INITIAL OPERATING EXPERIENCE OF THE SOLID RADWASTE SYSTEM AT THE HOPE CREEK GENERATING STATION

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ABSTRACT

Performance testing of the Solid Radwaste System at Hope Creek includes the preparation of oxidized asphalt waste form samples, and determining the maximum evaporative rates and minimum temperature profiles of the extruder/evaporator for each of the expected liquid radwaste streams. The testing will verify conformance with the NRC approved Topical Report for waste forms produced with an oxidized asphalt binder. Initial operation of the Solid Radwaste System has shown that disposal costs will be cut in half for spent bead and powdered resin when compared with dewatering in High Integrity Containers.

INTRODUCTION

The Hope Creek Generating Station, a 1067 MWe Boiling Water Reactor, located in Hancocks Bridge, New Jersey, is currently in the process of starting up the Solid Radwaste System. The major components include the extruder/evaporator and associated centrifuge, slurry and concentrates feed systems.

Performance testing of the Solid Radwaste System started in January, 1988. The test program includes preparation of oxidized asphalt waste form samples for each of the expected liquid radwaste streams, to verify conformance with the NRC approved Waste Form Topical Report prepared by WasteChem Corporation. Oxidized asphalt waste forms produced by WasteChem's Volume Reduction and Solidification (VRS™) System evaluated in the Topical Report met and exceeded the stability requirements of 10CFR61 and the NRC Branch Technical Position on waste form. The maximum evaporative rates and minimum temperature profiles for the extruder/evaporator established for each radwaste stream, provide operating ranges while assure waste form conformance and equivalence to the results presented in WasteChem's Waste Form Topical Report.

A brief description of the solid radwaste system is provided below, followed by discussions of waste form certification, performance testing, system and operating experience as a result of startup efforts, and projected savings from system operation versus dewatering in high integrity containers or cementation.

SYSTEM DESCRIPTION

The Solid Radwaste System is an integrated process which volume reduces and solidifies liquid radwaste generated at Hope Creek. Liquid radwaste streams include spent bead and powdered (Ecodex) resin, fed to the extruder/evaporator either dewatered via a centrifuge or slurried from a decant tank, and concentrated floor drain or decontamination waste fed to the extruder/evaporator from a crystallizer evaporator system.

The centrifuge feed system consists of a centrifuge feed tank, a recirculation pump, redundant centrifuge feed metering pumps, and a Sharples-Penwalt centrifuge. The design flow rate is 663 liters/hr (1460 lbs/hr) of 15% by weight (dry) resin slurry. The centrifuge feed system feeds the dewatered radwaste resin from the centrifuge to extruder/evaporator "A". A resin slurry feed system is provided as a back-up in the event of an extended centrifuge outage. The slurry feed can be fed to either extruder/evaporator "A" or "B".

The crystallizer evaporator system manufactured by HPD Inc. and supplied by WasteChem, consists of the crystallizer vapor body, crystallizer heater, crystallizer recirculation pump, entrainment separator, desuperheater, crystallizer bottoms tank, bottoms tank recirculation pumps, bottoms tank agitator, bottoms tank vent gas cooler, sample sink skid, and caustic addition skid. The design flow rate to the crystallizer is 115.5 liters/min (30.5 GPM) at 2.5% by weight total solids while concentrating to 50% by weight. The design flow rate equates to a water removal rate or evaporative capacity of 6584 liters/hr (14,501 lbs/hr). The system can be operated using either mechanical vapor recompression or steam as the driving force. The concentrate is collected in the crystallizer bottoms tank where the pH is adjusted to between 8.0 and 10.0. The bottoms are recirculated through redundant pumps. Redundant concentrates metering pumps can feed either extruder/evaporator "A" or "B" from the recirculation line.

