PROCESS CONTROL PROGRAM

CHAPTER 18

SOLID WASTE DISPOSAL SYSTEM

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PROCESS CONTROL PROGRAM (continued)

I. PURPOSE

1. To provide appropriate radwaste system feed rates necessary to achieve the waste to cement ratios required to assure solidification of liquid radioactive wastes.

2. To provide results of tests performed to determine the waste to cement ratio required for solidification of the radioactive wastes (evaporator bottoms, boric acid and spent resins) generated at Beaver Valley. These results form the basis for set points indicated in Chapter 28 (Solid Waste Disposal System) of the Unit 1 Operating Manual.

3. To indicate the requirements for disposal of radioactive filter cartridges, rags and other solid objects in the matrix of the solidified concrete.

4. To indicate critical set points and limitations for operation of the radwaste solidification system.

5. To indicate surveillance requirements for solidified waste shipped off-site.

PROCESS CONTROL PROGRAM (continued)

II. SOLID WASTE DISPOSAL SYSTEM DESCRIPTION

A. FUNCTION

The Solid Waste Disposal System (SWS) is designed to provide holdup, packaging, and storage facilities for the eventual off-site shipment and ultimate disposal of radioactive waste material. Liquid wastes are immobilized in a concrete matrix using a ATCOR solidification system provided for this purpose. A facility is also provided to wash shipping containers after loading to prevent release of activity to the environment.

B. SUMMARY OF SYSTEM OPERATIONS

The waste solidification system consists of a cement storage bin, cement feeder, mixer-feeder, resin waste hold tank, evaporator bottoms hold tank, resin hold and bottoms hold tank feed pumps, and the necessary piping, valves and instruments for the system to function. This equipment is used to immobilize the following wastes: (1) spent resin, (2) concentrated liquid wastes, and (3) solid wastes such as filter cartridges and polyethylene bags containing contaminated rags or other radioactive debris. Solid wastes are contained within an open-mesh metal basket located in the approximate center of the concrete liner. The basket is suspended off the bottom so that the concrete mixture will totally surround the basket.

Wastes are solidified in a carbon steel liner which has a total capacity of approximately 65 cubic feet. This liner is moved into position under the mixer-feeder by transfer cart through remote control operation. Where solid waste disposal is involved, the metal basket containing the wastes is placed within the concrete liner prior to moving the liner into position. Transport of the liner is performed with the operator stationed behind a concrete wall at the waste solidification control panel. A television camera is provided for operator view of operations involved with solidification.

Liquid wastes requiring solidification come from either the evaporator bottoms hold tank or the resin waste hold tank. Schematic design of the overall system is shown in Figure 1. System parameters are listed in Table 1. Equipment design requires that each waste form be processed separately. Though capable of automatic operation, the system is operated in the manual mode to ensure that the system is operating properly and that the set points for cement-liquid waste ratios are as required to achieve solidification. Operator attention is required to actuate the controls for each stop of the operation. Metered flow of cement and waste solution are combined at the mixer-feeder which discharges into the concrete liner. Cement feed is maintained at a constant rate for all solidification operations. Liquid waste flows are adjusted as required to provide for a higher liquid waste to cement ratio in the case of boric acid solutions. The normal operating limit for boric acid concentration in wastes to be solidified is a nominal 12%. A waste to cement ratio in range of 0.9 to 1.1 is specified for the solidification of boric acid solutions. Other wastes require less cement to achieve solidification.

After the liner has been filled with concrete, it is covered with a lid and the liner is moved from the loading area. The liner is allowed to set for five days or more. While the controls exercised in maintaining a proper cement/liquid ratio ensure solidification, an inspection of containers from each shipment is also performed to check for free water. In the event that water is present, cement will be added as required to achieve a water free mix. The lid is then fastened in place and sealed to the liner with a metal seal. The outside of the liner is washed with a series of spray nozzles to remove any surface contamination resulting from loading operations. A smear check is performed prior to moving the liner from the loading area to the clean side.

The sampling system consists of the appropriate valves and sink located at the discharge of the motoring pumps (SW-P-6) and (SW-P-7). When the desired amount of waste for solidification is in the hold tanks (SW-TK-2) resin hold tank or the bottoms hold tank (SW-TK-8), these tanks are mixed to a desired consistance by running the agitator in the resin hold tank or recirculating the bottoms hold tank as per the operating manual. Before the solidification process begins a sample is obtained for ratio/analysis of radionuclides.

