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INTEGRATED RADWASTE TREATMENT SYSTEM LESSONS LEARNED FROM 2 ½ YEARS OF OPERATION

Topical Report

By
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May 1997

Worked Performed Under Contract No. DE-AC24-81NE441139

Prepared by
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Prepared for
U.S. Department of Energy
Assistant Secretary for Nuclear Energy

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ABSTRACT

The Integrated Radwaste Treatment System (IRTS) at the West Valley Demonstration Project (WVDP) is a pretreatment scheme to reduce the amount of salts in the high-level radioactive waste (vitrification) stream.

Following removal of cesium-137 (Cs-137) by ion-exchange in the Supernatant Treatment System (STS), the radioactive waste liquid is volume-reduced by evaporation. Trace amounts of Cs-137 in the resulting distillate are removed by ion-exchange, then the distillate is discharged to the existing plant water treatment system. The concentrated product, 37 to 41 percent solids by weight, is encapsulated in cement producing a stable, low-level waste form.

The Integrated Radwaste Treatment System (IRTS) operated in this mode from May 1988 through November 1990, decontaminating 450,000 gallons of high-level waste liquid; evaporating and encapsulating the resulting concentrates into 10,393 71-gallon square drums.

A number of process changes and variations from the original operating plan were required to increase the system flow rate and minimize waste volumes.

This report provides a summary of work performed to operate the IRTS, including system descriptions, process highlights, and lessons learned.

EXECUTIVE SUMMARY

This report provides a summary of work performed to operate the Integrated Radwaste Treatment System (IRTS) following nonradioactive testing.

The IRTS is designed to decontaminate high-level waste (HLW) liquid produced as a byproduct of plutonium uranium reduction extraction (PUREX) spent fuel reprocessing.

The initial decontamination of the HLW liquid takes place in four ion-exchange columns arranged for series flow. The columns are designed to remove 99.9 percent of cesium-137 (Cs-137), the most prevalent radioisotope in the waste liquid.

Following ion-exchange, the resulting dilute decontaminated liquid is volume-reduced by evaporation. This volume reduction results in a direct lessening of the need for downstream cement solidification by lowering the number of drums to be produced.

The concentrated decontaminated liquid is encapsulated in cement and poured into 71-gallon square drums.

At first, the raw HLW liquid was decontaminated in the ion-exchange columns as it was removed from the HLW tank. Later, the HLW liquid was diluted with demineralized water prior to ion-exchange. This technique resulted in less shock to the ion-exchange system, with reduced zeolite consumption.

As the Cs-137 is removed, the ion-exchange media becomes loaded with Cs-137 ions. The decontamination factor (DF) is defined as the inlet radioisotope concentration divided by the outlet radioisotope concentration. DFs can be applied to a single ion-exchange column or to the series of columns. When the DF of the lead column begins to decline, the column is nearly loaded (the ion capture sites are occupied). The loaded zeolite is dumped from the lead column then that column is refilled with fresh zeolite and placed in the last or polishing position.

When the decontaminated supernatant tank is full, it is sampled. When all calculations and analyses are completed, the decontaminated supernatant is pumped to the evaporator feed tank. The evaporator feed tank is then sampled and evaporation may begin.

Operation of the evaporator subsystem is semiautomatic with selected operator-initiated actions. The resulting concentrated decontaminated supernatant is cooled then stored in one of two concentrates storage tanks.

Trace amounts of Cs-137 in the resulting distillate are removed by ion-exchange, then the distillate is discharged to the existing plant water treatment system.

A full spectrum of analyses are performed on the concentrates: 1) complete radioisotopic analysis for waste classification 2) gross alpha and beta for drum dose estimates and 3) processability/presolidification verification.

Encapsulation of the waste liquid in cement is automatic; with all mixing, chemical additives, drum handling, and data acquisition functions controlled by microprocessors. Drums are loaded onto a shielded transport truck semiautomatically. The drums are taken to the on-site Drum Cell for retrievable storage.

Very few improvements or adjustments to the original IRTS operating philosophy were instituted during the operating period. A number of repairs or workarounds were implemented to keep the systems operating at the most efficient rates.

Some adjustments were made to: 1) minimize zeolite usage 2) maximize the decontamination factor (DF) (minimize the drum dose rate) and 3) maximize waste loading (minimize drum production).

1.0 INTRODUCTION

The West Valley Demonstration Project (WVDP) Act of October 1, 1980 (Public Law 96-368) directed the United States Department of Energy (DOE) to carry out a high-level radioactive waste (HLW) management demonstration at the former Western New York Nuclear Service Center (WNYNSC) site located in West Valley, New York. Under the Act, the DOE is responsible for removing HLW from underground storage tanks and solidifying it into a form suitable for transportation to a federal repository for final disposal. The facility at West Valley, New York was formerly operated by Nuclear Fuels Services, Inc. (NFS) as a commercial nuclear fuel reprocessing plant. West Valley Nuclear Services Co., Inc. (WVNS), a subsidiary of Westinghouse Electric Corporation, was selected to be the prime contractor for site operations and assumed control February 1982.

The West Valley site was the location of the only operating commercial nuclear fuel reprocessing plant in the United States. NFS operated this facility from 1966 to 1972, processing 640 metric tons of commercial and defense fuels using the PUREX (plutonium uranium reduction extraction) process. Approximately 2.1 million liters of liquid fuel reprocessing wastes resulted from this operation. These wastes are stored in an underground storage tank designated as 8D-2. The bulk of the tank's contents was formed by adding excess caustic (NaOH) to a nitric acid-based stream originating from essentially the first solvent extraction cycle (although other additions of decontamination and cleanup wastes have been made). Concentration of the neutralized solution has resulted in the formation of a sludge layer at the bottom of the waste tank.

1.1 Early in the project, two decisions were made that determined the major thrust of the HLW solidification effort:

1.1.1 Separation of the HLW Alkaline Supernatant

The HLW alkaline supernatant would be separated from the sludge and the radioactive components in the supernatant would be chemically separated and combined with the sludge into a terminal HLW form. The treated (or decontaminated) supernatant would be processed into a suitable low-level waste (LLW) form (the separated salt/sludge option of the Final Environmental Impact Statement [FEIS]).

1.1.2 Terminal HLW Form

The terminal HLW form would be borosilicate glass.

The decision on the processing scheme was based on chemical, radiochemical, and physical property characterizations performed on samples of the PUREX HLW.

The steps to be performed prior to the HLW processing are listed in the Process Overview (see figure 1).