The VRS systems at Hope Creek supplied by Waste-Chem Corporation consist of two extruder/evaporators ("A" and "B"), waste feed metering pumps, auxiliary boiler and steam system, asphalt storage and transfer system, drum fill station, drum handling crane and conveyor, vent hood filters and exhauster, drum capper and seamer, and drum swipe station. The design evaporative capacity of each extruder/evaporator is 120 l/hr (264 lbs./hr). The flow rate to the extruder/evaporator is dependent upon the water content in the radwaste feed stream.

The extruder/evaporator simultaneously evaporates water from liquid wastes while encapsulating the residual solids in an ASTM D312 Type III oxidized asphalt binder. The final end product contains no free water. The extruder-evaporator consists of seven connected Nitroloy (deep-nitrated carbon steel) barrels. Cooling water and process heating steam flow through closed-loop passages within the barrel walls. Two self-cleaning corotating kneading and conveying screws are contained within the connected barrels.

Molten asphalt is fed into the extruder/evaporator upstream of the waste inlet. Low-pressure steam is delivered to the barrels through control valves which allow the temperature of each barrel to be adjusted. The extruder/ evaporator operates in a closed cycle. Process heating steam does not contact the waste and is condensed and returned to the boiler.

As the asphalt/waste mixture is conveyed through the extruder by the screws, water is evaporated and the waste residue is homogeneously mixed with the asphalt. The vapor exits the extruder through three devolatizing domes located along the top of the barrels. This vapor is condensed, filtered and released to the plant floor drain system. The oxidized asphalt/waste mixture exits the end of the extruder and flows into a 200-liter (55-gallon) drum, solidifying upon cooling. The process is non-chemical and is approved by the existing burial sites and the U.S. Nuclear Regulatory Commission for disposal of Class A, B, and C wastes.

Table I lists the liquid waste streams generated at the Hope Creek and the process utilized for treatment in the solid radwaste system. Although, the radwaste system at Hope Creek has the capability to regenerate resins, the results of an economic evaluation provided justification for *direct* disposal. However, condensate demineralizer resins are further utilized in the radwaste demineralizer. This operating mode provides extended usage of the resin's ion exchange capacity.

WASTE FORM EQUIVALENCE

In the NRC's approval letter dated January 22, 1988 for WasteChem's Waste Form Topical Report, the NRC requested that each utility owner of the VRS System demonstrate waste form equivalence. The purpose of the demonstration is to verify WasteChem's contention that quality of the waste form produced with the oxidized asphalt binder is independent of extruder/evaporator size. In response to the NRC, WasteChem proposed a methodology to demonstrate equivalence between waste forms produced on the full scale VRS system installed at each nuclear facility versus the pilot scale VRS system utilized for the 10CFR61 qualification testing. The methodology described below was accepted by the NRC and implemented at Hope Creek.

For each radwaste stream at Hope Creek, identified on Table 1, full size waste forms (200 liter/55 gal. drums) and several small scale waste forms (5 cm diam. cylinder, 10cm long) will be produced while operating the full size VRS system near the maximum waste solids loading and process/evaporative limits.

The two full-scale waste forms will be subjected to the free-liquids test method described in ANS 55.1. Following this, each waste form will be sectioned along a vertical centerline to produce two symetrical half cylinders. Acceptance criteria for tests performed on the full-scale waste specimens shall be, 1) waste forms shall be free standing monoliths with less than 0.5 percent free liquids by volume and 2) container fill efficiency shall be greater than or equal to 85%.

Duplicate specimens of the small scale waste forms will be subjected to compressive strength tests followed by post-immersion compressive strength tests. Test procedures and acceptance criteria for these specimens shall be in accordance with the descriptions contained in WasteChem's Topical Report on waste form.

To date, waste form samples have been produced by the full size VRS system at Hope Creek for bead resin and powdered resin with precoat material (Ecodex P202H) radwaste streams in the slurry process mode. The full scale samples were free standing monoliths with no observable free liquids and each attained a fill efficiency of approximately 95%.

