COMPACT LIQUID WASTE EVAPORATOR FOR CLEANUP OF HANFORD'S HOT CELLS

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ABSTRACT

Removal of radionuclide and hazardous contaminants from hot cells in Hanford's 324 Building will produce an aqueous waste stream requiring volume reduction and packaging. This paper describes a compact and remotely-operated evaporator system that was designed for use in the 324 Building's B-Cell (a shielded hot cell) to volume-reduce the waste waters that are generated from pressure washing of hot cell ceiling, wall, and floor surfaces. The evaporator incorporates an electric-heated reboiler to provide evaporation and drying to allow disposal of waste material. Design features of the evaporator system were strongly influenced by the need for remote handling and remote maintenance. Purified water vapor from the evaporation process will be released directly to the hot cell ventilation air.

INTRODUCTION

Facility History and Contamination

The Hanford Site and specifically the 300-Area are shown on Figure-1. R&D technology support and nuclear fuel production were products of the 300-Area during the active years of processing on the site.

The roughly 100,000 sq ft (9,450 sq m) 324 Building was constructed in the early 1960s and had an active mission until the mid-1990s. The 324 Building was designated as the Fuel Recycle Pilot Plant and later changed to the Waste Technology Engineering Laboratory. Waste technology studies included the chemical and physical processing of high activity radioactive materials (including vitrification), characterization of physical and chemical properties of irradiated materials, and non-radioactive process development. The 324 Building is presently a Category 2 nuclear facility based on the radionuclide inventory.

The 324 Building is currently in a transition to complete deactivation and decommissioning. Over the last few years, considerable waste material has been packaged, removed and shipped to waste storage and disposal facilities in Hanford's 200 West Area. Recently seven commercial power spent fuel bundles were transferred to casks and shipped to Hanford's 200 Area. The 324 Building is located within ¼ mile of the Columbia River and just north of the city limits of Richland, Washington.

Fig. 1. Location of Hanford's 300 Area and 324 Building.

The 324 Building contains two large hot cell structures known as the Shielded Materials Facility (SMF) and the Radiochemical Engineering Cell (REC). Sealed source work was done in the SMF which is an 80ft long hot cell assembly. SMF cells are of conventional design and have good access by master slave manipulators plus overhead cranes. Process development was done in the REC complex which is roughly a 70 ft by 70 ft structure, three stories high. Most of the estimated 65,000 Ci radionuclide inventory in the building resides in B-Cell, the largest of the cells in this group. Residual activity is deposited on the hot cell walls and ceiling from previous development programs. Much of the cell inventory is on the floor in the form of solid waste (grout and process spillage) in the sump cavity area. Roughly one-third of the inventory is located in two of the storage vessels (High Level Vault) serving this cell group. D-Cell, in the REC group, has lower levels of contamination from prior fuel pin cutting and waste handling.

Decontamination Challenges

Smear samples from B-Cell wall surfaces indicate contamination concentrations in the 50-300 uCi/sq dm (1.8E4 -1.1E5Bq/sq cm) range, and floor dose rates range from 100R/hr to >25,000R/hr (1Gy/hr-250Gy/hr). Planning is in place to reduce the smearable and dispersible levels to a minimal level to facilitate demolition actions at a later date. Mobile radiological activity will seriously interfere with demolition actions. Cleanup of piping imbedded in the thick concrete shield walls may also contribute to liquid decontamination waste volumes. Most of the facility can be decontaminated with existing technology without specialized designs. Dominant beta gamma isotopes are Cs-137 and Sr-90/Y-90. Alpha nuclides are primarily Am-241, Cm-243/-244 and Pu isotopes.

Waste handling associated with decontamination waste solutions has changed dramatically over recent years. Until several years ago, the 300 Area was served by a railcar transport system for liquid waste. This option disappeared when the waste terminal and rail network were shutdown. The site also has both shielded and unshielded mobile tank units; these units carry only limited activity solutions. However, costs and procedure associated with shipment are substantial and tend to eliminate the option of handling of large volumes of wastewater. Processing wastewater at the source is an attractive option where possible.

An earlier attempt at developing decontamination and waste processes for the 324 Building was based on chemical decontamination with subsequent treatment of the waste solutions. A RCRA "clean surface" condition was initially used as a facility endpoint; this would have required a significant level of cleaning. Since organic chelating compounds are frequently used for this purpose the liquid waste process contained the classical unit operations of destructive oxidation, filtration, adsorption, TRU removal and various ion exchange materials. Initial cost estimates for this approach were set at 7 million dollars.