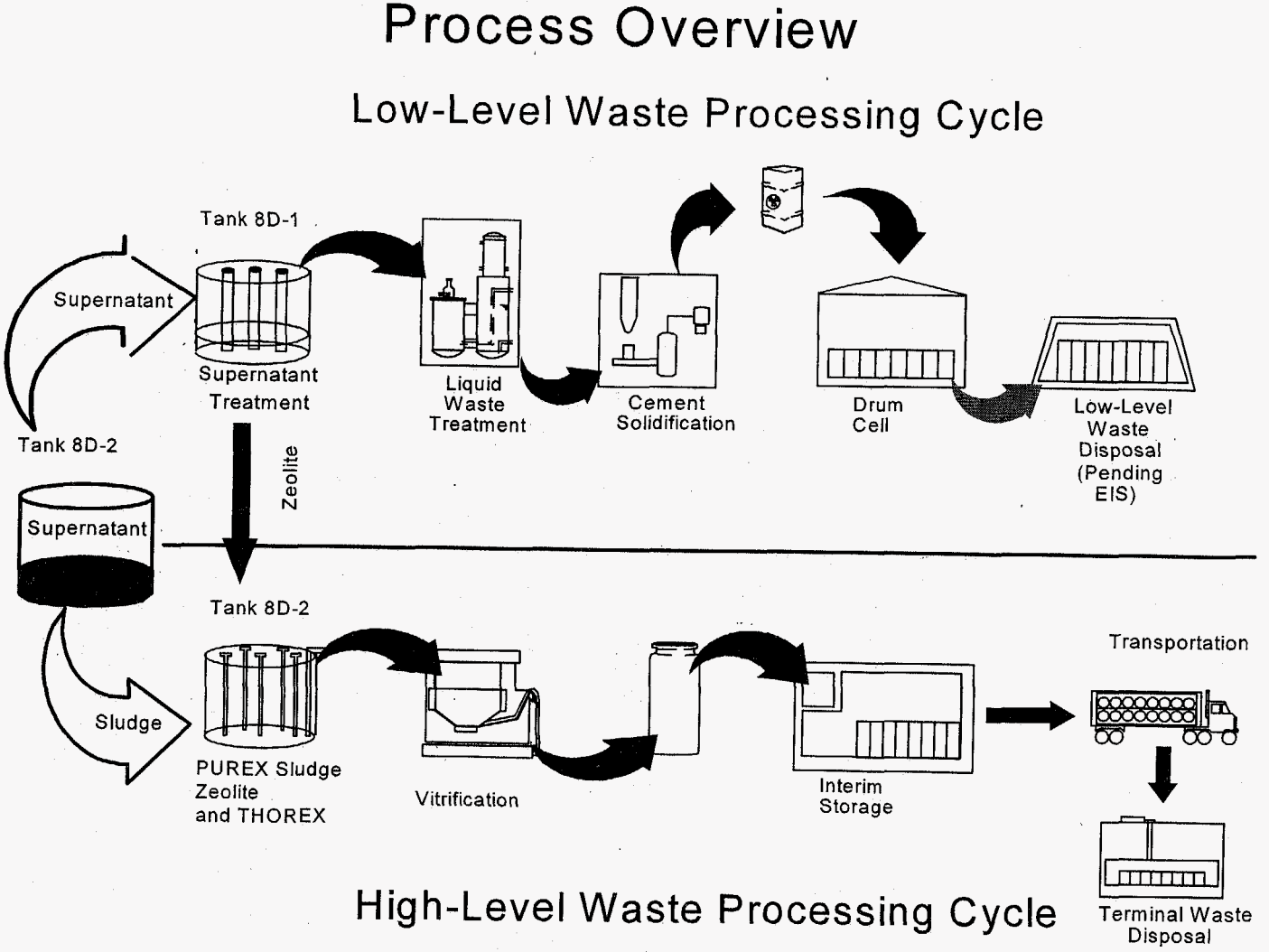

Figure 1. Process Overview

1.1.3 Supernatant Treatment is Necessary

The large quantity of sodium (Na+) salts, which are incompatible with the glass recipes, must be removed and encapsulated in cement, the LLW form.

Removal by ion-exchange of Cs-137, the major radioactive constituent, results in the highest possible radionuclide content in the HLW product (borosilicate glass) and, correspondingly, low radionuclide content in the LLW (cement) product.

1.1.4 Reuse of Existing Facilities

Reuse of existing facilities to the maximum extent required decontamination of the former reprocessing cells and equipment, and the reactivation of the cells for containment of the new treatment equipment.

1.1.5 High- and Low-level Treatment Processes

Refer to figure 1 for a graphic representation of the high- and low-level treatment processes.

2.0 SUPERNATANT TREATMENT SYSTEM (STS)

The processing goals for the Supernatant Treatment System (STS) are the removal and decontamination of the alkaline PUREX waste liquid stored in HLW Tank 8D-2. Using existing ion-exchange technology, the STS mobilizes, filters, and collects the supernatant liquid in 8D-2. All equipment is located in spare HLW Tank 8D-1 and the adjacent STS Building (see figure 2).

2.1 Principle processing steps and related equipment:

2.1.1 Supernatant Removal Subsystem

Removal of the supernatant liquid from 8D-2 is accomplished by air-operated, double-diaphragm Pump 50-G-001 located in a shielded pump pit adjacent to HLW Tank 8D-2. The pump is equipped with a floating suction head so that the sludge layer is not disturbed.

2.1.2 Prefiltration Subsystem

A back washable, cross-flow sintered metal filter, 50-F-001, is used to remove particulate matter that could plug the downstream ion-exchange equipment.

2.1.3 Supernatant Feed Subsystem

The supernatant feed subsystem consists of an intermediate tank and pump as well as a dilution water system. The supernatant feed pump is a variable-speed electric motor-driven pump mounted inside the feed tank.

2.1.4 Supernatant Cooling Subsystem

Ion-exchange of Cs-137 with zeolite is enhanced by lower temperature operation. The supernatant cooling subsystem includes a supernatant cooler (shell-and-tube heat exchanger; brine: shell side/supernatant: tube side), brine cooler (shell-and-tube heat exchanger; brine:shell side/Freon-22: tube side), and chiller unit. This subsystem provides two levels of isolation between the contaminated supernatant liquid and normally occupied areas.

2.1.5 Ion-exchange Subsystem

Continuous processing ability is provided by four ion-exchange columns operating in series. At any time, three columns may be "on-line" while the fourth is isolated for spent zeolite removal and fresh zeolite recharge.

2.1.6 Final Filtration (Postfilter) Subsystem

As supernatant is processed through the columns, fine particles of zeolite may be carried through the

