THE COST IMPACT OF IMPLEMENTING 10CFR61

AN EQUIPMENT SUPPLIER'S PERSPECTIVE ON WASTE FORM QUALIFICATION

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ABSTRACT

A program is being implemented to formally develop data on the properties of asphalt-solidified radioactive waste forms produced by an extruder-evaporator Volume Reduction and Solidification (VRS™) System. The program is in compliance with the guidelines of the NRC's Waste Form Technical Position for 10CFR61. This paper presents the structure and costs of this qualification program.

INTRODUCTION

In mid-1983 the Nuclear Regulatory Commission formally issued two Low Level Waste Licensing Branch Technical Positions (BTP's) which provided guidance to the implementation of the waste classification system and waste form performance requirements established by 10CFR61. When 10CFR61 requirements became law in December 1983, all Class B and C waste and non-segregated Class A waste offered for burial had to conform to the stability requirements imposed by the BTP on Waste Form.

The consequence of these new requirements for all waste producers is that solidified waste forms and process control programs (PCP's) by which they are produced must be (re)qualified to assure that the stability requirements of 10CFR61 are satisfied. The new BTP on Waste Form requires an extensive analytical program to qualify Class B and C waste products and their PCP's. Specific waste form performance tests include compressive strength, radiation resistance, resistance to bacterial and fungal attack, leach resistance and resistance to thermal degradation. Given the scope and level of sophistication of the foregoing tests, the costs associated with this aspect of implementing 10CFR61 can be appreciable for waste generators with multiple process waste types; i.e. bead resins, powdered resins, sulfates, etc.

This document examines the scope of and *estimates costs for* implementing a generic waste form qualification program for nuclear power plants which utilize a WasteChem Volume Reduction and Solidification System.

PROGRAM STRUCTURE

The Branch Technical Position (BTP) on Waste Form provides specific guidance regarding the number and types of tests to be performed on simulated waste forms. However, much latitude is provided in the areas of generic waste characterization, selection of analytical test procedures and general program implementation. Therefore, total program costs are largely influenced by decisions regarding the number and type of waste forms to be tested, the number of samples of each waste form to be tested, selection of analytical procedures, etc. The principal program cost elements identified by WasteChem from the foregoing considerations are as follows:

1. Number of generic waste forms and waste formulations to be tested.
2. Scale of hardware used to manufacture waste forms.
3. Analytical test procedures.
4. Manpower/labor.

GENERIC WASTE FORMS/FORMULATIONS

While each light water reactor (LWR) produces wastes which are in some respects unique, for practical purposes all LWR process waste can be classified into the following seven generic types:

1. Bead Resin (PWR/BWR)
2. Precoat Filter Cake with Powdered Resin (BWR)
3. Precoat Filter Cake with Diatomaceous Earth (BWR)
4. Chemical Regenerant (BWR)
5. Chemical Regenerant (PWR)
6. Boric Acid (PWR)
7. Decontamination Waste (PWR/BWR)

The waste types and formulations for each have been characterized by Brookhaven National Laboratory[1]. The generic WasteChem VRS waste form qualification program discussed herein addresses solidification and testing of each of these waste types as the means to demonstrate generic conformance of all VRS-produced waste forms to the requirements of 10CFR61.

The Brookhaven work[1] provides multiple formulations (principally differences in water content) for each generic waste type based upon selected standard unit operations used to preconcentrate wastes prior to solidification. Although differences in water content of waste materials is an important variable for waste solidification agents which require chemical reactions to effect solidification, e.g. cement, an extruder-based VRS process using asphalt as the solidification agent does not rely on chemical reactions to determine product properties. In the VRS system, process wastes are dehydrated and the dried residues are mixed in asphalt. Therefore solidification takes place from a change in state due to cooling. If the VRS system process control program is needed, product properties are independent of initial water content of the waste and are only dependent on the waste species present, the asphalt type used and the ratio of dried residue to asphalt in the product. Consequently, all asphalt-solidified waste forms produced by LWR's can be characterized by testing solidified samples of the seven generic waste types irrespective of their initial water content. To account for differences in waste loading (ratio of waste solids to asphalt) in the product, both the maximum and normal waste loading is assumed to be a nominal 50% solids and the extreme of lesser loadings is characterized by the properties of pure asphalt. Thus the complete range of product performance characteristics can be determined by testing product samples of the seven generic waste types at a 50% solids loading and samples of pure asphalt (0% solids loading).

WASTE FORM MANUFACTURING METHODS

Three alternative methods exist for producing generic waste samples suitable for testing:

1. produce samples (radioactive) in solidification hardware in operation at a power plant
2. produce samples (nonradioactive) in solidification hardware in conjunction with a plant start-up
3. produce samples on reduced scale equipment in a pilot facility

WasteChem has decided to use reduced scale equipment for the following advantages offered by this alternative:

A. Small batch sizes can be utilized to limit the amount of simulated waste required to produce samples.
B. Waste feeds can be changed with short turn-around.
C. This equipment offers the ability to precisely duplicate large scale process conditions and products in a laboratory environment.
D. All generic waste types can be processed in a single facility.

