United States Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555

# TECHNICAL EVALUATION REPORT - ADDENDUM

related to

Topical Report Addendum DT-VERI-100-NP/P-A
Revision 1, Addendum 1
ENCAP™ Encapsulation Utilizing
The VERI™ Solidification Process

Diversified Technologies
Docket No. WM-105

Prepared by: Uranium Recovery and Low-Level Waste Branch
Division of Waste Management
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ABSTRACT

This Technical Evaluation Report (TER) Addendum has been prepared by the Office of Nuclear Material Safety and Safeguards of the U.S. Nuclear Regulatory Commission for Diversified Technologies Services Inc. (DTS) Topical Report (TR) Addendum, DT-VERI-100-NP/P-A, "ENCAP™ Encapsulation Utilizing the VERI™ Solidification Process," Revision 1, Addendum 1, (Docket Number WM-105). The TR Addendum presents information and data to support a process for spent filter cartridge encapsulation in a polymer matrix. The polymer matrix consists of the VERI™ (Vinyl Ester Resin in Situ) waste form, previously described in DTS's TR, "VERI™ Solidification Process for Low-Level Radioactive Waste," and the associated NRC TER, dated December 1992.

The TER Addendum presented here addresses only those aspects of the TR Addendum which differ from the previously approved process. That is, the filter encapsulation will be addressed, but specifics on the VERI™ waste form will not be revisited. For information on the VERI™ waste form, please see the VERI™ TR and associated TER.

From the information presented, the staff concludes that the VERI™ waste form (as previously approved), when used for spent filter cartridge encapsulation, as described in the TR Addendum, should result in waste forms that meet the structural stability requirements of 10 CFR Part 61, the guidance provided in the Branch Technical Position on Waste Form, Revision 1, January 1991, and the guidance provided in the Branch Technical Position on Concentration Averaging and Encapsulation, January 1995. Limiting conditions for use of these waste forms may be specified by the regulating authority for a particular disposal site.

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# TECHNICAL EVALUATION REPORT - ADDENDUM FOR SPENT FILTER CARTRIDGES ENCAPSULATED USING THE DTS VERI™ WASTE FORM (WM-105)

## 1.0 BACKGROUND

This report provides the evaluation results of the technical review of information and data submitted by Diversified Technologies (DTS) in the Topical Report (TR) Addendum entitled, "ENCAP™ Encapsulation Utilizing the VERI™ Solidification Process," Revision 1, Addendum 1, DT-VERI-100-NP/P-A, May 1, 1994 [1]. This Technical Evaluation Report (TER) Addendum is an evaluation of the waste form qualification test data provided by DTS to confirm that this spent filter cartridge encapsulation process will produce a waste form that meets the regulatory requirements of 10 CFR Part 61 with respect to structural stability. This TER Addendum addresses only those aspects of the DTS TR Addendum which differ from the previously approved process. That is, the filter encapsulation will be addressed, but specifics on the VERI™ waste form will not be revisited. For information on the VERI™ waste form, please see the VERI™ TR [2] and associated TER [3].

Once a topical report review has been completed and the associated product(s) has been approved, the TR process allows a user to reference the report to demonstrate that the subject area the report addresses has been through the regulatory review process and is acceptable to the staff. Thus, the TR process allows the use of a repeated process, action, etc., at several facilities after a single successful review has been completed. However, for waste form TRs, waste generators must take additional actions (e.g., plant-specific process control procedures) to demonstrate that all portions of Part 61 have been met. Note that the low-level waste (LLW) TR review process at the NRC has been discontinued [4]. This TER Addendum has been written for an LLW TR review that was in progress at the time of the review process termination. No further LLW TR reviews will be performed by the U.S. Nuclear Regulatory Commission (NRC).

### 1.1 Regulations

By Federal Register Notice dated December 27, 1982 (47 FR 57446), NRC amended its regulations to provide specific requirements for licensing of facilities for the land disposal of LLW. Most of these requirements are now contained in Part 61 to Title 10 of the Code of Federal Regulations (10 CFR Part 61) entitled "Licensing Requirements for Land Disposal of Radioactive Waste" [5]. These regulations are the culmination of a set of prescribed procedures for LLW disposal proposed in the Federal Register on July 24, 1981.

