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DRAFT REGULATORY GUIDE AND VALUE/IMPACT STATEMENT

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FRACTURE TOUGHNESS CRITERIA FOR FERRITIC STEEL SHIPPING CASK CONTAINMENT VESSELS WITH A MAXIMUM WALL THICKNESS OF FOUR INCHES (0.1 m)

A. INTRODUCTION

Title 10, Code of Federal Regulations, Part 71,[1] "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions," requires that packages used to transport radioactive materials withstand the normal conditions and hypothetical accident conditions of Appendices A and B of Part 71. These accident conditions may occur at an initial temperature of -20°F (-29°C). At this temperature, several types of ferritic steels are brittle and subject to fracture. This guide describes fracture toughness criteria and test methods acceptable to the NRC staff for use in evaluating Type B(U) and Type B(M)[2] ferritic steel shipping cask containment vessels having a maximum thickness of 4 inches (0.1 m) and having a maximum static yield strength of 100 ksi (690 kPa). The guide is applicable to the containment vessel only and not to other components of the package.

Alternative fracture toughness criteria and test methods may be used provided the applicant can demonstrate that their use will ensure equivalent safety.

Any guidance in this document related to information collection activities has been cleared under OMB Clearance No. 3150-0008.

[1]All references to 10 CFR Part 71 in this draft regulatory guide refer to the proposed version that was published for comment on August 17, 1979 (44 FR 48234).

[2]Type B(U) and Type B(M) are defined in § 71.4 of 10 CFR Part 71.

B. DISCUSSION

This guide presents fracture toughness criteria and test methods that can be used for evaluating ferritic steel containment vessels having a maximum wall thickness of 4 inches (0.1 m) with a maximum static yield strength of 100 ksi (690 kPa).

Section III of the ASME Boiler and Pressure Vessel Code[3] contains requirements for material fracture toughness; however, these requirements were developed for reactor components only and do not address hypothetical accident conditions (e.g., level D service limits or severe impact loads). Therefore, the code requirements are not directly applicable to shipping container design.

NUREG/CR-1815, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick,"[4] contains background and other information pertinent to the development of the criteria in this guide. These criteria are divided into three categories that are associated with the levels of safety for the types of containers and radioactive contents being transported. Table 1 in this guide identifies the radioactivity limits for each of the three categories. Tables 4,[5] 5, and 6 in NUREG/CR-1815 list the fracture toughness criteria associated with each category. A qualitative description of the margins of safety against brittle failure for each of the three categories is given in Appendix C to NUREG/CR-1815.

Additional information regarding the basis for the criteria is contained in Appendix B of NUREG/CR-1815.

The Regulatory Position endorses the criteria contained in Section 5 of NUREG/CR-1815. These criteria identify the following two options, either of which will demonstrate adequate toughness of containment vessels.

1. Material properties in accordance with the standards specified in Tables 4,[5] 5, or 6 of NUREG/CR-1815, as appropriate.

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[3]Copies may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

[4]A copy of this document can be obtained by writing the Division of Technical Information and Document Control, Document Sales Office, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, or by phoning (301) 492-9530.

[5]The third line in the criteria in Table 4 should read: "Additionally, if the steel has $\sigma_{ys} \geq 70$ ksi, either:"

2. Full-scale drop tests in accordance with paragraphs 5.1.4 and 5.2.4 of NUREG/CR-1815.

For Category II and III containers, the highest nil ductility transition temperature (T_{NDT}) specified for the material in either Figure 1 or Table 3 of NUREG/CR-1815 may be used in lieu of conducting tests to determine the actual T_{NDT} of the material.

Use of Option 2 (full-scale drop tests) for demonstrating the toughness of the containment vessel requires introduction of one or more flaws into the test specimen. Determination of proper flaw size, location, and orientation depend on several variables (e.g., container test orientation, stress magnitude and distribution, NDE procedures). Therefore, the technical details for conducting full-scale drop tests under Option 2 must necessarily be considered on a case-by-case basis.

Although NUREG/CR-1815 addresses the use of ferritic steels only, it does not preclude the use of austenitic stainless steels. Since austenitic stainless steels are not susceptible to brittle failure at temperatures encountered in transport, their use in containment vessels is acceptable to the staff and no tests are needed to demonstrate resistance to brittle failure.

C. REGULATORY POSITION

The criteria contained in Section 5.0 of NUREG/CR-1815 are acceptable to the NRC staff for assessing the fracture toughness of thin-wall (up to and including 4 inches (0.1 m)) ferritic steel containment vessels for the categories identified in Table 1.

