OPERATIONAL EXPERIENCE WITH VOLUME REDUCTION AND BITUMEN SOLIDIFICATION AT CLINTON POWER STATION

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ABSTRACT

Experience with the Clinton Power Station (CPS) solidification program for wet low-level radioactive wastes is presented. Illinois Power Company's only nuclear facility, a General Electric Company boiling-water-reactor (BWR) facility, utilizes the Associated Technologies, Incorporated (ATI) Transportable Volume Reduction and Bitumen Solidification System (TVR-III). This work summarizes results of a six month effort by a utility-consultant-vendor team. For those six months of system operations during 1987 IPC, RLD, and ATI personnel collaborated in an effort to improve system performance and analyze performance data. During the period, wastes from all five primary wet waste streams (spent bead resin, concentrate wastes, primary cleanup loop sludges, fuel pool and suppression pool cleanup sludges, and waste filter sludges) were processed using the TVR-III system. The authors present interpretations of their experience in three primary areas of interest--quality control, waste characterization, and volume reduction.

BACKGROUND AND SYSTEM DESCRIPTION

Plant Description

Clinton Power Station (CPS) is a single-unit 985 MWe General Electric boiling-water reactor (BWR) facility which began operating in 1987. The station is located in central Illinois and is the only nuclear facility operated by Illinois Power Company (IPC). The power plant is equipped with deep-bed condensate polishers. The primary coolant cleanup equipment is of the pre-coat design using combined filter/demineralizer media.

Wet wastes at CPS have been separated into the following principal streams:

SR = spent (bead) resins (condensate and radwaste)

CW = concentrate wastes (evaporator bottoms)

PS = phase separator filter/demineralizer sludges

FS = fuel pool filter/demineralizer sludges

WS = waste sludges (radwaste filter sludges)

The spent bead resins (SR) from both the condensate polisher system and the radwaste demineralizers are discharged into a single spent resin tank. Condensate polishers are not chemically regenerated; they are discharged from service when effluent conductivity values exceed prescribed limits. The radwaste demineralizer beds are chemically regenerated. These beds are discharged from service when they fail to rinse to quality specifications after two successive regeneration attempts.

Concentrate wastes are collected in one of two concentrate waste holding tanks. The tanks are maintained in a heated and agitated condition to prevent either settling or crystallization.

Spent primary coolant cleanup filter/demineralizer pre-coat material is discharged to one of two phase separators. The sludges are retained in the phase separator vessels to allow for decay of short-lived radionuclides.

Spent fuel pool cleanup filter/demineralizer pre-coat material is discharged to one of two fuel pool filter/demineralizer sludge tanks. Although called the fuel pool filter/demineralizer sludge tanks, these vessels also receive filter/demineralizer sludge from the cleanup of suppression pool water.

Spent radwaste filter pre-coat material is discharged to one of two waste sludge tanks. The radwaste filters are normally charged with a filter aid material. However, these filters are occasionally charged with varying combinations of filter aid, powdered ion exchange media, and activated carbon.

Solidification System Description

All wet waste solidification to date at CPS has been performed using the services of Associated Technologies

Incorporated (ATI). The vendor services are provided by means of an on-site transportable volume reduction and bitumen solidification system--TVR-III. By design, the TVR-III system produces solidified waste product in 55-gallon drums. These services have been used for all of the five wet waste streams previously described.

The solidification system is located in the radwaste shipping bay. Interfaces include electrical connections, water connections, and a waste delivery valve and manifold arrangement. A typical delivery configuration is presented by the schematic drawing of Fig. 1.

Typically the plant waste holding tanks are of the order of a few thousand gallons in processing capacity. This is contrasted with the relatively small capacity (approximately 300 gallons) of the TVR-III waste processing tank. Pretreatment and concentration adjustments take place in the TVR-III waste processing tank prior to metering the waste to the thin film evaporator. Water is removed from the waste as it travels down the walls of the evaporator. The resultant waste solids commingle with the bitumen and exit the evaporator bottom into 55-gallon drums.

