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Defense Waste Processing Facility - Radioactive Operations - Part III - Remote Operations(U)

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Radioactive Operation - Part III - Remote Operations

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Radioactive Operation - Part III - Remote Operations

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ABSTRACT

The Savannah River Site's Defense Waste Processing Facility (DWPF) near Aiken South Carolina is the nation's first and world's largest vitrification facility. Following a ten year construction period and nearly three years of non-radioactive testing, the DWPF began radioactive operations in March 1996.

Radioactive glass is poured from the joule heated melter into the stainless steel canisters. The canisters are then temporarily sealed, decontaminated, resistance welded for final closure, and transported to an interim storage facility. All of these operations are conducted remotely with equipment specially designed for these processes.

This paper reviews canister processing during the first nine months of radioactive operations at DWPF. The fundamental design considerations for DWPF remote canister processing and handling equipment are discussed as well as interim canister storage.

INTRODUCTION

The DWPF facility is designed to immobilize radioactive waste stored in 51 underground storage tanks at SRS. These wastes are immobilized by incorporating them into a borosilicate glass matrix to reduce the mobility of radionuclides. The glass is then poured and sealed in stainless steel canisters for long-term off-site storage in an underground repository. The waste treatment and glass making processes are discussed in Reference 2 and operating experiences relating to remote in-cell processing equipment are discussed in Reference 3. This report examines the equipment performance relating to remote canister processing and impact on attainment during initial radioactive operations. Canister processing steps include:

- Installation of the temporary seal used to prevent water intrusion during canister decontamination
- Leak testing of the temporary seal to ensure that water will not enter the canister during decontamination
- Decontamination of all external canister surfaces using a glass frit-water mixture
- Smear testing to ensure removal of transferable external contamination
- Final closure welding of the canistered waste form
- Transport of the canister to the on-site interim storage facility

The facility underwent three years of non-radioactive operational tests to demonstrate equipment, process, and product performance prior to being granted permission to introduce radioactive waste in March 1996. Eighty-five canisters were processed prior to radioactive startup and eighty-two radioactive canisters have been processed during the first nine months of radioactive operations.

TEMPORARY CANISTER SEAL

After glass-filling has been completed, each canister is sealed using an inner canister closure (ICC) plug. The purpose of the ICC plug is to provide a temporary, water-tight seal to prevent the ingress of foreign material into the canister during canister handling activities, especially during the canister decontamination process. Later in the canister handling process, this temporary closure is replaced by a final closure weld.

The normal inner canister closure configuration is composed of a tapered sleeve (installed into canister throat during canister manufacturing) and an ICC tapered plug. The ICC plug is installed into the canister throat when a sufficient temperature differential exists between the canister and plug. As the canister cools, a shrink fit forms between the canister throat sleeve and ICC plug. Normally, the ICC plug is installed at the Melter Pour Turntable shortly after completion of glass pouring and while the canister is sufficiently hot. However, if the required temperature difference between the canister flange and ICC plug is not available at the pour turntable, the ICC plug is installed by reheating the canister flange using a resistance heater assembly located at the ICC Station. The canister is moved from the melter pour turntable to the ICC Station, also located in the Melt Cell (MC) with a remotely operated crane.

To date, approximately two-thirds of all ICC plug installations for radioactive canisters have been performed at the Melter Pour Turntable. The remaining one-third required reheating of the canister flange at the ICC Station to obtain the required canister flange temperature for ICC plug insertion. The high percentage of canisters requiring ICC plug installation at the ICC Station is primarily due to Melter pouring interruptions that prevent continuous filling of canisters and result in lower canister flange temperatures at completion of the pour.

The ICC Station also includes equipment needed to perform pressure decay leak testing of the ICC seal. This equipment includes a bell jar, seal gasket, pressure and temperature instrumentation, and helium supply equipment. A swing arm positions and then lowers the bell jar assembly and seal gasket onto the canister flange. The bell jar is pressurized using helium and then isolated. Pressure and temperature data are collected over approximately three hours. The temperature compensated pressure drop is used to calculate the ICC seal leak rate using Ideal Gas Law equations. The ICC leak rate must be less than or equal to 2.0×10^{-4} atm-cc/sec Helium to be considered acceptable. If a leak test fails to meet acceptance criteria, an evaluation is performed to determine if the leak was caused by an ICC seal failure or failure of the leak test equipment seals. ICC seal failures are reworked by using the ICC Station heater system to rapidly heat the canister flange, causing the flange to expand and allow both the ICC plug and canister throat sleeve to fall into the canister. An ICC repair plug is then installed and leak tested to the same acceptance criteria.

