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TRAINING IN THE APPLICATION OF THE ASME CODE TO TRANSPORTATION PACKAGING OF RADIOACTIVE MATERIALS*

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ABSTRACT

The Department of Energy has established guidelines for the qualifications and training of technical experts preparing and reviewing the safety analysis report for packaging (SARP) and transportation of radioactive materials. One of the qualifications is a working knowledge of, and familiarity with the ASME Boiler and Pressure Vessel Code, referred to hereafter as the ASME Code. DOE is sponsoring a course on the application of the ASME Code to the transportation packaging of radioactive materials. The course addresses both ASME design requirements and the safety requirements in the federal regulations. The main objective of this paper is to describe the salient features of the course, with the focus on the application of Section III, Divisions 1 and 3, and Section VIII of the ASME Code to the design and construction of the containment vessel and other packaging components used for transportation (and storage) of radioactive materials, including spent nuclear fuel and high-level radioactive waste. The training course includes the ASME Code-related topics that are needed to satisfy all Nuclear Regulatory Commission (NRC) requirements in Title 10 of the Code of Federal Regulation Part 71 (10 CFR 71). Specifically, the topics include requirements for materials, design, fabrication, examination, testing, and quality assurance for containment vessels, bolted closures, components to maintain subcriticality, and other packaging components. The design addresses thermal and pressure loading, fatigue, nonductile fracture and buckling of these components during both normal conditions of transport and hypothetical accident conditions described in 10 CFR 71. Various examples are drawn from the review of certificate applications for Type B and fissile material transportation packagings.

BACKGROUND

The Department of Energy (DOE) conducts operations that involve fissile and radioactive materials including spent nuclear fuel, high level waste, radioisotopes and by products. These fissile and radioactive materials must be processed, used, stored, and disposed of by DOE at various locations in the US and elsewhere, and their safe transportation is of paramount importance in sustaining the various activities. The fissile and radioactive materials are often of different shape, size, and form that may require transportation packaging with different structural, thermal, shielding, and criticality characteristics.

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Thus, the contents of a package will generally drive the packaging design, which must satisfy the three fundamental safety requirements in the containment of radioactivity, protection against radiation, and, in the case of fissile materials, maintenance of subcriticality under both normal conditions of transport and hypothetical accidents.

Fissile and radioactive materials are generally transported in two types of packages: Type A and Type B. The Type A package is restricted to carrying less than Type A quantities of radioactive material, as identified in 10 CFR 71, Appendix A (CFR 2004). These packages are usually small, often require little shielding, and are therefore given a general license. The Type B package is used to transport greater than Type A quantities, that is, highly radioactive materials, including significant quantities of fissile materials.

Department of Transportation (DOT) Regulation 49 CFR 173.7(d) states that Type B packagings can be certified by DOE if they are evaluated by standards equivalent to those in 10 CFR 71. DOE Order 460.1B states that an application for a fissile or Type B package certification must include a Safety Analysis Report for Packaging (SARP), which demonstrates that the packaging conforms with the standards of 10 CFR Part 71, Subparts E, F, G, and H, and any other applicable standards that the Assistant Secretary for Environmental Management or the Secretarial Officer/Deputy Administrator, National Nuclear Security Administration may determine applicable for granting a certificate. The Package Approval Standards in Subpart E, 10 CFR 71.41(a) state that a packaging must be evaluated by tests or another method of demonstration acceptable to the Nuclear Regulatory Commission (NRC). NRC Regulatory Guide 7.6 states that an acceptable method to evaluate Type B packaging is by analysis using the ASME Code. A combination of testing and analysis is often used to evaluate packaging performance.

Design of a Type B and fissile packaging involves complex and interrelated evaluation of contents, materials, structural integrity, thermal heat transfer, containment, shielding, criticality, operating procedures, acceptance tests, maintenance, and quality assurance. Therefore, the design of a Type B and fissile packaging is, by necessity, performed by a group of engineering specialists working as a team in the development of a SARP. The time and cost of obtaining a certificate of compliance (CoC) for a package from the certification authority depends directly on the quality of the SARP that must demonstrate package compliance to all applicable safety standards. DOE has developed guidelines for qualifications, education, and training for members of the SARP Writing Team (DOE 2004). DOE also sponsors five training courses annually which are conducted by staffs at several national laboratories: (1) Methods for reviewing SARPs and performing confirmatory analysis; (2) management of SARP preparation; (3) SCALE code for radiation shielding and criticality analyses; (4) quality assurance for radioactive material packaging; and (5) application of the ASME Code to radioactive material transportation packaging. Information on these training courses can be found in the DOE-sponsored website www.RAMPAC.com (DOE 2003). Description of the quality assurance training course is also given in a paper at this conference (Fabian et al. 2005).

