TECHNICAL EVALUATION BY THE OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

Report Number: VRS-002

Report Title: 10 CFR 61 Waste Form Conformance Program for Solidified Process Waste Products Produced by a Waste Chem Corporation Volume Reduction and Solidification (VRS) System.

Originating Organization: Waste Chem Corporation, Paramus, NJ

Reviewed by: Technical Branch
Division of Low-Level Waste Management and Decommissioning (NMSS)

INTRODUCTION

Compliance with the regulatory requirements and recommendations for disposal of low-level radioactive waste would normally require detailed inspection at each licensee facility. To expedite determination of compliance, NRC has encouraged preparation of a Topical Report (TR) by each vendor for his particular packaging method or system. The TR approach provides a centralized national level of review with active participation by the States.

On May 30, 1986, WasteChem Corporation submitted (Ref. 1) its Topical Report for a formal NRC review. On August 5, 1986, it submitted (Ref. 2) Supplement No. 1, Biodegradation Test Results. Copies of the TR and Supplement were subsequently transmitted (Ref. 3) by NRC to the States of Washington and South Carolina. Consolidated comments and questions from NRC and the States were sent (Ref. 4) to WasteChem on November 5, 1986. WasteChem responses (Revision 1) were received (Ref. 5) by NRC on September 25, 1987. On December 16, 1987 WasteChem submitted Revision 2 of its Topical Report (Ref. 6).

This Technical Evaluation Report (TER) contains a detailed evaluation of the extent the generic waste processed by VRS can satisfy regulatory requirements on waste form.

SUMMARY OF TOPICAL REPORT

The TR documents the results of tests performed to demonstrate compliance with 10 CFR Part 61 criteria for asphalt-encapsulated waste forms produced by Waste-Chem Volume Reduction and Solidification (VRS) Systems.

A VRS system was used to prepare the following eight types of waste to simulate generic process wastes produced by commercial PWR's and BWR's:

$ Bead Resin
$ Precoat Filter Cake with Powdered Resin
$ Precoat Filter Cake with Diatomaceous Earth
$ Evaporator Concentrates - Neutralization Waste
$ Evaporator Concentrates - Floor Drain
$ Evaporator Concentrates
$ Decontamination Waste
$ Mixed Resin and Filter Cake Waste

Appendix A of this evaluation report contains information on the composition and preparation of the waste streams and the maximum evaluated waste-to-asphalt ratio.

The VRS system used is a heated extruder-evaporator (53 mm D). During operation, wet solid waste and ASTM-D-312 Type III asphalt (a high-viscosity, oxidized, petroleum based asphalt) are simultaneously fed to the system. Free water in the waste stream is evaporated and condensed in the extruder steam dome coolers and drained by gravity to a liquid waste collection system. The remaining waste solids are encapsulated into a molten asphalt matrix and are discharged from the system into waste containers.

The solidified waste products (listed above) have been tested in accordance with procedures recommended by NRC's 1983 Technical Position on Waste Form for compressive strength, radiation stability, biodegradation, thermal degradation, leach resistance, immersion and free liquid content. Test results were compared with the acceptance criteria recommended by th. Technical Position on Waste form.

REGULATORY REQUIREMENTS

The basic technical requirements for waste classification and waste characteristics are given in 10 CFR 61 Section 61.55 and 61.56, respectively (Ref. 7). The Technical Position papers and Regulatory Guides the NRC has issued provide guidance to aid in implementation of the regulations. The information provided in the Technical Position papers and Regulatory Guides are presented as recommendations. They are not legal requirements and, therefore, a vendor can offer alternatives.

WASTE CLASSIFICATION AND WASTE CHARACTERISTICS

The waste classification system (10 CFR 61.55) divides low-level wastes acceptable for near-surface disposal into three categories designated as Classes A, B, and C on the basis of the half-lives and concentrations of certain radionuclides. Class A wastes have the lowest concentrations of radionuclides and are required to meet only minimum waste form requirements. Class B wastes have higher concentrations and must also meet stability requirements. Class C wastes have even higher concentrations of radionuclides and besides meeting the requirements of Class B wastes must be disposed of with protection for an inadvertent intruder. The structural stability requirements for Classes B and C wastes currently are achieved by the use of high integrity container (HICs), by solidification of the waste, or by taking credit for the inherent stability of the waste.