All radioactive canisters processed through the ICC Station during this period have successfully met the leak test acceptance criteria of less than or equal to 2.0×10^{-4} atm-cc/sec He using the normal ICC plug. Thus, no ICC repair plug installations have been required. One canister initially failed leak test requirements. An attempt to heat the canister flange and drop the ICC failed. An additional leak test was performed on the ICC and found to be within acceptance criteria. Review of process data showed that the plug installation occurred when the canister flange temperature was at the minimum allowed temperature and proper plug sealing is not believed to have occurred. The subsequent reheat and cool cycle during the attempt to drop the ICC plug caused it to properly seat against the canister throat sleeve resulting in the successful leak test.

Figure 1 shows the final leak rate and plug insertion temperatures for all radioactive canisters. Although not conclusive, many of the higher leak rates have occurred on canisters that had an ICC plug installed at a canister flange temperature near the minimum allowable temperature.

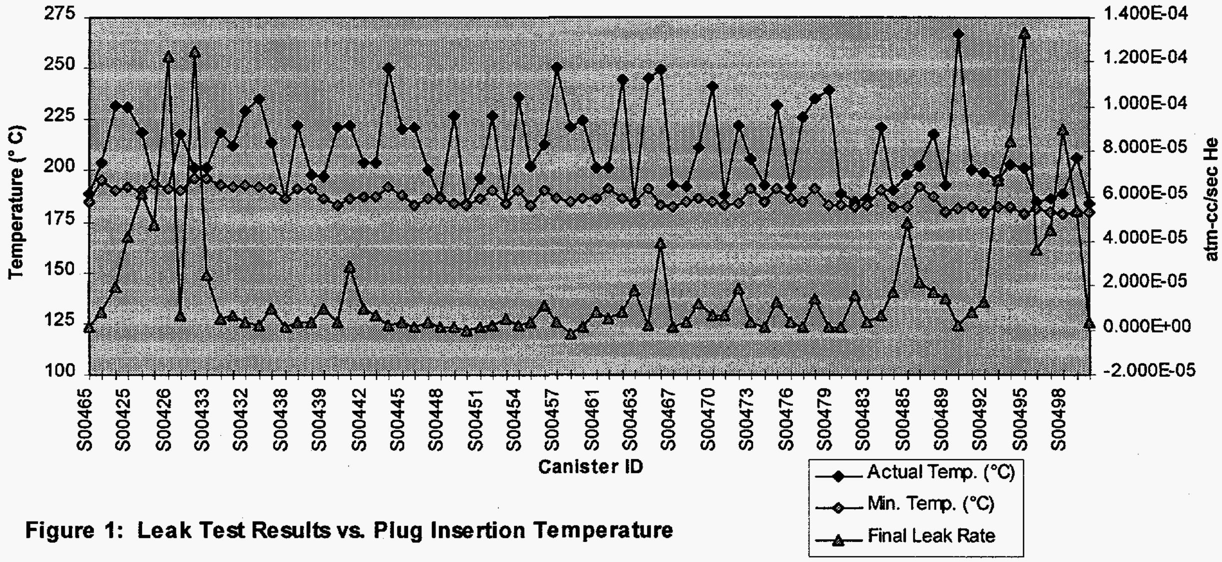

Figure 1: Leak Test Results vs. Plug Insertion Temperature

Out of 82 canisters, six have failed their initial ICC leak tests. Of these six, five of the leak test failures were found to be due to equipment problems preventing an adequate seal between the leak test equipment and the canister flange. When failure of a canister leak test occurs, a leak test is performed on a test flange to determine if the leak path is through the seal gasket (which seals the ICC bell jar to the canister flange surface) or other pressure boundary besides the ICC plug. After resolution of any equipment deficiencies, the suspect canister is retested. The most common equipment problem is a seal gasket failure, usually due to gasket damage from normal wear and tear and this is relatively simple and inexpensive to replace. Other ICC Station equipment problems require remote decontamination and relocation to a hands-on maintenance cell for repair work. Problems encountered include the following:

- Insulation damage to the Leak Test Swing Arm motor leads occurred due to cyclic cable movement against a sharp metal edge. To permit continued ICC Station operation until a planned maintenance window was available, the swing arm was remotely uncoupled from the motor and manually positioned using Master Slave Manipulators (MSM).