A Category I container qualified in accordance with this guide is acceptable for transporting either Category II or Category III radioactive materials. Similarly, a Category II container qualified in accordance with this guide is acceptable for transporting Category III materials.

Table 1

Categories and Associated Radioactivity Limits
for Shipping Containers

CATEGORY I	CATEGORY II	CATEGORY III
Applies if quantity per package is:	Applies if quantity per package is:	Applies if quantity per package is:
greater than or equal to $3(10)^4$ Ci, $3(10)^3A_2^*$, or $3(10)^3A_1^*$.	less than $3(10)^4$ Ci and $3(10)^3A_2$ but greater than or equal to $30A_2$ and less than $3(10)^3A_1$ but greater than or equal to $30A_1$.	less than $30A_2$ and $30A_1$. Also applies if contents are (1) low specific activity materials or (2) objects with fixed contamination (not readily dispersible) and the total quantity per package is less than $3(10)^4$ Ci, $3(10)^3A_2$, and $3(10)^3A_1$.

*Defined in § 71.4 of 10 CFR Part 71.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the staff's plans for using this regulatory guide.

This draft guide has been released to encourage public participation in its development. Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods to be described in the active guide reflecting public comments will be used by the NRC staff in evaluating applications for new package designs and requests for existing package designs to be designated as Type B(U) or Type B(M) packages. These applications should be accompanied by information demonstrating that the package design meets the criteria to be specified in the active guide.

DRAFT VALUE/IMPACT STATEMENT

SUMMARY

Fracture toughness is one of the important safety issues that must be considered in the design and evaluation of shipping containers. Since design criteria associated with fracture toughness of thin-wall ferritic steels have been developed, it is important that this information be documented to aid in the design and subsequent evaluation of these types of containers.

A regulatory guide has been determined to be the best procedural approach to document this information since this is the most common vehicle for obtaining public comments.

The criteria were developed by considering information in the open literature. NUREG/CR-1815, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers up to Four Inches Thick," which is the result of this development effort, serves as the basis for the regulatory guide.

Although the guide applies to ferritic steels only, it does not preclude the use of stainless steels for container application.

1. PROPOSED ACTION

1.1 Description

Establish staff positions on fracture toughness design criteria and identify acceptable methods for assessing fracture toughness for thin-wall ferritic steel containers.

1.2 Need and Justification

Appendices A and B of 10 CFR Part 71* identify normal and accident conditions that a shipping container must withstand without releasing radioactive

*All references to 10 CFR Part 71 in this draft regulatory guide refer to the proposed version that was published for comment on August 17, 1979 (44 FR 48234).

materials that exceed specified limits. One of the accident conditions requires that containers be able to withstand a drop from a height of 30 feet (9 m) onto an unyielding surface when the ambient temperature is -20°F (-29°C). At this temperature, many steels are brittle and are subject to fracture under certain conditions of flaw size, flaw location, and stress level. Therefore, it is necessary that the containers have sufficient toughness at -20°F (-29°C) to withstand the impact loads.

There are currently no documented staff positions on design criteria regarding fracture toughness of shipping containers. Since thin-wall designs comprise the majority of container configurations, it is important that guidance on fracture toughness criteria be issued as soon as possible to support licensing decisions and to be available for future designs.

1.3 Value/Impact

1.3.1 NRC

The fracture toughness design criteria are of value since the criteria are necessary for ensuring the structural integrity of shipping containers subjected to accident conditions that are representative of those that may occur during transport. These criteria will also aid in expediting the licensing process by providing a set of consistent levels against which fracture safety margins of specific designs can be evaluated.

1.3.2 Other Government Agencies

These criteria may be beneficial to the Department of Energy, to the Department of Transportation, and to the International Atomic Energy Agency.

1.3.3 Industry

The criteria and associated expected safety margins would provide a set of levels acceptable to the NRC staff that designers may use to meet the requirements of 10 CFR Part 71. Therefore, the design process should be expedited with the issuance of this guidance. Also, methods that can be used to qualify the designs and materials for the specific applications would be identified.

The guidance is intended to apply to all new package designs and to requests for package designs to be designated as Type B(U)* or Type B(M).* For new Category I containers, e.g., spent fuel containers, it is clear that high-quality steels will be necessary to meet the criteria. It is also clear that the criteria for new Categories II and III containers, although less than the Category I criteria, will require good-quality steels.