The purpose of this paper is to describe the salient features of the ASME Code training course, with the focus on the application of Section III, Divisions 1 and 3, and Section VIII, Division 1, of the ASME Code to the design, fabrication, inspection, and testing of the containment vessel and other packaging components used for transportation (and storage) of radioactive materials, including spent nuclear fuel and high-level radioactive waste (ASME 2004a). Typical Type B and fissile packaging components and the applicable ASME Code Sections for their designs are described in the next section, followed by descriptions of the main topics in the ASME Code training course.

TYPICAL TYPE B AND FISSILE PACKAGING COMPONENTS AND APPLICABLE ASME CODE SECTIONS

A Type B packaging typically consists of a stainless steel containment vessel surrounded by shielding and insulation/impact-absorption material, and a stainless or ferritic steel outer skin. The top and bottom of the containment vessel is also protected by shielding and insulation/impact-absorption material. Closure of the containment vessel is typically accomplished by bolting with elastomeric, double O-ring seals. The containment boundary generally includes the containment vessel, flange, bolts, and the inner O-ring. An example of the containment vessel and the packaging is shown in Figs. 1 and 2, based on the 9975 packaging designed by the Westinghouse Savannah River Co (WSRC 2002).

Since different safety functions of a Type B packaging are provided by various packaging components, the USNRC report NUREG/CR-3854 specifies the applicable subsections of ASME Code Sections III and VIII for Type B and fissile packaging components, as shown in Table 1 (Fisher and Lai 1985). In this table the contents of a Type B package are divided into three categories I, II, and III, based on the level of radioactivity of the contents. NRC Regulatory Guide 7.11 (RG 7.11) specifies the radioactivity limits for each category (USNRC 1991), which are graphically displayed in Fig. 3.

Table 1 also shows three component safety groups in containment, criticality, and other safety functions. For the 9975 packaging shown in Figs. 1 and 2, the contents and the primary and secondary containment vessels (PCV and SCV) are classified as Category I so that both have been designed according to Section III, Division 1, Subsection NB, or

Section III, Division 3, Subsection WB that became available in 1997. The drum and its bolted flange closure perform other safety functions and they were designed according to Section III, Division 1, Subsection NF, or Section VIII, Division 1. The ASME Code does not include all materials used in packaging or provides design requirements for all components. For example, lead, Celotex, aluminum, and elastomeric O-rings are used, respectively, for shielding, insulation/impact absorption, bearing plates, and seals in the 9975 packaging; none of them is considered as a Code material. The ASME code does not provide design requirements for these materials; the ASME Code training course, however, discusses application of non-Code materials in the packaging design.

MAIN TOPICS IN THE ASME CODE TRAINING COURSE

The flow chart (Fig. 4) shows the main topics covered in the ASME Code training course. The course begins with the regulatory aspects, code background and structure, and general requirements in Sections III and VIII, followed by materials, design, fabrication, examination, testing, and quality assurance. Special topics such as non-ductile fracture, thermal stresses, bolted closure and buckling are included in the course because they are judged important and treated as extensions to the main topics. In the remainder of this paper, only the main topics are discussed and their salient features highlighted. The entire course consists of approximately 20 to 24 lecture units to be delivered in 2.5 to 3 days.

Regulatory Aspects

This part of the training course describes the certification process for radioactive material transportation packaging, focusing primarily on the DOE and NRC package certification requirements. The terms specific to Type B and fissile packages are defined and applicable regulatory documents, including federal regulations, regulatory guides, and pertinent NRC NUREG/CR reports, are identified. The package design requirements of 10 CFR 71 are summarized by paragraphs in Subpart A to Subpart H. Recent amendments of 10 CFR 71, published in the Federal Register on January 26, 2004, are also discussed. (These amendments are part of the Final Rule change in 10 CFR 71 that has since become effective on October 1, 2004.) These amendments addressed compatibility with the International Atomic Energy Agency (IAEA) Transportation Safety Standards (TS-R-1) and other transportation safety amendments and included a total of 19 issues. Eleven of these issues were adopted to make 10 CFR 71 compatible with the IAEA standards (IAEA 2000), whereas the eight remaining issues address NRC-initiated issues. Several of the 19 issues are associated with the design and testing requirements of fissile material packages. For example, one issue removes the exemption from the crush test for fissile packages that contain less than 1000 A_2 activity [10 CFR 71.73(c)(2)] so that criticality safety of the package is assessed against a potential crush test accident condition. Another issue removes the requirement of double containment for shipments of plutonium greater than 20 Ci (10 CFR 71.63) because this requirement was neither risk-informed nor performance-based; the A_2 values of many nuclides are the same as or lower than that of plutonium for which double containment has not been required. The issue that addresses expansion of Part 71 quality assurance requirements to Certificate of Compliance (CoC) holders and applicants is potentially significant, because the law holds them responsible under 10 CFR 71.115 for assuring their contractors and subcontractors (e.g., fabricators) are implementing adequate QA programs. Violations are legally binding with the issuance of Notice of Violation.