PROCESS CONTROL PROGRAM (continued)

III. OPERATIONS PERFORMED TO VERIFY SOLIDIFICATION OF RESIN WASTES

Testing performed at Beaver Valley demonstrate that solidification of resin with a high resin to water ratio will consistently occur at a waste to cement ratio (W/C) of 1.25 to 1.75. A high resin to water ratio is obtained during initial processing of a full resin waste hold tank. When the resin waste solution is largely water, as in the case when the resin hold tank level indication decreased to below 20 inches, a W/C ratio of 1 to 1.50 is required to achieve solidification. Results of the test operations are reported in the Appendix to this procedure.

Solidification in this application can be achieved by adjusting the feed rate of the liquid waste to produce a W/C ratio in the range of 1.25 to 1.75 or 1 to 1.5 dependent on resin hold tank level indication. Ratios of about 1.7, and 1 are maintained in actual plant solidification operations with flow rate adjustment made at about the 20 inch level. This is not meant to imply that there is a sudden change in resin to water ratio at this level. Rather, the change is gradual with the 20 inch indication level serving as a benchmark to indicate that the corresponding change in the W/C ratio is required. Control of waste flow rate and cement feed to obtain the desired ratio is acheieved as follows:

A. FEED RATE CONTROL

Three separate feed rates combine to makeup the resin concrete mixture formed in the mixer-feeder of the solidification system. These are as follows:

1. Cement Feed Pump

   The feed rate of this pump is adjustable over a wide range with good reproductibility as shown in the calibration data presented in the Appendix to this program. Flow is held constant at a dial setting as noted in Chapter 18 of the Operating Manual. With this setting, the pump will deliver the proper amount (lbs) of cement per minute.

2. Resin Waste Hold Tank Metering Pump

   When the level indicator is reading between predetermined levels noted in the Operating Manual, the dial of the metering pump is set to provide a normal deliver rate of 7 gpm. As the waste tank volume decreases, so does the percent concentration of resin in the water. Current experience has shown that there is little resin left in the tank at a level of about 20 inches and the waste is composed largely of water. This requires a lower W/C ratio to achieve solidification. At this level (approximately 20 inches), the dial of the metering pump is adjusted to give a feed delivery rate of approximately 4 gpm.

3. Seal Water Flow to Pump

This flow is held constant at the minimum flow requirements to protect pump bearings. Flow adjustment is made using a low range flow meter.

NOTE: Excessive seal water flow will change the W/C and therefore, limits noted in operating procedure must be followed.

B. OPERATOR FOLLOW

As described above, solidification of resin wastes is achieved by combining two constant flow rate systems with one adjustable flow system (waste metering pump). The liquid waste to cement ratio is maintained within a relatively narrow band in the range where solidification is known to occur on a consistent basis. With only one control valve to adjust, the operator can maintain close surveillance of solidification operations. Full time operator attention is maintained since the system is operated in the manual mode. The system holds at the completion of each step until the operator activates a control to continue the sequence of operations.

C. FINAL INSPECTION

As a final check, a visual inspection is performed to determine the presence of free liquid prior to shipment of the full liner. If free water exists, dry cement is manually added to achieve solidification of this water.

PROCESS CONTROL PROGRAM (continued)

IV. OPERATIONS PERFORMED TO VERIFY SOLIDIFICATION OF EVAPORATOR BOTTOM WASTES

The liquid wastes generated at Beaver Valley will typically contain significant concentrations of boric acid. While boric acid is known to retard the solidification of cement, the inhibiting properties of boric acid can be overcome by increasing the concentration of cement in the mixture and the limiting the boric acid concentration in the waste solution. Testing performed at Beaver Balley indicate that the criterion of good solidification with no free water an be achieved by maintaining a W/C ratio of 0.9 to 1.1 (by weight). It is expected that solidification will also occur at lower W/C ratios, however, this would result in the excessive use of cement. Good solidification will also occur with up to 14-16% boric acid concentrations using this ratio. Results of this work are reported in the Appendix to this procedure.