With regard to the impact of these criteria on already approved container designs, the staff believes that many present designs would satisfy the criteria with little or no modification. Although some designs would not meet the criteria, continued use of these containers would be permitted provided they are not to be designated either Type B(U) or Type B(M).

The basis for the approach used for specifying the toughness is discussed in NUREG/CR-1815. In addition, four experts in the field of brittle fracture have provided valuable input to the development of these criteria and all have concurred with the recommendations in NUREG/CR-1815. Therefore, the staff believes that materials selected and qualified in accordance with the proposed guidance will result in containers with adequate safety margins to meet the normal and accident conditions identified in 10 CFR Part 71.

1.3.4 Public

A shipping container whose design satisfies the fracture toughness acceptance criteria may be used with assurance that the public will not be exposed to unacceptable radiation levels if the container experiences an event encompassed by the specified design conditions. Therefore, no direct impact on the public is foreseen.

1.4 Decision

Since the release of radioactive materials must not exceed specified limits in the event of an accident during transport, it is necessary that containers be designed to resist fracture. Fracture toughness design criteria for thin

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*As defined in § 71.4 of 10 CFR Part 71.

ferritic steels have been developed with NRC funds; therefore, it is important that these criteria be made available for use. Publication of these criteria and associated guidelines will aid in expediting the design process.

The proposed guidance is applicable to all new container designs and to existing container designs to be designated either Type B(U) or B(M). Although some existing containers will not meet these criteria, the containers can still be utilized for continued operation provided they are not to be designated either Type B(U) or B(M). Therefore, the impact of these criteria on current inventories will be small.

Although quality steels will be necessary to satisfy the appropriate criteria for each of the three categories of containers, it is important that adequate safety margins be demonstrated to meet the requirements of 10 CFR Part 71.

In light of the above discussion, it is concluded that the criteria should be published.

2. TECHNICAL APPROACH

The criteria were developed by the Lawrence Livermore National Laboratory under a technical assistance contract with the Office of Nuclear Materials Safety and Safeguards of the Nuclear Regulatory Commission. Since the scope of the work was limited, the criteria were developed from the open literature. NUREG/CR-1815 documents the results of the development effort and serves as the basis for the guidance.

The approach that is recommended is based upon principles of fracture mechanics. Specifically, the nil ductility transition temperature (T_{NDT}) is the parameter that is used to describe the toughness of the material. Other methods such as the elastic-plastic fracture mechanics approach based on such concepts as the J integral have not been considered.

The method also requires that the radioactive material being transported be categorized into one of three categories that depend on the consequences of failure. Material fracture toughness capability is based on these categories.

In addition to the toughness criteria, methods for evaluating compliance with the criteria and procedures for qualifying the selected steels are identified for each of the categories.

3. PROCEDURAL APPROACH

The NRC staff determined that the best procedural approach for the documentation of these criteria is a regulatory guide. A regulatory guide provides the most common vehicle for obtaining public input and also provides a convenient method for periodically upgrading the information if necessary.

The regulatory positions in the guide specifically identify the three categories of container radioactivity limits; however, because the associated fracture toughness criteria associated with these categories have already been published, the guide will incorporate the criteria by endorsing Section 5 of NUREG/CR-1815, in which they appear. In order to ensure that recipients of the draft guide can review and provide comments on the criteria and the basis therefor, a copy of NUREG/CR-1815 will be furnished on request.

4. STATUTORY CONSIDERATIONS

4.1 NRC Authority

The authority for the proposed action is derived from the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974, as amended, and is implemented through the Commission's regulations, in particular 10 CFR Part 71.

4.2 Need for NEPA Assessment

Shipping containers designed in accordance with the information to be documented in the regulatory guide have no direct bearing on the environment. Therefore, an environmental impact statement is not required.

5. RELATIONSHIP TO OTHER EXISTING REGULATIONS OR POLICIES

Conflicts with other agencies or other regulatory guides are not expected. Rather, the toughness criteria will supplement Regulatory Guides 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," and 7.8, "Load Combinations for the Structural Analysis of Shipping Casks," that currently do not consider fracture toughness. These guides address the

design criteria for structural analysis of shipping containers and the loading combinations that must be considered to fulfill the requirements of 10 CFR Part 71.

6. CONCLUSION

Fracture toughness design criteria, staff positions, and methods regarding the design of thin-wall ferritic steel shipping containers should be documented in a regulatory guide to provide a uniform basis for the design and the review of license applications.

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