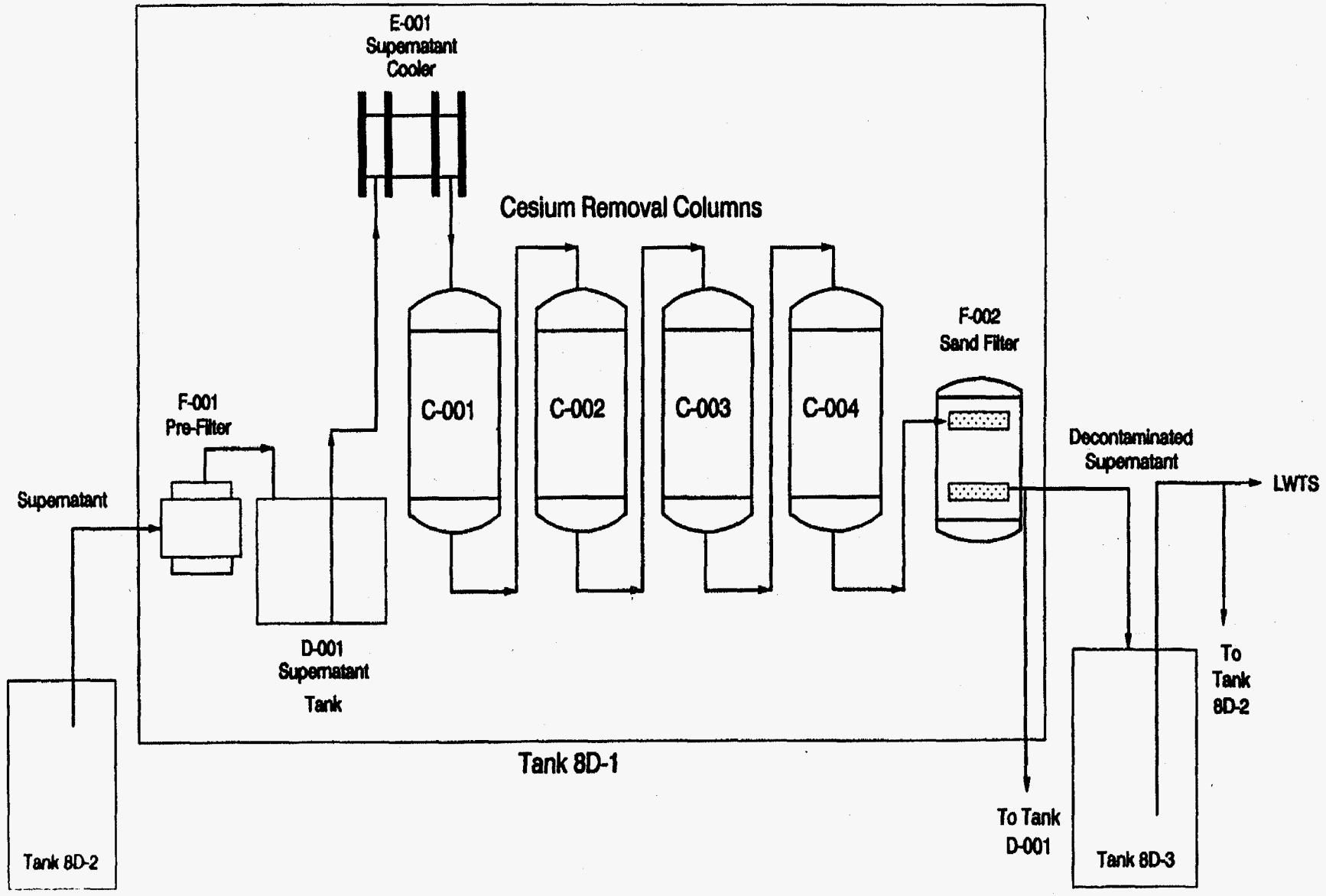

Figure 2. Supernatant Treatment System

with the decontaminated supernatant. A sand filter, 50-F-002, is used to remove 99 percent of the particles greater than one micron.

2.1.7 Decontaminated Supernatant Collection and Transfer

Decontaminated supernatant is stored in existing underground HLW Tank 8D-3 in a batch/continuous process. This tank provides intermediate storage and allows for supernatant sampling and monitoring. Supernatant from the postfilter is continuously fed into 8D-3. Once a sample is analyzed to verify decontamination, the contents of 8D-3 are pumped to the Liquid Waste Treatment System (LWTS) evaporator feed tank.

2.1.8 Fresh Zeolite Fill Subsystem

Once per cycle, fresh zeolite is charged into the ion-exchange columns in the form of a water slurry using the zeolite batch tank and sluice tank. Zeolite handling is a hands-on operation.

2.1.9 Spent Zeolite Discharge

An exhausted zeolite ion-exchange column is isolated from the process and sluiced to spare HLW Tank 8D-1. The spent zeolite, as well as sludge particles, becomes the HLW feed material for vitrification.

2.1.10 Ventilation Subsystem

Ventilation and process off-gas handling for all STS process vessels, all connecting pipe trenches, the valve gallery, and the STS Building are provided with a cascade-type controlled ventilation system. The flow path is from the least contaminated zone to the most contaminated zone. The subsystem is provided with moisture entrainment separators, roughing, and high-efficiency particulate air (HEPA) filters.

3.0 LIQUID WASTE TREATMENT SYSTEM (LWTS)

The Liquid Waste Treatment System (LWTS) is used to process decontaminated supernatant through evaporation into a minimum volume ready for encapsulation in the Cement Solidification System (CSS) and to decontaminate the water removed by ion-exchange to allow the water to be either recycled or released to the environment. The LWTS process uses both new and existing tanks and equipment, and existing cell, aisles, and containment systems (see figure 3).

3.1 The principle subsystems of the LWTS are listed below:

3.1.1 Waste Transfer Subsystem

Decontaminated supernatant is pumped to existing Evaporator Feed Tank 5D-15B. Transfer Pump 71-P-01 acts as a booster pump.

3.1.2 Evaporator Subsystem

Evaporator 31017 is used to concentrate supernatant by boiling off excess water. Steam and flow rates are balanced so that the level can be kept constant while withdrawing product from the bottom and at the same time maintaining a flow of distillate out through the condenser.

3.1.3 Distillate Ion-exchange Subsystem

The distillate ion-exchange subsystem completes the decontamination of the waste liquid begun in the evaporator. Overheads produced in the evaporator flow out of the condenser and are held in a surge tank then pumped through an ion-exchange column. The ion-exchange media is zeolite, selected and tested for its ability to capture Cs-137 ions. Flow is modulated by a control valve located downstream of the column, allowing it to always flow full.

3.1.4 Concentrates Cooler Subsystem

The concentrated waste product is reduced to temperatures below its critical temperature in the concentrates cooler, a shell-and-tube heat exchanger. The flow of concentrates is modulated by a control valve and intermittent operation of a pump to maintain the evaporator pool at the desired density.

3.1.5 Concentrates Storage and Transfer Subsystem

Decontaminated supernatant, which was concentrated in the evaporator and then cooled, is routed to either of the two Concentrates Storage Tanks, 5D-15A1 or 5D-15A2. These existing tanks are actually a single stainless steel tank divided into two sections of 10,000 and 5000 gallons, respectively. Each is furnished with inlet and outlet piping, level and density instruments, and transfer pumps.

