DEVELOPMENT AND TESTING OF A RESIN DEWATERING SYSTEM AND PROCESS CONTROL PROGRAM FOR COMPLIANCE WITH 10CFR61

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ABSTRACT

To improve TVA's liquid radwaste processing and decrease the time required to dewater TVA-fabricated dewatering liners; changes were made in the design of the liner, dewatering equipment, and the process control program. The primary objective of the program was to compile enough data to write a summary report with documentation sufficient for submission to regulatory agencies. During the dewatering runs, a moisture content probe was also tested and it demonstrated that an in-situ sensor could be used to accurately measure the retained water content and confirm compliance.

INTRODUCTION

Powdered and bead ion-exchange resins are used throughout TVA's nuclear plants to remove chemical and radioactive ions from the water.

The life of the resin is dictated either by chemical depletion or by the retention of suspended solids. The suspended solids buildup in a bed of powdered resin can reach a point where the pressure drops across the unit increases and further operation is not practical.

At TVA, radioactive powdered and bead resins are not chemically regenerated or ultrasonically cleaned. When expended, either by depletion or by binding with solids, the resins are replaced with new ones and the old resins are processed for disposal. At TVA's nuclear power plants, spent resins are vacuum dewatered in preparation for transportation and burial.

With the advent of the high integrity container, powdered and bead resins can, in lieu of solidification, be dewatered if the remaining drainable liquid does not exceed one percent of the container volume.

This report summarizes the work done by TVA regarding the dewatering of powdered and bead resins in TVA containers to meet the burial site criteria.

TEST PHASE I

Information from previous testing at TVA was used to characterize the flow rate of water through various types of filter cartridges. Comparison of filter data from that testing indicated only minimal filtering differences between cotton-wound, resin-bonded and polyethylene-spun filters. Phase I was intended to further establish what differences might exist between the resin-bonded filter currently being used in TVA-constructed liners and the spun-type filter. Since all the various filters exhibited similar filtering characteristics when used in filter assemblies, filter loading data utilizing standard techniques and simulated lab scale dewatering data was established as the basis for deciding which type filter would be tested in TVA's new underdrain configuration.

Two seperate tests were performed on the cartridge filters. The first was designed to illustrate the loading capacity of 25 micron resin bonded, 20 micron Hytrex spun-wound, and 30 micron Hytrex spun-wound filters.

A filter test apparatus was constructed and used to continuously apply a resin slurry to the cartridge filter until the maximum loading capacity had been attained. Dry resin was added in increments of 20 grams to the mixing chamber, which contained 6 liters of water. This slurry was circulated through the cartridge filter until the effluent water clarity had stabilized, then an additional 20 grams of resin was introduced into the mixing chamber. After each subsequent addition of resin, the flow rate of the effluent water and the pressure differential across the filter was recorded. This process was repeated until the pressure differential across the filter reached approximately 25 psi.

The results showed that the resin-bonded types had slightly higher loading capability.

TEST PHASE II

This second phase was conducted to compare the dewatering characteristics of the resin-bonded and the 20 micron Hytrex cartridge filter. This test required that the filter element be sealed at one end with a flexible hose connected to the opposite end. Dewatering of the resin slurry was accomplished by submerging the filter into the slurry and connecting the flexible hose to a vacuum pump. The slurry was dewatered for one hour, which was sufficient to remove over 50 percent of the water. The volume of water removed and the corresponding run time was recorded throughout the experiment to provide comparative information between the two filters. Percent moisture calculations were performed by collecting representative samples of the resin after dewatering, weighing the moist resin, and reweighing after drying in an oven. These calculations were used to determine the filter's effectiveness in allowing the removal of water from the resin slurry, which simulated the actual function of the filters when installed in the radwaste liner underdrain system. To help ensure realistic and reliable results, the resin used in the test was the same type used at one of TVA's plants.

The 20 micron Hytrex and the 25 micron resin-bonded cartridge filters were the subjects of the dewatering experiment. The resin-bonded filter removed 2100 ml of water or 56.66 percent of the water by weight in the resin slurry, and the Hytrex filter removed 2408 ml of water or 58.13 percent of the water.

Although the Hytrex filter exhibited a higher dewatering ability when compared to the resin-bonded filter, the difference was minimal (i.e., the Hytrex filter only removed about 3 percent more water than the resin-bonded).

