FEB - 4 1993

MEMORANDUM FOR: Vandy L. Miller, Assistant Director
for State Agreements Program
Office of State Programs

FROM: Paul H. Lohaus, Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Material Safety
and Safeguards

SUBJECT: TECHNICAL EVALUATION REPORT ON THE DIVERSIFIED TECHNOLOGIES, INC., TOPICAL REPORT, "VERI" (VINYL ESTER RESIN IN SITU) SOLIDIFICATION PROCESS FOR LOW-LEVEL RADIOACTIVE WASTE," REPORT NUMBER DT-VERI-100-NP/P, REVISION 0, DECEMBER 1, 1991, DOCKET NUMBER WM-105

Four copies of the subject Technical Evaluation Report (TER) and our letter of transmittal are enclosed. The TER approves the Diversified Technologies topical report on the VERI™ Solidification Process when the final revised topical report is submitted. Please note that final approval is contingent on a revised topical report and satisfactory resolution of the open issues identified in Section 3.0 of the enclosed TER. The revised topical report is due to the Nuclear Regulatory Commission on April 5, 1993.

Please transmit the TER's and cover letters to the Host States. If you have any questions regarding this letter, please contact Jennifer Davis at (301) 504-2697.

Paul H. Lohaus, Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN - 4 1993

Mr. Charles E. Jensen
Vice President, Operations
Diversified Technologies, Inc.
103 Dixon Drive
Chestertown, MD 21620

Dear Mr. Jensen:

The Nuclear Regulatory Commission has completed its review of topical report, DT-VERI-100-NP/P, "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste." The technical review included information contained in the topical report (TR), and further information that was submitted as a result of the review. The Technical Evaluation Report (TER) for this review is enclosed.

We have concluded that the topical report supplemented by additional information that was provided in response to staff comments and questions adequately describes low-level radioactive waste forms produced through use of the VERI™ process. This process applies to the solidification of two waste streams, mixed bed bead resins, and LOMI resins.

We also conclude that the solidified waste forms described meet the structural stability requirements of 10 CFR 61 for the disposal of Class B and Class C wastes. These conclusions are predicted based on satisfactory completion of a final revised topical report which should include all applicable information developed during the technical review, a copy of the enclosed TER, and the following conditions:

1. The VERI™ waste solidification process shall be used in accordance with the limitations called out in Section 3.1 of this Technical Evaluation Report, and all additional restrictions and requirements specified by the disposal facility operators and governing state agencies.

2. Diversified Technologies must notify users of the VERI™ waste solidification process that they shall certify that all restrictions and required procedures have been adhered to, and that the waste forms do not contain proscribed chemicals or waste materials.

3. Diversified Technologies must characterize the chemical nature of the resins used in the qualification tests so that users of the process can know what kind of resins can be satisfactorily solidified. This information must be clearly specified in the final revised TR and operating procedures.

4. Diversified Technologies must resolve the outstanding issues specified in Section 3.2 of the enclosed TER.

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Note that Final Approval is contingent on completion of a revised TR which includes satisfactory resolution of the outstanding issues in 3 and 4 above. The revised topical report should be submitted to the NRC within 90 days of this letter.

It should be noted that notwithstanding NRC's decisions on the adequacy of the VERI™ polymer solidified wastes, the sited States have regulatory authority concerning the conditions of acceptance of waste forms at their disposal facilities. It is therefore the licensee's responsibility to contact the State regulatory authorities to determine the acceptability of the polymer solidified wastes at their State's facilities.

Copies of the enclosed TER and this letter are being forwarded to the States of Nevada, South Carolina and Washington for their information and use.

If you have any questions on this matter, please contact me at (301) 504-3450, or Jennifer Davis at (301) 504-2697.