The use of laboratory facilities to manufacture the necessary samples is a readily identified cost. WasteChem operates such test facilities as a service to its customers on a cost reimbursable basis.

TEST SPECIMENS

Simulated wastes will be "doped" with non-radioactive tracers (salts of Cesium, Cobalt and Strontium) to simulate the predominate fission and activation products in LWR wastes. These wastes will be processed in an extruder-evaporator and solidified in nominal two-inch diameter, thin wall aluminum sample containers. These containers are used because their geometry is compatible with the sample sizes required by BTP/ASTM tests and they can be stripped from the sample without the use of lubricants or parting compounds which could interfere with leach rate testing.

Test samples will be produced at multiple waste solids loadings starting at ten percent waste solids and increasing in ten percent increments to the maximum achievable. Only waste forms produced at or near the maximum waste loadings will be evaluated per the tests specified in the BTP. The balance will be held in reserve in the event that a highly loaded (high VR) product does not perform satisfactorily. To ensure repeatability and minimize analytical costs, duplicate samples of each waste type will be submitted for all tests required by the BTP.

ANALYTICAL TESTING

The BTP on Waste Form identifies five general categories of performance tests to which solidified waste forms of each generic waste type must be subjected. The specific performance tests and acceptable criteria are shown in Table 1.

Compressive Strength Test

Two samples of each type of waste form will be compression tested in accordance with paragraph 6.3 of ASTM - D1074 "Compressive Strength of Bituminous Mixtures". Additionally, product samples previously subjected to other tests, i.e. radiation resistance, resistance to fungal and bacterial attack, resistance to immersion and resistance to thermal degradation, will be compression tested to determine the influence of the foregoing simulated environmental stresses on the compressive strength of the samples.

Radiation Resistance Test

Two samples of each waste type will be irradiated to a total exposure of 10^8 rads in a gamma (Co-60) irradiation. Exposure rate must be controlled to prevent overheating (melting) of the product. It is estimated that the total irradiation time must be approximately 4 weeks to prevent melting.

Following radiation exposure, compressive strength tests will be performed on all samples to determine radiation effects on compressive strength.

Resistance to Fungi

Two samples of each waste type will be tested for resistance to attack by fungi in accordance with both the BTP and ASTM G21 "Standard Recommended Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi". Following this test sequence, samples will be tested for compressive strength.

Resistance to Bacteria

Two samples of each waste type will be tested for resistance to attack by bacteria in accordance with both the BTP and ASTM G22 "Standard Recommended Practice for Determining Resistance of Plastics to Bacteria". Subsequent to this, compressive strength measurements will be made on each product sample.

Bartha-Pramer Biodegradation Rate Tests

Two samples of each waste type will be tested to determine their degradation rate in soil samples taken from the Barnwell facility. Similarly, samples will be tested in soils from the Richland facility. Test duration for each will be six months and test results will be extrapolated to a 300 year period per the BTP.

Leach Testing

Waste specimens "doped" with non-radioactive tracers (salts of Cesium, Strontium and Cobalt) will be subjected to leach testing in accordance with the procedure described in ANS 16.1 (Draft dated 11/16/82) "Measurement of the Leachability of Solidified Low-Level Radioactive Wastes". The test procedure will be modified to include three extra data points (days 19, 47 and 90). Two different leachants will be used: demineralized water and simulated seawater. Leachant solutions will be analyzed for tracer content by means of atomic absorption spectrophotometry.

Immersion Testing

Specimens will be immersion tested in demineralized water for a 90 day period. Following this testing, compressive strength tests will be performed.

Thermal Degradation Testing

Specimens in their sample molds will be exposed to 30 thermal cycles between 60°C and -40°C. The apparatus used for this test will conform to the description contained in ASTM B 553, Section 3. Following this testing, compresssive strength tests will be performed.

TABLE I

Waste Form Performance Tests for Asphalt Encapsulated Waste Products

Performance Test	Acceptance Criteria
1. Compressive Strength, ASTM D1074	Compressive strength 50 psi
2. Radiation Resistance + Compressive Strength	Irradiate to gamma exposure of 10^8 rad Post-irradiation compressive strength 50 psi
3. Biodegradation	
A. Resistance to Fungal Attack, ASTM G21 + Compressive Strength	No fungal growth Post-test compressive strength 50 psi
B. Resistance to Bacterial Attack, ASTM G22 + Compressive Strength	No bacterial growth Post-test compressive strength 50 psi
C. Biodegradation Rate (Bartha-Pramer*)	Less than 10% total carbon loss over projected 300 year period
4. Immersion	
A. Leach Rate, ANS 16.1 **	Leachability Index 6
B. Immersion + Compressive Strength	Post-immersion compressive strength 50 psi
5. Thermal Degradation + Compressive Strength	Post-termal test compressive strength 50 psi

* To be performed if fungal or bacterial growth is detected in 3 A or 3 B.

