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HOW TO AVOID ERRORS IN THE DESIGN AND FABRICATION OF TRANSPORTATION PACKAGES

by

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ABSTRACT

The purpose of this paper is to discuss the errors and omissions most often identified when reviewing the design and fabrication of a packaging to transport high-level radioactive materials. The design and fabrication criteria recommended by the U.S. Department of Energy, Office of Facility Safety Analysis, for containment vessels of Type B commercial packagings containing high-level radioactive materials is based on the requirements of Section III, Division 1, Subsection NB of the ASME Boiler and Pressure Vessel Code. However, most packaging designers, engineers, and fabricators are intimidated by the sheer volume of requirements contained in the Code; as a result, the Code is not always followed and many requirements that do apply are often overlooked during preparation of the Safety Analysis Report for Packaging that constitutes the basis for evaluating the packaging for certification.

INTRODUCTION

The design and fabrication criteria recommended by the U.S. Department of Energy (DOE, 1988), Office of Facility Safety Analysis, for containment vessels of Type B commercial packagings containing high-level radioactive materials is found in Section III, Division 1, Subsection NB of the ASME Boiler and Pressure Vessel Code (1995). This Code provides specifications for material, design, fabrication, examination, and testing of nuclear power plant components. Consequently, many of the requirements listed in the Code are not applicable to transportation containment vessels commonly made from austenitic stainless steel with austenitic- or ferritic-steel bolting. Typically, most packaging designers, engineers, and fabricators are intimidated by the sheer volume of requirements contained in the Code; as a result, the Code is not always followed and many requirements that do apply are often overlooked during preparation of the Safety Analysis Report for Packaging (SARP) that constitutes the basis for evaluating the packaging for certification (DOE, 1995). Further, the guidance on standard format and contents for a SARP contained in Regulatory Guide 7.9 (NRC, 1980) is often overlooked.

The purpose of this paper is to discuss the errors in design and fabrication most often identified when reviewing a packaging for certification to transport high-level radioactive

materials. The paper also discusses the most common omissions of supporting information and data that should be provided in a SARP. The emphasis of this paper is to address the errors and omissions for design and fabrication that are found in Chapter 1 (General Information) and Chapter 2 (Structural) of the SARP. Because many of these issues overlap both Chapters, they are addressed by the categories of Design and Fabrication.

DESIGN

Common Design Errors and Omissions

The six most common design errors and omissions found in the review of SARP's are:

- Utilization of an appropriate design criteria.
- Provision of bolting analysis data.
- Discussion of chemical and galvanic reactions.
- Consideration of low-temperature materials behavior.
- Complete description of materials.
- Listing of design stresses or deformations.

Design Criteria. A design criteria is a set of rules that provides guidance to design a structure for a specific application. Typically, a design criteria considers the mechanical and environmental loadings, failure modes, structural materials, allowable stresses, and safety factors. Guidance for selecting a design criteria appropriate for the radiological activity of the contents of a transportation packaging is found in NUREG/CR-3854 (NRC, 1985) along with the NRC Regulatory Guide 7.11 (NRC, 1991). For Type B commercial packagings containing high-level radioactive materials, the packaging is defined as Category I, and design criteria for the containment boundary vessel is Section III, Division 1, Subsection NB of the ASME Boiler and Pressure Vessel Code. For components that provide protection against criticality, the criteria is Section III, Division 1, Subsection NG. For all other safety related components, the criteria is Section VIII, Division 1. These design criteria should be identified in both Chapters 1 and 2 of the SARP.

Other Design Errors. The SARP should discuss the measures taken to avoid chemical or galvanic reactions between the packaging materials, and between the packaging and contents. Although the general effects of aging are addressed in the chapter on Acceptance Tests and Maintenance Program (Chapter 8), the design should consider the behavior of all materials over the entire design life of the packaging. Therefore, the effect of aging on materials performance should be addressed as part of the design process, especially for some impact-mitigating materials like foam.

As a demonstration of compliance to the regulations, 10 CFR §71.41(a) states "The effects on a package of the tests specified in §71.71 (Normal Conditions of Transport) and the tests specified in §71.73 (Hypothetical Accident Conditions) must be evaluated by subjecting a sample package or scale model to test, or by other method of demonstration acceptable ...." This statement is generally interpreted as meaning that a package can be qualified either by physical testing or by analysis.