- The actuator arm for the limit switch associated with positioning the leak test swing arm became loose and was not reliably actuating the limit switch.

After the canister successfully passes leak testing and before it is moved from the ICC Station, it is visually inspected for adhering glass. Any glass is removed from external surfaces using a needle gun. This has not been required during the first nine months of operation. Otherwise, the canister is transferred from the Melt Cell through a transfer tunnel and into the Canister Decontamination Cell (CDC).

CANISTER DECONTAMINATION

Heat from the molten glass in a filled canister causes an oxide layer to form on the outside surface of the canister. The oxide layer that forms on the canister could trap radioactive contamination present in the Melt Cell. To prevent the spread of contamination, the oxide layer is removed before welding operations and canister storage. Canister decontamination is accomplished by blasting the canister surface with a frit-slurry consisting of about eight weight percent frit in water. The frit-slurry is pumped at low pressure to blast nozzles, where it is injected into a compressed air stream and accelerated onto the canister surface. After the canister is frit-blasted, the same nozzles are used to water rinse and then air dry the entire canister.

There are two identical decontamination chambers, chamber 1 and chamber 2, inside the CDC. Both chambers contain the same equipment and capabilities so that either can perform decontamination operations. Once the filled canister arrives from the Melt Cell it is placed in a decontamination chamber with a crane. A "dirty" grapple is used to transport the contaminated canisters. The dirty grapple is also used to position the Canister Manipulating Mechanism (CMM) over the contaminated canister. The CMM is a machine designed to lift and rotate the canister past an array of stationary spray nozzles. System interlocks prevent frit blasting unless the canister is rotating. The canister decontamination operation consists of five distinct automatic sequences:

- Frit blast and rinse canister flange
- Frit blast and rinse CMM grapple
- Frit blast and rinse canister bottom, flange, and sides
- Rinse grapple
- Rinse canister and chamber; air dry canister; transfer spent material to Chemical Processing Cell (CPC).

Once the cleaning process is complete, the CMM returns the canister to its chamber support and releases the canister. The dirty grapple removes the CMM from the chamber, and is then removed from the in-cell crane and replaced with a clean grapple. The canister is transported by the in-cell crane to the CDC Smear Test Station (STS) to be surface smeared for contamination. Canisters that fail the smear test are returned to a decontamination chamber for additional decontamination. The process is repeated until the canister passes the smear check.

During 1996 radioactive operations, blasting operations were completed on 82 radioactive canisters. All 82 canisters have passed DOT smear testing requirements (Reference 1). None have required a second cleaning. Equipment problems interrupted blasting operations 18% of the time. Most of the equipment problems occurred in chamber 1 and this resulted in chamber 2 being used for 81% of radioactive blasting operations. Several of the system problems encountered to date have been summarized below:

Moisture-Related Electrical Problems:

- Standing water was found in CMM electrical jumpers that caused electrical faults between the lift and rotate motors. The source of the water was believed to be from in-cell washing that leaked in through remote electrical connectors or from condensation. The problem was corrected by providing drain path to prevent moisture accumulation.
- Pin to pin shorts occurred on the CMM electrical connector plates.
- Electrical connector on a transfer motor failed.
- Remote electrical connector for the recirculation pump electrical jumper shorted and failed.

Other:

- Limit switches for the CMM grapple and lift motors have failed.
- CMM rotational indicator failed to operate during blasting operations. A key that transmits torque from the shaft to the gear hub was found to be missing.