The 10CFR61 waste form acceptance criterion for compressive strength is greater than 60 psi, using the ASTM D-1074 test method. Results of the compressive strength testing performed on the small scale waste form samples produced at Hope Creek from the full size VRS system were, on average, greater than 200 psi.

Oxidized asphalt waste form samples produced at Hope Creek with are compared with the pilot scale VRS system and the 10CFR61 waste form acceptance criteria on Tables II and III.

TABLE I

Radwaste Streams and Treatment Process

Radwaste Stream	Treatment Process
Bead Resin	Centrifuge feed to Extruder/Evaporator
Bead Resin	Slurry feed to Extruder/ Evaporator
Powdered Resin w/Precoat Material	Centrifuge feed to Extruder/ Evaporator
Powdered Resin w/Precoat Material	Slurry feed to Extruder/ Evaporator
Floor Drain Waste	Crystallizer Concentrates feed to Extruder/Evaporator
Decontamination Waste Solution	Crystallizer Concentrates feed to Extruder/Evaporator
Chemical Regeneration Waste(1)	Crystallizer Concentrates feed to Extruder/Evaporator

(1) Note: Chemical regeneration waste is not currently generated.

TABLE II

Waste Form Equivalence Results Full Scale Waste Forms

	Free Liquids		Fill Efficiency	
Radwaste Stream	Hope Creek	Acceptance	Hope Creek	Acceptance
Bead Resin Slurry	0%	0.5%	95%	85%
Powdered Resin Slurry (Ecodex P202H)	0%	0.5%	95%	85%

(1) A full scale sample at Hope Creek is a 200 liter (55 gallon) drum

TABLE III

Waste Form Equivalence Results Small Scale Waste Forms

	Compressive Strength(1)		
Radwaste Stream	Hope Creek	Pilot Scale	Acceptance
Bead Resin Slurry	246 psi	190 psi	$\geq$ 60 psi
Powdered Resin Slurry (Ecodex P202H)	202 psi	173 psi	$\geq$ 60 psi

(1) Compressive strength results presented are the average of duplicate samples tested.

These results verify the equivalence of the oxidized asphalt waste forms produced by the full size and the pilot scale extruder/evaporators and the capability of waste forms produced by the VRS system to meet the stability requirements of 10CFR61 and the NRC Branch Technical Position on waste form.

Efforts are continuing to complete demonstration of waste form equivalence for the other Hope Creek radwaste streams, listed on Table I. Note that compressive strength of samples produced from the Hope Creek VRS system are slightly higher than those produced from the pilot scale system. This is due to the slightly higher crosshead speed of the equipment utilized on the Hope Creek samples for testing (0.225 in/min versus 0.2 in/min).

PERFORMANCE TESTING

When operated within process limitations, the variables which affect the properties and consistency of the solidified oxidized asphalt waste forms produced by the VRS system are 1) asphalt type and 2) waste type and waste-to-asphalt ratio. A process control program (PCP) has been defined for the extruder/evaporator which establishes the waste process rate (or evaporative rate) and process temperatures. These limits are verified and operating ranges defined during performance testing. The process variables and performance testing at Hope Creek are discussed below.

The asphalt used in the VRS system is a high viscosity, oxidized, asphalt conforming to ASTM D-312, Type III requirements. The Pioneer Asphalt Corporation product, Pioneer 318, utilized at Hope Creek conforms to the referenced ASTM specification and ensures the waste forms produced are represented in WasteChem's Topical Report.

The waste type and ratio of waste-to-asphalt contained in the end product has the most bearing on the viscosity and physical properties and performance of the waste forms produced by the VRS system. For the radwaste streams generated at Hope Creek the maximum ratio of waste-to-asphalt evaluated in WasteChem's Topical Report, and approved by the NRC, are listed on Table IV.

Products with waste loadings lower than the Table IV values were evaluated in the WasteChem Topical Report by subjecting a zero percent solids product (pure oxidized asphalt) to all stability tests, thereby "bracketing" the full range of waste loadings from zero to the maximum values.