Operating temperatures are such that both sluice water and chemically bound water are removed from waste materials. That is, the temperatures are sufficiently high to break down bead resin and release the water which is part of the normal bead structure. The distillate from the process is condensed and collected separately.

The TVR-III system has an average evaporative capacity of about 36 gallons per hour with a maximum capacity of about 58 gph. The normal TVR-III staffing during solidification is two operators.

Because of the time and cost involved with the analysis of each batch of waste to be processed, it is beneficial to define a batch as the largest possible volume. With this in mind, the CPS waste holding tanks are used to define a waste batch. The various holding tanks can be isolated with minimal negative impact on plant operations.

When using the TVR-III system, a plant holding tank is isolated and defined as a batch. A relatively small portion of the isolated batch is then transferred to the TVR-III system for processing. The plant holding tank is maintained in the isolated condition while the TVR-III tank is

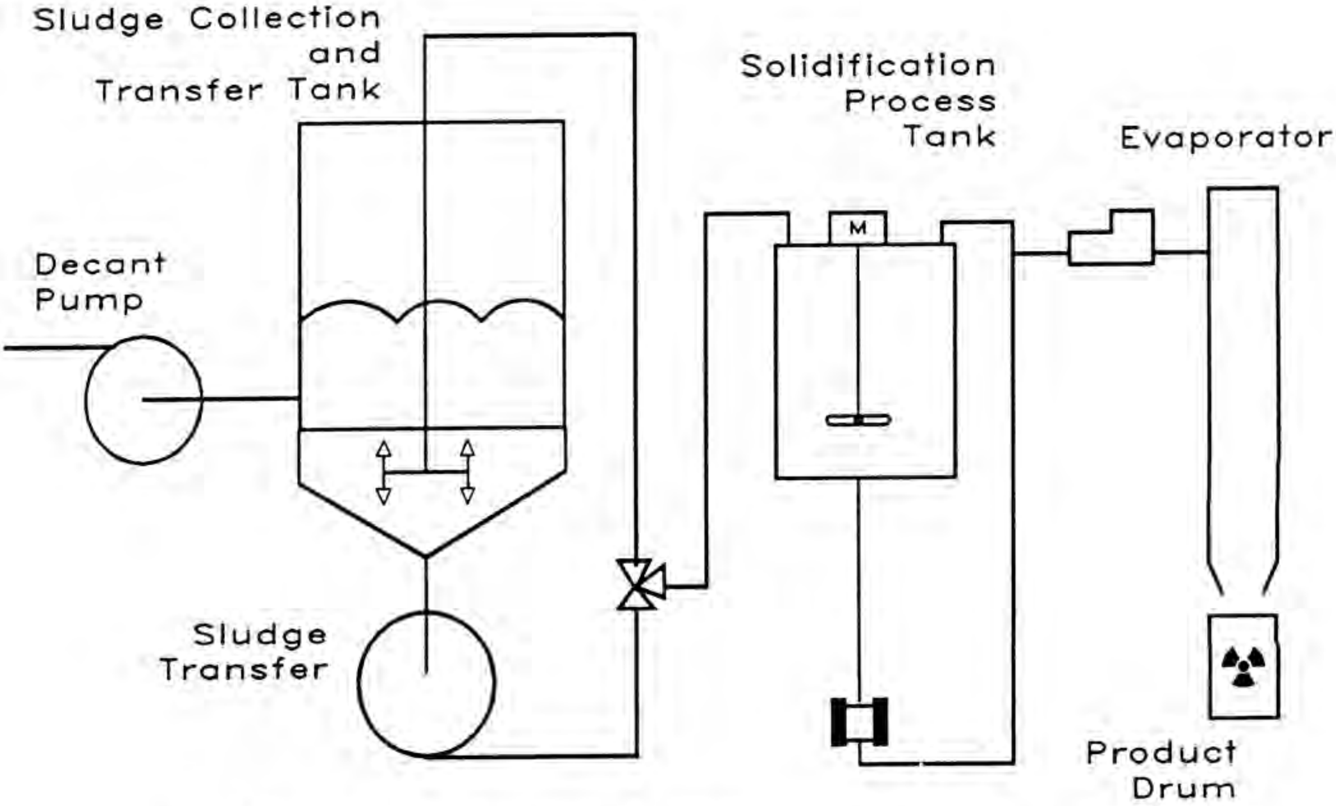

Fig. 1. Typical Operating Configuration for CPS Waste System and Solidification System.

processed. Then, another transfer to the TVR-III tank is made. The sequence is repeated several times until the entire isolated batch has been processed.

Typical chemistry parameters which must be determined for waste processing include the following:

- for slurry wastes (resins and sludges):

pH

weight fraction dry solids

radionuclide concentrations

volume fraction settled solids

- for concentrate wastes:

pH

density

sulfate concentration

weight fraction dry solids

radionuclide concentrations

reducing agent concentration (normality)

OPERATIONAL EXPERIENCE

In the remainder of this paper, the authors will describe their experiences with operations of the TVR-III system at the Clinton Power Station (CPS) through the end of 1987. Throughout the period of service, CPS has produced only 10 CFR Part 61 (1) Class A wastes not required to be stabilized by either federal or disposal site criteria. Therefore, this paper will not discuss any additional processing details which might be required to meet the more stringent stability requirements for Class B and Class C wastes.

The paper has been divided into three major subject areas. The first deals with quality control. The second section explains the approach taken to meet the various regulatory requirements related to waste characterization. The third section discusses the volume reduction experience resulting from the use of the TVR-III at Clinton Power Station.

QUALITY CONTROL

Introduction

The Clinton Power Station (CPS) quality control program for contractor on-site solidification operations involves the following elements:

1. processing wastes in accord with an established and NRC approved Process Control Program (PCP)