Contaminated material removed by the cleaning process is transferred directly back to the vitrification process, to the Slurry Mix Evaporator (SME). Radioactive canister decontamination has generated an average of 5700 liters of frit slurry transferred to the SME per each canister blast. The spent frit slurry consists of approximately 950 liters of decontamination frit slurry (frit and water) and 4750 liters of flush rinse and prime water. Changes to system design and operating procedures are currently underway to reduce the volume of waste water generated during each canister blast.

There is no holding tank for the spent frit from the CDC chambers. Therefore, the operation of the decontamination chambers must be coordinated within the SME processing cycle. Spent frit processing has not been impactive during the first nine months of radioactive operations because sludge processing and sampling activities are currently process limiting. Canisters are decontaminated in a batch sequence. A backlog of leak-tested canisters accumulate in the Melt Cell until the SME batch is ready to receive frit. Then the canisters are campaigned through the CDC at a rate of one to two canisters a day. Between each canister blast, the SME is concentrated by evaporating off water prior to the next canister blast. Approximately six canisters can be produced from each SME batch. DWPF is currently evaluating design changes to minimize the impact of spent frit on the DWPF process.

CANISTER SMEAR TESTING

The Smear Test Stations (STS) provide the means for measuring the effectiveness of the canister decontamination process. This is accomplished by collecting remotely smeared samples of the canister's exterior to verify that radioactive contamination is below Department of Energy prescribed limits that are based on Department of Transportation (DOT) wipe limits (Reference 1). These DOT requirements and the DWPF smear testing acceptance criteria is alpha radiation less than 220 dpm/100 cm^2 and beta/gamma radiation less than 2200 dpm/100 cm^2. This standard applies to external surfaces of shipping casks. While the canister is not exposed to the environment like a shipping cask (Canisters will be contained in a shipping cask for shipping), this standard was applied to provide conservative limits for on-site storage.

The canisters undergo two separate smear tests: one after the canister decontamination process and the other after the final canister closure weld. The purpose of the Canister Decontamination Cell smear testing is to ensure the effectiveness of the canister decontamination process and to limit the potential spread of transferable contamination. The purpose of the Weld Test Cell smear testing is to provide final verification that the external canister surface is free of transferable contamination before transporting the canister to the Glass Waste Storage Building (GWSB) for on-site storage.

Each station has a lift platform and a turntable to lift and rotate the canister for the smear test. Smearing of the canister is performed remotely using MSM's with the aid of Closed Circuit Television (CCTV) and direct visual observation through a shielded window. Prior to setting a canister in the turntable platform a smear is collected from the bottom of the canister. The canister is then placed on the turntable platform. The elevating and rotating platform and the STS trolley can be programmed to position the canister at a specific elevation and orientation for smearing or resmearing. A minimum of 5 smears are taken at each STS for each canister covering 1000 square centimeters of the canister surface area.

After smears are taken, they are placed in the carrier of the pneumatic transfer system that moves the smears through the shield wall to a radio bench hood. If the radiation level is too high, an Area Radiation Monitor (ARM) located in the hood will alarm and the sample would be returned to the cell for disposal. If the radiation level is acceptable, the operator removes the carrier containing the smear sample and sends it for isotopic contamination counting. All eighty-two radioactive DWPF canisters decontaminated to date were found to have contamination levels less than 20 dpm/100cm^2 alpha and 200 dpm/cm^2 beta/gamma, well below the DOT limits.

FINAL CANISTER CLOSURE

The WTC contains the remote canister handling equipment needed to perform the final canister closure weld and prepare the canister for transfer to the GWSB.