The minimum requirements (10 CFR 61.56(a)) are intended to ensure operator safety during handling of the wastes. The stability requirements are intended to minimize subsidence effects in the disposal facility by maintaining gross physical properties and identity for a minimum of 300 years. Section 61.56(b) clarifies the meaning of stability and identifies several expected disposal conditions which the wastes must withstand: external load, moisture, microbial activity, radiation, and chemical attack with respect to Class C waste, barriers against inadvertent intrusion should have an effective life of at least 500 years.

TECHNICAL POSITION ON WASTE CLASSIFICATION

Section 61.55 of 10 CFR Part 61 contains two tables listing limiting radionuclide concentrations for three classes of wastes considered suitable for near-surface disposal. The classifications take into account the radiological hazard of the nuclides of concern and also provide for wastes containing mixtures of nuclides. Any licensee who transfers waste either to a land disposal facility or to a waste collector must classify the waste transferred. Any licensed waste processor who treats or repackages waste for disposal must also classify those wastes.

All licensees must carry out a compliance program to assure proper classification of waste. The objective of these programs is to ensure realistic representation of the distribution of radionuclides with the wastes. The program is expected to be more sophisticated for wastes containing higher concentrations of nuclides, as in waste Classes B and C, and for cases in which minor variations in process conditions could result in a change in classification or in which there is a reasonable chance that Class C limits might be exceeded.

In recognition of the difficulties in sampling and measurement, a reasonable target for accuracy is determination of concentrations to within a factor of 10. Concentrations may be determined by direct measurement, indirectly by correlation factors, by materials accounting by source, or by gross activity measurements.

TECHNICAL POSITION ON WASTE FORM

The 1983 Technical Position on Waste Form (Ref. 8) elaborates on the provisions of Section 61.56.

Class A wastes, having low concentrations of nuclides, do not have to be stabilized, but on disposal must be segregated from Classes B and C wastes. If

Class A wastes are solidified and segregated from Class B and Class C wastes, they need only be free-standing monoliths having a free liquid content no more than 0.5% by volume. If not segregated, such wastes must meet the structural stability requirements of Classes B and C wastes.

Classes B and C wastes are intended to maintain their gross physical properties and physical identity over a 300-year period. The demonstration of the required structural stability can be done by subjecting samples of the waste forms to a series of tests. The recommended tests include initial compressive strength, leach resistance to appropriate aqueous media, compressive strength after immersion in water, resistance to biological attack, radiation resistance and thermal cycling stability.

Stability can also be achieved through use of high integrity containers (HICs). These should also have a minimum life-time of 300 years. Tests to which HICs must be subjected include consideration of their mechanical strength, the impact of thermal loads, chemical and biological interactions with both the disposal environment and the contained waste, gamma and ultraviolet radiation, and the ability to withstand various handling tests.

EVALUATION

COMPOSITION OF WASTE FORMS TESTED

The composition of the eight waste types used by WasteChem are similar to the waste types for which some test data were developed by BNL (Ref. 10, Appendix A). However, waste stream formulations were provided (in the topical report) without providing any indications as to the range of their characteristics, i.e., concentrations of organic chemical constituents, within which acceptable waste forms can still be made. The maximum achievable waste/asphalt ratio is different for such waste type, and waste characteristics apparently depend on both waste feed stream chemistry and waste/asphalt ratio. This review and evaluation, therefore, apply only to the formulation listed in Appendix A of this Evaluation Report.

The pH's for the formulations were also not provided for most cases. The TR states that solidification of asphalt containing waste is not sensitive to pH. However, it was also stated that pH must be controlled to minimize corrosion of the process equipment (pp. 20 and Section A-3.2). It is therefore necessary to include such information and any other waste characteristics important to process control, equipment protection or waste product acceptability as part of the Process Control Plan (see discussion on page 15). (It is noted that in the revised report, it is stated that waste feed pH must be controlled to a value of 7 or greater to minimize corrosion of equipment.)

One constituent of particular concern is lubricating oil, present in simulated evaporator concentrates (PWR) and decontamination waste (BWR/PWR). Oils and organic solvents will generally soften asphalt waste forms; hence, some upper limit to oil and organic concentrations in the waste stream should exist to achieve an acceptable waste form product. The waste streams listed as approved in Table 1 of Appendix A of this report should not contain oils in greater concentrations than those listed for the respective waste streams tested in Appendix A.