2. maintaining waste batch information and drum information records to fully document proper processing and packaging
3. tracking wastes from source to drum to assure knowledge of disposal package contents and application of correct processing
4. monitoring and trending of various processing parameters to assure prompt observance of deviations from normal
5. conducting all activities according to written policies, practices, and procedures.

A detailed discussion of all aspects of the overall quality control program is beyond the scope of this paper. Selected specific aspects, related to the subject of this paper, are discussed in this section.

Records

Specific information collected as part of the solidification quality control program tend to be associated either with the waste batch or with the drums produced. Accordingly, records are separated along those two subject lines.

The batch information records include data related to the following elements:

- waste batch holding tank identification
- sequential fill number for waste processing tank
- volume of waste delivered to the TVR-III system
- volume of decant returned to CPS
- analytical results for each waste batch
- analytical results for each fill of the ATI tank
- process control information
- distillate total organic carbon (TOC) content
- bitumen certification sheets

The drum information records include data related to the following elements:

- identification number for each drum
- waste stream contained in each drum
- amount of waste processed into each drum
- weight of product in each drum
- surface dose rate of each drum
- percent filled volume for each drum

PARAMETER MONITORING

The records described in the prior paragraphs provide the input data for analysis and interpretation. Using the records data base, monitoring and trending was established for the following parameters:

- batch radionuclide composition
- drum weight
- drum surface dose rate
- drum loading (amount of waste in drum)
- drum percent filled
- distillate TOC
- volume of waste processed
- volume of decant returned

In this section specific monitoring and trending techniques are presented with their meanings and examples.

Batch radionuclide composition monitoring, while simple to employ, provides several items of quality control information. This single technique is used to simultaneously document the following:

- verification of batch isolation integrity
- verification of reproducibility of waste transfers
- verification of representativeness of waste sampling
- identification of minimum number of batches requiring
- complete 10 CFR Part 61 analyses

Benefits of the method include the following:

- control of sample size is not required
- sample treatment is not required
- instrument (efficiency) calibration is not required analysis of results is relatively simple

Typical results for successive fills of the TVR-III processing tank are presented in Table I. This table includes results from all seven transfers from one isolated batch (called batch 03E) of waste sludge processed during August, 1987.

