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MEMORANDUM FOR: Frank J. Arsenault, Director
Division of Health, Siting,
and Waste Management, RES

FROM: John B. Martin, Director
Division of Waste Management, NMSS

SUBJECT: REGULATORY GUIDE PREPARATION

We are enclosing for your use a copy of our Branch Technical Position (BTP) on Waste Form. We request that this BTP be developed into a Regulatory Guide by your staff. A draft BTP was submitted to RES on February 24, 1981. The enclosed BTP is a revised version which incorporates comments we have received from industry and other interested parties.

In discussions with N. Costanzi of your staff a tentative completion schedule was established. It was agreed that a completed Regulatory Guide would be completed in November 1982.

If you have any questions regarding this request, please contact R. E. Browning or T. C. Johnson.

Original Signed by
Robert E. Browning
for John B. Martin, Director
Division of Waste Management, NMSS

Enclosure: BTP

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DATE	06/ /82	06/14/82	06/16/82	06/16/82			

Technical Position--Waste Form

A. Introduction

The regulation, "Licensing Requirements for Land Disposal of Radioactive Waste," 10 CFR 61, establishes a waste classification system based on the radionuclide concentrations in the wastes. Class B and C wastes are required to be stabilized. Class A wastes have lower concentrations, are segregated, and do not require stabilization. Structural stability is intended to assure that the waste does not degrade and promote slumping, collapse, or other failure of the cap or cover over the disposal trench and thereby lead to water infiltration Stability is also a factor in limiting exposure to an inadvertent intruder since it provides greater assurance that the waste form will be recognizable and nondispersable during its hazardous lifetime. Structural stability of a waste form can be provided by the waste form itself (as with activated stainless steel components), by processing the waste to a stable form (e.g., solidification), or by emplacing the waste in a container or structure that provides stability (e.g., high integrity container).

This technical position on waste form has been developed to provide guidance to waste generators on test methods and criteria for waste forms acceptable to the NRC staff for implementing the 10 CFR 61 waste classification system. This position includes guidance on the processing of wastes into an acceptable, stable waste form and for the design of acceptable high integrity containers.

This technical position applies to all waste generators who solidify wastes or use high integrity containers in order to meet the Class B and C stability requirements in the 10 CFR 61 waste classification system. It is the intent of the NRC staff to add other guidance on waste form in additional technical positions as necessary.

B. Background

Historically, waste form and container considerations were considered of secondary importance to good site selection; the combination of a properly operated site having good geology and hydrology characteristics were considered the only barriers necessary to isolate low-level radioactive wastes from the environment. Experience in operating low-level waste disposal sites indicates the waste form and container should play a major role in the overall plan of environmental containment.

The proposed rule for near-surface disposal of radioactive wastes, 10 CFR 61, includes requirements which must be met by a waste form and be acceptable for near-surface disposal. The proposed rule includes a waste classification system which divides waste into three general classes: A, B, and C.

This classification is based on the overall disposal hazards of the wastes. Certain minimum requirements must be met by all waste deemed disposable by near-surface burial. These minimum requirements involve basic packaging criteria and prohibitions against the disposal of pyrophoric, explosive, toxic, or infectious materials.

In addition to the minimum requirements, Class B and C wastes are required to have stability. As defined in the proposed rule, structural stability requires that the waste form maintain its form under the expected disposal conditions. Structural stability is necessary to inhibit slumping, collapse, or other failure of the disposal trench resulting from degraded wastes which could lead to water infiltration and radionuclide migration. Stability is also considered in the intruder pathways where it is assumed that after the active control period wastes are recognizable and, therefore, inadvertent intrusion is unlikely.

In order to assure that the waste or its container will maintain its stability, the following conditions need to be met:

a. The waste should be a solid form or in a container or structure that provides stability after disposal.

b. The waste should not contain free standing and corrosive liquids. That is, the wastes should contain only trace amounts of drainable liquid, and in no case should the volume of free liquid exceed one percent of the waste volume when wastes are disposed of in a container designed to provide stability or 0.5 percent of the waste volume for solidified wastes.

c. The waste should be resistant to degradation caused by radiation effects.

d. The waste should be resistant to biodegradation.

e. The waste should remain stable under a constant compressive load.

f. The waste should remain stable if exposed to moisture or water after disposal.

g. The waste should be compatible with the solidification media and not degrade the matrix.

A large portion of the waste produced in the nuclear industry is in a form which is either liquid or in a wet solid form (e.g., small particles such as resins, filter sludge, etc.) and requires processing to achieve an acceptable solid, monolithic form for burial. In order to assure that the solidification process will consistently produce a product which is acceptable for disposal, a process control program should be used. General requirements for a process control program are provided in the NRC Standard Review Plan 11.4, "Solid Waste Management Systems," (NUREG-0800) and its accompanying Branch Technical Position ETSB 11-3, "Design Guidance for Solid Waste Management Systems Installed in Light-Water-Cooled Nuclear Power Reactor Plants," (revised July 1981). These documents should also be used as the basis for individual solidification process control programs by other fuel-cycle and by non-fuel-cycle waste generators who would solidify wastes to meet the Class B and C stability requirements. The stability requirements in this technical position should be the basis for qualifying process control programs.