The effective date for the implementation of 10 CFR 20.311/20.2006, "Standard for Protection Against Radiation," which requires waste generators to meet the waste classification and waste form requirements in 10 CFR Part 61, was December 27, 1983. As set forth in 10 CFR 61.55, Class B and Class C waste must meet structural stability requirements established under 10 CFR 61.56(b). As noted in 10 CFR 61.56(b)(1), structural stability could be provided by (a) processing (i.e., solidification of) the waste form, (b) by the waste itself (as with large activated steel components), or (c) by placing the waste in a container or structure which would then provide the required stability (i.e., a high integrity container (HIC)). To the extent practical, Class B and C waste forms or containers should, according to Section 61.7 of Part 61, maintain structural stability for 300 years. In May 1983, NRC provided additional guidance by means of a Branch Technical Position (BTP) on Waste Form [6] that describes test procedures and criteria that can be used to demonstrate the required long-term, 300 year, structural stability. The most recent guidance on waste form is provided in Revision 1 to the Branch Technical Position on Waste Form, which was issued in January 1991 [7].

The waste classification requirements of 10 CFR 61.55 are based on the concentration of specific radionuclides contained in the waste. The regulation, at 10 CFR 61.55(a)(8) states that "the concentration of a radionuclide [in waste] may be averaged over the volume of the waste, or weight of the waste if the units [on the values tabulated in the concentration tables] are expressed as nanocuries per gram." Guidance, as the "Branch Technical Position on Concentration Averaging and Encapsulation," of January 17, 1995 [8], defines a subset of concentration averaging and encapsulation practices that NRC staff would find acceptable in determining the concentrations of the 10 CFR 61.55 tabulated radionuclides in low-level waste. This BTP was being developed while the DTS TR was being developed.

The purpose of this TER Addendum is to summarize the technical review of the information submitted by DTS (also referred to as the vendor), and to demonstrate that the spent filter cartridge encapsulation process described in the TR Addendum, "ENCAP™ Encapsulation Utilizing the VERI™ Solidification Process," and in associated documents, will meet the long-term (300-year) structural stability requirements of 10 CFR 61.56 and the relevant portions of the January 1991, NRC Branch Technical Position on Waste Form, and the concentration limits of 10 CFR 61.55, with the relevant portions of the January 1995, NRC Branch Technical Position on Concentration Averaging and Encapsulation [8].

## 1.2 Topical Report Addendum Submittal

NRC staff concluded in December 1992, that the TR for the "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste," [2] subject to certain conditions, provides reasonable assurance that identified waste forms produced through use of this process meet the structural stability requirements of 10 CFR Part 61 for the disposal of Class B and C wastes. This process applies to the solidification of two waste streams, mixed bed bead resins, and LOMI [low oxidation state transition metal ion] resins. The TR Addendum, "ENCAP™ Encapsulation Utilizing the VERI™ Solidification Process," [1] was submitted on May 1, 1994. The TR Addendum presents a process (ENCAP™), which utilizes the NRC-approved waste forms generated using the VERI™ process referenced in the VERI™ TR to encapsulate spent filter cartridges in the solidified free-standing monolith. Additional information was requested by NRC staff [9], and was provided by DTS in three subsequent submittals [10], [11], [12].

## 1.3 Diversified Technologies Encapsulation Process

The ENCAP™ process uses VERI™ solidification to create an enveloping monolith around a caged region of spent filter cartridges. This process involves preparing an encapsulation liner and internal cage, filling the internal cage with spent filter cartridges, then filling the entire assembly with spent ion exchange resins (of the type approved in the VERI™ TER [3]), and solidifying the resulting waste filled liner with the VERI™ polymer solidification process described in the VERI™ TR [2]. The VERI™ solidification process involves forcing (by pumping or suction) a catalyzed and promoted modified vinyl ester styrene through a disposal liner. As the binder flows through the resin bed, it fills the void spaces between the resin beads, as well as those inside and between the filter cartridges, and forces any free water in the liner into the bottom dewatering internals. After filling the void spaces, and displacing the excess water, the binder cures to form a liquid-free, hard, free-standing monolith inside the liner.