The consistency of the composition results over the ten-day processing period provides strong evidence for the plant capability to: maintain batch isolation; execute reproducible transfers of waste to the TVR-III system; and, collect representative samples. The power of the method rests in the fact that a variance in the percent solids transferred is not important. What is important is that the solids which are transferred to the processing tank represent essentially "the same" waste throughout the processing of the batch.

The continued batch radionuclide monitoring during the entire solidification campaign has led to other well documented results. For example, essentially all (that is, 99%) of the radioactivity is found in the solid phase of the samples. Although somewhat expected for spent resin and other slurry wastes, this result was not as expected for concentrate waste samples. It will be interesting to discover if this situation continues with time.

Drum weight monitoring was successfully used to discover a problem with the drum weighing equipment installed in the TVR-III system. Although variances in drum weights are expected, the drum weights for a given waste stream are not expected to change abruptly during the processing of a single batch. By plotting net drum weights for each waste stream separately, one can observe any such abnormality.

The successful use of drum weight monitoring is demonstrated by the results presented in Fig. 2 and Fig. 3.

TABLE I

Results of Radionuclide Assay (Fractional Composition) for Waste Sludge (WS) Samples From One Isolated Batch

Sample/Date	Cr-51	Mn-54	Fe-59	Co-58	Co-60
03E 07AUG87	.66	.13	.11	.08	.03
03E1 09AUG87	.63	.19	.08	.07	.03
03E2 11AUG87	.62	.20	.08	.07	.02
03E3 12AUG87	.64	.17	.08	.07	.03
03E4 13AUG87	.62	.21	.07	.07	.02
03E5 14AUG87	.66	.15	.09	.07	.02
03E6 15AUG87	.66	.16	.08	.07	.03
03E7 16AUG87	.61	.21	.08	.07	.02
Averages	.64	.18	.08	.07	.03

The figures present results from two different drum weighing methods. The results labeled "TVR" were obtained using the equipment installed in the TVR-III system. The results labeled "CPS" were obtained using the plant radwaste crane and a dynamometer.

The prior discussion focused on only two examples of the successful application of various monitoring and trending techniques. Similar trending of the waste loading into drums provides information related to the volume reduction of the process. This is considered in more detail in a later section of this paper.

Drum percent filled monitoring provides a rapid and easy method for assuring compliance with the disposal site requirements. In this case, monitoring is as simple as scanning a column of numbers.

Distillate TOC monitoring provides data necessary to make an informed judgement concerning acceptability of distillate for return to the plant.

The volume of waste processed and volume of decant returned, taken together, provide information related to how efficiently the plant is delivering waste to the service vendor. Higher volumes of returned decant indicate utilization of the service vendor for decanting of the waste streams. Although the TVR-III system provides the flexibility to accept varying concentrations of solids in the wastes, use of the system for decanting is not usually cost effective.

WASTE CHARACTERIZATION

Introduction

As previously stated, all solidified wet waste produced to date at CPS has been 10 CFR Part 61 (1) Class A with respect to radionuclide concentrations. Nevertheless, 10 CFR Part 20.311 (2) requires a reasonable effort be expended towards the end of identifying and quantifying the radionuclides which are present in the waste.

Prudent operations calls for a well documented characterization of a minimum number of distinct wet waste streams. Each waste stream must be characterized with respect to radionuclide composition. If the radionuclide composition changes beyond defined bounds, then the waste stream must be considered as having changed.