It should be noted that the latest 10 CFR 71 does not endorse ASME Code Section III, Division 3, because Division 3 was undergoing significant changes when 10 CFR 71 was being amended. The completed portions of the revised Division 3, including Subsection WB, have been published as part of the 2004 edition of the ASME Code. Division 3, Subsection WB is similar to Division 1, Subsection

NB, but has been streamlined for transportation packagings. Subsection WB is the preferred code for Type B transportation packaging design.

General Code Requirements

This part of the training course presents a brief history of the development of the ASME Code and describes its structure, especially the structure of Section III, Division 3 and Section VIII, Division 1, which had been used for design and fabrication of older transportation packagings and is recommended for containments of Category III packagings. Section III, Divisions 1 and 3 are *design by analysis* Codes, whereas Section VIII, Division 1, is a *design by rule* Code. The requirements of Section VIII, Division 1 differ from Section III, Division 3. For example, Section VIII, Division 1 considers general primary stress in the design and does not require fatigue evaluation, whereas Section III, Division 3 considers both primary and secondary stresses in the design and requires fatigue evaluation.

ASME Code Section III, Division 3, Subsection WA, General Requirements, is being revised. The revision will include a newly developed Subsection WC for storage containments, addition of basket design, and changes that make Division 3 requirements the same as those of Division 1 for Class 1 piping, valves and metallic materials, quality assurance, and inspection during fabrication. The main difference between Divisions 1 and 3 is that Division 1 assigns the overall responsibility of design and construction to the owner, whereas Division 3 assigns it to the certificate holder. The basic general requirement of Division 3 is an acceptable quality assurance program that is in compliance with the ASME NQA-1.

Packaging Materials

This part of the training course discusses design criteria for selecting the packaging materials, including both ASME Code and non-Code materials. Examples of Code materials are containment vessels and bolting materials. Examples of non-Code materials are materials such as lead for shielding, aluminum and wood for impact absorption, foam for insulation and impact absorption, and elastomeric O-ring for seal. To be considered a Code material, a material must be specified in the Code, certified by the manufacturer, and meet the Code marking and identification requirements. As far as the code materials are concerned, the materials requirements in Subsections WB and NB are the same. Subsection WB identifies structural materials permitted for containment vessels, and provides requirements for material qualification tests, examination, repair, and quality assurance. Non-Code materials may be acceptable for containment vessels and their bolting, if qualified by criteria equivalent to those applied to the Code materials. For example, the low-temperature fracture toughness of these materials should be adequate and be subject to nondestructive examination equivalent to the requirements given in Section III, Division 3, Paragraph WB-2500.

Non-Code materials should be procured according to authoritative material specifications such as those of the American Society for Testing of Materials (ASTM) or Military (MIL) Specifications, otherwise its identification should be sufficient to allow replacement without changing any of the results or conclusions in the SARP. Elastomeric O-ring materials may be selected according to the ASTM D 2000 specifications. The mechanical properties of these materials should be acceptable under normal and accident conditions. For example, in the HIFR spent fuel cask, the maximum and minimum seal temperatures are 300ºC and -40ºC, respectively. Both silicone and fluoro-silicone are suitable for at least 1,000 hours in the temperature range of -40 to 300ºC. However, in a radiation environment, compression set of silicone is smaller; therefore, silicone should be considered a primary candidate for seal material, other conditions being equal.

Packaging Design

Packaging design is the major portion of the training course that covers ASME Code Section III, Division 3, Subsection WB for the design of the containment vessel. Use of Subsection WB allows for a quantitative assessment of “Stress Margins” for containment. The training course also covers Division 1, Subsections NB and ND for buckling analysis criteria for cylindrical containment vessels. Subsection NB provides some guidance for the design of bolted closures. The training course also covers Subsections ND and NF, Division 3, and Section VIII, Division 1 for the design of criticality and other safety group components.

Category I Containment Design. Subsection WB, Article 3000, Federal Regulation 10 CFR 71, and NRC regulatory guides complement each other with respect to the design of Category I containments for Type B packaging. Article 3000 refers to 10 CFR 71 for normal conditions of transport (NCT), hypothetical accident conditions (HAC), tests and acceptance criteria, lifting and tiedown requirements, and pressure tests. The NCT tests, for example, include a water spray test that simulates an exposure to rainfall followed by a free drop through a specified distance onto a flat, essentially unyielding, horizontal surface. The HAC tests include sequential application of the free-drop, crush, puncture, and thermal tests on the same package so that the cumulative effect on the package can be determined. 10 CFR 71.43, 71.47, 71.51, 71.55 and 71.59 provide acceptance criteria for general and specific standards for Type B and fissile packages; for example, on the acceptable levels of surface temperature, external radiation dose rates, radioactivity release rates, and, in the case of a fissile package, conditions under which the package must remain subcritical under NCT and HAC. Also, NCT tests should not substantially reduce the effectiveness of the packaging. Both the federal regulations and the ASME Code specifically state that the packaging design shall preclude significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents, including possible reaction resulting from inleakge of water, to the maximum credible extent. The containment vessels are typically made of austenitic stainless steels, which remain ductile at the low operating temperature of -29ºC (-20ºF). Therefore, the containment vessels are not susceptible to brittle fracture.