Sincerely,

ORIGINAL SIGNED BY

John Thoma, Section Leader
Technical and Special Issues Section
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Material Safety
and Safeguards

Enclosure:
As stated

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

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

Diversified Technologies
Docket No. WM-105

Prepared by: Low-Level Waste Management Branch
Division of Low-Level Waste Management and Decommissioning
December 1992

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ABSTRACT

This Technical Evaluation Report (TER) has been prepared by the Office of Nuclear Material Safety and Safeguards of the US Nuclear Regulatory Commission for Diversified Technologies' Topical Report (TR), DT-VERI-100-NP/P, "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste," (Docket Number WM-105). This TR is based on work done in conjunction with the Dow Chemical USA Topical Report DNS-RSS-200-NP, "The Dow Waste Solidification Process For Low-Level Radioactive Wastes" (Docket Number WM-82). The Diversified Technologies' TR expands on the Dow TR in two areas. First, all of the approved Dow waste forms were limited to a maximum of 50 cubic feet. The Diversified Technologies' TR was designed to qualify solidification of spent ion-exchange resin in a 200 cubic foot liner, using a process similar to the Dow process. It also contains qualification test results for solidification of spent LOMI (Low Oxidation State Transition Metal Ion) ion-exchange resin, which was not one of the waste streams included in the Dow TR.

On the basis of the information presented, the staff concludes that this binder process, when applied to the specified waste streams, should result in waste forms that meet the structural stability requirements of 10 CFR Part 61 and the guidance provided in the Technical Position on Waste Form, Revision 1, January 1991. Limiting conditions for use of these waste forms may be specified by the regulating authority for a particular disposal site.

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DIVERSIFIED TECHNOLOGIES VERI™ PROCESS (WM-105)

1.0 BACKGROUND

This report provides the evaluation results of the technical review of information and data submitted by Diversified Technologies in a topical report (TR) entitled, "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste," DT-VERI-100-NP/P, December 1, 1991. This Technical Evaluation Report (TER) is a detailed evaluation of the waste form qualification test data provided by Diversified Technologies to confirm that this solidification process will produce a waste form that meets the regulatory requirements of 10 CFR Part 61 with respect to structural stability.

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, in the case of TR's for waste forms, waste generators must take additional actions (e.g., plant-specific process control procedures) to demonstrate that all portions of Part 61 have been met.

1.1 Regulations

By Federal Register Notice dated December 27, 1982 (47 FR 57446), the United States Nuclear Regulatory Commission (NRC) amended its regulations to provide specific requirements for licensing of facilities for the land disposal of low-level radioactive waste (LLW). The majority 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" (Ref. 1). These regulations are the culmination of a set of prescribed procedures for LLW disposal that were 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 that are 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 practicable, 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 the NRC provided additional guidance by means of a Technical Position on Waste Form (TP) (Ref. 2) 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 forms is provided in Revision 1 to the Technical Position on Waste Form, which was issued in January, 1991 (Ref. 3).

The purpose of this Technical Evaluation Report (TER) is to summarize the technical review conducted of the information submitted by Diversified Technologies (also referred to as the vendor), and to demonstrate that the polymer solidification of LLW by the process described in its topical report, "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste," (Ref. 4), and in associated documents, will meet the long-term (300-year) structural stability provisions of 10 CFR 61.56 and the relevant portions of the January 1991 NRC Staff Technical Position on Waste Form.

1.2 Topical Report Submittal

The NRC staff concluded on June 1, 1988 that the Topical Report for the Dow Waste Solidification Process (Ref. 5), 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 vinyl-ester-styrene (VES) solidification of the 7 waste streams that are described in Table A of the applicable NRC Technical Evaluation Report (Ref. 6).

Dow Chemical, USA decided not to market the VES process and placed its process and the associated topical report in the public domain. This enables waste generators and processors to utilize the VES material to solidify and stabilize low-level wastes subject to the conditions specified in NRC's TER.

One of the 7 waste streams approved for use with the Dow process was ion-exchange bead resin slurry. On November 14, 1989, Diversified Technologies held a meeting with NRC (Ref. 7), to propose an addendum to the Dow Topical Report which would permit solidification of ion-exchange resin beads in large liners (up to 200 ft^3). The original process was qualified only for volumes up to 50 ft^3.