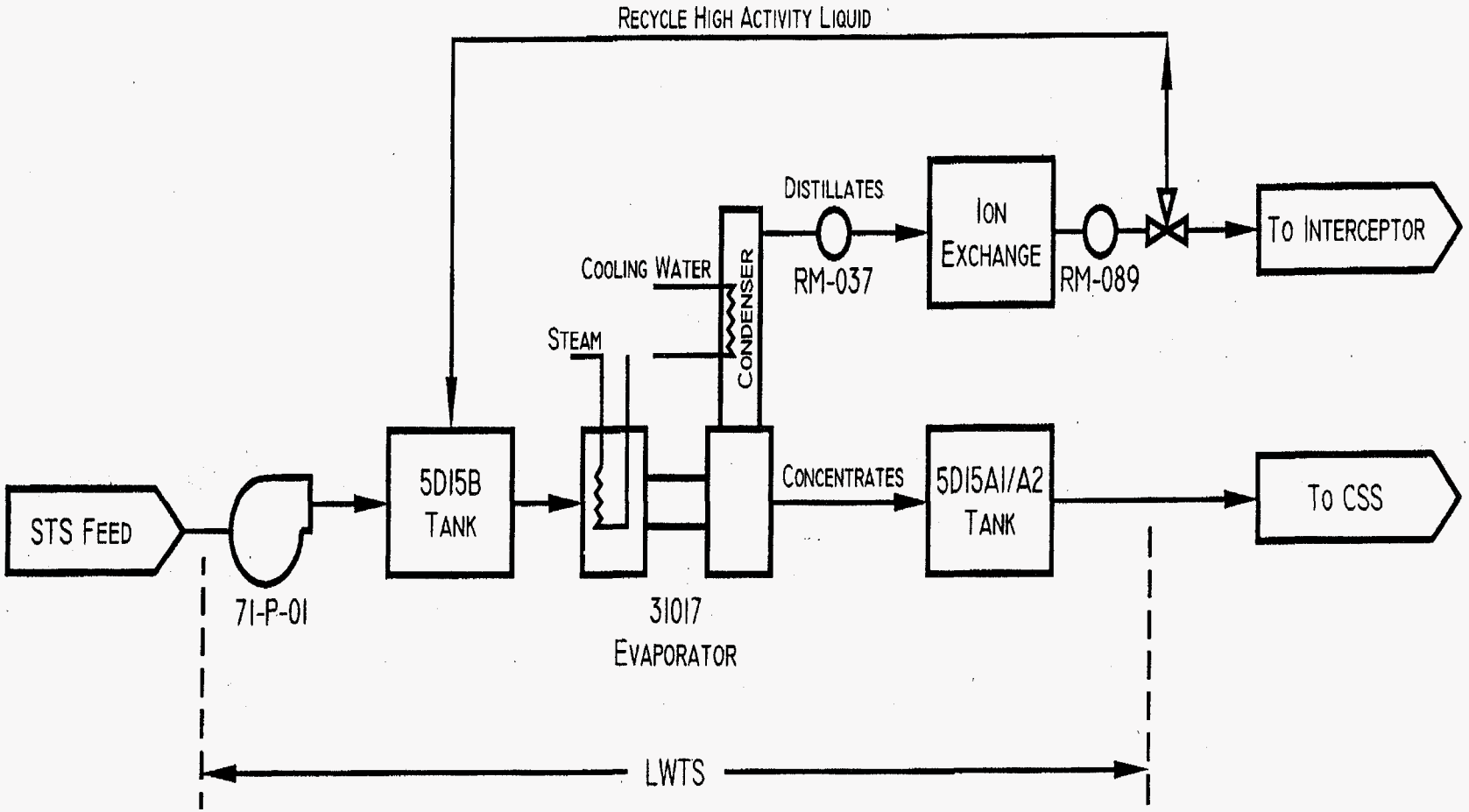

Figure 3. LWTS Simplified Process Flow Diagram

It is possible to transfer concentrates from one tank to the other if required for any reason. It is also possible to return concentrates from either tank to Evaporator Feed Tank 5D-15B for evaporation. Isolation valves are interlocked so that the concentrates will be routed to the other tank if one reaches high level.

3.1.6 Evaporator Waste Feed Subsystem

Dilute decontaminated supernatant is received from the Supernatant Treatment System (STS) and held in Evaporator Feed Tank 5D-15B. Supernatant is fed to the evaporator by Evaporator Feed Pump 71-P-04 in response to changing evaporator level.

3.1.7 Zeolite Loading Subsystems

Fresh zeolite is loaded into a hopper and sluiced to the zeolite ion-exchange column.

3.1.8 Sampling Subsystem

Existing sample stations permit sampling of the feed or receiving tanks. The sample stations utilize an airlift or eductor-type system to draw the sample into a bottle. Sampling is performed in a glove box that can be drained back into the tank. Controlled ventilation of the glove box and the bag-out port prevent the spread of contamination.

4.0 CEMENT SOLIDIFICATION SYSTEM (CSS)

The Cement Solidification System (CSS) is located in the 01-14 Building south of the Main Process Building. The CSS consists of the following subsystems (see figure 4):

4.1 Waste Storage and Dispensing Subsystem

The waste dispensing vessel (WDV) is a 500-gallon, conical shaped stainless steel tank with an associated pump and recirculation line. Waste is continuously recirculated to ensure homogeneity. Automated valves control delivery of the waste to the mixers.

4.2 High-shear Mixing Subsystem

This subsystem is comprised of two identical 40-gallon stainless steel mixing vessels mounted on the upper platform of the CSS process cell. All waste, cement, and additives are fed directly into the mixer top. Sufficient discharge head is produced at a mixer speed of 1000 rpm to pump the contents through horizontal discharge valves into empty drums located below the mixers.

4.3 Cement Storage, Transfer, and Metering Subsystem

A 100-ton bulk storage silo is equipped with pneumatic systems for transfer of dry cement into and out of the silo. The day bin uses a loss-in-weight basis for metering cement to the mixer. The CSS utilizes Portland Type I dry cement.

4.4 Chemical Additives Subsystem

Calcium nitrate is blended with the dry cement by the vendor at a nominal 5.7 weight percent. It is used as a set-enhancing compound.

Antifoam (GE AF-9020) is added to the liquid batches to reduce air entrainment in the waste product. Sodium silicate is added following cement addition as a second component of the set enhancer.

4.5 Drum Positioning and Transfer Subsystem

This subsystem includes all conveyors, motors, and equipment used to move empty drums into the process cell, through the stages of filling and capping, and placement of full drums on the shielded transport truck.

4.6 Ventilation Subsystems

The 01-14 Building supply and exhaust system is designed to prevent the spread of airborne contamination. This is accomplished by routing ventilation air from areas of lowest contamination potential to areas of highest contamination potential. Exhaust air is drawn through a bank of twelve absolute filters. Stack monitoring equipment continuously counts a sample of stack exhaust.