MINIMUM REQUIREMENTS FOR WASTES, 10 CFR 61.56(a)

This section of the evaluation examines the adequacy of VRS products' waste characteristics.

Section 61.56(a) of 10 CFR Part 61 contains the minimum requirements for all classes of waste and are intended to facilitate handling at the disposal site and provide protection of health and safety of personnel at the disposal site.

(a) Packaging

As indicated in 10 CFR 61.56(a)(1), waste must not be packaged for disposal in cardboard or fiberboard boxes. The waste form is packaged in suitable waste containers (55 gallon steel drums) and thus satisfies the requirement.

(b) Liquid Waste

As required by 10 CFR 61.56(a)(2), liquid waste must be solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid. Liquid wastes are completely solidified in normal operation.

(c) Free Liquid

As indicated in 10 CFR 61.56(a)(3), free standing liquid in the solid waste shall not exceed 1% of the volume of the solid waste.

Free liquid content was determined in accordance with the method prescribed by ANS 55.1 "American National Standard for Solid Radioactive Waste Processing System for Light Water Cooled Reactor Plants," Appendix 2. No free liquid was found in any of the samples tested. This satisfies the requirement of no more than 1 percent by volume of free standing liquid.

(d) Reactivity of Product

As indicated in 10 CFR 61.56(a)(4), the waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.

The waste asphalt matrix produced does not appear to contain any substance capable of detonation or explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.

(e) Gas Generation

The waste asphalt matrix satisfies the requirement stated in 10 CFR 61.56(a)(5) because it does not contain or appear to be capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling or disposing of the waste form.

(f) Pyrophoricity

The waste asphalt matrix satisfies the requirement stated in 10 CFR 61(a)(6) because it does not contain materials which are pyrophoric as defined in 20 CFR 61.2.

(g) Gaseous Wastes

This provision (10 CFR 61(a)(7)) is not applicable to WasteChem's waste form which is either solid or solid containing less than the 1% by volume of free standing liquid.

(h) Hazardous Waste

Under the Resource Conservation and Recovery Act (RCRA), the U.S. Environmental Protection Agency (EPA) has jurisdiction over the management of solid hazardous wastes with the exception of source, byproduct, and special nuclear material, which are regulated by the NRC under the Atomic Energy Act (AEA). Low-level radioactive wastes (LLW) contain source, byproduct, or special nuclear materials, but they may also contain chemical constituents which are hazardous under EPA regulations promulgated under Subtitle C of RCRA. Such wastes are commonly referred to as Mixed Low-Level Radioactive and Hazardous Waste (Mixed Waste).

Applicable NRC regulations control the byproduct, source, and special nuclear material components of the Mixed LLW (10 CFR Parts 30, 40, 61, and 70); EPA regulations control the hazardous component of the Mixed LLW (40 CFR Parts 260-266, 268 and 270). Thus, all of the individual constituents of Mixed LLW are subject to either NRC or EPA regulations. However, when the components are combined to become Mixed LLW, neither agency has exclusive jurisdiction under current Federal law. This has resulted in dual regulation of Mixed LLW where NRC regulates the radioactive component and EPA regulates the hazardous component of the same waste.

Under Section 10 CFR 61.56(a)(8) waste containing hazardous, biological, pathegenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the non-radiological materials. The waste form consisting of ASTM-D-312 Type III asphalt plus the waste stream materials listed in Appendix A of this evaluation does not contain biological, pathegenic or infectious material, and thus satisfies these requirements of 10 CFR Part 61.

It should be noted, however, that the NRC Topical Report review of the Waste Chem VRS-002 bitimunization process asphalt did not address any applicable EPA requirements relating to hazardous solid waste for which the vendor or waste generator using the Waste Chem VRS-002 bitimuninization process for LLW may be legally responsible under RCRA.

STABILITY REQUIREMENTS OF 10 CFR 61.56(b)

The requirements in 10 CFR 61.56(b) are intended to provide stability of the waste. Stability is intended to ensure that the waste does not structurally degrade and affect overall stability of the site through slumping, collapse, or other failure of the disposal unit and thereby lead to water infiltration. Stability is also a factor in limiting exposure to an inadvertent intruder, since it provides a recognizable and nondispersible waste.