Diversified Technologies submitted their topical report, DTI-WMS-100-NP, in August 1990 (Ref. 8). The "VERI™" process described in the topical report differs from the Dow "VES" process in several ways. The VERI™ process involves forcing (by pumping) or drawing (by suction) a catalyzed and promoted modified vinyl ester resin through an expended ion-exchanger resin container. The Dow solidification method is a mixing process. In addition, the binder and promoter specified by Diversified Technologies differ slightly from those used by Dow. Diversified Technologies also proposed qualification of a waste stream not qualified by Dow; spent LOMI (Low Oxidation State Transition Metal Ion) ion exchange resin. The original Diversified Technologies' topical report also included information on two other Diversified Technologies low-level waste processing methods that were not part of this review. The NRC concluded that the TR was not an addendum to the approved Dow solidification TR, but was a new TR based on a new process (which results in a polymer waste form similar to those from the Dow process). The NRC requested Diversified

Technologies to submit a revised TR, which they did on December 1, 1991 (Ref. 4). This TER is written to describe and approve only the revised and reissued TR and associated documentation. This associated documentation includes a second NRC Request for Additional Information (RAI #2) (Ref. 9) and Diversified Technologies' Response (Ref. 10). Note that some information in the original TR was not included in the revised TR, but will be reinstated per RAI #2 and the responses to RAI #2. This material will be discussed, as it is integral to the TR review. Note that for all future purposes, the December 1991 TR will be considered the "original" Diversified Technologies TR.

1.3 Diversified Technologies Vinyl Ester Resin In-Situ Process

The proposed solidification process involves forcing (by pumping, or suction) a catalyzed and promoted modified vinyl ester styrene through a disposal liner, demineralizer column, or other expended ion exchange resin container. As the binder flows through the resin bed, it fills the void spaces between the resin beads, and forces any free water in the container into the bottom dewatering internals. After filling the void spaces in the resin bed, and displacing the excess water, the binder cures to form a liquid-free, hard, free-standing monolith inside the container.

2.0 TECHNICAL EVALUATION

The information presented in the topical report and Diversified Technologies' letter responses to NRC's comments provide the basis for the technical evaluation presented in the following sections. The review and evaluation was 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 and the guidance on solidified waste forms in the Revised TP (Ref. 3).

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 are only required to meet these minimum requirements if they are segregated and are not solidified waste forms. Class A wastes that are 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.

The characteristics the waste form classified as Class B or Class C should exhibit to meet the stability requirements of 10 CFR 61.56(b), are those that will enable the waste form to maintain its stability and package integrity during waste-handling and emplacement, as well as 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 TR and subsequent documentation identified the two waste streams listed below.

- Ion-exchange bead resin. For the test solidification, this waste stream consisted of non-radioactive ion-exchange bead resin obtained from a commercial resin supplier. The supplied resin consisted of at least eight discrete types of resin beads, inorganic oxides, and water processing media; however, no more explicit information was provided regarding the approximate quantities or specific types of resin. This should be provided by Diversified Technologies in their revised topical report. Some of the material used for the test solidification had been stored for up to a year, and other material had been used for sludge filtration after their useful life was expended.

- LOMI bead resin. For the test solidifications, a licensed LOMI vendor prepared surrogate LOMI resin beads by loading LOMI chemicals and non-radioactive metals and oxides on cation and anion resins to simulate a typical ion-exchange loading for decontamination of spent LOMI decon solution.

2.3 Minimum Requirements [10 CFR 61.56(a)]

Section 61.56(a) 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 TR was evaluated against each requirement contained in 10 CFR 61.56, as well as the guidance contained in the revised TP on Waste Form (Refs. 1 and 3).

2.3.1 Packaging

Section 61.56(a)(1) of 10 CFR Part 61 specifies that waste must not be packaged for disposal in cardboard or fiberboard boxes. The waste form is contained in steel drums or liners and thus satisfies this requirement.

2.3.2 Liquid Waste

Section 61.56(a)(2) of 10 CFR Part 61 specifies that liquid waste must be solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid. The liquid wastes addressed by the subject topical report and subsequent vendor communications, are solidified and, therefore, fulfill this requirement.

2.3.3 Free Liquid

Section 61.56(a)(3) of 10 CFR Part 61 specifies that free standing liquid in the solid waste shall not exceed 1% of the volume of the solid waste. In the

TR, the vendor states that "the binder cures, forming a <u>liquid-free</u>, hard, free-standing monolith inside the container" (emphasis added). The original TR (Ref. 8) stated that "upon cutting through the side of the liner, a small amount of water was observed, collected and measured. [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 monolith." Diversified Technologies' discussion of this phenomenon points out that the amount was less than 0.15% of the waste volume as well as being less than 0.10% of the liner volume. 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 a sample is removed from its mold, a small amount of moisture is evident on its surface. This surface moisture appears to be independent of the degree of pre-dewatering. Although here may be some free water present following solidification as demonstrated, the volume is well within the maximum, and the waste forms therefore fulfill this requirement.