## 2.0 TECHNICAL EVALUATION

The information presented in the TR Addendum and DTS letter responses to NRC's Request for Additional Information (RAI) provides the basis for the technical evaluation presented in the following sections. The review and evaluation were conducted by NRC staff members. The determination of the acceptability of the submitted information is based upon a comparison with the applicable regulatory requirements of 10 CFR Part 61, the guidance on solidified waste forms in the BTP on Waste Form [7], and the guidance on encapsulation and concentration averaging in the BTP on Concentration Averaging [8].

Note that this is an addendum to the VERI™ TER [3], and is not a complete TER in itself. This addendum will therefore refer frequently to the VERI™ TER.

### 2.1 Waste Characteristics

The minimum set of characteristics that all LLW intended for near-surface land disposal must meet is defined in 10 CFR 61.56(a). These requirements are intended to provide for ease of waste-handling and to provide for the protection of the health and safety of the personnel at the disposal site. Class A wastes only need to meet the minimum requirements, as long as they are segregated, and are not solidified waste forms. Class A wastes solidified and disposed of with Class B and Class C wastes shall meet the stability guidance for these wastes, in addition to meeting the minimum set of characteristics.

Waste forms classified as Class B or Class C should exhibit characteristics to meet the stability requirements of 10 CFR 61.56(b), that will enable the waste form to maintain its stability and package integrity during waste-handling and emplacement, and after disposal. Stability is intended to ensure that the waste does not structurally degrade and affect the 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.

### 2.2 Waste Streams Considered

The ENCAP™ process is designed to encapsulate spent filter cartridges in the VERI™ matrix described in the VERI™ TR [2]. The spent filter cartridges are not controlled with respect to source, waste loading or chemical loading. The TR Addendum lists waste types that are prohibited for physical or regulatory reasons, but no chemical "bad actors" have been identified, and the wastes are not expected to contain materials identified or defined as hazardous, biological, pathogenic or infectious. There are two limitations on the spent filter cartridges. First, the size is limited so that the void space created by the entombed object must be less than the span or diameter discussed in Section 2.4.3. Note that the item can be loaded to minimize its cross-section (shadow) when viewed from above. Secondly, spent cartridge filters that would provide a dose equal to or greater than $10^8$ rad to the polymer matrix are prohibited. The VERI™ waste form has been shown to withstand doses of $10^8$ rad in conjunction with testing to meet the BTP on Waste Form. See the VERI™ TR [2] and VERI™ TER [3] for more details. Larger doses could negatively impact the VERI™ matrix.

Spent ion exchange resin beads, qualified for use with the VERI™ system, are described in the VERI™ TR [2] and the associated TER [3], and will not be discussed here.

### 2.3 Minimum Requirements [10 CFR 61.56(a)]

Section 61.56(a)(1) of 10 CFR Part 61 contains the minimum requirements for all classes of waste. These requirements are intended to facilitate handling at the disposal site and provide for the protection of health and for the safety of personnel at the disposal site. The waste form resulting from the VERI™ process described in the VERI™ TR [2] was evaluated against each requirement contained in 10 CFR 61.56, and the guidance contained in the BTP on Waste Form [7]. This evaluation remains wholly applicable to the waste form resulting from the ENCAP™ process described in TR Addendum. Please see Section 2.3 of the VERI™ TER [3] for the complete discussion.

### 2.4 Stability Requirements [10 CFR 61.56(b)] and Recommendations of the Branch Technical Position on Waste Form

The requirements of 10 CFR 61.56(b) are intended to result in waste products that exhibit structural stability. 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. The Branch Technical Position on Waste Form elaborates on the provisions of Section 61.56.