Within 10 minutes the resin-bonded filter had removed 2000 ml of water while the Hytrex filter had removed 2200 ml of water. After this time, the rate of water removal began to stabilize, therefore, the Hytrex 20 micron filter exhibited a slightly better dewatering capability. It should be noted that new resin typically has a 60 percent moisture content by weight, so both filters allowed the resin to be dewatered below the 'from the factory' moisture content.

These differences were considered to be insignificant as were the loading differences in Phase I test, so either filter would be acceptable for further testing. The spun and wound filters, however, could be obtained in one-piece construction, while the resin-bonded required that several filters be used per lateral. This fact narrowed our choice and further testing of the spun type filter continued.

TEST PHASE III

Test 3 was designed to determine the water flow characteristics through a multilegged underdrain system. Also, based on the methods used and data collected during this phase of testing, a new process control program was developed.

A series of dewatering runs in a test container were conducted to obtain data which would determine the time necessary to dewater the container to meet burial site criteria and, concurrently, the influence of various combinations of powdered and/or bead-type resins on dewatering.

Moisture sensing probes manufactured by Digital Liquid Systems, Inc. were also used during the testing to determine if remote monitoring could be used to verify compliance with the allowable free standing water requirements of 10CFR61.

Core samples were taken every 15 minutes during the dewatering period and analyzed. The results of multiple tests of various powder/bead resin ratios were also compared to the moisture probe readings.

Apparatus and procedures

The underdrain system utilized in the test consisted of a one-inch diameter carbon steel header having four dewatering filter legs evenly spaced along the header. Each leg was made up of a 20 micron filter with PVC pipe, 43 inches long with an I.D. of 3/4 inch and an O.D. of 2 1/2 inches. Each leg was threaded on one end to fit the header and the other end was sealed with a PVC cap. The carbon steel header had a one-inch diameter discharge line connected to the side of the container to which the dewatering pump was connected.

Figure 1 shows a plan view of the container bottom with the location of the underdrain plumbing and the five sample locations. Moisture sensing probes were positioned at each of the numbered locations. Core samples were also taken in the immediate vicinity of these locations.

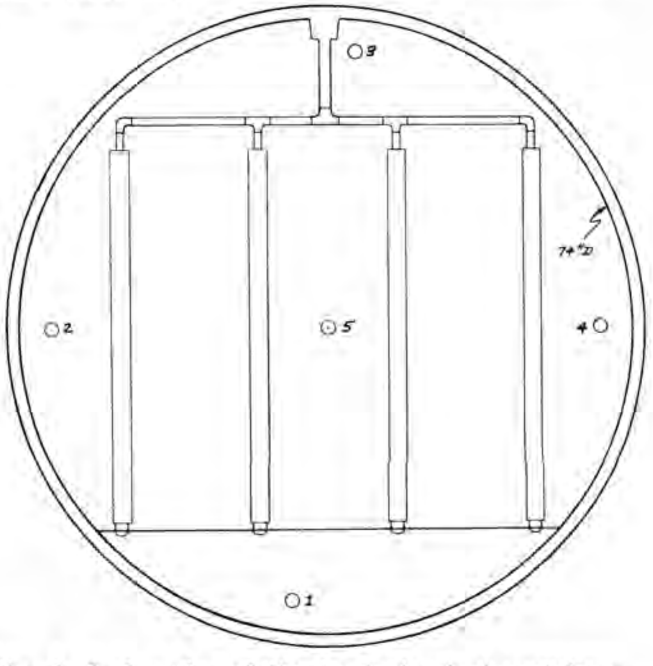

Fig. 1. A plan view of the dewatering test container.

Figure 2 is a photo of the dewatering test skid which contained the vacuum pump, a water collection tank with sight glass, and an air heater. Temperature and pressure gauges were located at the inlet to the tank. Connection to test container was through a 2 inch hose. The complete assembly was mounted on a wheeled 3 by 5 foot skid for maneuverability.

Fig. 2. The dewatering test skid.

Core samples were extracted from the general vicinity of the 5 numbered sites in Fig. 1, stored in sealed poly-bags and labeled as to date, time and location. The following day, portions of the samples were weighed, dried in a microwave oven for 7 1/2 minutes and re-weighed to obtain a measure of the percent moisture by weight. Equation 1 was used to compute percent moisture by weight (PMW), where b = the weight before drying and a = the weight after drying.

$$\text{PMW} = 100(1-a/b) \qquad (1)$$

New resin as received from the factory was also dried and weighed to obtain a baseline moisture reading for resin containing no drainable liquid. Fresh resin values were 59.94 percent by weight and within 10 samples, the RMS deviation was 0.4 percent.