2.3.4 <u>Reactivity of Product</u>

Section 61.56(a)(4) of 10 CFR Part 61 specifies that the waste must not be readily capable of detonation, explosive decomposition, or reaction, at normal pressures and temperatures, or of explosive reaction with water. After solidification, the waste forms described in the subject topical report do not contain any substances capable of such reactions and thus satisfy this requirement.

2.3.5 <u>Toxic Gas Generation</u>

Section 61.56(a)(5) of 10 CFR Part 61 specifies that the waste must not contain or be capable of generating toxic gases, vapors, or fumes harmful to persons transporting, handling or disposing of the waste form. The solidified waste forms emit no such gases, vapors, or fumes and thus satisfy this requirement.

2.3.6 <u>Pyrophoricity</u>

A waste must not be pyrophoric, as defined in 10 CFR 61.2 and prohibited in 61.56(a)(6) of the regulations. The solidified waste forms are not pyrophoric nor do they contain materials which are pyrophoric; therefore, the solidified wastes satisfy this requirement.

2.3.7 <u>Gaseous Wastes</u>

This solidification process is not proposed for use on gaseous wastes, so that 10 CFR 61.56(a)(7) of the regulation is not applicable to the Diversified Technologies waste forms.

2.3.8 <u>Hazardous Waste</u>

Under Section 10 CFR 61.56(a)(8), waste containing hazardous, biological, pathogenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the non-radiological materials.

Neither the VERI™ polymer binder material, nor the waste stream materials identified in the TR contain biological, pathogenic or infectious material. Therefore, the requirements of 10 CFR 61.56(a)(8) have been met.

It should be noted that the NRC topical report review of the Diversified Technologies VERI™ solidification process did not address any applicable U.S. Environmental Protection Agency (EPA) requirements relating to hazardous solid waste, for which the vendor or waste generator using the Diversified Technologies VERI™ process for LLW may be legally responsible under the Resource Conservation and Recovery Act (RCRA).

Under RCRA, the EPA has jurisdiction over the management of solid hazardous wastes with the exception of source, byproduct, and special nuclear material, which NRC regulates under the Atomic Energy Act. LLW's 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, wherein NRC regulates the radioactive component and EPA regulates the hazardous component of the same waste.

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

The requirements of 10 CFR 61.56(b) are intended to result in waste products with 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 1991 revised 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, such as has been proposed by the Diversified Technologies' polymer solidification process. The proposed waste forms resulting from the Diversified Technologies VERI™ process will be packaged in suitable containers, but the containers 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. Additional guidance on meeting the regulatory requirements has been provided in the TP.

The following sections summarize the qualification testing of the Diversified Technologies' polymeric waste forms as described in the documents identified in Section 1.2, above, and evaluate the test results utilizing the criteria recommended in the revised TP on Waste Form. Note that the Dow samples were tested and approved in accordance with the original TP on Waste Form (Ref. 2), which is very similar to the revised TP with respect to polymer waste forms. The Diversified Technologies samples were also tested in accordance with the original TP, but will be qualified according to the revised TP.

2.4.1.1 As-Cured Compressive Strength

The 1983 TP recommended that the minimum compressive strength for a solidified waste product be at least 50 psi as measured in accordance with the procedure of ASTM C39 (Ref. 11). The minimum allowable compressive strength was later raised to 60 psi to take into account the increase in burial depth (and thus burial loading) at Hanford from 45 feet to 55 feet. The term "compressive strength testing" as used in this section of the TER is limited to testing of as-cured solidified waste forms. "As-cured" testing refers to testing performed on specimens which have not been subjected to environmental influences which have the potential to degrade the specimen (e.g., immersion, thermal cycling, irradiation), hence the equivalent term "pre-environmental."