#### 2.4.1 Structural Stability

A structurally stable waste form will generally maintain its physical dimensions and its form under the expected disposal conditions such as weight of overburden and compaction equipment, the presence of moisture and microbial activity, and internal factors such as radiation effects and chemical changes. Structural stability can be provided by processing the waste to a stable form, as proposed by DTS for the ENCAP™ process. The proposed waste forms resulting from the DTS ENCAP™ process will be packaged, but the liners are given no credit for stability. The waste form has been evaluated for use in direct trench burial, but can also be used in improved disposal conditions, such as in a high-integrity container or an engineered barrier system that might use a concrete vault.

##### 2.4.1.1 Structural Stability of the VERI™ Encapsulation Media

Discussion of as-cured compressive strength, radiation resistance, biodegradation resistance, leachability, immersion resistance and thermal cycling, as applied to the VERI™ waste form has been provided in the VERI™ TR [2] and VERI™ TER [3]. The test results and analyses are considered fully applicable to the ENCAP™ waste form described in the TR Addendum [1], except for the as-cured compressive strength. No other characteristics measured with the tests described in the BTP on Waste Form [7] are expected to be affected by filter encapsulation. Compressive strength tests, however have indicated that there could be issues associated with slumping or creep of the polymeric waste form. These issues and their resolution are discussed below.

2.4.1.2 Tensile and Compressive Strength of the ENCAP™ Waste Form

A waste form must have sufficient compressive strength to generally maintain its physical dimensions and its form under the expected disposal conditions, such as weight of overburden and compaction equipment. The minimum allowable compressive strength for polymeric waste forms is 60 psi [7]. The VERI™ waste form compressive strength, as demonstrated in the VERI™ TR [2], is expected to be well above the minimum. Test results were on the order of 2000 psi. However, the waste form exhibits some plasticity during compressive strength testing. That is, the VERI™ waste form bulges circumferentially without failure when subjected to maximum yield compressive forces.

Tensile tests were performed to determine the maximum void space which could be tolerated as a result of spent filter cartridge loading, which would still permit the ENCAP™ monolith to withstand the theoretical 60 psi overburden. Tensile strength results are provided in the TR Addendum (Appendix B), however, no data were provided to address deformation under load in tension. Information was requested [9] to address how the material in flexural tension above a permitted void space will behave with respect to time. The concern is whether or not plastic tensile flow or tensile creep can occur over time until a void is filled from above. This would, in effect, create a condition over the waste form similar to vertical settlement and have a potential impact on stability. DTS therefore performed tensile creep testing on VERI™ samples cut from the monolith prepared for testing for the VERI™ TR [2]. The tensile creep testing was performed according to ASTM D2990, "Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics," [13]. The results [11, 12] show that tensile creep samples loaded to 50% of the average measured tensile strength can withstand more than 4000 hours of creep test conditions without rupture. (The test method requires only 1000 hours.) Therefore, the permitted void space from filter cartridge loading was recalculated using 50% of the average measured tensile strength. (See Section 2.4.3.)

2.4.1.3 Correlation Testing

The BTP on Waste Form [7] indicates that if small, simulated laboratory-size specimens are used for the qualification testing program, test data from sections or cores of the anticipated full-scale products should be obtained to correlate the characteristics of actual size products with those of simulated laboratory size specimens. Full size specimens were manufactured and tested for both the VERI™ TR [2] and ENCAP™ TR Addendum [1], so correlation testing is not necessary.

2.4.1.4 Homogeneity

In addition to correlation testing, it is necessary to show that the product is homogeneous to the extent that all regions in the product have compressive strengths analogous to those of the lab-scale specimens. Homogeneity for the VERI™ waste forms was addressed in the VERI™ TR and VERI™ TER. With respect to the ENCAP™ process, the BTP on Concentration Averaging and Encapsulation [8] states that "the bounding volumes and weights [in Appendix

C] will ensure that the potential radiological impacts from encapsulated, single discrete source disposals are within the envelope of impacts that would be calculated if the radioactivity were homogeneously distributed throughout the encapsulating media." The ENCAP™ waste forms are expected to meet the criteria specified in Appendix C, and therefore are considered to act as though they were homogeneous. (See discussion in Section 2.5 for more information.)