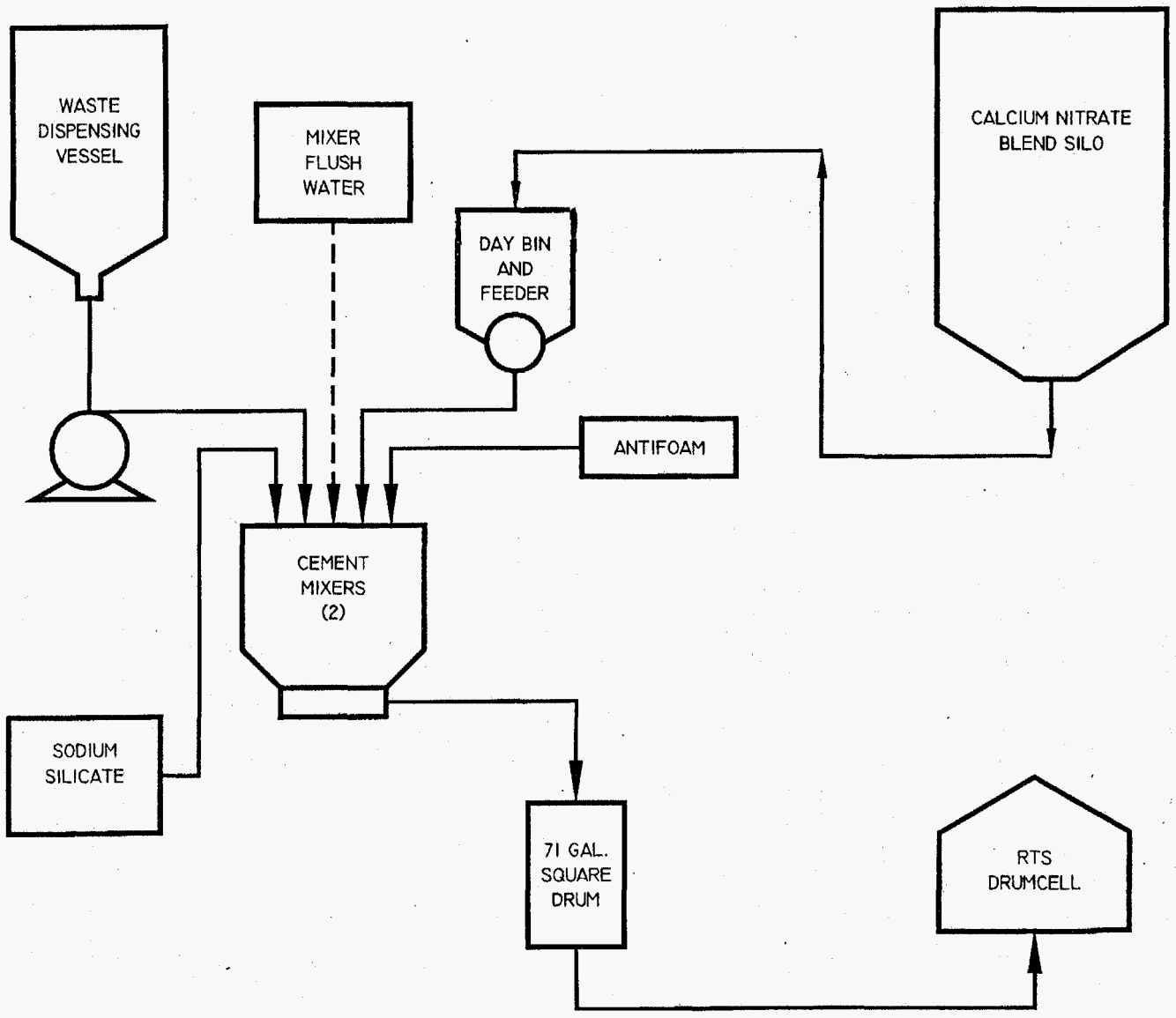

Figure 4. CSS Simplified Process Flow Diagram

5.0 SUPERNATANT TREATMENT SYSTEM (STS) - LESSONS LEARNED

5.1 Process Control and Column Loading

The focus throughout the supernatant processing was zeolite consumption and its impact on the later vitrification phase of the Project. Initially, raw (undiluted) supernatant was pumped from HLW Tank 8D-2 to feed the Supernatant Treatment System (STS). This was felt to be the best means of assuring that all capture sites in the zeolite were used for Cs-137 removal.

Cesium loading and column breakthrough in the early campaigns were calculated based on sample results and compared to the data established by earlier testing. Two parameters affected the column loading curves: 1) variable sample results and 2) variable process radmonitor indications.

Process control of the STS was accomplished by sampling the feed tank and the liquid downstream of each column. With the flowpath in series, the outlet of each column was the inlet of the column that followed it (see figure 2). Note that sampling the last column is not performed due to the supernatant header arrangement that placed raw supernatant (which has the most activity) on the opposite side of the sample valve of the final column (which has the least activity). It was therefore too risky to sample the final column outlet for fear of cross-contamination.

A related problem was associated with the sampling technique. The column outlet valves were equipped with sample needles. Sampling required the operator to purge the sample needle for a period of time to flush out the previous sample material. The technique also utilized a sample sequence from less activity to more activity so that the cleanest samples were not taken from the needles that recently had the most contaminated samples.

There was also some variability in the lab procedure that included diluting the high-activity samples before handling under the hood and then back-calculating the activity of the undiluted sample. An error of less than 0.1 percent was encountered.

At no time were the process radmonitor indications directly proportional to the sample results for process liquids at the corresponding location. A review of the process piping arrangement revealed that, in some cases, the raw supernatant pipe was 9 inches away from the decontaminated supernatant radmonitor causing a background dose equivalent to 2000 cpm in the decontaminated supernatant radmonitor. The effect of background was not uniform since it changed depending upon the column sequence.

In the early campaigns, attempts were made to limit column loading to 80 percent for the lead column and 10 percent for the second column. Later, with increased focus on throughput, the STS was allowed to process as many gallons as possible, especially in the last week of a campaign. Column loading was allowed to reach 90 percent for the lead column and 20 percent for the second column.

In hindsight, there was no particular advantage in adjusting column loading in this manner. Long campaigns will be followed by short campaigns, or maximum loading of the lead column will be followed by less throughput in the next campaign.

The final attitude was to maximize throughput (and column loading).

5.2 Dump Valve Failure

At the completion of campaign 3, spent zeolite in column D was dumped to 8D-1. Closing the bottom dump valve was unsuccessful. A series of pressure tests and valve tests were performed to determine this. Finally, a video camera was lowered into the tank on a hydraulic arm (figure 3). The valve operator shaft was found to have failed. The direct cause of this failure was attributed to excessively hard valve seat material. The dump valves were equipped with "PEAK" material that provided a strong material intended to be abrasion resistant, but which also required excessive breakaway torque from the operator.

Using a variety of tools at the end of the hydraulic arm, the valve body bolts were loosened in an attempt to close the valve. The eight body bolts were each loosened two turns, but the valve did not close.

A can-opener device was placed on the valve ball in an effort to pry the ball open, but this also was unsuccessful. Finally, a cap was placed on the open end of the valve.

Spent zeolite in the column was emptied as well as possible but a heel of cesium-loaded zeolite remained in the column which resulted in an unacceptable activity in the column product. Activity was so high that the column was limited to the lead or second position only.

Meanwhile, a series of tests were performed to determine if the spent zeolite could be sluiced out of the column using a sparge stream of water or air to provide particle buoyancy. A full-scale mockup of the column and partially closed dump valve was constructed. Over 120,000 pounds of clean zeolite was added to and dumped from the test column in a test evolution over a period of 12 months. A variety of sparge fluids and flow rates were tested, as well as various orifice sizes. The remaining heel of wet zeolite ranged from 0 to 150 pounds. This was felt by project management to be sufficiently small to allow the column to be used in the third or even the final position, so the sparge device was built and installed.

Operations of the sparge unit was normal in all respects, except that the resulting outlet product was still unsuitable for use as a last column.

At the completion of campaign 14, the dump valve in column B did not stroke completely. The dump valve was finally stroked to the open position to eliminate the same condition as column D. A second hydraulic arm unit was lowered in proximity to column B and the column was capped.

This cap-and-uncap operation was repeated for subsequent operation of column B.

The final and most attractive technique for column unloading was sluicing the spent zeolite out of the columns using a spare nozzle in each column designated as "J." This spare nozzle, added as an afterthought late in the drawing approval process, extended to a location approximately 6 inches from the bottom of the column. At the end of a processing campaign, a sizeable quantity of water is added to the column and the spent zeolite is sluiced into 8D-1.

Later, a radmonitor was installed on the sluice pipe. During the sluicing operation, the radmonitor would indicate dose rates as high as 600,000 mR/hr, which would taper off to the tank background exposure rate of 200 mR/hr. This proved to be the most reliable indicator of spent zeolite removal.