Regulatory Guide 7.6 provides further guidance: the design criteria for NCT are similar to those for Level A Service Limits and those for HAC are similar to those for Level D service Limits for Division 1, Class 1 components, including bolting. The design criteria include limits on primary, secondary, and peak stresses for packagings. The stresses for the packaging containment components are based on linear elastic analysis. Subarticle WB-3230 provides design stress limits for bolting. These limits should include stresses due to prying effects, which cause the bolts to be loaded because of rotation of the closure plate, and should treat the thermal stresses due to differences in temperature or thermal expansion coefficients as primary stresses.

Regulatory documents contain implicit and explicit requirements to avoid buckling failures. For example, 10 CFR 71.61 states that a package for irradiated nuclear fuel shipments must be so designed that its undamaged containment system can withstand an external water pressure of 2 MPa (290 psi) for a period not less than 1 hour without buckling or inleakage. Regulatory Guide 7.6 also states that buckling of the containment vessel should not occur under normal or accident conditions. The rules for evaluating the buckling of containment vessels are under development for Section III, Division 3, Subsection WB; therefore, the application of Division 1, Subsection NB criteria are suggested as interim buckling analysis criteria for Category I containment vessels.

Categories II and III Containment Designs. Section III, Division 3 does not contain applicable subsections for the design of these containment vessels. Subsection ND of Section III, Division 1, and Section VIII, Division 1 are specified for the design of these components, as listed in Table 1. Subsection ND applies to design of Category II containment vessels. It specifies the allowable stress values that are generally lower than the allowable stress intensity values specified by Subsection WB. Subsection ND allows *design by rule* and provides extensive guidance for determination of shell thickness. Section VIII, Division 1 applies to the design of Category III containment vessels and follows the *design by rule* approach and, like Subsection ND, also specifies an allowable stress value, which is generally lower than the allowable stress intensity values specified by Subsection WB. The application of Section III, Division 1, Subsection ND criteria is suggested as interim buckling analysis criteria for both Categories II and III containment vessels.

Design of Criticality Safety Group Components. Fissile material packagings (e.g.. spent fuel casks) contain support structures, or baskets, that contribute to the maintenance of subcriticality under both normal and accident conditions. If the basket structure is important to criticality safety, it must not exceed the yield strength of material in any substantial portion so that its structure does not change geometry by deforming. This requirement ensures that the geometry analyzed for criticality safety is maintained. Limited plastic deformation around the outer edge of a basket is permitted if the outer edge does not establish an important geometry. In addition, the basket structure must not buckle.

One typical basket design is shown in Fig. 5. This basket consists of long tubes for full-length spent fuel assemblies supported by intermittent spacer disks. These spacers create water gaps that act as “flux traps” for criticality safety and must not be subject to relative motion. ASME Section III, Division 1, Subsection NG applies to the design of the basket components. Subsection NF is suggested as a guide for buckling analysis of plates and columns employed in the basket design.

A thermal gradient in the spent-fuel-cask baskets may cause significant thermal expansion of the basket at maximum operating temperature. The expansion of the basket may close the manufactured gap between the basket and cask and result in high stresses. If the spent fuel assemblies in adjacent cells generate different decay heat loads, the nonuniform heat generation may also result in thermal gradients in the basket and induce thermal stresses. These thermal stresses, even though secondary stresses in nature, need to be included in design calculations (including buckling analysis) for HAC along with the stresses caused by impact, pressure, and fabrication (Wells 1998). The approach is recommended by ASME Section III, Subsection NH, Class 1 Components in Elevated-Temperature Service, Appendix T Paragraph T-1510 (b), which states that such strain-controlled buckling must be avoided.

Design of Other Safety Group Components. Subsection NF, Component Supports, applies to other safety group components except containment and criticality group components. Articles NF-3200, *Plate and Shell-Type Supports*, NF-3300, *Linear-Type Supports*, and NF-3500, *Component Supports*, have the most applicability to packaging. Components made of ferritic steel must satisfy fracture toughness requirements of Article NF-2300. For HAC (Service Level D limits), Appendix F of Section III, Division 1 provides rules for evaluating other safety group components. ASME Section VIII, Division 1, Part UG can also be used for the design of shell-type supports. Article UG-84 provides Charpy V-notch impact test requirements for shell-type supports if they are made of ferritic steel.