The purpose of the final canister closure weld is to provide a permanent seal that is leak tight to 1.0×10^{-4} atm-cc/sec. The Final Canister Closure System is composed of a canister trolley, a 90,718 kg$_f$ hydraulic ICC press, and a 400,000 ampere DC capacity solid state resistance welder system. This in-cell equipment is supported by a dedicated 7500 KVA substation, weld controller, hydraulic system, high pressure nitrogen system, cooling water system, and data acquisition system. The canister closure sequence is controlled by a Programmable Logic Controller (PLC) control system and requires minimal operator interface. A canister is brought into the WTC and placed in the canister trolley using an in-cell overhead crane. The trolley transfers the canister to the ICC Press where the ICC plug and sleeve are pressed down into the canister neck to allow space for the weld plug. The trolley returns the canister to an intermediate position between the ICC Press and Welder station and a weld plug is installed into the canister throat by the operator using MSM's. The trolley then transfers the canister into the Welder station. The upper electrode ram lowers onto the weld plug and applies the required weld force. When the weld is initiated, a controlled DC voltage is applied across the upper and lower electrodes for a preset duration resulting in weld current flow from the upper electrode, through the weld plug and canister flange, to the lower electrodes. The weld current through the plug-flange interface creates sufficient heat to cause plastic flow of metal, allowing the plug to be pushed into the canister throat under the applied ram force. During the weld, a PC-based data acquisition system (DAS) monitors and stores 54 different welder system parameters at 300 samples per second. A backup DAS collects data in case of primary DAS failure. The DAS summarizes and displays to the operator the data necessary to determine the acceptability of the weld. If the DAS weld data meets all acceptance criteria, the final closure weld is accepted.

The weld acceptance criteria are based on a welder parametric study that was performed prior to radioactive operations to identify the required ranges of weld force, weld duration, and peak weld current required to ensure the minimum leak rate requirement is met. The welder parametric window is as follows:

Peak Weld Current: 248,000 ± 22,000 ampere
Weld Force: 36,287 + 11,340/-2267 kg$_f$
Weld Duration: 95 ± 15 cycles (@ 60 Hz) or 1.583 ± 0.250 seconds

Weld data has been collected and trended since before radioactive operations and has proved useful for system performance monitoring and troubleshooting. Weld data includes: non-radioactive canister welds, radioactive canister welds, and test nozzle welds. Test nozzle welds are similar to canister welds except the test nozzle can be removed from a reusable test canister body after completion of the weld to permit detailed weld analysis and destructive testing.

Between January 1995 and December 1996, 151 closure welds were completed, 90 of which were on radioactive canisters. Welder system problems impacted weld data results on four of these welds, three of which involved recorded weld data results outside the welder parametric window. A brief description of the problems encountered follows:

- On two occasions, C-phase firing pulse from the weld controller microprocessor was interrupted due to intermittent electrical connection. Peak weld current results were outside parametric window. The canister was returned to the Melt Cell Inner Canister Closure Station where it was pressure decay leak tested. The canister weld was accepted based on an acceptable leak test result.

- Electrical noise on a firing pulse signal resulted in early and late conduction of one of the twelve silicon controlled rectifiers (SCR's) used to control the flow of weld current. The weld duration, calculated by the DAS, was outside the parametric window. The canister weld was accepted based on an engineering analysis indicating weld currents at the beginning and end of the weld were of insufficient magnitude to permit welding at the plug-canister flange interface.

- Although the welder performed satisfactorily the Primary DAS failed to collect data for the entire weld. Backup DAS data used to confirm weld acceptability.

Figure 2 shows a chart of peak and average weld currents for the 151 welds. This chart demonstrates that during normal Welder System operation, weld current variances are normally small (approximately ± 5000 ampere) compared to that permitted by the parametric window (± 22,000 ampere). For this reason, weld acceptance criteria specified in operations procedures are tighter than parametric window requirements and are based on typical Welder System performance. The intent of the procedural weld acceptance criteria is to ensure that abnormal Welder System performance is quickly identified and corrected before a weld outside the welder parametric window is produced.