If a waste stream is determined to have changed, then the licensee is obligated to expend the funds and resources required to perform the so-called "10CFR61" analyses. This usually involves sending samples to a contractor laboratory

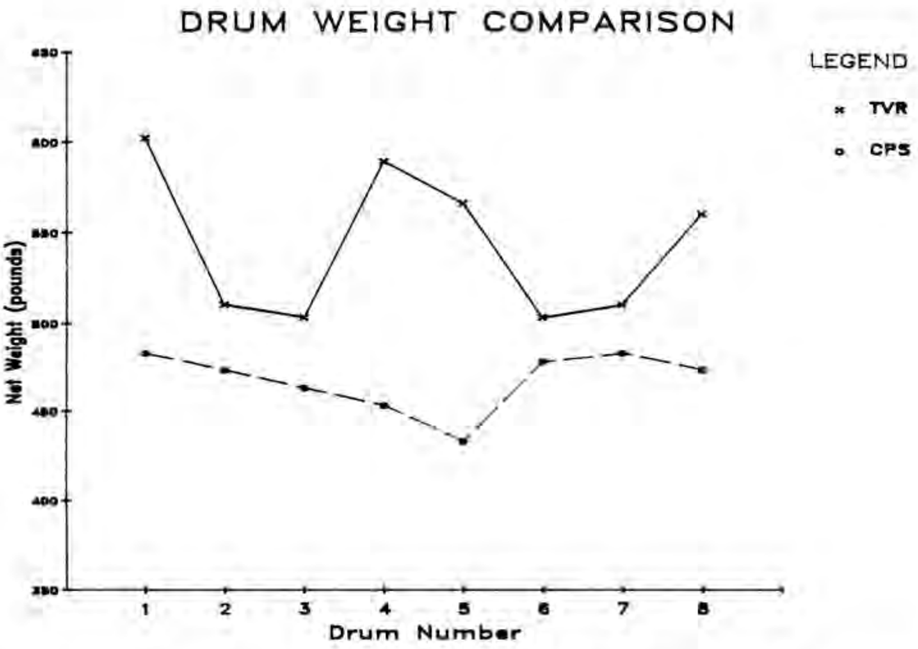

Fig. 2. Drum Weights by Two Different Methods Prior to Correction of Weighing Equipment Problem.

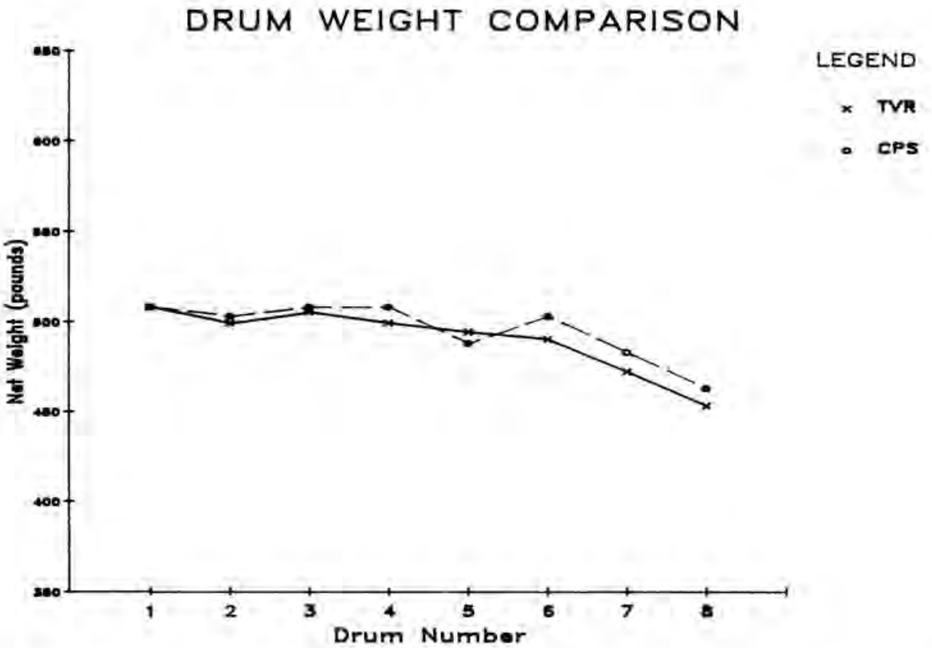

Fig. 3. Drum Weights by Two Different Methods After Correction of Weighing Equipment Problem.

for analysis to determine the quantities of "difficult-to-measure" radionuclides and transuranic radionuclides.