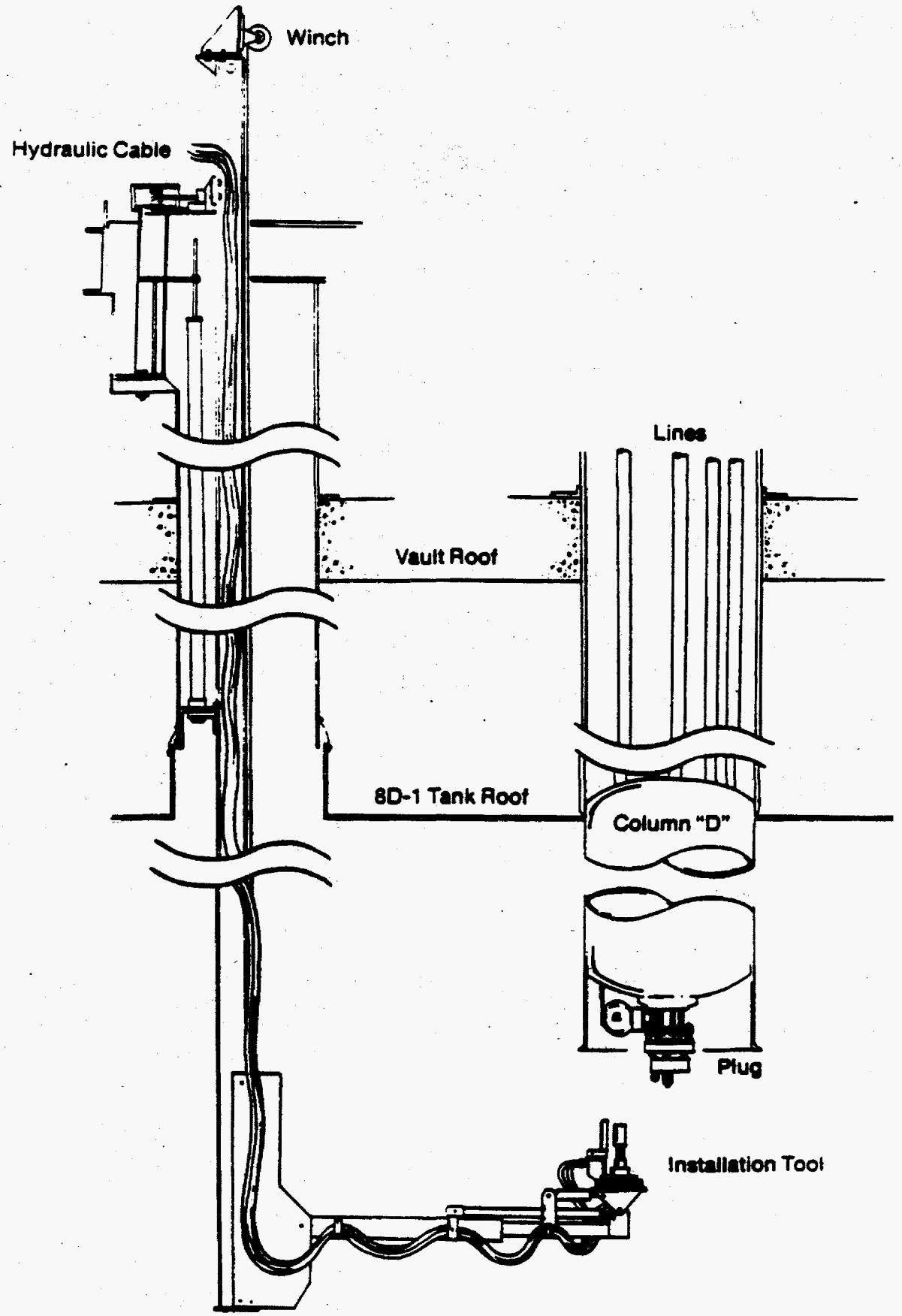

Figure 5. Use of Remote Hydraulic Arm to Plug Ion-exchange Column Malfunctioning Valves

Prior to the start of each processing campaign, the columns would be subjected to a pressure decay test to verify that no leaks were present. Occasionally the tests would fail indicating a zeolite particle in the valve seating area. The valve would be stroked and flushed with water. This was sufficient to wash any particles out of the valve seating area.

5.3 Replacement Jumpers

Several jumpers originally constructed for canyon-remote operation early in supernatant processing that were critical for process flow control malfunctioned. Valve 50-FV-007, a manual control valve for raw supernatant flow, as well as 50-FV-064, an automatic three-way valve selecting either product flow or recirculation in the event of high product activity, exhibited stiff operation. The valve pneumatic operators were found to have excessive amounts of oil in the exhaust air. The exact cause was not determined, but the operators use lubricated air. It was felt that either the wrong or excessive amounts of lubricants were used. The valves were freed by purging the air supply tubing with clean, dry air. Later, the airline lubricators were filled with WD-40 to flush out the heavy oil. This last technique proved reasonably successful.

Eventually, both jumpers were replaced with new jumpers. The new jumper for Valve 50-FV-064 was furnished with a three-way valve from a different manufacturer. Proper automatic function of this valve was felt to be critical in an emergency situation when excessive product activity required a quick switchover of recirculation.

Later, a failed flow element in the raw supernatant line prevented automatic control of raw supernatant flow. The flow element was replaced with an identical unit in a new jumper.

Eventually, a technique was developed that allowed jumpers to be removed from the backwall, flushed sufficiently to reduce the dose rates to acceptable levels, and brought out of the valve gallery into a glove tent for minor repairs such as limit switch adjustments.

Failed jumpers that could not be repaired were eventually brought out of the valve gallery and stored in shielded boxes for later repair or disassembly.

5.4 Dilution

Early campaigns exhibited lower than anticipated throughputs but better than expected decontamination factors. A certain amount of this lower throughput was caused by inexperience with column loading (see section 5.1 above). Later, the system was operated using demineralized water to dilute the raw supernatant from the as-received solids' content of 28 weight percent solids to approximately 10 percent solids.

The benefits of dilution were: increased throughput, less shock to the system as it was started or restarted, and improved cesium loading of the zeolite.

The penalty for dilution was only that increased water had to be evaporated by the Liquid Waste Treatment System (LWTS) downstream. Since the LWTS could maintain a feed rate of approximately 10 gpm, the total flow rate in the STS (raw supernatant plus dilution water) was maintained at 6 gpm.

For additional discussion of system flow rates, see LWTS, section 6.

6.0 LIQUID WASTE TREATMENT SYSTEM (LWTS) - LESSONS LEARNED

6.1 Processing Rates - Problems Identified

Two factors were immediately recognized as inhibitors against acceptable evaporation rates at the start of Integrated Radwaste Treatment System (IRTS) processing. The first was that the effluent from Radiation Monitors RM-037 and RM-089 was directed back into Evaporator Feed Tank 5D-15B. The first condition resulted in processed liquid being returned to the feed tank during the evaporation process. And the second showed that the condensate return system for the 25-psi steam heater in the evaporator was insufficient in removing condensate.

The first condition resulted in approximately 3 gpm of processed liquid being returned to the feed tank during the evaporation process. With the second situation the steam coils became burdened with condensate and the system could not produce the necessary steam flow rate (5000 lbs/hr) to achieve the desired LWTS process rate of 10 gpm. The steam coils are also equipped with a 15-psi supply of utility air to ensure positive pressure on the coils whenever the steam is turned off. This air supply had the effect of cooling the steam during system operation and further lowering the overall steam flow rate.