Packaging Fabrication and Examination

Federal Regulation 10 CFR 71.85 requires that the licensee shall ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the packaging. 10 CFR 71.119 presents further requirements for fabrication and examination. Monroe et al. (1984) recommends welding criteria for use in the fabrication of shipping containers for radioactive materials.

Fabrication. ASME Section III, Subsection WB ensures compliance with the Regulations by requiring that special fabrication processes, including welding, heat-treating, examination, and acceptance testing for containment are controlled and accomplished by qualified personnel who follow qualified procedures. Article WB-4000, *Fabrication and Installation*, ensures that all containers are identical with respect to materials and fabrication so that qualification test results on a prototype represent the expected behavior of subsequent copies, or that the design assumptions used in the analysis confidently represent the actual components.

ASME Section VIII, Division 1, provides requirements for fabrication of other safety components that differ from those in Section III, Division 3. Section III, Division 3 contains more quality-assurance-related requirements than Section VIII, Division 1. The allowed weld joints are also different because of the methods of design. For example, full weld-metal penetration need not be required for some Section VIII joints.

Some of the most common fabrication deficiencies in design and fabrication include fabrication not to the ASME Code requirements, incomplete construction drawings, and failure to identify all materials. If the fabrication methods differ from those in the ASME Code, the SARP should provide sufficient information showing that they are equivalent to the Code requirements.

Examination. Examinations verify that the fabricated packaging components are in conformance with the specified ASME Code requirements. Subsection WB-5000 provides requirements for examination of containment components. An authorized nuclear inspector verifies and monitors qualification of examination procedures and personnel. The Code-required nondestructive examination methods include visual inspection, radiography, and magnetic-particle, liquid-penetrant, and ultrasonic examinations. The code specifies the time and type of examination for base materials and welds.

Packaging Testing

ASME Code Section III, Division 3, Subsection WB requires a hydrostatic test of the containment vessel before its first use. In addition, Subsection WB refers to 10 CFR 71 for the tests associated with NCT and HAC. The acceptance criterion for the hydrostatic tests is no visible leak when examining at a pressure after the required holding period at the pressure. 10 CFR 71 requires a pressure test when the maximum normal operating pressure is greater than 5 psig. The NCT test procedure allows the use of separate specimens for the free-drop, compression, and penetration tests, if each specimen is subjected to the water spray test before being subjected to any of the other tests. The HAC test procedure requires the sequential application of the following tests, in the order indicated, to determine their cumulative effect on a package: free drop test, crush test, puncture test, thermal test, and immersion test for fissile packages. In addition, the procedure requires a test on an undamaged specimen subject to water pressure equivalent to immersion under a head of water of at least 15 m. As discussed before in the section Category I Containment Design, 10 CFR 71.51 provides acceptance criteria for these tests.

Quality Assurance for Packaging

Federal Code 10 CFR 71, Subpart H describes a compliance-based quality assurance (QA) program for packagings. This program comprises all those planned and systematic actions necessary to provide adequate confidence that a packaging and its components will perform satisfactorily in service. The key characteristics of the QA program are that it is process oriented and requires independent verification and documentation of the planned actions. The program is based on 18 QA elements and provides requirements for design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, testing, operation, maintenance, repair, and modification of components of packaging that are important to safety.

The standard ASME NQA-1-2004, *Quality Assurance Requirements for Nuclear Facility Applications*, satisfies 10 CFR 71, Subpart QA requirements (ASME 2004b). The standard is used in all aspects of nuclear facilities including design, construction, operation, and decommissioning. The standard is also flexible and the organization that invokes the standard specifies the extent of the requirements to be used. The standard represents a unified QA standard, includes 18 requirements, and describes essential features of each requirement. One of the requirements, for example, is related to design control. Design control includes identification and documentation of design requirements; description of design methods and selected materials; specification of inspection and testing, including acceptance standards; design analysis, with sufficient details and documentation; identification and documentation of the methods used for verifying the design; justification and evaluation of design changes; and documentation of the software design process and requirements for management of software configuration.

Federal Code 10 CFR 71.101(b) states that each licensee, certificate holder, and applicant for a CoC shall apply each of the applicable criteria using a graded approach, that is, to apply it to an extent that is consistent with its importance to safety. Therefore, a graded approach is followed when the NQA-1 program is applied. A component or system is classified as important to safety if its failure would lead to loss of containment, loss of contents subcriticality, or loss of shielding. To facilitate the application of the graded approach, the packaging components and related activities are classified in three quality categories, Categories A, B, and C, with decreasing importance to safety. For example, primary containment would be Category A; impact limiter, Category B; and tamper-indicating device, Category C. The QA requirements are the most demanding for Category A components. The Categories A and B components are generally designed using the ASME Code.