(a) Structural Stability

According to 10 CFR 61.56(b)(1), the waste form must maintain its physical dimensions and its form, under the expected disposal conditions such as weight or overburden and compaction equipment, the presents of moisture, and microbial activity, and internal factors such as radiation effects and chemical changes. The WasteChem product will be packaged in suitable containers, but no credit for stability will be taken for the containers. The evaluation for structural stability is presented below under recommendations of the 1983 Technical Position on Waste Form (Ref. 8 and 9).

(b) Free Liquid

During operation of the VRS system, free liquid in the waste stream is essentially completely removed. The requirement that free liquid be no more than 0.5% of the volume of the waste is satisfied.

(c) Void Spaces

Section 61.56(b)(3) of 10 CFR 61 states that void spaces within the waste and between the waste and its package must be reduced to the extent practicable.

Containers holding the processed waste form will be filled to 90% or more of capacity while the waste form is still fluid. Care is taken not to overfill the container or spill the waste. Void spaces within the waste and between the waste and the containers are, therefore, reduced to the extent practicable.

RECOMMENDATIONS OF THE 1983 TECHNICAL POSITION ON WASTE FORM

The general applicability of the 1983 Technical Position on Waste Form is discussed on page 3 of this evaluation report.

(a) Compressive Strength

For bituminous products, the 1983 Technical Position on Waste Form recommends that solidified specimens should have compressive strengths of at least 50 psi when tested in accordance with ASTM D1074. However, the State of Washington has since notified NRC that due to the State's (U.S. Ecology) plan on placing additional soil over completed trenches, review criteria for stability requirement for the State of Washington need to be modified to accommodate maximum burial depths of 55 feet, not 45 feet as was the previous criterion (Ref. 12). As a result of this change, the previous compressive test strength criterion of 50 psi has been changed to 60 psi.

Duplicate samples of each waste form were prepared from cylindrical, thin-wall aluminum sample molds nominally two inches in diameter by five and a half inches in length. The samples were chilled to reduce the adhesive bond between the specimen mold and the sample molds. After the molds were stripped away, test samples were cut to length by a high-speed saw to yield a length-to-diameter ratio of approximately 2. Compressive strength tests for the sample products were performed in accordance with ASTM D1074 as recommended by the Technical Position on Waste Form.

The compressive force applied to each sample was recorded at 10% sample deformation, and the corresponding strength of each was calculated based upon the original cross sectional area. The compressive strengths at 10% deformation ranged from 108 psi to 262 psi., all greater than the 60 psi strength currently specified for all waste from samples tested. It is noted that they are all higher than the 75.0 to 97.9 psi for samples of pure ASTM-D-712 Type III asphalt.

(b) Radiation Resistance

Duplicate samples of each waste form in their sample molds were exposed in cobalt-60 irradiator to a gamma field in two batches averaging 0.96 megarads per hour and 0.93 megarads per hour and cumulating 100.13 and 100.35 megarads, respectively. The compressive strength after irradiation ranged from 55.6 psi for 50% loaded Evaporator Concentrates (PWR) to 124 psi for 45% loaded Mixed Resin and Filter Cake Waste (BWR). The compressive strength of 55.6 psi for Evaporator Concentrates is less than the 60 psi requirement. Tests for compressive strength after irradiation exposure of 108 rads over a 239.9 hour period were repeated on December 10, 1987, for a gamma field of 0.418 x 106 rad/hr which was less intense than those reported in the May 30, 1986 report. Post irradiation compressive strengths of 220 and 270 psi were obtained for the two samples tested. This demonstrated that the 60 psi minimum compressive strengths could be maintained after irradiation.

(c) Biodegradability

The Technical Position on Waste Form (TPWF) recommends three levels of testing. The first two levels are primarily screening tests to determine resistance to biodegradation. If no fungal (as defined in ASTM G21) or bacterial (as defined in ASTM G22) culture growth is visible, the specimen waste forms are considered to have passed biodegradation resistance at the first level of the then recommended tests. No further testing for biodegrability is then required. On the other hand, if the waste forms fail the first level tests, the second level of test must be performed. This consists of washing the failed specimens with water and light scrubbing, extraction of surface contaminants with an appropriate organic solvent if necessary; air drying at room temperature, and repeating the G21 and G22 procedure. Waste forms are considered to have passed at the second level tests provided culture growth does not exceed a rating of 1 in G21 and no growth is visible in G22. In both cases, the specimen must show a compressive strength greater than 60 psi following the tests.