An alternative to processing some waste streams, particularly ion exchange resins and filter sludges, is the use of a high integrity container. The high integrity container would be used to provide the long-term stability required to meet the stability requirements in 10 CFR 61. The design of the high integrity container should be based on its specific intended use in order to assure that the waste contents, as well as interim storage and ultimate disposal environments, will not compromise its integrity over the long-term. As with waste solidification, a process control program for dewatering wet solids should be developed and utilized to ensure that the free liquid requirements in 10 CFR 61 are being met.

For wastes in the form of filter cartridges which require stability, the waste generator will be required to demonstrate that the selected approach to providing stability is adequate. Encapsulation of the filter cartridge in a solidification binder or the use of a high integrity container are acceptable options for providing stability.

C. Regulatory Position

1. Stability Requirements for Processed (i.e., Solidified) Wastes

a. The stability requirements for processed wastes in this technical position should be implemented through the qualification of the individual licensee's process control program. The tests identified may be performed on radioactive or non-radioactive wastes. Through the use of a well designed and implemented process control program, frequent retesting of wastes is expected to be unnecessary to demonstrate stability.

b. Solidified waste specimens should have compressive strengths of at least 50 psi when tested in accordance with ASTM C39. The failure mechanism should be considered to be by cracking or crumbling. At least three waste specimens for each proposed waste stream to be solidified should be tested. Compressive test results should be statistically valid. Many solidification agents will be easily capable of meeting the 50 psi limit for well solidified wastes. For these cases, process control parameters should be developed to achieve the maximum practical compressive strengths, not simply to achieving the minimum acceptable compressive strength.

c. The waste specimens for each proposed waste stream should remain stable after being exposed to a radiation field equivalent to the maximum level of exposure expected from the proposed wastes to be solidified. At least three waste specimens per waste stream should be exposed to a minimum of 10^8 Rads in a gamma irradiator or equivalent. The irradiated specimens should have a minimum compressive strength of 50 psi.

d. At least three waste specimens for each proposed waste stream should be resistant to biodegradation as tested in accordance with ASTM G21 and ASTM G22. No indication of culture growth should be visible. Specimens should be suitable for compression testing in accordance with ASTM C39. Following biodegradation testing, specimens should have compressive strengths greater than 50 psi.

For polymeric or bitumen products, some visible culture growth from additives or biodegradable components on the specimen surface which do not relate to overall substrate integrity may be present. For these failures, additional testing should be performed.

If culture growth is observed upon completion of the test for polymeric or bitumen waste forms, remove the test specimen from the culture, wash it free of all culture and growth with water and only light scrubbing. Extract the specimen by immersing completely for five minutes in ethanol, five minutes in acetone and one minute in methanol. The specimen should be agitated or the liquid stirred to assure effectiveness. If any or all of the solvents mentioned are inappropriate due to incompatibility with the substrate or failure to extract the suspected minor chemical fraction, then an appropriate solvent should be substituted and/or delete one or two steps in the extraction process. Air dry the specimen at room temperature and repeat the test. If, in the repeated test, a growth rating at least one number lower on the 0-4 scale of G-21 is obtained and the observed culture growth is rated no greater than 1 on this second test, then the test will be considered as being passed.

If a specimen solidified using bitumen or polymeric materials showed growth during G-22, the test should be repeated following the extraction procedure described above. Any growth observed after the second test should be considered a failure.

e. Leach testing should be performed for a minimum of 90 days in accordance with ANS 16.1. Specimen sizes should be consistent with the samples prepared for the ASTM C39 compressive strength tests. A minimum of three specimens should be tested for each proposed waste stream and each leachant used. In addition to the demineralized water specified in ANS 16.1, the additional leachants specified in ANS 16.1 should also be tested. After the five day test duration specified in ANS 16.1, sampling and leachant replacement should be performed daily for a total period of fourteen days and weekly thereafter.

f. Waste specimens should maintain a compressive strength of a minimum of 50 psi as tested in accordance with ASTM C39 following immersion for a minimum period of 90 days. Immersion testing may be performed in conjunction with the leach testing.

g. Waste specimens should be resistant to thermal degradation. The heating and cooling chambers used for the thermal degradation testing should conform to the description given in ASTM-B553, Section 3. A minimum of four samples suitable for performing compressive strength tests in accordance with ASTM-C39 should be used. Each sample should be placed in a container which is large enough that it does not provide support to the sample. The container should close tightly so there will be no evaporative loss of any free liquid. Containers can be made of metal or any material unaffected by the test conditions.

   Marked containers with samples should be placed in the test chamber and a series of 30 thermal cycles carried out following the directions given in Section 5.4.1 through 5.4.4 of ASTM B553. The high temperature limit of the cycles should be 60°C and the low temperature limit -40°C. During the cycling, samples should be rotated randomly or in a predetermined manner to compensate for any thermal gradients in the temperature-controlled chambers.