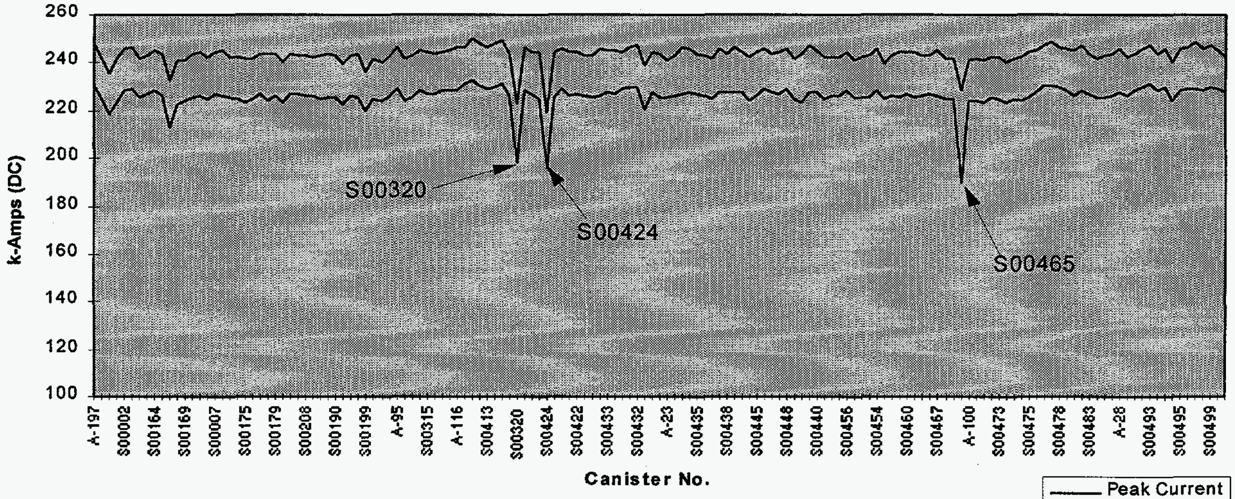

Figure 2: Peak and Average Weld Currents

The Welder System design includes various interlocks and system diagnostic circuits to prevent initiating a weld attempt if any monitored function or parameter is unacceptable. Therefore, most system problems are identified and corrected before initiation of the weld. These include equipment problems such as low cooling water flow, insufficient weld force or ram cylinder pressure, high or low supply voltages and frequency.

Some Welder System malfunctions, however, are not identifiable except for during the actual weld. Statistical trending of Welder System performance is used to help predict these types of system failures before they can have an impact on weld quality. However, intermittent failures such as those which occurred on the two canisters discussed are impossible to reliably predict. To minimize these types of failures, routine preventive maintenance has been established on electrical connections related to circuits critical to successful performance of a weld. In addition, because the parameter ranges of the welder parametric window were chosen very conservatively, DWPF has begun efforts to expand the welder parametric window to encompass the most likely failure modes.

TRANSPORT TO INTERIM STORAGE FACILITY

Once welding is complete and smear testing verifies canister surface contamination is below acceptable limits the canister is transported to the interim storage facility, the GWSB. Filled canisters are first transported by in-cell crane from the Weld Cell STS to the canister exit tunnel. A transfer car in the exit tunnel then drives the canister to a position just below the Canister Loadout Area where the canister is accessible for loading into the transport vehicle, the Shielded Canister Transporter (SCT). The SCT transports canisters from the Vitrification Building to the GWSB.

The SCT is a two-wheel drive vehicle, equipped with a center module, frame, and operations cab. The center module comprises a hoisting system, including primary and a backup 3630 kg$_f$ hoists, and shielding cask for moving canisters as well as a plug hoisting system for moving floor plugs during loading and unloading operations. The center module is supported by a bridge and trolley system that is used to move it forward and backward or side to side without repositioning the entire SCT vehicle. The center module is raised and lowered by a hydraulically driven lifting system.

Canister handling operations are controlled entirely from the operator's cab, normally in the automatic mode by a PLC with monitoring by the SCT operator. In the automatic mode, the PLC software ensures proper equipment position and load indication prior to execution of a step. In addition, the automatic sequence is designed to continuously monitor the status of the SCT field equipment, and stop the sequence if at any time there is an improper equipment control or improper field indication. If necessary, all operations can be performed by the SCT operator using manual.

During canister loading operations, a floor plug is lifted into the SCT floor plug cavity, the bridge is moved forward to position the canister hoist above the floor plug opening, the center module is lowered to the floor, and the canister is hoisted into the shielded cask. The shield valve in the cask bottom is then closed and locked, and the canister is secured in position by snubbers located inside the shielded cask to keep the canister from swinging during transport. Once the floor plug is reinstalled and the center module is raised, the SCT is driven to the GWSB.

In the GWSB, the operator locates a preselected storage vault location and places the filled canister in the underground vault. The procedure for unloading the canister in the storage vault is identical to the previously described loading operation.