Moisture probes were also used during these tests to record the percent retained moisture. These were designed to be low-cost disposable units installed in the liner prior to filling with resin. The principle of operation is based on the change in electrical capacity of the resin as a function of the moisture present. The active sensing portion of the probe takes the form of a 4 inch long cylinder and has an approximately linear transfer function. A coaxial cable is lead out through a top opening for connection to the external readout device.

The probes were oriented with the long axis vertical and with the tip approximately 1/2 inch from the bottom. For these tests, five probes were used and at the appropriate sample time (i.e. every 15 minutes) the operator sequencially connected the cable leading from each of the probes and recorded the instantaneous value seen on the display of the a battery-powered hand-held reader.

The reader was designed to display values from 0.00 to 99.9. These readings were then converted to moisture values using a conversion chart constructed from the following equation,

$$\text{PMV} = (r-z)/k \qquad (2)$$

where PMV is the percent moisture by volume, r is the reader reading when immersed in resin, z = 11, the reader reading when immersed in dried resin and k is a factory determined calibration coefficient, 1.6. Fresh resin had a measured moisture of 13 percent by volume using Eq. 2.

A test run began by filling the container with sufficient water to saturate the resin and then stirring until uniformly mixed. Probes were then inserted in the slurry at the locations described above. Probe readings were recorded under these initial conditions and then dewatering was started. No core samples were taken until the pump lost suction, although moisture probes were read every 15 minutes from the starting saturation. Once suction was lost, the rate of water removal was significantly slower and was recorded by observing the level change on the dewatering skid sight glass. Core sampling was also started at this time and continued every 15 minutes until day's end. During each run, on the order of 120 resin samples were extracted and dried to determine the percent moisture by weight. Suction pressure remained essentially constant (10-13 inches of Hg) throughout all tests.

Results

Figure 3 illustrates the results of a typical dewatering cycle (run #11-012) using 5 moisture probes and taking core samples every 15 minutes. The bead to powdered proportions for this run was 30 and 70 percent, respectively. Other ratios were also tested (e.g., 10, 20, 50 and 100 percent bead). Examples of results using 100% bead are included in Table I for both ambient and heated air.

The numbers, 1 through 5, refer to the locations in Fig. 1, the tank drawing. The ordinate of the graph is percent moisture by volume, the abscissa is elapsed time in 15 minute intervals.

For the purposes of this graph and to show the shape of each curve without overlap, successive curves were offset vertically in increments of 5 percent.

As mentioned in earlier text, the probes initially read saturated resin values and then decreased rapidly as water was removed from the tank. Toward the right side of Fig. 3 the curves flattened when the pump was no longer able to remove additional water from the resin. These final dewatered readings varied somewhat from station to station (+/-2% is typical) about a mean retained moisture by volume of 22 percent. These variations are the result of three factors, minor variations in the depth of probe placement, differences between probes, and the horizontal variations in the dewatering efficiency of the underdrain laterals.

The time to dewater the resin was a function of the powdered/bead ratio with longer times necessary with increasing powdered resin. In Fig. 3, the elapsed time across the graph is 6 hours.

Note also, some curves began to fall earlier in the dewatering cycle. This is also the result of the asymmetry of the underdrain system, which caused the volumes near the periphery to began draining last. Probe 5, the center probe, consistently begins to decrease earlier than the probes at the other sites.

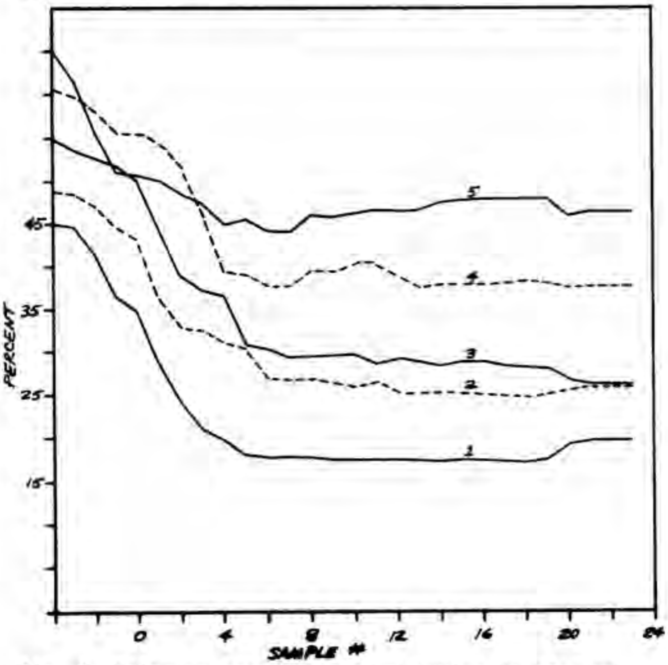

Fig. 3. Moisture content vs time during dewatering

All moisture probe readings were seen to follow the regular shape shown in Fig. 3, except when it was noted that, while taking core samples, an individual probe was accidently dislodged in the resin. This usually resulted in a step decrease in the reading at that location. When rigidly mounted in the bottom of full-size liners movement of the probe would not be expected.

