Use of the ASME Codes in Designing Type B Shipping Packages for the DOE

D. R. Henley
Argonne National Laboratory
Transportation of Hazardous Materials Section
Argonne, Illinois 60439, USA

ABSTRACT

The Code of Federal Regulations[1] states that the effects of the normal condition of transport loads and the hypothetical accident condition loads "must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstration acceptable to the Commission." In Regulatory Guide 7.6, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,*[2] the U.S. Nuclear Regulatory Commission (NRC) indicates that portions of the ASME Boiler and Pressure Vessel Code[3] "form acceptable design criteria for shipping cask containment vessels." It also points out, however, that the Code does not present adequate criteria for bolted closures, particularly for their response to impact loading, or criteria to prevent brittle fracture. In a similar fashion, NUREG/CR-3854[4] and NUREG/CR-3019[5] indicate that several portions of the ASME Code provide acceptable criteria for the fabrication of shipping package components. This paper will furnish guidance for selecting the appropriate ASME Code and Code Sections or Subsections, including NUPAC (Section III, Division 3), for the design and fabrication of various packaging components. In addition, areas not currently covered by existing codes or standards will be addressed and appropriate criteria will be suggested.

INTRODUCTION

The ASME Boiler and Pressure Vessel (ASME B&PV) Codes were originally prepared as a means of ensuring uniform, high-quality design and fabrication of pressure vessels in order to protect the public. The principal loading on these vessels was pressure, although it was recognized that other loads such as piping loads and thermal loads would exist. In their current format, the Codes are designed to control both the design and the fabrication of pressure vessels. Activities controlled by the Codes include, among others:

- Responsibilities and Duties of Owners, Designers, Inspectors
- Quality Assurance
- Authorized Inspection
- Certificates of Authorization, Nameplates, Stamping, and Data Reports
- Material
- Testing
- Fabrication and Installation
- Design

DISCUSSION

In the design and fabrication of Type B shipping packages, the first four items listed above are typically superseded by requirements in Title 10 of the Code of Federal Regulations (10 CFR), Part 71. Both the NRC and the U.S. Department of Energy (DOE) provide interpretations of this portion of the CFR. Required ASME Code documents, such as the Design Specification and the Design Report, are replaced with the Safety Analysis Report for Packaging (SARP). The CFR states that the effects of the normal conditions of transport loads and the hypothetical accident condition loads "must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstration acceptable to the Commission." There is no mention in the CFR of the ASME Codes. Even though other NRC guidance[2] states that the design-by-analysis portions of Section III of the Code "form an acceptable design criteria for shipping cask containment vessels," neither the DOE nor the NRC require that vessels used in Type B Packages be Code-stamped. However, for independent spent fuel storage installations, the NRC does require that all exceptions to the Code are identified and that the replacement criteria are justified.[6]

Since the CFR does not require the use of the ASME Codes, should the Codes be used? This is a question that must be answered for each new Type B packaging design. The final decision should be based on a careful evaluation of the appropriateness of the Code, the availability of data to support Code analysis, and the cost of analysis versus the cost of testing. Some licensed Type B packages are no more than wooden boxes and are not subject to pressure. Obviously, the ASME Codes do not provide reasonable criteria for the design or fabrication of these packages. Unique designs and materials may make use of the ASME Code totally inappropriate. In some cases, the fabrication criteria from the Code may be appropriate but the requirements for design may be overly restrictive.

Typically, one of the most difficult tasks in performing a Code analysis for a containment vessel in a Type B package is to determine the dynamic loads that will be applied to the vessel. Most packages use highly nonlinear materials for absorbing and distributing impact loads. The properties of these materials can change with temperature, loading rate, direction, age, and whether the material has been in contact with water or other detrimental environments. In addition, even if the loads are well known, the stress intensity limits in the Code may not be adequate to ensure that joints will remain sealed. Conversely, it is possible that for a particular design, the Code stress intensity limits or displacement limits could be exceeded while the containment still remains leak-tight. Finally, the costs of determining material properties, performing a nonlinear analysis to establishing the loads on the containment vessel, performing benchmark tests, and doing the Code analysis must be compared to the costs of performing an exhaustive series of tests that bound the loading combinations defined in the CFR. These tests must cover all vessels fabricated within the tolerances specified in the drawings and must produce the greatest challenge to each package component that performs a safety-related function.

Ultimately, if Code criteria are not used, the applicant must develop alternate criteria and convince the appropriate reviewers that these alternate criteria are ensure that the package will meet the containment, criticality, and shielding requirements of the CFR. For fabrication, it is almost always easiest to use ASME Code materials, procedures, examinations, and tests rather than to develop new criteria. The NRC provides two documents[4,5] that outline a graded approach to fabrication of all package components. These two documents categorize the contents of radioactive packages based on total curie content and the number of A_2s in the package. Based on the category of the contents and the function of the component, various levels of fabrication are suggested, ranging from ASME Section VIII, Division 1, to ASME Section III, Division 1, Subsection NB. Only in very rare cases is this range of fabrication requirements overly restrictive. An example of such a case might be spacers that are part of the package. The spacers may indeed perform a safety function, but probably need not meet ASME specifications.