The waste process rate, whether expressed as a waste feed rate at a specified content of non-volatile solids or as an evaporative rate, is an important process variable because it can influence properties of the final product. Waste forms generated for the 10CFR61 waste form conformance program on the pilot scale extruder/evaporator were produced at waste process rates within the evaporative capacity of that extruder. To assure that waste forms produced on the full size extruder at Hope Creek are equivalent, the corresponding evaporative capacity of the full size extruder must not be exceeded.

TABLE IV

Hope Creek Solid Radwaste System Maximum Ratio of Waste-to-Asphalt

Radwaste Stream	Maximum Waste-to-Asphalt Ratio (by dry weight)
Bead Resin - Dewatered	50/50
Bead Resin - Slurry	50/50
Powdered Resin - Dewatered	25/75
Powdered Resin - Slurry	25/75
Floor Drain Concentrates	45/55
Decon. Waste Concentrates	30/70
Chem. Regen. Concentrates(1)	60/40-Class A Unstable 25/75-All Waste Classes

(1) Note: Chem. Regen. waste is not currently generated.

The evaporative capacity of any radwaste extruder is the evaporative rate beyond which the product discharged from the extruder exhibits excess moisture, i.e. residual moisture, not free water. For a given extruder, each waste type and waste feed mode (slurried or dewatered feed) will exhibit its own characteristic evaporative limit. This limit is identified at each plant for each radwaste stream during startup/performance testing. After this limit has been identified and written into the PCP either directly as a limiting evaporative rate or indirectly as a set of feed conditions, e.g. waste concentration and feed rate, the operator needs only to observe this limit and any other PCP requirements to assure that a conforming/equivalent product is being produced.

The extruder/evaporator is presented below in Table V. The evaporative capacity will be established for each of the radwaste streams generated at Hope Creek, listed on Table I. Once the maximum evaporative rate for each radwaste stream is determined, the waste feed will be gradually decreased until a good product is observed. At that point, small scale samples will be taken for compressive strength and immersion testing. Extruder/evaporator operation below the established maximum feed rates will assure a conforming waste form. The preliminary results of the maximum waste process rate or evaporative capacity testing indicate that the VRS System will operate close to design capacity for powdered resin (Ecodex P202H) slurry feed at the maximum waste-to-asphalt ratio.

Extruder temperature profile plays an important role in process control and is used as a backup to process/evaporative capacity to assure that conforming/equivalent products are produced. The typical temperature profile identified in the Topical Report is a recommended starting point for conduct of startup/performance testing. The actual temperature profiles to be included in each plant's PCP are established during startup/performance testing.

Extruder process temperatures are controlled by control valves which regulate the flow of heating steam to the heating bores which jacket the extruder. The performance testing conducted at Hope Creek to determine the minimum temperature profiles involves the restriction of steam supply to the extruder/evaporator in predetermined intervals while radwaste is fed to the unit at a rate corresponding to the evaporative capacity of the unit. The temperature profile is recorded following each restriction interval, when the extruder/evaporator heating barrels stabilize. This test is conducted for each radwaste feed stream to determine the minimum temperature profile below which non-conforming/non-equivalent products can be produced. Small scale samples will be taken for compressive strength and immersion testing. Extruder/evaporator operation above the minimum temperature profile will assure a conforming waste form.

The preliminary results were obtained at Hope Creek of the minimum temperature profile testing for powdered resin (Ecodex P202H) slurry feed at the maximum waste-to-asphalt ratio. At a steam pressure of 3.5 Kg/cm^2 (50 psi) a product with high residual moisture was observed at the extruder/evaporator discharge. At that point the process temperatures were recorded, thus establishing the low temperature set points.

SYSTEM AND OPERATING EXPERIENCE

Recommendations were developed as a result of system startup efforts, operating experience during performance testing and visits to operating radwaste extruder/evaporators in Europe. General recommendations regarding system operation are provided below followed by specific equipment recommendations.