Solidification in this application is achieved by using approximate equivalent weights of waste and cement in forming the concrete and by limiting the concentration of boric acid in solution to 12%. With a W/C ratio in the range of 0.9 to 1.1 and a maximum boric acid concentration of approximately 12%, all operations are performed below the point where free water will form after solidification. Control of boric acid concentration, waste flow rate and cement feed to obtain the desired ratio is achieved as follows:

A. BORIC ACID CONCENTRATION

Waste liquids in the evaporator are sampled periodically during evaporation to determine boric acid concentration and curie content of the liquid. Hot samples are pipetted into a volumetric flask and diluted to prevent precipitation prior to analysis. Solidification of the wastes is performed when the following limit is attained.

A nominal 12% boric acid concentration in the liquid.

Some dilution of the boric acid concentration will result from the primary grade seal water flow added at the mixer-feeder system during the solidification process. This dilution is not considered in calculating boric acid concentration in the end product.

B. FEED RATE CONTROL

Three separate feed rates combine to makeup the evaporator bottoms-concrete mixture formed in the mixer-feeder of the solidification system. These are as follows:

PROCESS CONTROL PROGRAM (continued)

1. Cement Feed Pump

The feed rate of this pump is adjustable over a wide range with good reproductibility as shown in the calibration data presented in the Appendix to this program. Flow rate is held constant at a flow rate setting as noted in Chapter 18 of the Operating Manual. With this setting, the pump will deliver the proper amount (pounds) of cement per minute.

2. Evaporator Bottoms Hold Tank Metering Pump

The dial of the metering pumps is set to give a feed delivery rate as identified in the Operating Manual. A waste-to-cement (W/C) ratio of approximately 1 is achieved with this feed rate.

3. Seal Water Flow to Pump

This is held constant at the minimum flow required to protect pump bearings. Flow adjustment is made using a low-range flow meter.

NOTE: Excessive seal water flow will change the W/C ratio; therefore, limits noted in the operating procedure must be followed.

C. OPERATOR FOLLOW

As described above, solidification of evaporator bottom wastes is achieved by combining two fixed flow rate systems with one adjustable flow system (waste metering pump). The liquid waste-to-cement ratio is maintained within a relatively narrow band in the range where solidification is known to occur on a consistent basis. With only one control to adjust, the operator can maintain close surveillance of solidification operations. Full time operator attention is maintained since the system is operated in the manual mode. The system holds at the completion of each step until the operator activates a control to continue the sequence of operations.

D. FINAL INSPECTION

As a final check, a visual inspection is performed to determine the presence of free liquid prior to shipment of the full liner. If free water exists, dry cement is manually added to achieve solidification of this water.

PROCESS CONTROL PROGRAM (continued)

V. DISPOSAL OF SOLID OBJECTS IN CONCRETE LINERS

Solid wastes such as filter cartridges and contaminated rags or other radioactive debris will, on occasion, be placed within an open-mesh metal basket and immobilized in the concrete of the waste being solidified. The basket is suspended off the bottom so that the concrete mixture will surround the wastes in the basket. Liners that contain solid objects will be so identified. Radcon will be notified prior to placing solids into a liner to enable appropriate sampling.

PROCESS CONTROL PROGRAM (continued)

VI. CRITICAL ITEMS LIST

The following list indicates set points and items in the solidification system operating procedures (Chapter 18 - Solid Waste Disposal System). Close operator follow is required in these areas to assure proper operation of the system and to verify solidification of resin hold tank or evaporator bottom hold tank wastes.

1. Feed rate of the cement feed pump is held constant at a dial setting as indicated in the operating procedures for all solidification operations performed at Beaver Valley. Any variation in this dial setting will affect solidification of the concrete. Since this is an adjustable pump, the dial setting should be checked prior to performing any solidification operation.

2. When the level indicator of the resin waste hold tank is reading between predetermined levels as indicated in the operating procedures, the dial of the metering pump is set to provide a W/C ratio of 1.25 to 1.75. A low flow rate setting can result in an overly dry mix with perhaps some void areas in the liner. High flow rate settings can result in free water on the top of the liner. It has been established that good results are achieved with the W/C ratio of about 1.7 (currently in use for solidification); therefore, this ratio should be maintained.

   The W/C ratio is determined as follows:

   $$\frac{\text{GPM X 8.6 lbs/gal of resin slurry}}{\text{lbs cement/min}}$$

3. At a level indication of approximately 20 inches, the dial of resin waste metering pump is set to provide a W/C ratio of 1 to 1.5. Low or high flow rate settings can result in an overly dry mix or free water in the liner. Good results are achieved with the W/C ratio of about 1 (currently in use), therefore, this ratio should be maintained.