The compressive strength tests were conducted in accordance with the procedure of ASTM C39 using cylindrical samples machined to a diameter of 1.25" and a length of 2.5". The tests were conducted by an independent laboratory on three replicates of each type. The compressive strengths follow:

Table I - As-Cured Compressive Strengths

Compressive Strength (psi)	Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft^3 Liner Run	Surrogate LOMI Resin Data
Lab Sample	1919 ± 40	2052 ± 294	4176 ± 232
50 ft^3 Sample	5848 ± 86	---	---
200 ft^3 Sample	---	2633 ± 798	---

* Original Dow Topical Report

The compressive strengths of all solidified waste forms tested were well above the 60 psi minimum specified by the Technical Position on Waste Form, and are acceptable.

2.4.1.2 Radiation Resistance

The Technical Position on Waste Form recommends that specimens of each proposed waste stream formulation should remain stable after exposure to an absorbed gamma ray dose of 10^8 rad (or greater if the expected maximum accumulated absorbed dose of the waste is greater). The irradiated waste form specimens should have the "maximum practical compressive strengths" (Ref. 3), (i.e. a minimum compressive strength of 60 psi).

The Diversified Technologies' waste forms were subjected to 10^8 rads at Neutron Products, Inc., and after inspection were shipped to an independent laboratory for compressive strength testing. One Dow ion-exchange bead resin sample was also subjected to 10^8 rads, and the compressive strength result for that sample is listed below. The radiation exposure evaluations were performed on three samples of each Diversified Technologies' formulation. The samples were 1.25-inch diameter by 2.5-inch long cylinders. The following are the results of compressive strength testing on the irradiated samples:

Table II - Compressive Strengths Following Irradiation

Compressive Strength (psi)	Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft^3 Liner Run	Surrogate LOMI Resin Data
Lab Sample	1980	...	4950 ± 508
200 ft^3 Sample	...	2908 ± 253	...

* Original Dow Topical Report

All post-irradiation compressive strength test values listed are greater than 60 psi, are comparable to the non-irradiated compressive strengths listed in Table I, and are therefore acceptable.

2.4.1.3 Biodegradation Resistance

The technical position recommends that waste form specimens for each proposed waste stream formulation be tested for resistance to biodegradation in accordance with both ASTM G21 (Ref. 12) and ASTM G22 (Ref. 13), which are tests for resistance of synthetic polymeric materials to degradation by fungi and by bacteria, respectively. For polymeric products, some visible culture growth from contamination, additives, or biodegradable components on the specimen surface that do not relate to overall substrate integrity may be present. If this happens, additional testing should be performed. Following biodegradation testing, polymeric waste form specimens should have the "maximum practical compressive strengths" (Ref. 3), (i.e. a minimum compressive strength of 60 psi).

The 1.25-inch diameter by 2.5-inch long cylindrical specimens were evaluated for resistance to fungal and bacterial growth. There was no visible fungal or

bacterial growth on any of the specimens. The compressive strength values after the fungal and bacterial testing are as follows:

Table IIIa - Compressive Strengths Following Biodegradation Testing (Fungal)

Compressive Strength (psi)	Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft^3 Liner Run	Surrogate LOMI Resin Data
Lab Sample	2015 ± 88	...	4010 ± 57
200 ft^3 Sample	...	2059 ± 677	...

* Original Dow Topical Report

Table IIIb - Compressive Strengths Following Biodegradation Testing (Bacterial)

Compressive Strength (psi)	Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft^3 Liner Run	Surrogate LOMI Resin Data
Lab Sample	2524 ± 291	...	3806 ± 647
200 ft^3 Sample	...	1810 ± 567	...

* Original Dow Topical Report

All post-biodegradation compressive strength test values listed are greater than 60 psi, are comparable to the pre-biodegradation compressive strengths listed in Table I, and are therefore acceptable.

2.4.1.4 Leachability

The 1991 TP recommends that leach testing be performed for a minimum of 90 days in accordance with the procedure described in ANSI/ANS-16.1 (Ref. 14). In addition to the demineralized water test specified in ANSI/ANS-16.1, the TP recommends that the samples be tested with the synthesized sea water leachant. The TP also recommends that radioactive forms of cobalt, cesium and strontium should be used as tracers. The leachability index, as calculated in accordance with ANSI/ANS-16.1, should be greater than 6.0.

