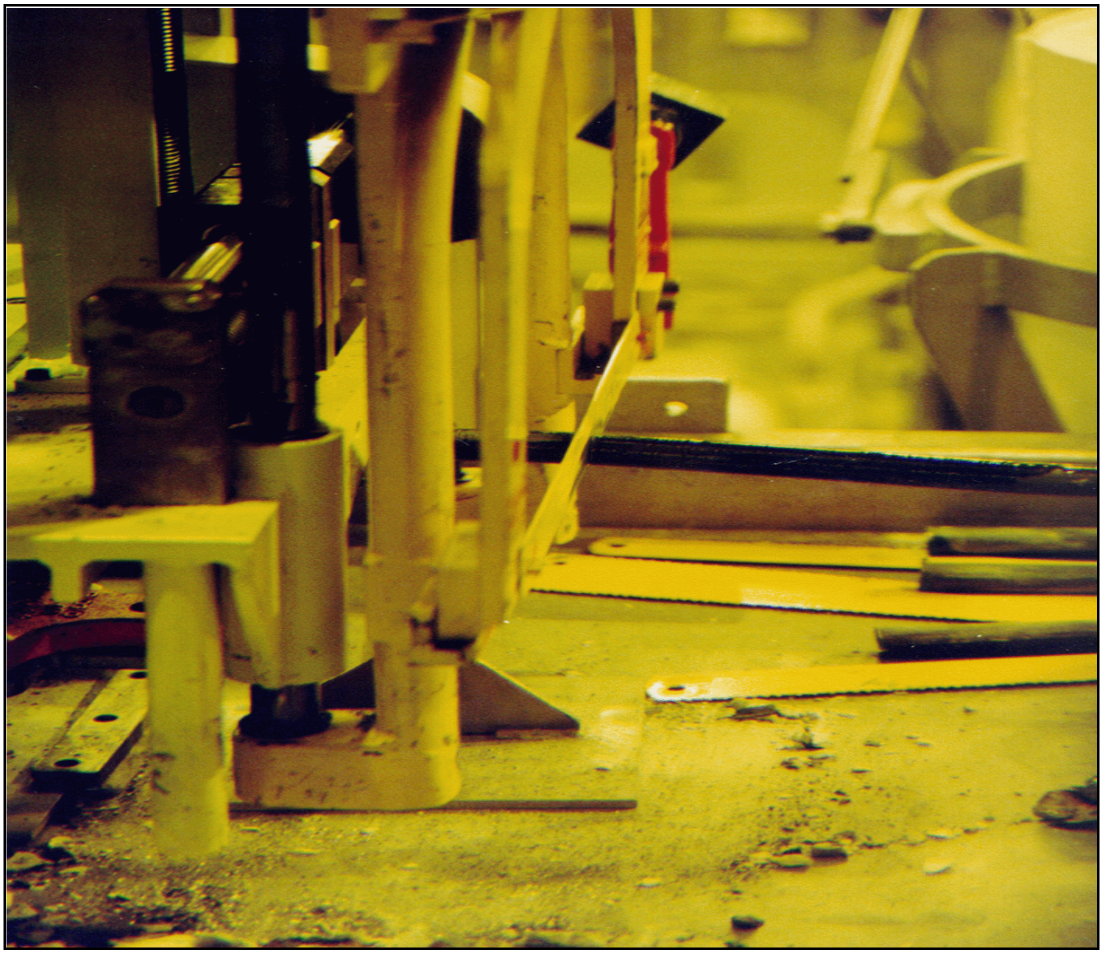

**Figure 4. Guillotine Saw Cutting a Thermowell**

Table II lists the additional tools that have been developed, but not deployed.

**Table II. Additional In-Cell Tools Developed but not Deployed**

| Quantity | Equipment Developed But Not Deployed |
|---|---|
| 1 | Electric Shear |
| 1 | Remote Band Saw |
| 1 | Pneumatic Hacksaw |
| 1 | Remote Cast Cutter |
| 1 | Electric Assembly Grabber |

## CONTINUING VEMP OPERATIONS

The VEMP Program is the first step toward the next phase of the WVDP, that is, to decontaminate and decommission facilities used to vitrify HLW. As a result, lessons learned and tooling developed during the VEMP Program can be applied to future WVDP work activities such as the Remote-Handled Waste Facility (a facility designed to remotely decontaminate, size-reduce, and package equipment from a variety of waste streams and future D&D programs). Tool durability, effectiveness, operator involvement, and remote maintenance are key lessons that can be applied to other remote projects.

As of November 1999, approximately 25% to 30% of the glass-contaminated thermowells in storage have been size-reduced, segregated, and packaged. The WVDP is currently focusing on processing the remaining glass-contaminated expended material since this waste stream is under consideration for integration into and disposition with the remaining vitrification canisters. Second generation tooling, such as remote drum capping, is being developed to support size reduction of the balance of expended materials in inventory. The VEMP Program is also evaluating technologies to implement larger, long-term D&D efforts. Finally, in keeping with WVDP’s philosophy to “touch waste once,” the Project intends to complete analytical activities to support classification, and package the wastes accordingly. The Project began removing segregated LLW in 1999.