2.4.2 Free Liquid

Section 10 CFR 61.56(b)(2) requires that wastes processed to a stable form have a liquid content that does not exceed 0.5 percent of the volume of the waste. The BTP on Waste Form [7] addresses this requirement. Section C.2.g recommends that waste specimens have less than 0.5 percent by volume of the waste specimen of free liquids as measured using the method described in ANS 55.1 [14]. Free liquids should have a pH between 4 and 11.

During testing for the VERI™ TR [2], a small amount of water was discovered when the liner was cut open to retrieve test samples. There were approximately 1.5 gallons (less than 0.10% of the liner volume) located in the small circumferential void between the liner and the solidified VERI™ monolith. Inspection indicated that the water was probably driven off the monolith by the exotherm and volume shrinkage experienced during the binder curing process. This is supported by bench scale testing. When samples are removed from their molds, a small amount of moisture is evident on the surface. This surface moisture seems independent of the degree of pre-watering. Although there may be some free water present following solidification, the volume is well within the maximum, and the VERI™ waste forms therefore fulfill this criterion. The pH of the liquid was determined to be about 6.0 to 6.5, which is well within the permitted range.

The spent filter cartridges encapsulated by this process may contain small amounts of liquid which are not displaced by the binder. All excess liquid is removed during the dewatering process described in the VERI™ TR [2]. Any remaining liquid associated with the spent filter cartridges will be encapsulated. Due to the general imperviousness, and the immersion characteristics of the VERI™ waste form (as discussed in the VERI™ TR [2] and VERI™ TER [3]), such liquids will be effectively isolated within the monolithic waste form, and are not free to migrate to the environment. Therefore, water present inside encapsulated filters does not constitute free liquid as defined by 10 CFR 61.56(a)(3).

2.4.3 Void Spaces

Section 61.56(b)(3) of 10 CFR Part 61 states that void spaces within the waste and between the waste and its package must be reduced to the extent practicable. The polymer binder is forced through the waste and around the spent filter cartridges, then the waste form solidifies in the liner. A circumferential void usually forms between the liner and the final solidified monolith when the curing binder undergoes shrinkage (approximately 2-5%). Otherwise, the solidification reactions are usual polymerization reactions and do not involve formation of gaseous byproducts which might create gas-filled voids within the solidified waste form. No voids were noted during visual inspections of the solidified monolith during testing for the VERI™ TR [2]. The process is effective in minimizing void spaces to the extent practicable, however, it is the responsibility of the user to ensure that liners are filled to reduce void spaces.

The void space in the waste cage (i.e., the central cage filled with spent filter cartridges) is expected to be minimal. The low viscosity of the VERI™ binder, and its natural wetting properties enable migration of the binder throughout the monolith, including the waste cage, while displacing both air and water. This causes the binder to flow into areas previously occupied by air or water. The air and water are swept toward the dewatering internals by the driving force of the vacuum being applied, and are pulled into the dewatering internals due to their lower viscosities. The more viscous binder meets more resistance in attempting to pass into the dewatering internals.

Although void spaces are expected to be filled during dewatering, binder addition, and binder solidification, DTS measured the tensile strength of VERI™-solidified resin, and calculated the maximum void space in the caged area that could be tolerated by the 4-inch VERI™ -solidified protective boundary surrounding the cage. (The cage is fully surrounded by at least 4 inches of VERI™ -solidified resin on every side, including the top and bottom.) These calculations indicated that the ENCAP™ monolith is structurally secure if underlying void spaces are less than 20.2 inches in diameter. Analysis of possible filter loading configurations showed that no single element could create a void large enough to endanger the integrity of the monolith. During loading, filters can be positioned to preclude creation of void spans or diameters greater than the permitted values. Loading specifications can be found in the "General Operating Procedure DT-VER-03, ENCAP™ Debris Loading" [15].

NRC raised questions [9] regarding creep; specifically, whether plastic tensile flow or tensile creep could occur over time until a void is filled from above. This would, in effect, create a condition over the waste form similar to vertical settlement and have a potential impact on stability. The maximum permissible void space was recalculated [11] using 50% of the observed VERI™ tensile strength. (Section 2.4.1.2 discusses how the 50% factor was selected.) The revised calculations [11], [16] indicated that a void space with a dimension not to exceed a diameter of 13.25 inches will maintain its integrity when subject to the overburden of the burial site. Appendix B to the TR Addendum [1], and the General Operating Procedure [15] should be revised to reflect the smaller void space permitted, and the associated limitations on filter loading and positioning.