   The W/C ratio is determined as follows:

   $$\frac{\text{GPM X 8.3 lbs/gal of resin slurry}}{\text{lbs cement/minute}}$$

4. The correct resin-water ratio must be maintained as indicated in the operating procedure. Insufficient water can result in the loss of water from the resin beads during the hydration process involved as the concrete sets. The hydrated resin can swell on subsequent exposure to water creating tensile forces which can damage concrete integrity. Too much water can result in free water on the top of the liner.

PROCESS CONTROL PROGRAM (continued)

5. Seal water flow to the metering pumps must be held at a minimum as indicated in the operating procedure. Excessive seal water flow will change the W/C ratio, thus can affect solidification of the concrete.

6. The dial of the evaporator bottoms hold tank metering pump should be set to five to give a W/C ratio in the range of 0.9 to 1.1. (Existing control procedures result in a W/C ratio of approximately 1.) Flow rate requirements are identified in the operating procedure. If flow rates differ widely from the norm, a good solidification may not occur or there can be free water on the top of the linr.

7. Boric acid determinations are required during evaporation to control a boric acid concentration in the nominal 10 to 12% range at the waste tank. Below 10% there can be free water in the liner for at least the first day after solidification. This water will be absorbed within the concrete. With concentrations above 12%, solidification of lines can occur.

8. Activity determinations are performed when required of evaporator feed and/or bottoms during evaporation so that the activity level of the evaporator bottoms can be estimated. The curie content is estimated/calculated to minimize radiation level control problems during processing and shipment of the liner.

9. Contaminated oil or items with contaminated oil in them will be processed by an approved method.

PROCESS CONTROL PROGRAM (continued)

VII. LIMITATIONS AND SURVEILLANCE REQUIREMENTS

A. LIMITATIONS

1. If solid wastes (e.g., filters cartridges, rags, etc.) are immobilzed in the concrete matrix, the wastes will be contained within an open mesh matal basket located in the approximate center of the concrete liner. The basket is suspended off the bottom so that the concrete mixture will surround the basket.

2. The concrete in the liner must be solified and have no free water as determined by visual inspection prior to sealing the liner. The liner is inspected for free water prior to sealing which occurs 5 days or more after the liner is filled.

B. SURVEILLANCE REQUIREMENTS

1. The Effluent and Waste Disposal Semi-annual Report shall include the following information for each type of solid waste shipped off-site during the report period:

   a. Container volume

   b. Total curie quantity (determined by measurement or estimate)

   c. Principal radionuclides (determined by measurement or estimate)

   d. Type of waste (e.g., spent resin, evaporator bottoms)

   e. Type of container (e.g., LSA, Type A, Type B, large quantity), and

   f. Solidification agent

TABLE 1

SYSTEM PARAMETERS PERTINENT TO THE PROCESS CONTROL PROGRAM

Liner capacity	Approximately 65 cubic ft.
Liner dimension	49 inches diameter x 62 inches high
Liner weight (fully loaded)	Approximately 6000 lbs
Shipping container types for liner (if necessary)	1.5 inches steel 1.5 inches lead equivalent 4 inches lead equivalent vendors containers as required
Liquid wastes solidified	Spent resin (bead form) Evaporator bottoms which can contain boric acid
Solidification material	Cement (Specification provided by ATCOR)
Solid wastes immovilized in liner	Filter, cartridges, rags, etc.
Waste to cement (W/C ratio for evaporator bottoms.	0.9 to 1.1 Typical = 1
W/C ratio for resin wastes (high resin content)	1.25 to 1.75 Typical = 1.7
W/C ratio for resin wastes (low resin content)	1 to 1.5 Typical = 1
Maximum boric acid concentration in evaporator bottoms hold tank	Approximately 12%
Detection of free water	Visual inspection on liner prior to sealing the lid
Curie content in liner	Determined by analysis of the waste solution or estimated, based on gamma survey performed after solidification
Identification on principle radionuclides	Estimated by gamma ray spectrum of waste prior to or after concentration by ratio and analysis.