Startup efforts should involve the future operating staff. In addition, systems modification should incorporate input from the operating staff. To provide working flexibility for system operators the integrated system should be operated in the range of 70 to 90 percent of capacity.

Proper installation of the asphalt feed lines and heat tracing to the extruder/evaporator is critical to system operation. Specifically, the asphalt tank should be as close to the extruder/evaporator as possible, the asphalt pipe hangers should be insulated, and the heat tracing should be carefully installed to avoid cold spots. To eliminate tripping the asphalt recirculation pump during cold startup, a bypass line should be installed. The bypass line permits a gradual pressure increase in the asphalt recirculation line.

The 55 gallon drums purchased for the asphalted waste products should be compatible with the Drum Capper and Seamer supplied with the system. Compatibility will ensure the remote capping and seaming operation is properly executed without operator intervention.

All modifications performed which affect the piping arrangements in the solid radwaste system must consider pressure losses and line blockage, particularly in the resin transfer lines. Piping to and from the centrifuge feed tank, which will contain spent bead and powdered resin, should be free of sharp bends. For efficient operation of the centrifuge feed tank, decant capabilities must be maintained as well as the ability to return waste to the sources.

PROJECTED SAVINGS

Operation of the Solid Radwaste System at Hope Creek will reduce transport and disposal costs by 50 percent for spent bead and powdered resin (Ecodex) when compared with dewatering in High Integrity Containers (HICs). Significantly more savings will be realized with the disposal of concentrates.

For the disposal of 5.7 cubic meters (200 cubic feet) of spent bead resin, twelve (12) 200 liter (7.5 cubic feet) drums are filled with asphalted waste, equal to 2.55 cubic meters (90 cubic feet) of burial volume. The same amount of spent bead resin would be greater than 5.7 cubic meters (200 cubic feet) of burial volume in a dewatering HIC. For the disposal of 5.7 cubic meters (200 cubic feet) of spent Ecodex sixteen (16) 200 liter (7.5 cubic feet) drums were filled with asphalted waste, equal to 3.4 cubic meters (120 cubic feet) of burial volume. The same amount of spent Ecodex would be greater than 5.7 cubic meters (200 cubic feet) of burial volume in a dewatering liner.

The expected volume reduction factors through use of the Solid Radwaste System and solidification with the oxidized asphalt binder over dewatering bead resin and Ecodex in HIC's are 2.22 and 1.67, respectively. A volume reduction factor of at least 4.4 is expected over solidification of concentrates in cement.

Additional cost savings result from use of 200 liter (55 gallon) drums instead of HIC's and elimination of on-site vendor costs. The cost of a 5.7 cubic meter (200 cubic feet) HIC is approximately $8,000. The cost of 200 liter (55 gallon) drums for the same amount of waste is approximately $500. Using drums instead of a projected 50 HIC's per year will save $375,000.

The average cost for an on-site vendor to process waste is approximately $18,000 per month. This includes equipment rental, labor and living expenses. The projected savings using the Solid Radwaste System instead of the on-site vendor is $216,000 per year. The PSE&G manpower with the Solid Radwaste System in operation will remain the same.

CONCLUSIONS

Initial results of waste form equivalence and performance testing for spent bead and powdered (Ecodex) resin have shown that the solidified asphalt/waste product of the Solid Radwaste System at Hope Creek will meet and exceed the stability requirements of 10CFR61 and the NRC Branch Technical Position on waste form. In addition, experience to date at Hope Creek has also shown that substantial operational and economic benefits can be gained through involvement of the operations staff during startup and performance testing.

Operation of the Solid Radwaste System at Hope Creek has shown when compared to dewatering in HIC's and solidifying in cement the following benefits will be realized:

Significant Volume Reduction of all Liquid Radwaste Streams

- Fewer Radwaste Shipments
- Significant Direct and Indirect Cost Savings
- Future Protection Against Disposal Price Increases
- Future (Potential) On-site Storage Requirements will be Substantially Reduced