The start-up plant challenge is to define a reasonable program without exceeding the bounds of common sense with respect to the resources, time, and effort spent on sampling and analysis. This section describes the CPS approach towards meeting the combined compliance-prudency goal.

Definition For Change In Composition

A decision criterion was defined for determining when a wet waste stream had changed in composition. The criterion was defined in accordance with the NRC Branch Technical Position on waste classification (3) which states that radionuclide concentrations are reasonably determined if accurate to within a factor of ten. The criterion is represented by the following inequality:

$$0.10 \text{ X } R(\text{reference}) \leq R(\text{test}) \leq 10. \text{ X } R(\text{reference})$$

where:

R(reference) = the ratio of the fractional composition of the two most prominent radionuclides in the reference batch(es) of waste (with the larger value as the numerator)

R(test) = the corresponding ratio for the same two radionuclides in the waste batch being tested for possible change in composition

As an example application of the decision criterion, results are presented in this work for all waste sludge processed. The reference ratio for this waste stream was determined from all batches processed between July, 1987 and November, 1987. (Similar results were obtained for the other waste streams.) The determined fractional radionuclide compositions representative of the waste sludge batches are presented in Table II.

Prior to use, the population extremes from the data set of Table II were tested to ensure that those extremes were within the limits of the decision criterion. As can be verified from the data, the extreme ratios ranged from a minimum of 1.9 to a maximum of 8.1. These are to be compared with the reference ratio of 4.4 (.69/.16).

As long as a subsequent batch of waste sludge has the same two most prominent radionuclides with a corresponding ratio which falls within the decision criterion limits, one can conclude that the radionuclide composition has not significantly changed for the purposes of 10CFR61.

VOLUME REDUCTION

Definitions

Traditionally, volume reduction (V/R) has been defined a number of ways. When investigated in detail, one is likely to discover that different definitions are used for

TABLE II

Waste Sludge (WS) Fractional Radionuclide Composition

Batch	Cr-51	Mn-54	Fe-59	Co-58	Co-60
01E	.64	.12	.13	.08	.03
02E	.65	.09	.14	.08	.03
03E	.64	.18	.08	.07	.03
04E	.64	.19	.07	.07	.03
05E	.60	.19	.07	.07	.07
06E	.68	.17	.06	.06	.03
07E	.78	.12	.04	.04	.02
08E	.79	.12	.04	.04	.02
09E	.81	.10	.04	.03	.02
10E	.78	.13	.04	.03	.02
11E	.79	.11	.04	.04	.02
12E	.76	.14	.04	.04	.02
13E	.66	.20	.05	.05	.03
14E	.64	.20	.06	.06	.04
15E	.54	.28	.05	.07	.04
avg.	.69	.16	.06	.06	.03

different purposes. Although such individual definitions might make sense in isolation, the differences among the definitions make it difficult, if not impossible, to directly compare the performance of different processes.

For example, the V/R for de-watering of bead resin wastes has been listed as 1.0, exactly. The reasoning being that the de-watering process neither adds volume to nor removes volume from the waste. The key assumption here is that the "waste" is implicitly defined as de-watered resin. If one were to define the "waste" as the resin-water slurry which exists in the plant, then the V/R for de-watering would be greater than unity. Such a definition, however, does not account for any secondary waste generation resulting from the return to the plant of the decant waters.