If failure at the second level occurs, the TPWP recommends that the biodegradation rates be determined by longer-term testing using the Bartha-Pramer method. (Ref. 13 and 14). Soils used in this test should be representative of those at burial grounds. Degradation rates determined from this level of testing are to be extrapolated for full-size waste form to 300 years. Waste forms pass this test if the extrapolation indicates that biodegradation will cause less than a 10 percent loss of the total carbon in the waste form. The minimum time recommended for the Bartha-Pramer testing is six months. No compression tests are required following this test.

Some G21 and G22 tests were conducted by Brookhaven National Laboratory on generic-type bituminized waste materials. Results from those tests (Ref. 9) indicated that bituminized waste forms were susceptible to fungal and bacterial growth.

Based on the BNL test results, and in accordance with the option defined in the 1983 Technical Positions, WasteChem elected to have Bartha-Pramer biodegradation rate tests performed on specimens in place of the ASTM G21 and G22 tests. Duplicate samples of each waste form were tested over a 26-week period with Hanford soil and with simulated Barwell soil. The test results were extrapolated to predict performance of 55 gallon drum waste forms after 300 years of burial. Total carbon loss over 300 years was projected to be from not measurable to .029% for Hanford soil and not measurable to .025% for Barwell soil. This was less than a 10 percent loss of the carbon in the waste form. Therefore, the recommendations for the TPWF on biodegradability were satisfied.

WasteChem did not perform post biodegradation compression tests on the specimen because no G21 and G22 tests were performed and because the specimens prepared for Bartha-Pramer tests were not cut for dimensions suitable for compression tests. However, degradation in compressive strength due to biodegradation is judged to be negligible since the projected total carbon loss was less than .029%, a much smaller loss than the 10% maximum allowed for by the TPWF.

(d) Leachability Index

The TPWF recommends that leach indices be determined in accordance with the procedure in ANS 16.1 (Ref. 15) for a minimum of 90 days and that the leach indices so determined should be greater than 6.

Data and analysis for immersion tests using deionized water and three nonradioactive tracers; cesium, strontium and cobalt were reported. All samples tested satisfied the TPWF recommendation. The leach index range was 8.07 to 13.76. The TPWF recommendation is therefore satisfied.

(e) Immersion Resistance

The TPWF, as modified by Ref. 9 letter to amount for an increase in burial depth at Hanford, recommends that solidified waste forms must maintain a minimum compressive strength of 60 psi as tested using ASTM C39 or ASTM D1074 following immersion in water for a minimum period of 90 days.

Data for immersion resistance of duplicate samples of waste forms tested by WasteChem indicate that samples from all waste streams have compressive strength exceeding 60 psi (range 73.9 - 250 psi) except for samples made with simulated Evaporator Concentrates - Neutralization Wastes (BWR). Testing for the latter samples, loaded between 30% and 60% solids was terminated due to product swelling and subsequent loss of compressive strength. The tests were repeated with samples loaded with 25% and 15% solids. The resulting compressive strength varied from 98 psi to 108 psi, which exceeds the 60 psi requirement.

If swelling occurs during the leach test, the calculation of a leach index is questionable. However, it is noted that original values of dimensions were used in calculating the leach index. Therefore, the leach index so obtained is conservative.

In summary, samples of all waste streams satisfied immersion resistance requirements. It is noted that for simulated Evaporator Concentrates-Neutralization Wastes (BWR), waste loading must be equal or less than 25% to satisfy the compressive strength requirement for post immersion compression testing.

(f) Thermal Cycle Resistance

Solidified waste forms should retain a minimum compressive strength greater than 60 psi after 30 thermal cycles between 60 Celsius and -40 Celsius as per ASTM B553. The post-thermal compressive strength of the samples tested ranges from 81.2 psi to 276 psi. The current criterion for thermal cycling resistance is therefore satisfied.

(g) Free Liquid

No free liquids were observed upon removal of the small scale waste forms from the sample molds. Furthermore, during destructive examination of a 55 gallon drum containing a bead resin waste form, no free liquids were detected. This demonstrates that the recommendation that waste specimens should have less than 0.5 percent by volume of the specimen as free liquids was satisfied.