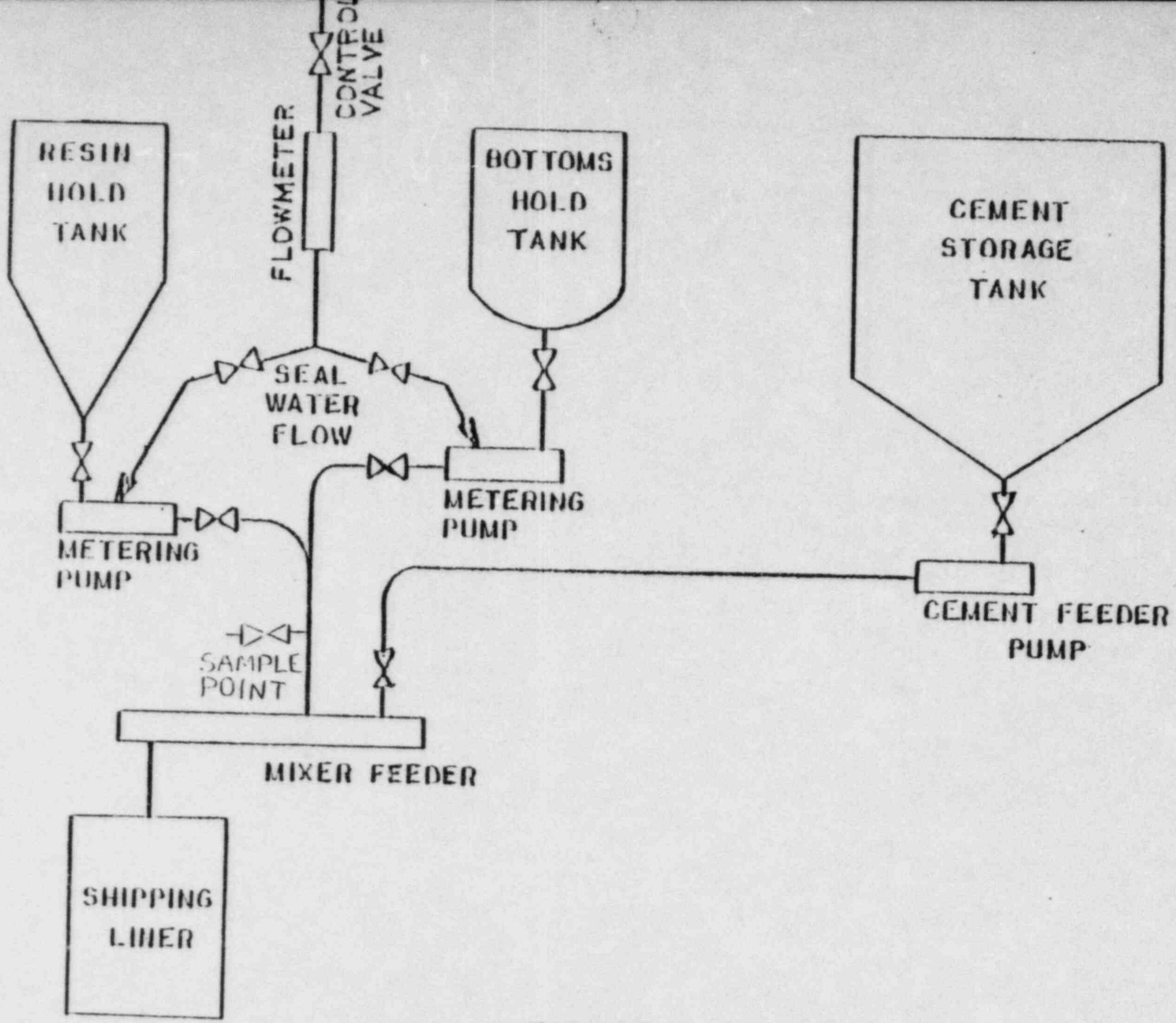

FIGURE I

BEAVER VALLEY #1 UNIT
SOLIDIFICATION SYSTEM

ISSUE 2
REVISION 4

APPENDIX A

CEMENT SOLIDIFICATION TESTS WITH RESIN AND EVAPORATOR BOTTOM WASTE SOLUTIONS

PROCESS CONTROL PROGRAM (continued)

I. INTRODUCTION

Testing has been performed at Beaver Valley to determine the W/C ratios required to assure solidification of resin and evaporator bottom waste solutions using cement as the immobilizing agent. The ratios used in this work are based on the cement and liquid feed rates specified in Beaver Valley Operating Procedures. Existing W/C ratios were selected as a starting point for this work because good solidification without free water is now achieved in solidification operations performed at Beaver Valley.