Much of the confusion arises because of a lack of consensus concerning how one is to measure the "volume" of a two-phase sample such as a resin-water slurry. Variations include measuring the "total" volume (at the top of the water phase), measuring the volume at the interface between the liquid and settled solid phase (assuming satisfactory settling occurs), measuring the volume of the wet solid phase (after draining away all liquid), and measuring the volume of the dry solid phase (after draining away the liquid and drying the solid).

Resolution of this situation is clearly beyond the scope of this work. The need for resolution is, nevertheless, apparent.

For this work, the following definition of volume reduction (V/R) is used:

V/R = Volume Processed / Disposal Volume

where:

Volume Processed = the total volume of waste slurry (solids and water) fed to the evaporator during processing of a single isolated batch

Disposal Volume = the total container volume of all drums filled during the processing of the same isolated batch

As indicated, the definition is applied on a batch basis. The batch application avoids the sometimes meaningless results one would obtain by considering certain individual drums in isolation.

Just as for de-watering, this definition of V/R does not consider any effect of decant returned to the plant. Using this definition, the process V/R can be greatly influenced by the concentration of solids in the evaporator feed. That is, a higher V/R is obtained when feeding a more dilute waste to the evaporator. (If one is interested in comparing the V/R provided by different processes, the comparison must be made using a defined concentration of solids in the waste feed.)

Similarly, the definition of V/R used in this work does not consider the impact of distillate returned to the plant. Initially, any potential impact of distillate return on process V/R was not considered because high quality distillate (suitable for use as cycled condensate) was expected. This has not turned out to be the case because of higher than expected concentrations of total organic carbon (TOC) in the distillate. Investigation is in progress to determine how to assure distillate quality limits are achieved. (When comparing processes, one must consider the effect of distillate returned to the plant.)

Again, it is not the purpose of this work to compare the V/R of various processes. Rather, the purpose of the present work is to share operational experience with one process at a particular operating plant. For this purpose, the working definition previously provided meets the need. The results described in the following paragraphs are typical of the processing conducted at CPS during 1987.

RESULTS

Table III presents the achieved volume reduction (V/R as defined earlier) for those three waste streams for which only a single batch was processed during 1987.

TABLE III

Volume Reduction (V/R) for Three CPS Waste Streams

Waste Stream	Batch ID	Volume Processed	Disposal Volume	V/R
FS	01F	3098	1155	2.7
PS	01G	3315	1045	3.2
CW	01H	1532	385	4.0

The corresponding results for the other two waste streams are presented in Table IV and Table V, respectively. In preparing the data for presentation, drums containing wastes from more than one isolated batch (transition drums) were excluded. Data from the first nine batches of spent resin wastes were also not analyzed because almost all of those drums were transition drums.

duced during calendar year 1987 at CPS. Using the disposal volume of 7.5 cubic feet per drum, this corresponds to a total disposal volume of 3112.5 cubic feet for solidified wet wastes. Table VI presents a disposal volume breakdown by waste stream together with the total for all solidified wet wastes. The contribution of the various wet waste streams to the total is expected to change as the plant matures.

The total quantity of solidified wet waste produced during the first year of operations at Clinton Power Station is much lower than one would expect. The amount is only about one third of the median volume produced by fresh water BWR plants from 1977 through 1985 (4). (To date, neither distillate waste oil nor spent distillate purification media have been discharged as waste. Although minor volume contributors, these wastes will add to the volumes of solidified wet wastes which are shipped for disposal.)