Several administrative controls were in place at the start of IRTS processing that delayed the sampling of the evaporator feed tank and the actual start-up of the evaporator itself. Tank 5D-15B was designated the controlling tank and evaporation of this tank's contents could not proceed until a satisfactory sample analysis was complete. The procedure for placing the evaporator in shut-down mode required emptying the vessel to its heel and then refilling it with demineralized water. Each time the evaporator was restarted, it was necessary to boil off the contents to achieve a density of 1.285 and allow actual feed from 5D-15B. The requirements resulted in 6 to 7 hours of dead time while the 8D-3 to 5D-15B transfer was completed and the sample analysis was turned over. Filling the evaporator with demineralized water at the completion of a run necessitated a 12- to 14-hour restart period for the next run.

Out-of-specification concentrates (not between 37 and 41 weight percent) became a problem in campaigns 6 and 7. Concentrates higher than 41 percent total dissolved solids (TDS) could easily be diluted with little impact on operating schedules. A TDS of less than 37 percent required that the entire batch of concentrates be reprocessed through the evaporator resulting in a delay of about 24 hours.

The ability to process decontaminated supernatant through the evaporator concurrently with the 8D-3 to 5D-15B transfer (i.e., feed and bleed) was recognized as desirable but was impossible due to a piping arrangement where the waste streams were directed into the single manifold. Concurrent processing as just described would have resulted in cross-contamination between the decontaminated supernatant feed to 5D-15B and the evaporator distillate stream.

6.2 Processing Rates - Solutions Implemented

The two radiation monitors' effluent lines merge to become one discharge line. This common discharge line was modified to include a manually operated 3-way ball valve that allowed for effluent flow to either Tank 5D-15B or the plant Low-level Waste Water Treatment Facility. The radiation monitors' effluents were sampled at the beginning of each evaporator run. The 3-way valve is initially positioned to direct flow to Tank 5D-15B. Upon confirmation that the total activity of the effluent flow is less than 0.005 microcuries per ml, the 3-way valve is positioned to direct this stream to the Main Plant interceptors. This modification increased the LWTS process flow rate by roughly 3 gpm.

Several modifications were made to the steam condensate return system in an effort to maintain sufficient steam flow to allow a processing rate of 10 gpm. The steam trap on the condensate line was upgraded to a larger size and a bypass line and valve were added to allow purging of the lines to a plant floor drain. These modifications gave temporary relief to the back pressure caused by condensate-laden steam lines. A knockout drum was installed downstream of the bypass line and the valve was left slightly open to provide a path for excess condensate. Since this arrangement caused clean water to be routed to a low-level waste water treatment facility, it was desirable to further modify the system. Installation of an air-driven pressure pump and reservoir on the condensate return line was ineffective due to improper venting and the presence of live steam at the reservoir. The knockout drum has been proven to be the most successful means of removing the condensate. The procedure to operate the evaporator was modified to allow closing the air supply valves to the steam coils during system operation. Cautionary statements were added to inform the plant operators of the importance of opening these valves immediately following evaporator shutdown.

Analysis of the decontamination factors (Dfs) over several STS campaigns showed the system to be removing Cs-137 at a level much greater than the anticipated design capacity. An engineer's worksheet was devised to show that the evaporation of decontaminated supernatant, based on 8D-3 sample results, would yield a product with an acceptable Cs-137 concentration. This calculation was performed prior to each 8D-3 to 5D-15B transfer and administrative controls were changed to allow evaporation of this liquid to start immediately following the transfer completion. Sampling and analysis of Tank 5D-15B was still required as a verification of data. Startup of the evaporator commenced 3 to 5 hours sooner per run as a result of this change.

Prior to campaign 15, the piping manifold was modified to prevent inadvertent discharge of decontaminated supernatant to the Process Building Interceptor System. This change made it physically possible to start evaporation of 5D-15B contents while the 8D-3 to 5D-15B transfer was still in progress. Cancellation of the requirements for lock and tag control over the manifold valves permitted campaign 20 to be run in a feed-and-bleed mode. This method of operation increased the capacity of the LWTS system flow rate so that it could easily handle the larger volumes and higher flow rates of the STS.

The problem of out-of-specification concentrates was most often due to inaccurate instrument readings. The evaporator density transmitter "drifted" off calibration on several occasions and was subsequently replaced. Evaporator instrumentation is now routinely checked before each run and the bubbler tubes purged with water and air. Since the Analytical Support Group could quickly turnaround a density and correlated total solids request, the practice of drawing an in-process sample was often used to verify Control Room density readings.

7.0 CEMENT SOLIDIFICATION SYSTEM (CSS) - LESSONS LEARNED

7.1 Mixer Buildup - Problem Identified

The most troublesome problem identified during uranyl nitrate and simulated supernatant cement processing was the residue weight of cement left in the mixer after the completion of each batch. Accumulation of 50 pounds of residue required the mixer be flushed with water. The resulting flush drums containing this material were not qualified under any approved waste recipe; special handling equipment and storage requirements were necessary to dispose of the drums. These flush drums were being processed at a rate of one per day.

7.2 Mixer Buildup - Solutions Implemented

As part of the cement waste form qualification, testing was performed with a variety of chemical combinations to produce a waste form that remained fluid enough to fully dispense from the mixer. By the start of decontaminated supernatant processing, chemical additive systems were in place to accelerate the gelation rate of the waste and control the rate at which the cement sets. Calcium nitrate was blended with the bulk dry cement as a gel-accelerating compound. Sodium silicate was added directly to the mixer as a set enhancer. Mixer residue was reduced to approximately 1 pound per batch prior to the start of IRTS operations.

Several modifications to the equipment and processes of the CSS further reduced the amount of cement buildup in the mixer. Initially, the CSS operated using two mixers concurrently. Early in the second campaign, mechanical difficulties in one mixer forced operations to continue using only the remaining mixer. It was observed that this method of operating allowed the one mixer to be charged with liquid nearly all the time. The mixer did not sit idle and effectively flushed itself with the addition of every waste batch. Cement solidification operations have since utilized only one mixer, decreasing the amount of buildup and allowing the luxury of maintaining a spare mixer to be at the ready at all times.

The efficiency of the Supernatant Treatment System in removing Cs-137 from the waste stream has resulted in dose rates at the CSS that allow access to the process cells and equipment. During each entry into the process cell for routine maintenance of drum sampling, the mixer was manually vibrated with a rubber mallet, allowing thin layers of cement product to dislodge from the mixer walls and be processed with the next waste batch.

Prior to campaign 7, buildup of cement in the mixer was significantly reduced by the replacement of two of the water flush nozzles with utility air nozzles. This technique used a curtain of air to blanket the inside wall of the mixer. During remaining campaigns 7 through 21 of the IRTS processing, mixer residue was maintained at less than 1 pound per batch.

7.3 Drum Lid Handling - Problems Identified

Two distinct problems with the drum tops and lids occurred repeatedly during the early campaigns of CSS processing. The first was related to the initial design of the lid handler system that utilized an inverted drum lid as a drip pan under the fill nozzle during drum changeout. This inverted lid, now contaminated with cement drippings, was flipped over and placed on top of the next process drum. The flip motion resulted in periodic contaminated drum tops and subsequent contamination of drum handling equipment. The second problem identified with the drum lids was caused by the large demand of air pressure by the cement silo transfer system. Each time a cement transfer from the silo was in progress, the air pressure available to other system components dropped, including the air-operated lid crimper. Several drums in the early campaigns were found to have less than satisfactory lid crimps.