## 2.5 Waste Loading, including Recommendations of the Branch Technical Position on Concentration Averaging and Encapsulation

The regulation, "Licensing Requirements for Land Disposal of Radioactive Waste," 10 CFR Part 61 [5], establishes a waste classification system based on the concentration of specific radionuclides contained in the waste. The regulation also states that, "the concentration of a radionuclide [in waste] may be averaged over the volume of the waste, or weight of the waste if the units [on the values tabulated in the concentration tables] are expressed as nanocuries per gram." The BTP on Concentration Averaging [8] defines a subset of concentration averaging and encapsulation practices that NRC staff would find acceptable in determining the concentrations of the 10 CFR 61.55 tabulated radionuclides in low-level waste. When the TR Addendum review began, the BTP on Concentration Averaging and Encapsulation was available only in draft form [17].

For filter encapsulation, concentration averaging may be over the volume or mass of the encapsulation providing that the volume and attributes of the waste comply with Appendix C of the BTP [8]. Review of the TR Addendum [1] indicates that the ENCAP™ waste forms can meet the criteria specified in Appendix C, as follows:

- A minimum amount of encapsulation is necessary to increase the difficulty of an inadvertent intruder moving the waste by hand.

  The waste form is approximately 200 $ft^3$ with the cartridge filters centrally encapsulated. The monolith is large enough to prevent an inadvertent intruder moving the waste by hand.

- The maximum amount of encapsulation is 0.2 $m^3$ unless a specific rationale is provided.

  This limit is provided to ensure that extreme measures are not taken solely for the purposes of dilution. DTS has presented a rationale for encapsulating multiple cartridge filters in 200 $ft^3$ liners. In Appendix A to the TR Addendum [1], the dilution factor for one filter cartridge encapsulated in a 55-gallon drum (0.2 $m^3$) is 7.35, which corresponds to a packing efficiency of 13.6%. The minimum packing efficiency for the ENCAP™ filter loading is expected to be 30% (by filter envelope volume), which is a lower "dilution" factor than that calculated from standard 55 gallon drum encapsulations.

- The maximum amount of gamma-emitting activity is that which, if credit is taken for a 500-year decay period would result in a dose rate less than 0.02 mrem/hr on the surface of the encapsulating media.

  In normal low-level waste, the classification-controlling nuclide is Cs-137. Cartridge filters generally do not contain enough of this nuclide, and their classification is usually controlled by either of the beta-emitting nuclides, C-14 or Ni-63. Most of the waste to be encapsulated using the ENCAP™ process does not contain long-lived gamma emitters. Therefore, this is not expected to be an issue. However, if any of the cartridge filters to be encapsulated contain gamma emitters which control the waste classification (see below), the surface dose rate should be calculated and must be less than 0.02 mrem/hr on the surface of the encapsulating media (after a 500-year decay period).

- The classification of the encapsulated package does not exceed Class C.

  Classification may be calculated as described below. Waste forms with radionuclide concentrations greater than Class C are not acceptable for disposal.

- The discrete activity source is reasonably centered in the encapsulation.

  The monolith is designed with a filter encapsulation cage centered within the monolith with not less than 4 inches of VERI™ waste form on every side. This criterion is met through design of the waste form.

- The structural form meets the requirements of 10 CFR 61.56 for Class B and C waste.

  See Section 2.4.

The determination of the waste classification of the disposal package containing the filters within the ENCAP™ liner may always be based on the highest classification associated with any filter, or alternatively, with any 0.2 cubic meter volume of the liner containing the encapsulated filters. Alternately, concentration averaging over the entire ENCAP™ liner containing the filters is permissible if: (a) the concentrations of the primary gamma emitters within individual filters within the ENCAP™ media are reasonably expected to be within a factor of 1.5 of the average concentration over all such filters[1] or (b) the concentration of the other 10 CFR 61.55, Table 1 or 2 nuclides within individual filters are within a factor of 10 of the average concentration over all encapsulated filters within that liner. In either case, the sum-of-the-fractions rule, described in 10 CFR 61.55(a)(7) would apply to the classification of the entire ENCAP™ volume or mass containing the filters.