(h) Full-Scale Specimen Tests Results

The 1983 TPWF recommends that test data from sections or cores of the full-scale products be correlated with test data from laboratory scale specimens. The full-scale WasteChem waste form is a 55-gallon drum containing a bead resin waste form.

A full size waste form (55 gallon drum) was produced from a bead resin feed to demonstrate that waste form properties are independent of waste form scale.

Correlation was demonstrated to the extent that all compressive strength values are well above the 60 psi minimum. No leaching index data for cut samples from a full-scale specimen were presented. However, the NRC staff do not anticipate that change in values of the leach index, if any, would be significant enough to have resulted in values below 6.

(i) Homogeneity

Data from four cut samples taken from different locations of the full-size 55-gallon drum containing bead resin showed compressive strengths ranging from 191 to 192 psi. After 90-day immersion in de-ionized water, the range was 172 - 182 psi. Homogeneity, therefore, was demonstrated in that all compressive strengths were well above the 60 psi minimum.

(j) Process Control Program

The report recommends that implementation of the stability guidance be achieved through a qualified process control program. Periodic demonstrations that the VRS system is functioning properly are recommended. The generic process control program provided by WasteChem appeared satisfactory except as noted below.

Instrument calibration should be performed periodically and at frequencies to be determined by WasteChem and the waste producer, and, based on actual experience, calibration may then be reduced to a less frequent basis.

The waste form has been qualified on the basis of maximum permissible waste loading. To ensure compliance with the stability requirements, the waste producer should provide accurate solids content data for each batch of waste based on the actual characteristics of each batch.

It is, therefore, necessary that a separate plant-specific Process Control Program be established for each waste producer. The plant-specific Process Control Program should be tailored to the characteristics of the producer's waste streams.

REGULATORY POSITION

In the evaluation of this WasteChem Topical Report, the NRC staff reviewed the waste form qualification test data for eight simulated waste streams to determine the waste forms' compliance with 10 CFR Part 61 criteria. This Topical Report dated August, 1986 is acceptable as a reference document for licensing asphalt-encapsulated waste forms produced by WasteChem's VRS systems subject to the following conditions:

1. The waste forms produced are limited to those wastes prepared from the reactants from which the test specimens were prepared and tested and specifically identified in this Topical Report.

2. The maximum waste loadings are as stated in Section A-3.3 of the Topical Report dated August, 1987 and in Table 1 Appendix A of this Evaluation Report.

3. Bitumen can exhibit creep flow under an applied load, thereby increasing the potential for trench instability if not sufficiently confined. The NRC recommends an administrative backfill procedure to ensure adequate confinement and to prevent creepflow. However, if the bitumen waste form is housed in high integrity containers (HICs) which by themselves can sustain the applied load in the disposal trench, the additional administrative backfill procedure will not be necessary.

4. The waste form shall be contained in 55 - gallon steel drums (if not contained in approved HICs).

5. The waste forms should be prepared using the procedures specified in the PCP. With the above limitations, asphalt-encapsulated waste forms produced by WasteChem's VRS system should be capable of meeting the waste form requirements of 10 CFR Part 61. Because waste streams produced at various nuclear power facilities vary, the licensee employing the VRS system must demonstrate that it is capable of following waste elements Process Control Program (above equivalent) and provide NRC with test results of solidified wastes which are representative of wastes produced by the system used.

REFERENCES

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2. WasteChem letter to USNRC (David N. Enegess of WasteChem to Malcolm R. Knapp of NMSS, USNRC) August 5, 1986.

3. USNRC letters to Department of Social and Health Services Washington State and to H. Shealy of South Carolina State June 26, 1986.

4. USNRC letter to WasteChem (K. Chang of USNRC to David N. Enegess of WasteChem) November 5, 1986.

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6. WasteChem letter to USNRC (William J. Klein of WasteChem to Michael Tokar of NMSS, USNRC) December 16, 1987.

7. Licensing Requirements for Land Disposal of Radioactive Waste, 10 CFR Part 61, Revised as of January 1, 1987.

8. Technical Position on Waste Form, Rev. 0. May 1983; Low-Level Waste Licensing Branch, Division of Waste Management, Nuclear Regulatory Commission, Washington, D.C.