Many packagings are qualified by testing a full scale model or prototype. When a packaging is qualified by testing, it is easier to test at ambient temperature than at the maximum or minimum temperatures expected during transport. However, it is critical that the low-

temperature behavior of the materials be considered, either by direct proof or by an authoritative reference. The regulations in §71.71(c)(2) for Normal Conditions of Transport (NCT) require that the minimum temperature that a packaging must be qualified for is -40°C (-40°F). The SARP must provide conclusive evidence that the packaging can function as intended by the regulations at this temperature. Three details of packaging construction are particularly troublesome for low-temperature service. These include the gaskets or seals, ferritic-steel bolting, and impact mitigating materials. Gasket or seal materials must be selected to withstand both the low- and high-temperature transportation environment without allowing release rates that exceed the regulatory limits. This may impose additional requirements for the composition of the gasket materials and for qualification tests to demonstrate the ability to function at the temperature extremes. The bolting must have sufficient low-temperature toughness to resist brittle fracture during drops or impacts. If a non-Code bolting material is used, the SARP must provide proof that the bolts possess adequate toughness. Similarly, the impact-mitigating materials must not become 'hard' at low temperatures and thus increase the impact loading to the packaging and contents. In addition, precautions should be taken to eliminate water from permeating into the foam, wood, or other porous materials used as impact-limiters. If thermal vent holes are provided in the metal covers that protect soft impact-mitigating materials, these holes should be sealed so moisture cannot ingress. However, the seals must be capable of burning away to vent the interior in the event of a fire. Finally, for packagings qualified by testing, many applicants do not seem to understand that all of the containers used for transport must be identical to the container qualified. This includes materials, fabrication, and examination.

Common Omissions. The SARP should also provide a complete description of all materials, including authoritative specification numbers. This includes the structural materials, bolting materials, gaskets, impact mitigating and thermal protection materials, coatings, adhesives, and inactive materials such as dunnage for the contents. The mechanical properties and appropriate physical properties should also be provided for information and to aid the independent confirmatory analyses during review.

Tabulated values of the allowable stresses or deformations for the structural materials should be included in the appropriate section of Chapter 2. All calculations should be clearly described, and contain reference to the applicable ASME Code section or Federal Regulation. The analysis of the bolting, including derivation of the bolt tightening torque, can be included as part of the structural design section or as an appendix. However, it is important that a complete bolting analysis be included in the SARP.

FABRICATION

Common Fabrication Errors and Omissions

The four most common deficiencies in describing the fabrication of a packaging found in the review of SARP's are associated with:

- Fabrication to ASME requirements.
- Complete construction drawings.
- Identification of all materials.
- Copies of all specifications and procedures.

Fabrication Criteria. Like the design criteria, guidance for selecting a fabrication criteria

appropriate for the radiological activity of the contents of a transportation packaging is found in NUREG/CR-3854 (NRC, 1985) along with the NRC Regulatory Guide 7.11 (NRC, 1991). These criteria are based on the same ASME Code Sections used for design, and they should be clearly stated in the SARP. Guidance for the specific Code paragraphs applicable to containment vessels can be found in Raske (1995).

Common Omissions. The construction drawings provided in the SARP should provide sufficient detail to fully describe the packaging geometry and structural features, spatial relationship of components, materials of construction, methods of construction, and methods of nondestructive examination (NDE). An acceptable set of construction drawings consists of assembly drawings and sufficient detail drawings to satisfy the above requirements. This includes a complete description of the materials, including specification numbers and appropriate reference to fabrication, welding, and NDE requirements. In addition, the fabrication , welding, and NDE specifications should be included as an appendix. The drawings provided in the SARP should be certified for construction and therefore represent the actual transportation packaging. In addition to certified construction drawings, the SARP should also contain schematic diagrams of the packaging. Exploded views are also useful to illustrate complex packagings.

A SARP will often contain reference to specifications or procedures that are proprietary or specific to a site. Unless these specifications or procedures can be replaced by generic or well known equivalents such as ASME or ANSI, they should be included as an appendix. Similarly, foreign or obscure specifications should be included in the SARP.

SUMMARY

This paper presented a discussion of the errors in design and fabrication most often identified when reviewing a packaging for certification to transport high-level radioactive materials. The paper also discussed the most common omissions of supporting information and data that should be provided in the SARP. The emphasis of this paper was to address the design and fabrication errors and omissions found in Chapter 1 (General Information) and Chapter 2 (Structural) of the SARP.

The most common errors in design are associated with the selection and utilization of a design criteria, provision of a bolting analysis, addressing chemical and galvanic reactions, and consideration of the low-temperature behavior of materials. Significant omissions in presenting the design analysis or qualification test results for review include: a complete description of the materials used in the packaging design, and a listing the allowable stresses or deformations.

For packaging fabrication, the most common error is not using the appropriate ASME Code requirements. Packages are often designed to ASME Code rules, but fabricated without using any authoritative guidance. In some cases, a SARP will refer to the Code as the basis for fabrication, but overlook many of the actual Code requirements. Significant omissions in describing the fabrication for review include: incomplete, non-certified, construction drawings, identification of all materials by authoritative specification numbers, and the provision of all specifications and procedures for review.

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