The majority of the Dow waste forms were tested before ANS 16.1 was developed and published. The Dow test methods were, however, similar to the ANS 16.1 method, and much of the Dow data has been verified by other researchers. The main difference between the ANS 16.1 procedure and the Dow test method is in the amount of leachant volume used in the test. The ANS 16.1 procedure specifies that a leachant volume 10 times the external surface area of the specimen be used. The leaching in the Dow tests was carried out with smaller amounts of leachant, 0.5 to 2 times the specimen surface area in order that the very low leach rates of the Dow specimens could be measured without

exceeding the sensitivity of available counting equipment. Independent leach testing on waste solidified using the Dow process indicated that the low amount of leachant used had no significant effect on the test results. (See Ref. 6 for further information.)

The leachant volume to sample surface area (V/S) was also lower than that specified by ANS 16.1 for the Diversified Technologies samples. The samples were 4.75 cm in diameter X 5.7 cm long, and were immersed in 250 ml of either demineralized water or synthesized sea water, for a V/S of approximately two. This V/S is deemed appropriate for this type of waste form only because the leach indices are relatively high, and because the independent testing indicated a correlation for the similar Dow waste forms.

The revised TP recommends that "[f]or proposed nuclear power station waste streams, cobalt, cesium and strontium should be used as tracers." The original TP did not specify tracers. The proposed waste forms were tested using the original TP, and the method described in the Dow TR (Ref. 5), and only cobalt was used as a tracer. The resulting leach indices in both synthesized sea water and demineralized water were more than three orders of magnitude greater than the TP criteria of 6. Because the leach indices for cobalt in these waste forms were so high, and because the available results are similar to the Dow results, which also showed a very low leachability for cesium, testing with cesium and strontium tracers is not required at this time. The results of the Diversified Technologies leach testing are listed in Table IV.

Table IV - Leachability Indices

LEACHABILITY INDEX (Co)	WASTE FORM		
	Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft³ Liner Run	Surrogate LOMI Resin Data
DEMINERALIZED WATER	16.3	11.9	11.6
SYNTHESIZED SEA WATER	10.1	9.8	9.5

* Original Dow Topical Report

All of the leach indices are greater than 6.0, and the leachability of these samples is therefore acceptable.

2.4.1.5 Immersion Resistance

The Technical Position on Waste Form recommends that waste specimens should maintain the maximum practical compressive strength as tested using ASTM C39 (Ref. 11) following immersion for a minimum period of 90 days. The immersion resistance tests were performed on 1.25-inch diameter by 2.5-inch high cylindrical samples immersed in demineralized water for 90 days. At the end of the 90-day period compression tests were performed on the samples. See Table V for the results of the compression tests for each waste stream.

Table V - Compressive Strengths Following Immersion

Compressive Strength (psi)		Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft^3 Liner Run	Surrogate LOMI Resin Data
Lab Sample	Before Immersion	1919 ± 40	2052 ± 294	4176 ± 232
	Following Immersion	2023 ± 86	2175 ± 421	3801 ± 644
50 ft^3 Sample	Before Immersion	5848 ± 66	...	...
	Following Immersion	4128 ± 128	...	...
200 ft^3 Sample	Before Immersion	...	2633 ± 798	...
	Following Immersion	...	2119 ± 486	...

* Original Dow Topical Report

The compressive strengths following immersion are well above the 60 psi required, and are similar to the compressive strengths prior to immersion. In addition, the test specimens were visually examined immediately after removal from the water in which they were immersed, and no changes in appearance or physical integrity were evident. The staff considers that the waste specimens have maintained the maximum practical compressive strengths, and the immersion test results for these samples are therefore acceptable.

2.4.1.6 Thermal Cycling

The Technical Position on Waste Form recommends that thermal cycling testing be conducted in heating and cooling chambers conforming to those described in ASTM B553, Section 3 (Ref. 15). A series of 30 thermal cycles between 60°C and -40°C should be carried out in accordance with ASTM B553. Following testing, the specimens should have the maximum practical compressive strengths.