The design of packaging components is a more complex problem. Reference 4 states that the design-by-analysis portions of Section III of the ASME B&PV Code provide acceptable design criteria for containment vessels used in packaging. This reference also points out some areas that the ASME Codes do not adequately address. Reference 7 provides guidance on which load combinations must be analyzed for large spent-fuel packages, but it also cautions that additional analysis may be required for lighter packages.

Six areas have been identified that the ASME B&PV Codes do not adequately address at present:

- Bolting
- Buckling
- Brittle Fracture
- Determination of Dynamic Loads
- Plastic Analysis
- Penetration

In an effort to provide guidance in these areas, the NRC has published several documents. References 8 - 13 indicate criteria that the Commission feels are appropriate. Cases may arise in which these documents do not provide appropriate or adequate criteria. In such cases, the applicant must establish the acceptance criteria and document why they are reasonable. This is particularly true for components other than the containment vessel. There is very little official guidance on how to design or analyze impact-absorbing structures. While several finite-element programs can perform impact problems such as this, it is very difficult to properly characterize many of the nonlinear materials used in these designs. Typically, material property values are adjusted for agreement with a few benchmark tests, and then parametric studies are performed to estimate the effects of other variables such as temperature or manufacturing tolerances.

While the original ASME B&PV Codes were written for pressure vessels, the ASME has recently published a new consensus standard that is intended to be applicable to both shipping and storage containers. This new code has been incorporated into Section III of the ASME B&PV Codes and is designated as Division III (and commonly referred to as NUPACK). Initially, this Division was simply a collection of items from various other parts of the Code, primarily Section 1, Division 1, Subsection NB, that were appropriate for the design of containment vessels. Now the ASME committee responsible for development of this Division of the Code is working on establishing consensus standards for containment vessels that address issues such as bolting, brittle fracture, and buckling. Future work will include development of design rules for internal supports and possibly other noncontainment structures.

RESOURCES

Other resources may be of help in establishing criteria that will ensure that all of the package components will perform as expected under both normal conditions of transport loads and hypothetical accident conditions loads. It must be demonstrated, through analysis or tests, that all packages that are designed and fabricated to this SARP will maintain containment, control criticality, and provide adequate shielding. This must be true for all specified loadings and conditions specified in the CFR and for the full range of fabrication tolerances. One extremely useful resource is the Internet site www.rampac.com. In addition to containing general information about the status of all of the packages approved or being reviewed by DOE, this site has links to many of the training courses being offered. The NRC has a similar site at www.nrc.gov. Lawrence Livermore National Laboratory offers a course titled “Methods for Reviewing SARPs and Performing Confirmatory Analysis.” Argonne National Laboratory offers two classes: “Applications of the ASME Code to Radioactive Packaging” and “Quality Assurance for Radioactive Packaging.”

ACKNOWLEDGMENTS

The U.S. Department of Energy, Office of Safety, Health and Security, under Contract W-31-109-ENG-38, supported this work. The encouragement by Michael Wangler, Headquarters Certifying Official, Package Approval and Safety Program, is greatly appreciated.

REFERENCES

1. *Title 10, Code of Federal Regulations, Parts 71*, Office of the Federal Registrar, Washington, DC.
2. Regulatory Guide 7.6, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels, Rev. 1*, U.S. Nuclear Regulatory Commission, Washington, DC.
3. *ASME Boiler and Pressure Vessel Code, An American National Standard*, American Society of Mechanical Engineers, New York NY.
4. *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854, U.S. Nuclear Regulatory Commission, Washington, DC, March 1985.
5. *Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials*, NUREG/CR-3019, U.S. Nuclear Regulatory Commission, Washington, DC, March 1984.
6. Spent Fuel Project Office, Interim Staff Guidance, ISG-10, Revision 1, Alternatives to the ASME Code, U.S. Nuclear Regulatory Commission, Washington, DC, Nov. 30, 2000.
7. Regulatory Guide 7.8, *Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Materials, Rev. 1*, U.S. Nuclear Regulatory Commission, Washington, DC.

8.*Stress Analysis of Closure Bolts for Shipping Containers,* NUREG/CR-6007, U.S. Nuclear Regulatory Commission, Washington, DC, Jan. 1993.
9.*Buckling Analysis of Spent Fuel Basket,* NUREG/CR-6007, U.S. Nuclear Regulatory Commission, Washington, DC, May 1995.
1.Regulatory Guide 7.11, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1m),* U.S. Nuclear Regulatory Commission, Washington, DC.
2.Regulatory Guide 7.12, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches (0.1m),* U.S. Nuclear Regulatory Commission, Washington, DC.
3.*Methods for Impact Analysis of Shipping Containers,* NUREG/CR-3966, U.S. Nuclear Regulatory Commission, Washington, DC, Nov. 1987.
4.*Puncture Testing of Shipping Packages under 10 CFR Part 71,* NRC Bulletin 97-01, U.S. Nuclear Regulatory Commission, Washington, DC, Sept. 1997.