II. EVAPORATOR BOTTOM SOLIDIFICATION TESTS

The evaporator bottom wastes generated at Beaver Valley will typically contain significant concentrations of boric acid. While boric acid is known to retard the solidification of cement, the inhibiting properties of boric acid can be overcome by increasing the concentration of cement in the mixture and by limiting the boric acid concentration in the waste solution. Maximum boric acid concentration in the evaporator bottoms at Beaver Valley is limited to approximately 12% because solidification in pipe lines can occur above this concentration. Thus 12% concentration was selected as a nominal value for solidification operations in this process.

Testing with simulated boric acid waste solutions was performed at W/C ratios of 1 and 1.5 with 8, 10, 12, 14 and 16% boric acid solutions. The W/C ratio of 1 was selected as a starting point based on its current use at Beaver Valley. The ratio of 1.5 was investigated to obtain information concerning permissible range of deviation with respect to waste or cement feed rates. A range was used to investigate solidification qualities of boric acid solutions at concentrations other than 12%. It is unlikely that the boric acid concentration will ever be above 12%, however, the conservative approach requires testing in this range.

Results of boric-acid-cement solidification tests performed are presented in Table 1A. Note that for a W/C ratio of 1, good solidification results were achieved within five days for the entire range of boric acid concentrations tested. Except for the 8% boric acid test, no free water was observed on any sample at the end of one day. Water in the 8% sample was gone at the end of two days. In terms of resistance to penetration with a sharp object, there was little or no difference between the 8, 10, and 12% concentrations at the end of five days and again at three weeks. Resistance to penetration could perhaps be described as fair at five days and good at three weeks. The 14 and 16% concentrations were less resistant to penetration.

Test specimens with a W/C ratio of 1.5 showed somewhat the same results as did the samples with a ratio of 1 with respect to the presence of free water. No free water was observed on any sample at the end of one day, except for the 8% concentration. This water was gone at the end of two days. At the end of five days all samples showed much less resistance to penetration than did the samples with a W/C ratio of 1. Solidification characteristics continued to improve with time, however, could not be described as good at any time within the three week test period. Resistance to penetration can be described as very poor at the end of five days and poor to fair at the end of three weeks. There was little if any difference in resistance to penetration damage (at five days or three weeks) for any of the boric acid concentrations tested (8, 10, 12, 14 and 16%) with a W/C ratio of 1.5.

PROCESS CONTROL PROGRAM (continued)

As a confirmatory test, two large-scale tests were performed to determine if results would vary when sample volume was increased. Total weight of each sample in this case was about 10 lbs. vs 0.5 lbs. for the samples previously tested. A W/C ratio 1 was used at boric acid concentrations of 12 and 14%. After mixing, the samples were covered with Saran Wrap to eliminate evaporation from consideration in checking for free water. As with the previous tests, there was no indication of free water at the end of one day. The samples were inverted with negative results to check for water. Both samples could be easily penetrated with a pencil point at the end of three days, however, were starting to solidify at the end of five days. As might be expected, these samples behaved as did the small-scale samples.

III. RESIN SOLIDIFICATION TESTS

Resin slurries constitute one of the waste forms that are solidified at Beaver Valley. In forming the slurry, the resin to water ratio is controlled by draining the waste resin hold tank and then adding water to about 4-5 inches above the resin level. Using this resin-water ratio, solidification operations are performed with a W/C ratio of about 1.7. For high water, low resin slurries, solidification operations are performed with a W/C ratio of about 1. Good solidification results are achieved in either case.

Testing with simulated resin waste solutions was performed at W/C ratio of 1, 1.25, 1.50 and 1.75. A range of resin-water mixtures was investigated in this work. Test conditions include the use of mixed bed resin and cation resin to simulate waste forms as occur in the plant. Rohm and Haas IRN-150 was used for the mixed bed resin. This consists of a chemically equivalent mixture of IRN-77 (strong acid) and IRN-78 (strong base). IRN-77 was used for the cation resin. All samples were covered with Saran Wrap after mixing with water and cement to eliminate evaporation from consideration in checking for free water.