The thermal cycling test was performed on cylindrical specimens measuring 1.25 inches in diameter by 2.5 inches high. The vendor ensured that the samples reached thermal equilibrium at each temperature by placing a thermocouple in the center of one of the waste forms. The sample was placed in the heating chamber, and the time required to reach 60°C was determined. The sample was allowed to cool to room temperature, then placed in the cooling chamber and the time required to reach -40°C was determined. The qualification test samples were then subjected to thermal cycling for thirty cycles, with the samples held at each temperature (-40°C, 20°C, and 60°C) for one hour after reaching thermal equilibrium. The following are the post-thermal-cycling compressive strengths:

Table VI - Compressive Strengths Following Thermal Cycling

Compressive Strength (psi)	Mixed Bed Resin Data from TR DNS-RSS-200-NP*	Mixed Bed Resin Data from 200 ft^3 Liner Run	Surrogate LOMI Resin Data
Lab Sample	2492 ± 35	...	5539 ± 336
200 ft^3 Sample	...	2914 ± 554	...

* Original Dow Topical Report

Following the thirty cycles, visual examination showed that the samples had maintained their appearance and physical integrity. In addition, all post-thermal cycling compressive strength test values listed are greater than 60 psi, are comparable to the pre-thermal cycling compressive strengths listed in Table I, and are therefore acceptable.

2.4.1.7 Correlation Testing

The TP 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. This testing may be performed on non-radioactive specimens. The full-scale specimens should be fabricated using actual or comparable solidification equipment. This correlation should be established by 90-day immersion tests (including post-immersion compressive strength tests). It is also suggested that the correlation testing should be performed on the most conservative waste stream intended for use for the particular solidification medium; that is, the waste stream that presents the most difficulty in producing stable products should be used.

In essence, this TR is designed for the purposes of correlation testing. The mixed bed resin waste stream was solidified in a 200 ft^3 liner, with lab scale samples manufactured for correlation, and for the leach tests. In addition, as a more conservative waste stream than the surrogate LOMI waste stream, the 200 ft^3 liner solidification qualifies the LOMI resin beads for large scale solidification as well. The results are summarized in Table V.

The full-scale and lab-scale specimens exceed the 60 psi compressive strength criterion, and exhibit similar compressive strengths, both before and after 90 day immersion. In summary, the full-scale specimen results satisfactorily demonstrate the correlation between full scale and lab scale samples.

2.4.1.8 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.

Eight vertical cores were taken from the solidified 200 ft^3 liner containing mixed bed resins. After coring, the samples were turned down on a lathe to 1.25 inches in diameter by 2.5 inches in length. When samples were tested in triplicate, each sample would be from a different core, and one each of the three samples would be from the top, bottom and middle of the liner.

The initial compressive test results on the cored samples were 2633 ± 798. These results exceed the 60 psi minimum, are similar to the lab scale results of 2052 ± 294, and show that the full-scale waste form is homogeneous to the extent required.

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 revised TP on Waste Form addresses this requirement. Section C.2.g recommends that waste specimens have less than 0.5 percent by volume of the waste specimen as free liquids as measured using the method described in ANS 55.1 (Ref. 16) . Free liquids should have a pH between 4 and 11.

See Section 2.4.3 for a discussion of free liquid found following liner solidification. The liquid amounted to less than 0.15% of the volume of the waste. The volume requirement has been satisfied. The pH of the liquid was not measured when the liquid was discovered, and it is no longer possible to make that determination. Diversified Technologies noted that the same phenomenon occurs in lab-size samples. The NRC recommends that lab-size samples of the LOMI and mixed bed resin be manufactured, and that the pH be determined and reported in the revised Topical Report.

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 the waste form solidifies in the container. 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. The process is effective in minimizing void spaces to the extent practicable, however, it is the responsibility of the user to ensure that containers are filled to reduce void spaces.

2.5 Process Control Program

The introduction to the Technical Position on Waste Form 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. Diversified Technologies has provided a set of operating procedures as part of the Topical Report. 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 RAI's and responses, are generally acceptable.

There is one exception, however. Both documents describe addition of modifiers when necessary. These modifiers are intended for use in depleting the ion exchange capacity of those resins which have too large a capacity remaining. This is a reasonable addition; however, the modifiers have not been qualified with the process described in the Diversified Technologies TR. Diversified Technologies should delete the references to modifiers #1 and #2 in the Process Control Procedure and the General Operating Procedure.