During the first nine months of radioactive operations the SCT was used to successfully move 82 radioactive canisters. Most equipment problems encountered to date were considered minor. Descriptions of two problems are summarized below:

- The center module lifting system includes a hydraulic motor that drives two 68,100 kg$_f$ jack screws, one on each side of the module. These jack screws are linked to the motor by gearboxes, shafts, and couplings. During pre-start checkout of the SCT the operator observed unusual noise and vibration while raising the center module. This was caused by a clutch coupling that began slipping as a result of the poor engagement. Consequently, the two jack screws became out of alignment with each other that caused the cask to become uneven (approximately 2 cm higher on one side and 0.5 cm off-center). Because the failure was identified during prestart checkout, canister movement was not impacted.

- The automatic sequence interlocked during unloading operations when the PLC detected a loss of parking brake engagement signal. Vibration caused the switch electrical connection to loosen to a degree where the circuit could momentarily open. This problem was difficult to detect because the momentary loss of signal was so rapid that it did not cause the indicator lamp on the operator console to flicker or extinguish. Canister movement was not impacted because the interlock occurred at a step prior to raising the canister into the SCT.

  Several similar interlocks have occurred due to loose electrical connections. Periodic tightening of SCT electrical terminations has been initiated as a preventative measure.

Radiological surveys performed during SCT operations have not detected radiation levels through the SCT shielding module. Operating procedures have been refined to the point where three canisters are routinely transferred to the Glass Waster Storage Building in one 12 hour shift. As a result, the operating strategy is to wait until a backlog of at least three welded canisters accumulate before moving canisters with the SCT. This strategy maximizes the use of equipment setup time and pre-operational briefings. When equipment problems have occurred during movement of canisters the operators have switched to manual mode and backup systems have been used to successfully place the equipment in a safe state.

INTERIM CANISTER STORAGE FACILITY

The GWSB is designed for safe handling and temporary storage of filled glass waste canisters while they await transfer to a permanent repository. The building was designed to store 2286 glass filled canisters, including 24 oversized canisters. However, 570 of standard canister storage locations and 23 of the oversize storage locations are not usable because of inadequate clearance between the floor plugs and inserts and/or out-of-roundness of the floor plugs and inserts. This problem surfaced during startup testing when several of the plugs bound or jammed in the insert during removal or insertion. As a result, all storage locations were tested by lifting each plug to three separate elevations with a mobile crane and rotating the plug 360 degrees. Plans have been developed to rework and recover all but 101 of the storage locations when required in the future.

The storage vault is an underground reinforced concrete structure divided into four separate compartments. All eighty-two radioactive canisters processed to date have been placed in the compartment farthest from the building entrance. Four exhaust fans provide ventilation to the vault areas to remove decay heat from canisters. The exhaust fans can be powered by standby diesel generators in the event that normal power is lost. High efficiency air particulate filters are installed in the ventilation system to remove any airborne radioactivity present as a precautionary measure. Directly above the vault is the GWSB operating area. Ventilation air is supplied to the operating area to remove the fumes from the SCT's diesel engine and summer heater buildup. For purposes of diesel fume removal, the supply fans for the operating area run whenever the SCT is operating in the building. The supply fans also serve to pressurize the operating area relative to the storage vault so that air flows from the operating area into the storage vault when the SCT removes a floor plug for canister handling.

Radiation shielding protection is provided by concrete walls, earth embedment, and a concrete deck that forms the floor of the operating area. Radiological surveys performed outside the GWSB vault thus far have not detected radiation levels.

CONCLUSION

During the first nine months of radioactive operation the remote canister handling processes have performed effectively and have not been rate limiting to the DWPF process. Efforts are underway to improve and optimize the canister handling processes to ensure canister processing will not limit attainment. This includes enhancing preventive maintenance activities on equipment prone to problems, such as electrical circuits in the CDC, WTC, and SCT systems. Process improvements to the CDC operating procedures and equipment design to minimize the impact of spent-frit processing and reduction of waste-water generated during the decontamination process are being evaluated. Operating experience during the first nine months has clearly demonstrated the value of having two identical CDC chambers because one chamber has frequently been in a maintenance mode. Performance monitoring and optimization will continue as the DWPF canister throughput increases.

ACKNOWLEDGMENT

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