The waste form also may contain spent ion exchange resin beads as part of the VERI™ matrix. In this case, "waste classification involving averaging the total activity over the total volume or mass of the waste in the [liner] would be accepted, if the classification of the mixture is not lower than the highest waste classification of any individual components [i.e., individual filter cartridges] of the mixture" [Reference 8, Section 3.8].

NRC staff recommends that the vendor or licensee classifying the mixture of filter cartridges [and spent ion exchange resin beads, if applicable] have in place a quality control program to ensure compliance with the waste classification provisions of 10 CFR 61.55.

## 2.6 Process Control Program

The introduction to the BTP on Waste Form [7] recommends that waste generators using an approved topical report process develop plant-specific process control procedures to demonstrate that a stabilized plant-specific waste stream satisfies Part 61 waste form requirements. DTS provided a set of operating procedures as part of the VERI™ TR. The operating procedures consist of PCP-03, "Process Control Procedure, Vinyl Ester Resin in Situ (VERI™) Solidification," and GOP-08, "General Operating Procedure, VERI™ Solidification." The Process Control Procedure (PCP) describes the method for developing the quantities of catalyst and promoter that will achieve the desired optimal solidification formulation. Once the amounts of catalyst and promoter necessary to achieve the desired gel time and quality of the final product have been determined, the General Operating Procedure lists the steps for final waste form solidification. These procedures, with the comments outlined in the associated RAI, were determined to be generally acceptable [3]. Note that use of modifiers, as described in these documents, has not been approved by the NRC. See the VERI™ TER [3] for details.

A General Operating Procedure specific to the ENCAP™ process has also been provided [15]. This document, when used with PCP-03 and GOP-08, described above, has been determined to be generally acceptable. It should be revised to reflect the updated limits on void spaces through revised criteria for filter loading and positioning according to the discussion in Section 2.4.3 above, and should also be revised to limit waste to spent filter cartridges only.

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[1] Applies if these nuclides would dictate the classification of the waste.

2.7 Reporting of Mishaps

According to the BTP on Waste Form [7], vendors and processors are included in the group who are requested to report mishaps. For the DTS ENCAP™ process the following types of mishaps should be reported for solidified Class B or Class C waste forms:

- Greater than 0.5 percent volume of free liquid.
- Concentrations of radionuclides greater than the concentrations demonstrated to be stable in the waste form in qualification testing accepted by the regulatory agency.
- Greater or lesser amounts of solidification media than were used in qualification testing accepted by the regulatory agency.
- Presence of chemical ingredients not present of accounted for in qualification testing accepted by the regulatory agency.
- Instability evidenced by crumbling, cracking, spalling, voids, softening, disintegration, non-homogeneity, or change in dimensions.
- Evidence of processing phenomena that exceed the limiting processing conditions identified in the applicable TRs or operating procedures such as foaming, excessive temperature, premature or slow hardening, production of volatile material, etc.
- The calculated classification of the encapsulated waste form exceeds Class C.

Waste form mishaps should be reported to the NRC's Director of the Division of Waste Management and the designated State disposal site regulatory authority within 30 days of knowledge of the incident. For any such waste form mishap occurrences, the affected waste form should not be shipped off-site until approval is obtained from the disposal site regulatory authority. Low-level waste generators and processors are required by 10 CFR 20.311/20.2006 to certify that their waste forms meet all applicable requirements of 10 CFR Part 61, and waste forms that are subject to the types of mishaps listed above may not possess the required long-term structural stability. When mishaps of the nature described above occur, it is expected that, before the waste form is shipped to a disposal facility, either adequate mitigation of the potential effects on the waste form, or an acceptable justification concerning the lack of any potential significant effects of the affected waste form on the overall performance of the disposal facility would be provided.