SUMMARY

Transportation of radioactive materials, like transportation of other non-radioactive hazardous materials, is a necessity if modern society is to enjoy the benefits from their use. To protect the safety and health of the public and environment, the packaging used to transport highly radioactive materials including spent nuclear fuel and high-level waste must be robust and maintain its integrity and safety functions during all modes of transport and under various severe accident conditions. It is not fortuitous that Section III, Division 3, Subsection WB for Category I containment parallels the rigor in Section III, Division 1, Subsection NB for Class 1 Metal Components in the nuclear reactors.

The design of Type B and fissile packaging involves complex and interrelated evaluation of contents, materials, structural integrity, thermal heat transfer, containment, shielding, criticality, operating procedures, acceptance tests and maintenance program, and quality assurance, under myriad of Federal Regulations, regulatory guides, and ASME and other professional society standards. DOE has taken a proactive approach and offers several training courses to the packaging community with the purpose of disseminating the knowledge and experience of its technical review teams to the future SARP preparers and reviewers. The time and cost of obtaining a Certificate of Compliance for a Type B and fissile package depends directly on the quality of the SARP that must demonstrate package compliance to all applicable safety standards. The training course *Application of the ASME Code to Radioactive*

Material Transportation Packaging provides a comprehensive review of the relevant ASME Code and Federal Regulation requirements for designing a Type B and fissile material packaging, and thus facilitates the construction of packaging that will protect public safety and health and environment, and expedite effective preparation and review of a SARP.

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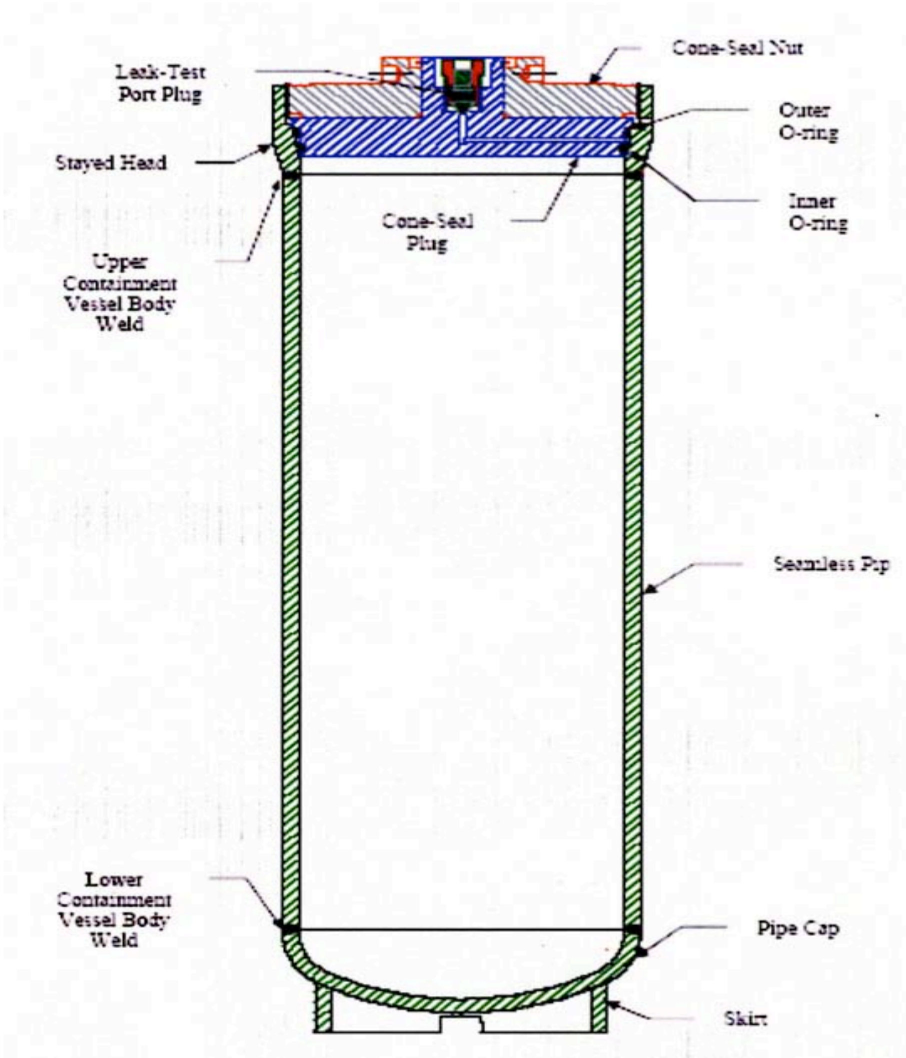