Figure 4 illustrates the percent moisture content by weight determined by drying the core samples taken at the same time and location as the probe readings in Fig. 3. These curves have also been offset by 5 percent, as was done in Fig. 3, to better show the shape of each plot. The sample interval is again, 15 minutes.

These curves indicate a slight downward trend with time, but the scatter is significantly greater than seen by the moisture probes. One reason given to account for the scatter is the observation that, by the following morning when the samples were analyzed, moisture from the samples had condensed on the inner surface of the storage bags.

Note, in Fig. 4, the moisture is given as percent by weight and includes water of hydration and possibly water of constitution, removed during the microwave drying process. The moisture read by the probe is a function of percent by volume, not percent by weight. Also it is most sensitive to free water in the surrounding volume, mostly ignoring bound water and water of constitution which is not free to vibrate under the influence of the alternating electric field. Free water, on the other hand, is not physically or chemically bound to the media, it occupys void spaces between particles and comes off easily under the action of a vacuum or gravity. For these reasons, the total moisture by weight, determined by drying of core samples, cannot be compared directly. Thus, only relative changes of moisture, from start to finish of a dewatering run, are compared.

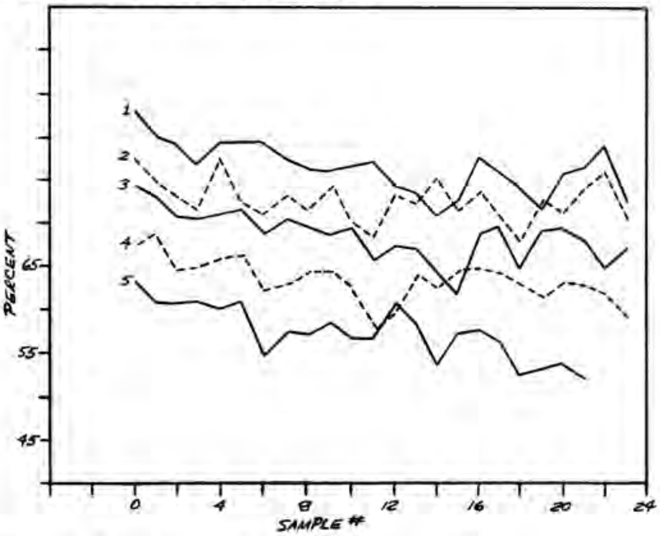

Fig. 4. Moisture content from core samples.

To compare the moisture probe and core sample data, the following technique was used. Curves as in Fig. 3 and 4 from all five sites were averaged and plotted as the change of percent moisture content from Fig. 5, also includes a curve representing the rate of water removal as measured by the sight glass and plotted as a percent of the test container volume.

It is obvious from these curves the moisture probes track the measured rate of water removal even early in the dewatering cycle when the resin is very damp. However, core samples show considerable scatter throughout the run even after averaging. Later in the run, the pump moisture approaches a constant value (linear slope), which is likely the moisture removed from the ambient air by the vacuum pump and not moisture removed from the resin.

The criteria used throughout these tests to define the completion of the dewatering process was the condition when the moisture content of the dewatered resin was less than that seen in fresh resin. Approximately 5 percent less was attainable using the new dewatering skid and underdrain system.

When using moisture probes to verify completion of the dewatering process, two approaches are appropriate. The first is to observe the reader output until it reaches a value as low as those seen at the finish of these qualification runs and conclude that dewatering is complete.

A more difficult method uses the moisture content of drained resin and assumes that any moisture above that value constitutes potential free standing water and can be expressed as a percent of container volume.