** To be performed in two leachants; demineralized water and seawater.

Free Liquids Testing

The free liquids content of waste specimens will be determined in accordance with the method prescribed by ANS 55.1 "Solid Radioactive Waste Processing System for Light Water Cooled Reactor Plants".

Table II indicates the number and type of waste samples to be subjected to the foregoing tests.

Sections or cores from a full scale waste product (55 gallon drum) will be used to validate the results of the foregoing tests. This validation is suggested by the BTP for programs based on the use of laboratory size specimens. This validation effort will be applied to only one waste form and will involve only compressive strength and immersion testing.

TABLE II

BTP Waste Form Conformance Program Testing

Product Sample Testing Plan

BTP Test \ Waste Form	Bead Resin	BWR Precoat Filter Cake (Powdered Resin)	BWR Precoat Filter Cake (DE)	BWR Chemical Regenerant Waste	PWR Chemical Regenerant Waste	Boric Acid Waste	Decon. Waste	Asphalt	Total No. of Samples
Compressive Strength	12(3)	12(3)	12(3)	12(3)	12(3)	18(3)(4)	12(3)	12(3)	102
Radiation Resistance (1)	2	2	2	2	2	2	2	2	16
Resistance to Fungi (1)	2	2	2	2	2	2	2	2	16
Resistance to Bacteria (1)	2	2	2	2	2	2	2	2	16
Biodegradation Rate (Bartha-Pramer)	4	4	4	4	4	4	4	4	32
Resistance to Leaching (2)	4	4	4	4	4	4	4	0	28
Immersion Resistance (1)	2	2	2	2	2	5(4)	2	2	19
Resistance to Thermal Degradation (1)	2	2	2	2	2	2	2	2	16
Free Water Detection	2	2	2	2	2	2	2	0	14

Notes: (1) Subsequent to the indicated test, samples will be tested for compressive strength.
(2) Two different leachants will be used, demineralized water and simulated seawater.
(3) Duplicate samples of each waste type will be tested. The balance of samples listed are specimens which will be exposed to multiple tests (see Note 1).
(4) Duplicate samples plus cored samples from full scale waste form for verification testing.

MANPOWER

One of the principal cost elements in this waste qualification effort is program manpower. Principal areas requiring manpower expenditure include:

1. Program management: Specific managerial functions include defining program scope and structure, identifying specific tasks, establishing budgets and schedules and broadly overseeing implementation efforts.

2. Program implementation: This function involves engineering activities which include preparation of detailed sample preparation and test procedures, identification and purchase of raw materials and consumables, administration of subcontracts (primarily analytical testing), supervision of sample preparation, dialogue with the NRC (where required), performance of leach tests, analysis of results, and compilation of all raw data, results and conclusions into a comprehensive report.

Since the skills required for both program management and implementation are comparable, it is assumed that these functions are fulfilled by a single individual.

INCIDENTAL COSTS

The final cost category in this program is incidental out-of-pocket costs associated with test consumables such as asphalt binder, chemicals and materials to simulate wastes, non-radioactive tracer matérials, sample containers, glassware for leach testing, etc.

COST SUMMARY

Table III presents the cost elements for the waste form qualification program described herein. This program represents a means of producing generic waste form performance data for qualifying asphalt solidified waste products to the performance criteria established by 10CFR61. The total cost of producing this qualification data for all (seven) generic PWR/BWR solidified process waste streams is estimated to be $160,000.

TABLE III

PROGRAM COST ELEMENTS

1. Pilot laboratory services, including labor, to manufacture solidified waste forms for testing (10 working days)

2. Analytical Costs

   A. Compressive strength testing per ASTM D1074 (102 specimens*)

   B. Radiation exposure testing (16 specimens*)

   C. Resistance to fungi per ASTM G21 (16 specimens*)

   D. Resistance to bacteria per ASTM G22 (16 specimens*)

   E. Biodegradation rate testing per Bartha-Pramer method (32 specimens*)

   F. Resistance to leaching per modified ANS 16.1 (28 specimens* - 10 leachant specimens will be produced and analyzed for each specimen).

   G. Immersion resistance (19 specimens*)

   H. Resistance to thermal degradation per BTP/ASTM B 553 (16 specimens*)

   I. Free water detection (14 specimens*)

3. Manpower for program management and implementation.

4. Incidental costs for consumables, etc.

*Per Table II

REFERENCES

1. P. Columbo and R. M. Neilson, Jr., "Properties of Radioactive Wastes and Waste Containers - First Topical Report", BNL-NUREG-50957, Nuclear Waste Management Research Group, Department of Nuclear Energy, Brookhaven National Laboratory, August 1979.