In order for the modifiers to be qualified, a separate, additional TR should be submitted, which demonstrates that samples manufactured with the VERI™ process, using the modifiers as additives, can be successfully solidified.

2.6 Reporting of Mishaps

As a result of the revision to the TP (Ref. 3), vendors and processors are included in the group who are requested to report mishaps. For the Diversified Technologies VERI™ process, the following types of mishaps are examples of instances that should be reported for solidified Class B or Class C waste forms exhibiting one of the following characteristics:

- 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 or 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 TR's or operating procedures, such as foaming, excessive temperature, premature or slow hardening, production of volatile material, etc.

Waste form mishaps should be reported to the NRC's Director of the Division of Low-Level Waste Management and Decommissioning 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. The reason for this is that the 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 mentioned 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 Diversified Technologies Topical Report, with the Diversified Technologies responses to NRC comments and questions, is acceptable as a reference document for licensing the waste form produced by the VERI™ process, subject to the certain limitations and further actions by Diversified Technologies.

3.1 Limitations

a) The waste forms produced are limited to those made from the reactants specifically identified in the TR as those used to prepare the test specimens on which the data were obtained.

Subject to the above limitation, and after completing the further actions listed below, the Diversified Technologies waste forms should be capable of meeting the stability requirements of 10 CFR Part 61 when produced using the process described in the Topical Report (Ref. 4).

3.2 Further Actions

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

1. Diversified Technologies must characterize the chemical nature of the resins used in the qualification tests so that users of the process can know what kind of resins can be satisfactorily solidified. Diversified Technologies should also state what actual nuclear power plant resins are represented by the simulated mixed bed resin waste stream.

2. Diversified Technologies stated that "each media type was separately tested and shown to successfully solidify." The results of these tests should be provided in the revised Topical Report, as they provide vital bounding information.

3. Diversified Technologies should determine the approximate pH of any free liquid resulting from the solidification process, and include the figure or range in the revised Topical Report. (See Section 2.4.2 of this TER for more details).

b) Diversified Technologies should revise the Process Control Procedure to include any limits on the types of resins that can be solidified using this process.

c) Diversified Technologies should delete the references to modifiers #1 and #2 in the Process Control Procedure and the General Operating Procedure.

REFERENCES

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

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

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

4. Diversified Technologies, Inc., Topical Report, "VERI™ (Vinyl Ester Resin In Situ) Solidification Process for Low-Level Radioactive Waste," DT-VERI-100-NP/P, December 1, 1991.

5. Dow Chemical Company, Topical Report, "The Dow Waste Solidification Process for Low-Level Radioactive Wastes -- Generic Waste Form Certification Results," DOW-RSS-200-NP-A, June 1984.

6. Technical Evaluation Report, "TER Related to the TR DNS-RSS-200-NP, Covering the Dow Polymer (Vinyl Ester Styrene (VES)) Process for Solidification of Low-Level Waste Form," April 1988.

7. Memo from E. Wick, through M. Tokar, to J. Surmeier, dated December 4, 1989, "Summary of November 14, 1989 Meeting with Diversified Technologies, Group, Inc."

8. Diversified Technologies, Inc., Topical Report, "A Waste Management System Utilizing WPS™, HVV™, and VERI™ Process Systems and Technology," DTI-WMS-100-NP, August 1990.

9. Memo from J. Kane (NRC) to C. Jensen (Diversified Technologies), dated April 14, 1992.

10. Memo from C. Jensen (Diversified Technologies) to J. Kane (NRC), "Response to Request for Additional Information (RAI) #2...," dated June 12, 1992.

11. ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," American Society for Testing and Materials, 1980.

12. ASTM G21, "Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi," American Society for Testing and Materials, 1970.

13. ASTM G22, "Standard Practice for Determining Resistance of Plastics to Bacteria," American Society for Testing and Materials, 1976.

14. ANS/ANSI 16.1, "Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Test Procedure," American Nuclear Society, 1986.

15. ASTM B553, "Standard Test Method for Thermal Cycling of Electroplated Plastics," American Society for Testing and Materials, 1979.

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