9. Bowerman B.S., Swyler K.J., Dougherty D.R., Davis R.E. Siskind B., and Barletta R.E., An Evaluation of the Stability Tests Recommended in the Branch Technical Position on Waste Forms and Container Materials, NUREG/CR-3829, Brookhaven National Laboratory, March 1985.

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12. Letter State of Washington (Nancy P. Keiner, Department of Social and Health Services) to USNRC (Donald A. Nusshammer) December 9, 1985.

13. R. Bartha, D. Pramer, "Features of a Flask and Method for Measuring the Persistance and Biological Effects of Pesticides in Soils, Soil Science 100 (1), pp-68-70, 1965

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15. Measurement of the Leachability of Solidified Low-Level Radioactive Wastes, ANS 16.1, American Nuclear Society Draft Standards, April 1981.

APPENDIX A

COMPOSITION AND PREPARATION OF GENERIC WASTE FEED STREAMS AND WASTE-TO-ASPHALT RATIO OF WASTE FEED EVALUATED BY WASTECHEM AND REPORTED IN WASTECHEM TOPICAL REPORT VRS-002

1. Bead Resin (BWR/PWR)

Material	Weight Percent in Extruder Feed
$ Bead Resin	94.84%
$ Tracers	
Cesium Chloride	0.77%
Strontium Nitrate	1.47%
Cobalt Sulfate	2.92%

Preparation:

Rohm and Haas, Amberlite IRM-150 mixed bead resin in the hydrogen and hydroxide form were batch contracted with an aqueous solution containing cesium chloride, strontium nitrate and cobalt sulfate to yield the foregoing percentages of ionic salts captured on the active sites of the resin (assuming 100% exchange efficiency). The resins were then drained, rinsed with demineralized water and dewatered for feeding to the extruder-evaporator. At the foregoing percentages the resins are approximately 50% expended, thus reflecting expected operating conditions.

The above formulation was used for production of all small scale bead resin waste forms. Since the cost of these non-radioactive tracers can be appreciable, the 55 gallon drum of resin product was produced from Amberlite IRN-150 resins which were expended to approximately 36% with sodium chloride. Tracers were not required in the full scale (55 gallon) waste form since samples removed from this waste form were not tested for leach resistance.

2. Precoat Filter Cake with Powdered Resin (BWR)

Material	Weight Percent in Extruder Feed
\$ Powdered Resin	73.80%
\$ Tracers	
Cesium Chloride	1.16%
Strontium Nitrate	2.23%
Cobalt Sulfate	4.40%
\$ Crud	18.41%

Preparation:

Graver Ecodex P-202H precoat material was batch contacted with an aqueous solution containing cesium chloride, strontium nitrate and cobalt sulfate to yield the foregoing percentages of ionic salts captured on the active resin sites (assuming 100% exchange efficiency). At these conditions, the ion exchange resin component(s) were approximately 36% expended, which reflects expected operating conditions. The material was drained, rinsed with demineralized water and dewatered to its equilibrium moisture content at room temperature. Ferric oxide was then added to simulate crud loading on a dewatered precoat sludge.

Note: Ecodex P-202H is a powdered precoat material containing strong acid cation resin, strong base anion resin and cellulose fiber in the following respective proportions (by weight): 29.5% 37.5% and 33%.

3. Precoat Filter Case with Diatomaceous Earth (BWR)

Material	Weight Percent in Extruder Feed
\$ Diatomaceous Earth	76.27%
\$ Crud	19.25%
\$ Tracers	
Cesium Chloride	0.61%
Strontium Nitrate	1.58%
Cobalt Sulfate	2.29%

Preparation:

The foregoing materials were dry mixed, i.e., in their as-delivered state, and fed to the extruder-evaporator.

Notes: $ While the tracer materials are soluble salts which would not be present in any appreciable fraction in a thoroughly dewatered sludge, they would be present in a slurry feed as a dissolved solid and are included to simulate a slurry feed.

$ Ferric oxide was used to simulate crud.