Fig. 1. Primary containment vessel in the 9975 packaging (WSRC 2002); courtesy of Westinghouse Savannah River National Laboratory

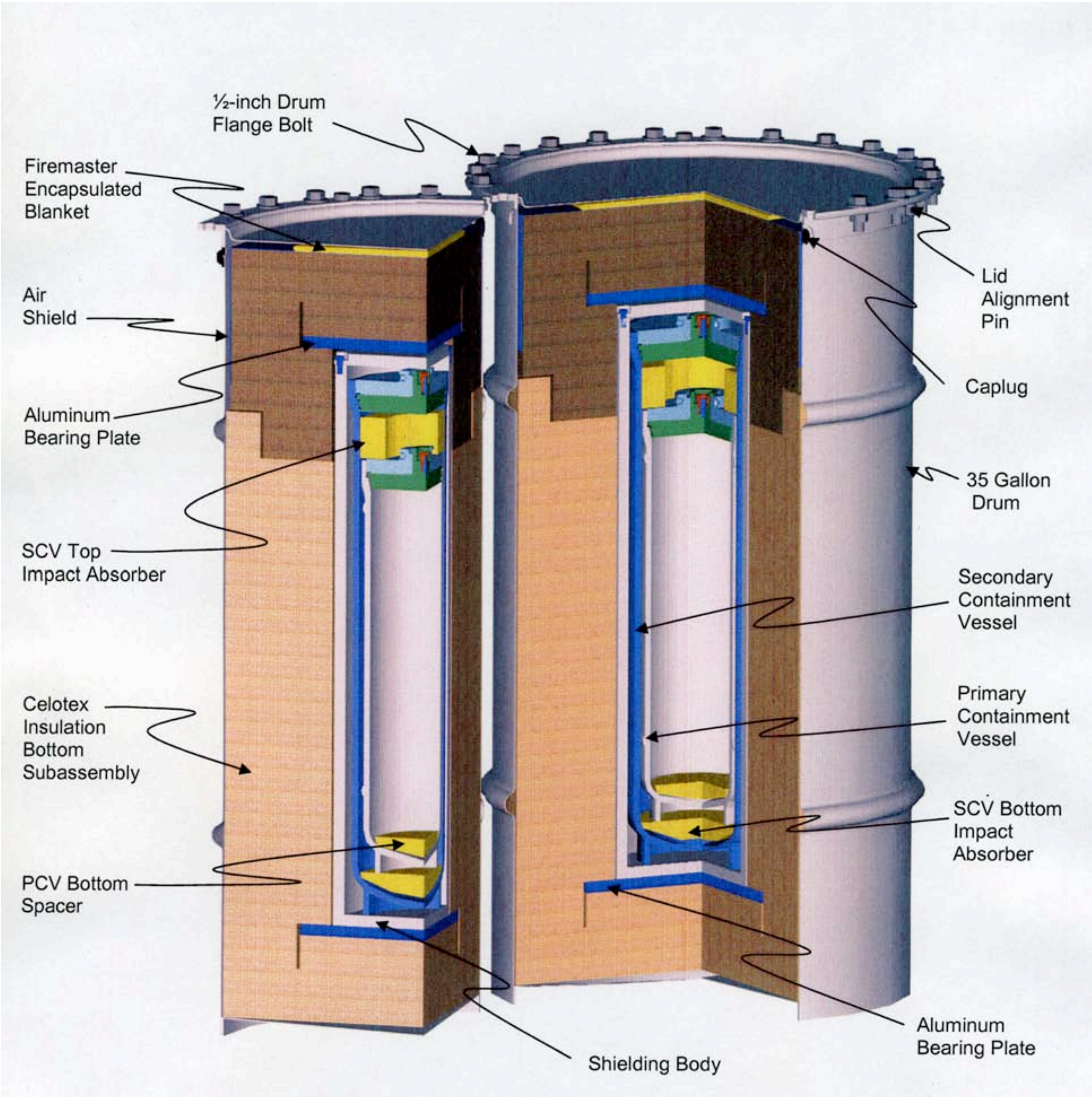

Fig. 2. Cutaway view of the 9975 packaging (WSRC 2002); courtesy of Westinghouse Savannah River National Laboratory