7.4 Drum Lid Handling - Solutions Implemented

The lid handler was modified to hold a disposable pie tin which could easily be removed and cleaned or replaced. The process controller was modified to eliminate the flip motion of the lid handler. These modifications greatly reduced the number of contamination incidents caused by drum top problems.

In addition, the air-driven lid crimper was modified with an alternate supply of air from compressed cylinders, regulated to 125 psi. The procedure for full drum loadout was also modified to include operator verification of satisfactory lid crimp. A manual, hand crimper device was fabricated to facilitate recrimping of lids. The crimper, however, has been 100 percent efficient since the installation of the bottled air supply.

7.5 Chemical Additive Systems - Problems Identified

During CSS processing of uranyl nitrate and simulated supernatant, the 2-inch cement transfer line from the dense phase transmitter (vessel) to the day bin was prone to complete plugging with small cement rocks. The vessel needed to be unassembled, cleaned, and reassembled. This process took a minimum of two hours and resulted in up to 1000 pounds of wasted cement. In humid weather, the cement mixture is especially clumpy and vessel cleanout was necessary twice per shift.

The initial design of the sodium silicate addition system required operators to handle several 55-gallon drums per shift, using portable pumps to transfer the silicate into a day tank that was located in an unheated truck garage. The drums were extremely difficult to handle and cold weather conditions affected the fluidity of the NaSi.

7.6 Chemical Additive Systems - Solutions Implemented

Prior to solidification of the decontaminated supernatant, a motor-driven pipeline delumper was installed between the cement storage silo and the dense phase transmitter (vessel). All cement transferred to the vessel is now crushed by the delumper. Since installation, no down-time has been required to clean the vessel and all cement transferred to the vessel has been used by the system. Some blockage has occurred in the cone portion of the silo during extreme humid conditions. The silo has been modified with an eccentric vibrator to prevent bridging of cement across the cone and the two small access ports. This allowed dislodging of cement rocks from the butterfly valve at the discharge of the silo. At the completion of decontaminated supernatant processing, the silo was emptied to allow installation of a knife-gate valve in place of the butterfly valve. This doubled the size of the opening leading into the delumper chamber, thus preventing clogging.

The bulk sodium silicate handling system was completely redesigned during the early campaigns of IRTS processing. A large addition to the building was constructed to house the NaSi day tank as well as a 1500-gallon storage tank. Handling of the 55-gallon drums was replaced by monthly off-loading of a chemical tanker truck. The storage tank and its associated pumps and piping were enclosed in a bermed area of the room. The day tank (from which the mixers were fed) was mounted on a Toledo scale with remote readout in the Control Room. A more accurate reading of the amount of NaSi delivered to the mixer could be obtained from this scale than from the mixer load cells, thus improving process control.

7.7 Suspect Drums - Problems Identified

The solidification of concentrated decontaminated supernatant yielded 10,393 process drums in 21 operating campaigns at an acceptance rate of 99.5 percent. A total of 50 drums were produced that were designated as suspect drums. These drums required further testing and analysis to determine if they met all the requirements of 10CFR61. Of the 50 suspect drums, 35 were attributed to cracked check valves on the antifoam addition lines. Low water-to-cement ratios (less than .54) accounted for 9 of these drums. Five drums were produced with one batch not receiving any sodium silicate.

7.8 Suspect Drums - Solutions Implemented

The 35 drums made with less than the nominal amount of antifoam occurred on two separate occasions, once in campaign 14 and once in campaign 19. Each time, the cracked antifoam check valve was discovered on the first operating shift of a new campaign.

The plastic check valves apparently broke during the high-pressure water cleaning of the mixer that takes place between operating runs. The cleaning operation involves removal of lines and equipment from the top of the mixer near the antifoam injection port and insertion of a waterspray wand. Corrective action following the first occasion was a procedural change to the pre-start checklist; adding a requirement to visually inspect the antifoam addition line to the mixer during the metering pump checkout.

Following the reoccurrence of this event in campaign 19, corrective actions included installation of metal check valves in place of plastic.

The nine drums with calculated water-to-cement ratios of less than .54 all were caused by an excess of cement being added to one of the mixer batches. It is suspected the excess addition was due to the pneumatic transfer from the storage silo to the day bin causing product flushing. This fluidization of the dry cement would occur at the worm gear auger, allowing the cement to flow around the auger into the feed tube until it dead-headed at the closed cement diverter valve. This cement would not be accounted for on the day bin scale since the feed tube is physically below the scale. Approximately 60 pounds of cement could be added to the mixer that would not show up on the day bin readout. Corrective actions included raising the low-level set point of the day bin to ensure the feed auger was not exposed during cement transfers to the day bin. The CSS program was modified to add a 15-second delay between opening the cement ram valve at the top of the mixer and starting the cement feeder. This allowed the operators time to carefully monitor the mixer load cell following the valve opening. If an increase was noted on the mixer load cell prior to the start of the cement feeder, the program could be halted and proper adjustments made to the cement addition.

Unlike the antifoam check valve and cement flushing problems described above, the five cement batches produced without sodium silicate were not traceable to one specific cause. A manual valve found in the closed position resulted in a change to the pre-start procedure to physically check the valve. The alarm response procedure was modified to address manually stroking the plunger of the piston-type pumps in an attempt to free them. Finally, a bypass valve and lines were installed to permit operation of the NaSi pumps to either of the two mixers.

Laboratory work was performed to produce cement cubes that mimicked the conditions of the suspect drums in an effort to qualify these drums as acceptable.

7.9 Use of Process Drums as Shield Drums

During campaign 3 it was recognized that some CSS process drums would be low enough in dose to be effectively used as shield drums in the Drum Cell. Concentrated decontaminated supernatant with a Cs-137 concentration of less than .03 microcuries per milliliter will produce cement drums with a dose rate of less than 10 mR/hr. Stacking these drums in the top layer of the Drum Cell will reduce the dose rates in the occupied areas of the Drum Cell as well as at the site boundaries.

7.10 Increase Batch Size to 20 Gallons

The batch size for the last seven drums of campaign 12 was increased from 19 to 20 gallons. Drum fill increased to approximately 92 percent and three inches of freeboard remained in each drum. The drums of all subsequent campaigns were made using a 20-gallon batch size; saving 185 drums from the expected total number of decontaminated supernatant drums.

8.0 SUMMARY

The Integrated Radwaste Treatment System (IRTS) operated at a rate in excess of the design rate with a decontamination factor (DF) approximately 50 times better than the design minimum.

Refinements in the Liquid Waste Treatment System (LWTS) and Cement Solidification System (CSS) allowed the production of fewer drums than originally anticipated. This resulted in a reduction in the number of drums that had to be produced. The lower number of drums, combined with superior DFs, reduced the process drum volume in the Drum Cell . The use of process drums in shield positions eliminated the requirement for "Cold" (nonradioactive) drums in the top layer and allowed the Drum Cell to fill up in its normal sequence with no special storage or handling requirements for shield drums.

All of the technical difficulties encountered during the more than two years of processing were resolved using available technology without compromising safety or product quality. There were no abnormal or unacceptable personnel exposures during the processing period.