The subsequent and current approach for decontamination processes in the 324 Building has simplified the overall method by eliminating chemical decontaminating agents, and rely on physical methods such as high pressure water and ultra-high-pressure water. Different criteria have also been established as an endpoint for decontamination. The overall goal is now to remove all possible dispersible and/or non fixed material, apply fixatives to immobilize remaining activity, and size reduce the structure for disposal in Hanford's 200 Area burial sites. Endpoint conditions heavily impact how the final breakdown work is conducted and what level of packaging is required.

LIQUID WASTE PROCESSING SYSTEM

Process Description

The liquid waste handling system design incorporates the process functions of accumulation, evaporation, drying, and residual waste packaging with one apparatus. The evaporator reboiler is modular and disposable. After sufficient material has accumulated in the unit, it will shift to drying mode and will eventually be loaded into a series of containers that fit into a shielded cask for disposal. When the waste operation is completed, the system will be flushed and size reduced for disposal as mostly low-level waste (LLW). A significant cost savings is realized when the evaporator overheads (purified water vapor) are released to the cell's ventilation air stream. This process requires control of cell humidity conditions. A programmable logic controller (PLC) unit monitors plant conditions and controls the relative humidity of the cell air effluent. Materials of construction are very important because the reboiler gamma field is significant.

Figure 2 shows a simplified view of the evaporation skid. All of the hardware is mounted in single supporting skid structure. Other geometry arrangements could be used depending upon the capacity, cell size and cell access. For the 324 Building application, the system had to be designed for remote operations because access to the lower cell area is difficult. During maintenance, the process skid is raised to the hot cell window elevation for access via the existing hot cell manipulators.

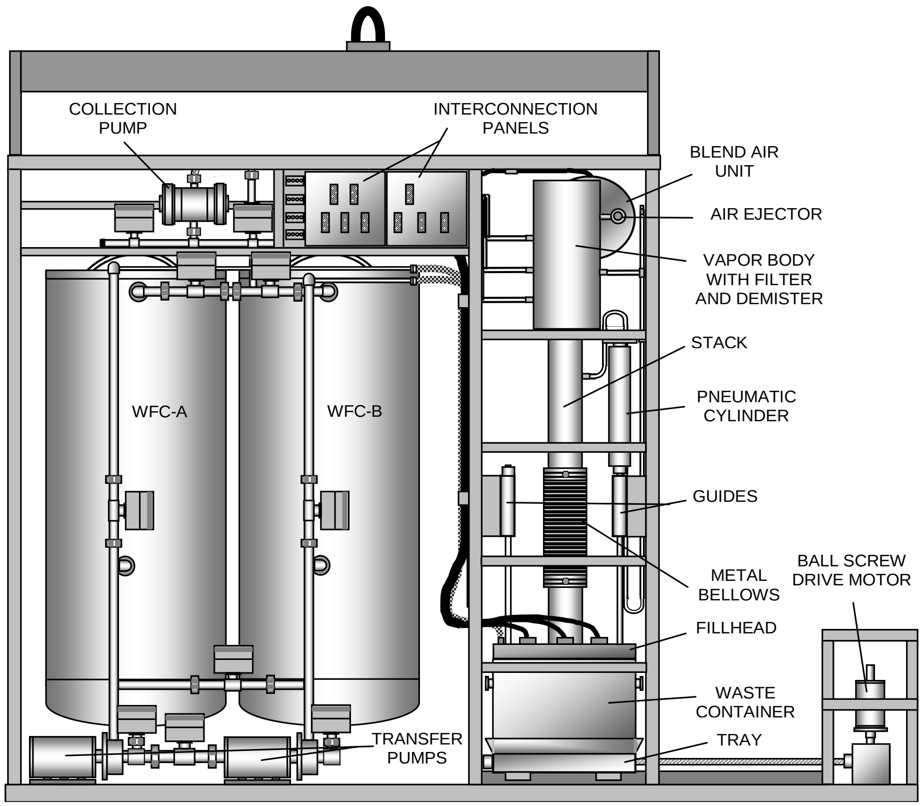

Fig. 2. Schematic of Hot Cell Evaporation Skid.

Two 500-gallon (1,890 liter) vessels are used to collect the waste liquid and particulates transferred by a diaphragm-driven slurry pump with a special strainer type pickup head that will pass 3/16"(0.47cm) particles. The 3HP centrifugal pumps recirculate the vessel contents. An eductor in each vessel is used to mix solid and liquid phases.

After sufficient feed has been accumulated, the evaporation cycle is started. Feed slurry from each recirculation loop is fed to the evaporator in short batches, and governed by float switches inside of the reboiler container. This process will continue until either a curie limit (5k to 10k Ci) (1.8E14 - 3.7E14 Bq) is reached or a solids inventory limit (11 cu ft (0.3 cu m) or 1000 lb (450 kG)) is reached; the later will likely dominate.