4. Evaporator Concentrates - Neutralization Waste (BWR)

Material	Weight Percent in Extruder Feed
$ Water	68.87%
$ Sodium Sulfate	16.92%
$ Evaporator Concentrates - Floor Drain Waste (excluding tracers - see Section 4.3.5)	13.44%
$ Tracers	
Cesium Chloride	0.11%
Strontium Nitrate	0.22%
Cobalt Sulfate	0.44%

Preparation:

The foregoing solution/mixture was prepared and fed to the extruder-evaporator as a liquid. This solution simulates a chemical regeneration waste which has been concentrated by a conventional evaporator.

5. Evaporator Concentrates - Floor Drain Waste (BWR)

Material	Weight Percent in Extruder Feed
$ Water	84.88%
$ Sodium Silicate	0.64%
$ (tri) Sodium Phosphate	3.64%
$ Sodium Bicarbonate	5.15%
Material	**Weight Percent in Extruder Feed**
$ Magnesium Sulfate	2.35%
$ Calcium Chloride	2.90%
$ Tracers	

Cesium Chloride	0.06%
Strontium Nitrate	0.13%
Cobalt Sulfate	0.25%

Preparation:

The foregoing solution was prepared and fed to the extruder-evaporator as a liquid. This solution simulates a floor drain waste which has been concentrated by a conventional evaporator. The principal ionic species present in this waste was obtained from an actual analysis of floor drain waste at Niagara Mohawk's Nine Mile 1 plant. The analysis provided was a two month composite of floor drain concentrates samples. Samples were taken three times a week for the two month period.

6. Evaporator Concentrates (PWR)

Material	Weight Percent in Extruder Feed
\$ Sodium Borate	9.31%
\$ Water	89.68%
\$ Potassium Chromate	0.16%
\$ Calcium Chloride	0.16%
\$ Lubricating Oil #2 (10W30)	0.03%
\$ Tracers	
Cesium Chloride	0.10%
Strontium Nitrate	0.19%
Cobalt Sulfate	0.37%

Preparation:

The foregoing solution was prepared by neutralizing a 12 weight percent boric acid solution to a pH end point greater than 7 (for corrosion protection of the equipment). The balance of ionic and non-ionic materials was then added to yield the foregoing mixture. This mixture simulates a borated waste concentrate with races of chemicals present from cooling water system corrosion inhibitors, aerated drains, etc.

7. Decontamination Waste (BWR/PWR)

Material	Weight Percent in Extruder Feed
$ Water	72.66%
$ Rad Clean-8	25.78%
$ Hydraulic Oil (BANDO HD63)	0.42%
$ Lubricating Oil (150 OMALA)	0.42%
$ Tracers	
Cesium Chloride	0.11%
Strontium Nitrate	0.21%
Cobalt Sulfate	0.40%

Preparation:

The foregoing solution/mixture was prepared and fed to the extruder-evaporator as a liquid. This mixture simulates a decontamination solution which has been concentrated by a conventional evaporator.

Note: Rad Clean-8 is a proprietary decontamination agent produced by Epicor, Inc.

8. Mixed Resin and Filter Case Waste (BWR)

Material	Weight Percent in Extruder Feed
Bead Resin	45%
Powdered Resin	50%
Diatomaceous Earth	5%

Preparation:

Dewatered bead resin, dewatered powdered resin and diatomaceous earth mixtures prepared for other generic waste types were dry mixed in the foregoing proportions and fed to the extruder-evaporator.

The maximum ratio of waste-to-asphalt for each waste feed which has been demonstrated to meet 10 CFR 61 stability requirements is as follows.

Table 1 Maximum Waste-To-Asphalt Ratios of Waste Feed Evaluated by Wastechem

	Feed	Maximum Elevated Ratio of Waste-to-Asphalt in the End Product (by Weight)
1.	Bead Resin (BWR/PWR)	50/50
2.	Precoat Filter Cake with Powdered Resin (BWR)	25/75
3.	Precoat Filter Cake with Diatomaceous Earth (BWR)	55/45
4.	Evaporator Concentrates - Neutralization Waste (BWR)	60/40 - Class A waste only 25/75 - All waste classes
5.	Evaporator Concentrates - Floor Drain Waste (BWR)	45/55
6.	Evaporator Concentrates (PWR)	50/50
7.	Decontamination Waste (BWR/PWR)*	30/70
8.	Mixed Resin and Filter Cake Waste (BWR)	45/55

*The Rad Clean-8 decontamination agent is the only approved one for use with the Waste Chem VRS system.