Even allowing for waste oils and spent purification media, the volume of solidified wet wastes produced during the first year of operations at CPS is far less than that produced by other recently started BWR facilities, such as Susquehanna and LaSalle County. In their first year of

TABLE IV

Volume Reduction for CPS Spent Resin (SR) Wastes

Waste Stream	Batch ID	Volume Processed	Disposal Volume	V/R
SR	10I	993	440	2.3
	11I	708	385	1.8
	12I	1106	495	2.2
	13I	988	495	2.0
	14I	725	385	1.9
	15I	1321	550	2.4
	16I	774	385	2.0
	17I	1352	605	2.2
	18I	1060	440	2.4
	19I	452	275	1.6
	20I	1076	715	1.5
	21I	625	330	1.9
	22I	1175	715	1.6
	23I	892	550	1.6
	24I	775	385	2.0
	25I	886	495	1.8
	26I	901	550	1.6
	27I	915	605	1.5
	28I	1047	660	1.6
		=====	====	===
Totals:		17771	9460	1.9

TABLE V

Volume Reduction for CPS Waste Sludge (WS) Wastes

Waste Stream	Batch ID	Volume Processed	Disposal Volume	V/R
WS	01E	1058	385	2.7
	02E	364	165	2.2
	03E	1302	495	2.6
	04E	312	110	2.8
	05E	1022	330	3.1
	06E	633	220	2.9
	07E	537	220	2.4
	08E	244	110	2.2
	09E	656	275	2.4
	10E	447	165	2.7
	11E	1048	330	3.2
	12E	443	165	2.7
	13E	752	385	2.0
	14E	358	220	1.6
	15E	663	385	1.7
	16E	306	110	2.8
	17E	1213	440	2.8
		=====	====	===
Totals:		11358	4510	2.5

TABLE VI

Volume of Solidified Wet Waste Produced at CPS in 1987

Amount	SR	CW	PS	FS	WS	WET
drums	250	7	22	21	115	415
cu. ft.	1875.0	52.5	165.0	157.5	862.5	3112.5
cu. m.	53.1	1.5	4.7	4.5	24.4	88.2

operations those plants produced 38,300 cubic feet and 7,800 cubic feet of solidified wet wastes, respectively.

It is interesting to consider what volume might have been produced had CPS not utilized a volume reduction service. The corresponding number of drums produced without any V/R can be calculated from the actual number of drums and the determined V/R for each waste stream. (The only assumption involved is that the early spent resin wastes were processed with an average V/R the same as those represented by the data of Table IV.)

Had there been no volume reduction (V/R = 1.0), the number of drums would have been 918. Had a technology been employed which adds to the volume of the solidified product, such as cement solidification, the number of drums would have been greater. If the overall V/R had been 0.75, the number of drums would have been 1377. If the overall V/R had been 0.5, the number of drums would have been 1836. These latter values for numbers of drums produced would yield disposal volumes more comparable to those experienced by other BWR plants.

SUMMARY AND CONCLUSIONS

Supporting quality control efforts have been more resource intensive than expected. The main reason was the incomplete understanding of data needs and recordkeeping requirements at the time of selection of the solidification service. Nevertheless, the benefits of the implemented monitoring and trending methods have become apparent.

Waste characterization techniques have been employed which both minimize analytical resource commitments and assure data integrity. A specific methodology for promptly identifying a change in the radionuclide composition of waste streams has been developed and implemented.

In comparison to not using the ATI service, utilization of the TVR-III at Clinton Power Station has provided significant reduction in the volume of solidified wet wastes sent for disposal. First-year volume reduction factors are higher than expected. The primary reason is the processing of wastes which contain lower concentrations of solids in comparison to the concentrations used in the original V/R projections.

REFERENCES

1. "Licensing Requirements for Land Disposal of Radioactive Waste," Title 10, U.S. Code of Federal Regulations, Part 61 (effec. January 26, 1983).

2. "Transfer for Disposal and Manifests," Section 20.311 in "Standards for Protection Against Radiation," Title 10, U.S. Code of Federal Regulations, Part 20, (effec. January 26,1983).

3. "Low-Level Waste Licensing Branch Technical Position on Radioactive Waste Classification," U.S. Nuclear Regulatory Position, May, 1983.

4. R. F. Coley, "Low-Level Radioactive Waste Generation Rates at Domestic Nuclear Power Plants -- 1982 through 1985 Update," in "Waste Management '87," Volume 3, Arizona Board of Regents, 1987.