## 3.0 CONCLUSIONS

The DTS Topical Report Addendum [1], with the DTS responses to NRC comments and questions [10, 11, 12] is acceptable as a reference document for licensing the waste form produced by the ENCAP™ process, subject to certain limitations and further actions by DTS. NRC staff recommendations are also listed.

3.1 Limitations

a) The resins used to produce the encapsulating waste forms are limited to those specifically identified in the VERI™ TR and associated TER as those used to prepare the test specimens on which the data were obtained.

b) The disposal unit containing the encapsulated mass must be segregated from disposal units containing Class A wastes that do not meet the structural stability requirements in 10 CFR 61.56(b).

c) If any of the cartridge filters to be encapsulated contain gamma emitters which control the waste classification (see Section 2.5), the calculated dose rate must be less than 0.02 mrem/hr on the surface of the encapsulating media (after a 500-year decay period).

3.2 Further Actions

a) Information to be added to the revised Topical Report Addendum:

1. Appendix B to the TR Addendum [1] should be revised to reflect the smaller void space permitted considering tensile creep test results.

2. The General Operating Procedure [15] should be revised to reflect the smaller void space permitted considering tensile creep test results, and the associated limitations on filter loading and positioning.

3. The General Operating Procedure [15] should be revised to limit waste to be encapsulated to spent filter cartridges.

4. Additions/alterations as discussed in the responses [10, 11, 12] to the NRC RAI [9].

3.3 Recommendations

a) NRC staff recommends that the vendor or licensee classifying the mixture of filter cartridges [and spent ion exchange resin beads, if applicable] have in place a quality control program to ensure compliance with the waste classification provisions of 10 CFR 61.55.

REFERENCES


1. "ENCAP™ Encapsulation Utilizing the VERI™ Solidifications Process," Revision 1, Addendum 1, DT-VERI-100-NP/P-A, May 1, 1994. (Docket Number WM-105).

2. "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low Level Radioactive Waste," DT-VERI-100-NP/P-A, April 5, 1993.

3. "Technical Evaluation Report related to Topical Report DT-VERI-100-NP/P, VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste," U.S. Nuclear Regulatory Commission, December 1992.

4. "Elimination of Low-Level Radioactive Waste Topical Report Review Program," Federal Register Notice dated May 17, 1995 (60 FR 26466).

5. Code of Federal Regulations, Title 10, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," U.S. Nuclear Regulatory Commission, Washington, D.C., January 1, 1991.

6. U.S. Nuclear Regulatory Commission, "Technical Position on Waste Form," Rev. 0, May 1983.

7. U.S. Nuclear Regulatory Commission, "Technical Position on Waste Form, " Rev. 1, January 1991.

8. U.S. Nuclear Regulatory Commission, "Issuance of Final Branch Technical Position on Concentration Averaging and Encapsulation," January 17, 1995.

9. Request for Additional Information from J. Thoma/NRC to C. Jensen/DTS, dated September 14, 1994.

10. Letter enclosing "Response to RAI #1," from C. Jensen/DTS to J. Thoma/NRC dated October 21, 1994.

11. Letter enclosing "Supplemental Submittal" from C. Jensen/DTS to J. Thoma/NRC, dated December 18, 1997.

12. Letter enclosing "ASTM Test Report, Supplement #2 to ENCAP™ RAI #1," from C. Jensen/DTS to J. Davis/NRC, dated March 23, 1998.

13. "Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics," ASTM D2990-90, American Society for Testing and Materials.

14. ANS 55.1, "American National Standard for Solid Radioactive Waste Processing System for Light Water Cooled Reactor Plants," American Nuclear Society, 1979.

15. "General Operating Procedure DT-VER-03, ENCAP™ Debris Loading," Rev. 0, Diversified Technologies, Inc.; December 4, 1994. Submitted via letter from C. Jensen/DTS to J. Thoma/NRC, December 6, 1994.

16. "VERI Liner Protective Cage Calculations," fax transmittal from C. Jensen/DTS to J. Davis/NRC dated 29 December, 1999.

17. Memorandum from M.R. Knapp/NRC to Distribution, "Final Branch Technical Position on Concentration Averaging and Encapsulation," dated April 21, 1994.