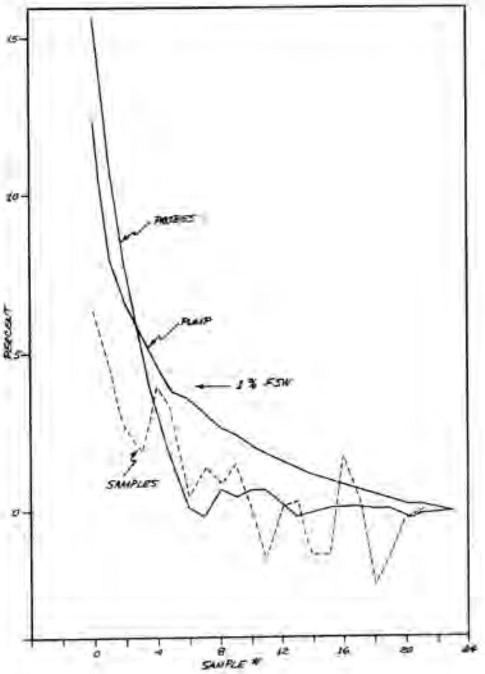

Fig. 5. Comparison of changes in moisture content as measured by probes, core samples and the dewatering pump.

Conversion of percent moisture by volume to percent free standing water is given by,

$$PFS = (r-d)h/H$$

where, assuming the probe is at the bottom and standing vertical,

PFS = the percent free standing water
r = the moisture read by the probe
d = the moisture read in drained resin
h = height of the probe sample volume, 4 in
H = height of the container.

Using Eq. 3, the one-percent free standing water point can be computed and is shown on Fig. 4.

TABLE I summarizes the moisture change during 10 dewatering cycles using probes, core samples and sight glass volumes. The moistures shown are changes from the time at which suction was lost, until the end of the run. Columns P1 through P5 are probes, S1 through S5 are samples and the Pump column is computed from the sight glass measurements. Two columns, Pa and Sa are averages, as is the last line in the table. Station 5 samples were not taken during some runs.

The first three runs (11-010, -011, 012) were done drawing ambient temperature air (25 C) through the resin. The next three runs in TABLE I were done using heated air (greater than 50 C). The resin ratio for the six runs was 30% bead and 70% powdered. It was observed that less water was removed (on the order of 8 percent) when the input was heated. This effect was not investigated further.

In TABLE I, for the first six runs, we see the good average agreement between the Pa and Pump columns. Although individual probe locations showed, because the dewatering rate varied across the container, a wide disparity in percent moisture change. See the last row in the table.

The final four runs examined 100% bead resin with the last two of these dewatered using air heated to greater than 50 C. The moisture changes seen by the probes are higher than during 30% bead tests. This would be expected if, when suction was lost, most of the remaining drainable liquid resided in the bottom of the container where the probes were located. This was confirmed by the smaller percent of water removed by the pump and the shorter dewatering time. The 100% bead resin also did not exhibit the sensitivity to heated air noted above.

TABLE I.

Change in percent moisture during dewatering cycle.

TEST #	P1	P2	P3	P4	P5	Pa	PUMP	S1	S2	S3	S4	S5	Sa
11-010	17.19	7.44	17.50	9.07	1.06	10.45	12.22	11.20	6.90	8.50	9.30	-1.30	6.92
11-011	19.94	9.88	32.12	10.06	.31	14.46	12.40	14.00	10.00	9.00	7.90	2.20	8.62
11-012	14.81	17.62	23.69	18.06	4.31	15.70	12.33	11.00	7.70	7.20	7.50	-4.80	5.72
11-013	3.62	9.81	6.81	1.63	1.93	4.76	4.79	7.20	4.60	.70	5.60	-----	4.53
11-014	8.87	8.81	12.12	10.37	3.44	8.72	7.47	2.10	3.60	9.80	2.30	-----	4.45
11-015	9.69	-4.32	15.31	8.19	3.44	6.46	4.90	8.60	2.40	3.20	2.80	-----	4.25
11-016	10.75	10.25	23.00	8.44	5.62	11.61	3.89	.20	.80	.70	.70	1.10	.70
11-017	14.56	13.62	16.87	13.19	13.81	14.41	5.28	1.10	5.90	.80	.10	6.50	2.88
11-018	20.06	17.37	16.75	15.00	13.75	16.59	6.84	1.90	1.50	3.20	2.70	-----	2.33
11-019	15.94	11.88	17.94	11.56	9.38	13.34	8.09	4.70	1.90	7.00	4.70	-----	4.58
ave	13.54	10.24	18.21	10.56	5.71	11.65	7.82	6.20	4.53	5.01	4.36	.74	4.17

CONCLUSIONS

Extensive tests of a new underdrain design, dewatering filters and moisture probes have shown that bead and powdered resin dewatering in TVA-type liners can now be accomplished rapidly, efficiently and remotely, while attaining moisture contents well below those required by 10CFR61.