Results of the resin solidification tests are presented in Table 2A. There was no indication of free water at the end of the first day in every test that simulated the ratios used in plant solidification operations. One test that was outside this range (No. 1) showed some indication of free water for two days, however, was dry on the third day. All concrete samples except No. 1 were hard by the fourth day. Test No. 1 was fairly resistant to penetration with a sharp object on the fourth day. Results of the resin solidification tests described here can be summarized by stating that all samples tested (including No. 1) met the required end conditions for shipment off-site.

PROCESS CONTROL PROGRAM (continued)

IV. CEMENT FEED CALIBRATION

Cement feed rate during solidification operations at Beaver Valley is held as a constant with a dial setting of 5. The vendor literature does not include data concerning reproductibility of the cement feeder so a calibration test was performed to obtain this information. The data is as follows:

Dial Setting	Cement Feed Rate for Three Runs (lbs/min.)		
4	28	28	28.4
5	34.5	34.5	34.5
6	45	45	45.3

The variation obtained in these runs will have no significant effect on W/C ratios obtained during solidification operations. In fact, a considerable wider latitude could be tolerated without problem.

PROCESS CONTROL PROGRAM (continued)

V. CONCLUSIONS AND RECOMMENDATIONS

A. EVAPORATOR BOTTOM WASTES

Results of the laboratory test presented in Table 1A indicate that a W/C ratio of approximately 1 (currently in use at Beaver Valley will achieve the required end product of good solidification with no free water present. While W/C ratio of 1 is recommended as a goal, a range of 0.9 to 1.1 should be specified in the operating procedures to provide for the minor deviations that can occur in the feed rate of cement or radioactive wastes. The data indicates that a plus deviation can be tolerated without problem while a minus deviation in the W/C ratio would improve solidification characteristics of the evaporator bottom-cement mixture.

B. RESIN WASTES

Results of the laboratory tests presented in Table 2A indicate that good solidfication will be achieved with a W/C ratio of 1.25 to 1.75 for wastes with a high resin content. For low resin content wastes, good solidification will be achieved with a W/C ratio of 1 to 1.5. Waste-to-cement ratio of about 1.7 for the high resin content and 1 for the low resin content are currently used for solidification at Beaver Valley. Good solidification results have been achieved, therefore, it is recommended that these ratios be maintained. The procedure should be modified to indicate that a deviation in these ratios can be tolerated.

TABLE 1A

BORIC ACID SOLIDIFICATION TESTS

% Boric Acid In Solution	Waste to Cement Ratio W/C*	Results At End Of Day 1	Day 2	Day 5	Day 21
				(Resistance to Penetration)	
8	1	Free Water	No Water	Fair	Good
10	1	No Water	No Water	Fair	Good
12	1	No Water	No Water	Fair	Good
14	1	No Water	No Water	Fair to Poor	Good to Fair
16	1	No Water	No Water	Fair to Poor	Good to Fair
8	1.5	Free Water	No Water	Poor	Fair
10	1.5	No Water	No Water	Poor	Fair
12	1.5	No Water	No Water	Poor	Fair
14	1.5	No Water	No Water	Poor	Fair
16	1.5	No Water	No Water	Poor	Fair
12**	1	No Water	No Water	Fair	--
14**	1	No Water	No Water	Fair	--

*Total weight of sample 0.5 lbs

**Total weight of sample 10 lbs

TABLE 2A

RESIN SOLIDIFICATION TESTS

Test No.	Dry Resin Volume (ml); M-B Form	Dry Resin Volume (ml); Cation Form	Total Volume With Water (ml)	Waste to Cement Ratio W/C	Results At End Of Day 1	Day 2	Day 3	Day 4 (Resistance to Penetration)
1	100	–	130	1.75	Free Water	Free Water	No Water	Fair
2	100	–	115	1.75	No Water	No Water	No Water	Good
3	100	–	130	1.50	No Water	No Water	No Water	Good
4	100	–	115	1.50	No Water	No Water	No Water	Good
5	100	–	130	1.25	No Water	No Water	No Water	Good
6	100	–	115	1.25	No Water	No Water	No Water	Good
7	10	–	100	1.50	No Water	No Water	No Water	Good
8	10	–	100	1.25	No Water	No Water	No Water	Good
9	10	–	100	1.00	No Water	No Water	No Water	Good
10		200	230	1.75	No Water	No Water	No Water	Good
11		100	115	1.50	No Water	No Water	No Water	Good
12		100	115	1.25	No Water	No Water	No Water	Good

M-B = Mixed bed form IRN-150
Cation Resin = IRN-79