The drying cycle utilizes the same heating elements as the evaporation cycle. A lower watt density level may be used to perform this step; prototypical testing will demonstrate this using waste simulants. This same testing will demonstrate the drying endpoint condition readout on Resistance Temperature Device (RTD) sensors in the evaporator reboiler. This is an important point for waste shipment due to limits on hydrogenous material in the cask. Verification of the drying endpoint will be done in the prototype testing.

Equipment Design and Description

The mechanical design of this system went through several iterations before settling on a single skid with a screw drive mechanism to move the waste container into and out of the evaporator. Initial concepts involved a two-piece skid that had a removable evaporator upper section. In that case, the modular replaceable reboiler unit was stationary and the evaporator top works was moved into and out of position for reboiler replacement. The logistics of skid fit up and alignments created difficulty with the design; it was abandoned. To alleviate this an earlier idea involving a one-piece skid with a moveable evaporator tower and a drive to transport the modular reboiler into and out of the operating position was chosen.

Two aspects of the skid system that required considerable design effort were equipment access and remote maintenance. Any component that may fail must be accessible by the master-slave manipulators, which are essentially two "hands" each with a "thumb and index finger." Once access is achievable, then the device must incorporate remote fastenings to allow its replacement. Pneumatic valves are designed with special unions that allow easy removal by manipulators. The centrifugal pumps presented a unique challenge in that they are too heavy for manipulator handling. Each pump is mounted on a ball platform that allows it to be horizontally transported from the skid to a shelf under the shielded hot cell window. A new pump is handled in the same way, but in reverse order. Each demister is replaceable. The blend air heater in the upper rack area is replaceable. All of this is achieved by using special electrical connectors and fastenings.

Modular Reboiler

Replacement of the modular reboiler consists of raising the tower base, and moving the reboiler out of the skid structure to its load out position. The loaded reboiler receives a cover and then is placed in the shielded cask liner box. Loading the new reboiler involves the same steps in reverse order. Exact positioning of the reboiler box is very important to achieve fit up of the tower base to reboiler box and of the electrical connections inside of the box.

Tower

The tower has two stages of demisting. A roughing demister with wash down is positioned in the top of the vapor duct and a much larger quartz/wool-type unit is positioned in the expanded tower portion. A hatch on the top allows replacement of both units remotely. An air ejector extracts the purified water vapor and delivers it to the blend air heater where it is mixed with a large flow of cell air and heated to prevent deposition in the cell exhaust HEPA filters. The lower portion moves vertically to allow input or load out of the disposable reboiler. Polymeric materials were considered for the bellows joint in the vapor riser. To avoid replacement, a metal bellows was incorporated here.

Materials of Construction

The key to success for this approach is the proper choice of materials to withstand the high beta gamma dose rates. All materials of construction in the reboiler / waste container / lower-evaporator module were carefully checked for composition. Special insulated wire was used for the high radiation areas of the skid. Polymers for this application must be specially formulated to withstand 2E8 RAD dose. There are very few of the reactor-era vendors left that provide this type of material.

Disposal

All parts of the system have been optimized for disposal at the end of the processing campaign. A final thorough flush campaign will be performed to maximize the amount of equipment waste that can be disposed as LLW. The reboilers will all go to cask disposal, and will contain the TRU and hazardous metals. Only the tower may have some residual that could require some special handling.

Humidity Analysis/Control

When releasing water vapor to water-sensitive systems, operating conditions are very important. Sufficient energy must be added to the air-water vapor mixture to prevent deposition of water in the filter media/filter loading, or on duct surfaces. A detailed heat and mass balance analysis (VB6 software) was done for the entire Zone-1 air path to assure that no adsorption, or condensing problems would occur prior to release to the stack. Data are taken from humidity instrumentation and temperature points throughout the building to provide input data for the program. Calculations incorporate the outside air conditions, preheating, spray-cooling and heat sources within the building. The most critical relative humidity conditions exist at the local filters inside B-Cell and adjacent to B-Cell in the primary filter vault. Sufficient heat must be added to reduce the relative humidity of the exhaust flow to prevent deposition on these filters. Moisture changes at the final building HEPA filters are relatively small and can be readily controlled. The added energy eliminates the moisture effect or reduces it to negligible values.

SUMMARY

Consolidation of waste collection, evaporation, and drying in one equipment system, coupled with direct water vapor release to the nuclear ventilation system, will result in significant cost savings relative to a chemical-based waste process. The absence of wastewater shipment represents a further cost savings by eliminating sampling, analysis, transfer, and shipment of wastewater. All final waste material will be in a solid and dry form.

The final design review was completed in September 2003. Fabrication proceeded from September 2003 to December 2003. The factory acceptance test is planned for February/March 2004. Operation in the 324 facility may occur in in 2005.