   At the conclusion of the 30 cycles, the samples should be removed from their containers and visual changes (e.g., shrinkage, cracking, spalling, deformation) noted. The amount of free liquid and compressive strength should be determined. If statistics are inconclusive for the four samples, the test should be repeated with a larger number.

   Waste specimens should liberate less than 0.5 percent by volume free liquids and have a compressive strength greater than 50 psi.

h. Waste specimens should have less than 0.5 percent by volume of the waste specimen free liquids as measured using the method specified in ANS 55.1. Free liquids should have a ph between 4 and 11.

i. If small laboratory size specimens are used for the above testing, test data from sections or cores of the largest anticipated full-scale waste products should be obtained to correlate the characteristics of actual size products with those of laboratory size specimens. This testing may be performed on simulated non-radioactive products.

j. Waste specimens from full-scale waste specimens should be destructively analyzed to assure that the product produced is homogeneous to the extent that all regions in the product have an acceptable compressive strength of at least 50 psi.

2. Radiation Stability of Organic Ion-Exchange Resins

In order to assure that organic ion exchange resins will not produce adverse radiation degradation effects, resins should not be generated that have loadings greater than 10^8 rads total accumulated dose. For Cs-137 and Sr^{90} a total accumulated dose of 10^8 rads is equivalent to a 10 Ci/ft^3 concentration. This requirement is applicable to resins in the unsolidified, as-generated form. In the event that the waste generator considers it necessary to load resins higher than 10^8 rads, it should be demonstrated that the specific resin will not undergo radiation degradation at the proposed higher loading. The test method should adequately simulate the chemical and radiologic conditions expected. A gamma irradiator or equivalent should be utilized for these tests. There should be no adverse swelling, acid formation or gas generation.

3. High Integrity Container Criteria

a. A process control program should be developed and qualified to ensure that the free standing liquid requirements in 10 CFR 61 will be met upon delivery of wet solid material to the disposal facility. This process control program qualification should consider the effects of transportation on the amount of drainage liquids which might be present.

b. High integrity containers should have as a designed goal a minimum lifetime of 300 years to provide 10 half-lives of decay for Cs-137 and Sr-90. The high integrity container should be designed to maintain its structural integrity over this period.

c. The high integrity container design should consider the corrosive effects of both the waste contents and the burial ground environment.

d. The high integrity container should be designed to have sufficient mechanical strength to withstand horizontal and vertical loads on the container equivalent to 45 feet of material having a density of 120 lbs/ft^3 (38 psi). This mechanical design strength should be jusitified in conservative design analyses.

The high integrity container should also be designed to withstand the routine loads from disposal site operations, such as trench compaction procedures.

e. For polymeric materials, design mechanical strengths should be extrapolated from creep test data.

f. The design should consider the thermal loads from processing, storage, transportation, and burial. Proposed container materials should be tested in accordance with ASTM B553 in the manner described in section 1(g). No significant changes in material design properties should result from this thermal cycling.

g. The high integrity container design should consider the radiation stability of the proposed container materials as well as the radiation degradation effects of the wastes. Radiation degradation testing should be performed using a gamma irradiator or equivalent. No significant changes in material design properties should result following exposure to a total accumulated dose of 10^8 rads. If it is proposed to design the high integrity container to greater accumulated doses, testing should be performed to confirm the adequacy of the proposed materials.

h. The high integrity container design should consider the biodegradation properties of the proposed container materials and any biodegradation effects of the wastes and disposal media. Biodegradation testing should be performed on proposed container materials in accordance with ASTM G21 and G22. No significant changes in material design properties should be observed in the specimens following the biodegradation tests.

i. The high integrity container should be capable of meeting the requirements for a Type A package as specified in 49 CFR 173.398(b). The free drop test may be performed in accordance with 10 CFR 71 Appendix A.

j. The high integrity container and the associated lifting devices should be designed to withstand the forces applied during lifting operations. As a minimum the container should be designed to withstand a 3g vertical lifting load.

k. The container should avoid the collection or retention of water on its top surfaces in order to minimize accumulation of trench liquids which could result in corrosive or other degrading effects on the container.

l. The container should remain sealed for the design lifetime of the container. However, passive vent designs which do not cause radionuclide migration over the design lifetime of the container may be utilized.

D. Implementation

This technical position reflects the current NRC staff position on acceptable means for meeting the disposal site stability requirements for processed wastes and for containers which would provide structural stability. Therefore, except in those cases in which the waste generator proposes an acceptable alternative method for complying with the stability requirements of 10 CFR 61, the criteria described herein will be used in the evaluation of waste forms acceptable for dispsoal at near-surface disposal facilities.

References:

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

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

3. ASTM B553, "Thermal Cycling of Electroplated Plastics," American Society for Testing and Materials, 1979.

4. ASTM C39, "Compressive Strength of Cylindrical Concrete Specimens," American Society for Testing and Materials, 1979.

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

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