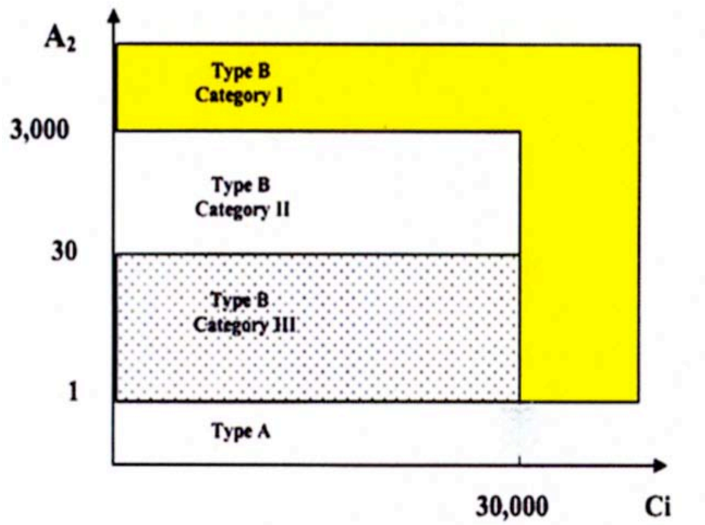

Fig. 3. Classification of Categories (I, II, and III) of Type B packaging by radioactivity limits A_2 and curies. [Adapted from NRC Regulatory Guide 7.11 and NUREG/CR-3854. A_2 values for radionuclides are listed in Table A-1, 10 CFR 71, and one Curie (Ci) represents 3.7×10^{10} disintegrations/s.)

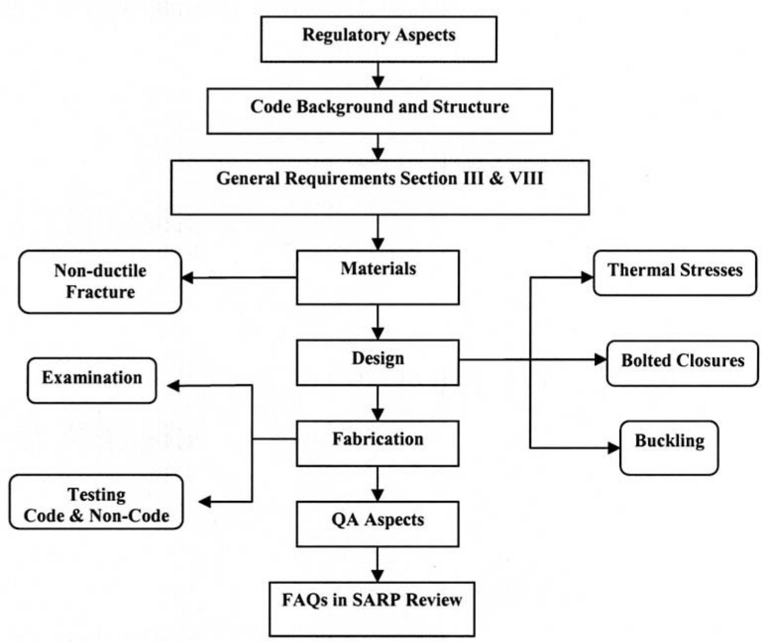

Fig. 4. Flow chart for the major topics in the ASME Code training course

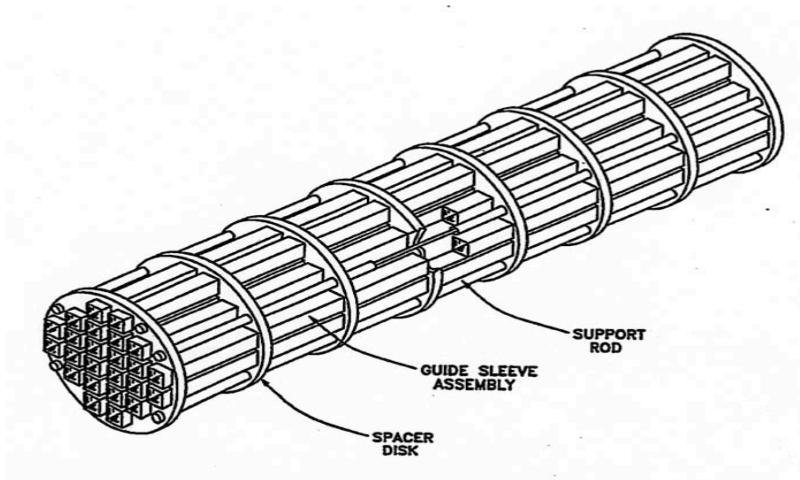

Fig. 5. A Flux-trap spent fuel basket with support disks (Wells 1998)

Table 1. Applicable ASME Code sections for the design of Type B packaging (ASME 2004a)*

Component Safety Group	Container Contents (decreasing radioactivity limits ⟶)		
	Category I	Category II	Category III
Containment	Section III, Division 1, Subsection NB or Section III, Division 3, Subsection WB	Section III, Division 1, Subsection ND	Section VIII, Division 1
Criticality	Section III, Division 1, Subsection NG		
Other Safety	Section VIII, Division 1 or Section III, Division 1, Subsection NF		

*This table has been modified slightly from Table 1.1 in NUREG/CR-3854 to include an annotation (in parenthesis) under the container contents, and Section III, Division 3, Subsection WB under Category I Containment. The latter became available in 1997.