

A Guide for the ASME Code for Austenitic Stainless Steel Containment Vessels for High-Level Radioactive Materials*

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INTRODUCTION

The design and fabrication criteria recommended by the U.S. Department of Energy (DOE), Office of Facility Safety Analysis, for containment vessels of Type B commercial packagings containing high-level radioactive materials are found in Section III, Division 1, Subsection NB of the ASME Boiler and Pressure Vessel Code (DOE 1985 and NRC 1994). This Code provides specifications for material, design, fabrication, examination, and testing of nuclear power plant components. However, many of the requirements listed in the Code are not applicable to containment vessels made from austenitic stainless steel with austenitic- or ferritic-steel bolting. Most packaging designers, engineers, and fabricators are intimidated by the sheer volume of requirements contained in the Code; consequently, 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.

The purpose of this guide is to provide a list of ASME Code paragraphs from Section III, Division 1, Subsection NB (ASME 1992) that are applicable to the design, fabrication, examination, and testing of containment vessels for high-level radioactive materials. Because of the high level of radioactivity in these vessels, they are defined as Category I containment vessels (DOE 1988). The guide is also intended to provide guidance for including the appropriate Code requirements when preparing a SARP, construction drawings, and specifications for materials, fabrication, and examination of Category I containment vessels. In addition, the guide lists DOE positions related to certain Code requirements that may be ambiguous with respect to the design and fabrication of Category I containment vessels that are used for transport.

Because the guide is intended to be helpful to those who are preparing a SARP, the presentation of the lists follows the outline recommended for a SARP in the NRC Regulatory Guide 7.9 (NRC 1980). The lists refer to applicable paragraphs of the Code by number and title within an outline of the pertinent chapters of a SARP. Code paragraphs that may be affected by DOE positions or requirements are followed by "/DOE Position." Additional comments that relate to how these Code requirements should be addressed in a SARP are also included, as are the applicable design and fabrication requirements contained in Title 10, Code of Federal Regulations, Part 71 (NRC 1994), as they relate to specific Code paragraphs. However, the lists do not contain all of the design and fabrication requirements contained in 10 CFR 71.

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ASME CODE REQUIREMENTS TO BE ADDRESSED IN THE SARP

SARP Chapter 1 GENERAL INFORMATION

1.2 Package Description

1.2.1 Packaging

A SARP must address the following requirements and state that the containment vessel is designed, fabricated, examined, and tested in accordance with the requirements of Section III, Subsection NB, 10 CFR Part 71, and DOE Order 5480.3.

Ref:	NB-1110	Aspects of Construction Covered by These Rules
	NB-1120	Temperature Limits/DOE Position
	NB-4121	Means of Certification

A SARP must address the following requirements and list the complete material specifications in the description of the packaging.

Ref:	NB-2121	Permitted Material Specifications/DOE Position
	NB-2128	Bolting Material/DOE Position
	NB-2190	Nonpressure-Retaining Material/DOE Position

Fabrication Specifications

Fabrication specifications should be appended to Chapter 1 and must address the requirements in the following paragraphs.

Ref:	ARTICLE NB-2000 MATERIAL	
	NB-2121	Permitted Material Specifications/DOE Position
	NB-2150	Material Identification
	NB-2180	Procedures for Heat Treatment of Material
	NB-2334	Preparation of Test Coupons and Specimens
	NB-2410	General Requirements (Welding Material)
	NB-2420	Required Tests (Welding Material)
	NB-2432	Chemical Analysis Test (Weld Metal)
	NB-2433	Delta Ferrite Determination (Weld Metal)
	NB-2510	Examination of Pressure Retaining Material
	NB-2531	Required Examination (Pressure Retaining Mtl.)/ DOE Position
	NB-2537	Time of Examination
	NB-2538	Elimination of Surface Defects
	NB-2539	Repair by Welding
	NB-2581	Required Examination (Bolting Material)
	NB-2587	Time of Examination
	NB-2588	Elimination of Surface Defects
	NB-2589	Repair by Welding

ARTICLE NB-4000 FABRICATION

	NB-4122	Material Identification
	NB-4130	Repair of Material
	NB-4132	Documentation of Repair Welds of Base Material
	NB-4321	Required Qualifications (Welding)
	NB-4323	Welding Prior to Qualifications
	NB-4331	Conformance to Section IX (Welding) Reqs.
	NB-4700	Mechanical Joints

ARTICLE NB-5000 EXAMINATION

	NB-5110	Procedures, Qualifications, and Evaluation
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ARTICLE NB-6000 TESTING

	NB-6110	Pressure Testing of Components
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NB-6120	Preparation for Testing
NB-6210	Hydrostatic Test Procedure
NB-6220	Hydrostatic Test Pressure Requirements
NB-6300	Pneumatic Tests
NB-6400	Pressure Test Gages

Welding Specifications

Welding specifications should be appended to Chapter 1, and they must address the requirements in the following paragraphs.

Ref: ARTICLE NB-2000 MATERIAL

NB-2121	Permitted Material Specifications/DOE Position
NB-2410	General Requirements (Welding Material)
NB-2420	Required Tests (Weld Metal)
NB-2432	Chemical Analysis Test (Weld Metal)
NB-2433	Delta Ferrite Determination (Weld Metal)

ARTICLE NB-3000 DESIGN

NB-3352	Permissible Types of Weld Joints
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ARTICLE NB-4000 FABRICATION

NB-4311	Types of Processes Permitted
NB-4321	Required Qualifications (Welding)
NB-4323	Welding Prior to Qualifications
NB-4331	Conformance to Section IX (Welding) Reqs.
NB-4410	Precautions To Be Taken Before Welding
NB-4430	Welding Of Attachments
NB-4450	Repair Of Weld Metal defects
NB-4600	Heat Treatment

ARTICLE NB-5000 EXAMINATION

NB-5120	Time of Examination of Welds and Cladding
NB-5140	Examination of Adjacent Base Material
NB-5210	Category A Vessel Welded Joints
NB-5220	Category B Vessel Welded Joints
NB-5230	Category C Vessel Welded Joints
NB-5240	Category D Vessel Welded Joints
NB-5260	Fillet, Partial Penetration, Socket, and Attach. Welds
NB-5270	Special Welds
NB-5320	Radiographic Acceptance Standards
NB-5330	Ultrasonic Acceptance Standards
NB-5350	Liquid Penetrant Acceptance Standards
NB-5530	Records (Qualification & Certification of NDE Personnel)

Drawings

Both the SARP text and construction drawings must list complete material specifications.

Ref:

NB-2121	Permitted Material Specifications/DOE Position
NB-2128	Bolting Material/DOE Position
NB-2190	Nonpressure-Retaining Material/DOE Position
NB-3132	Dimensional Standards for Standard Products

Construction drawings must show that all weld joints satisfy the requirements in the following paragraphs.

Ref:

NB-4240	Requirements for Welded Joints in Components
NB-4244	Category D Weld Joints
NB-4250	Welding End Transitions- Maximum Envelope

NB-4420 Rules For Making Welded Joints

Procurement Specifications

Procurement documents must refer to the following requirements:

Ref:	NB-2121	Permitted Material Specifications/DOE Position
	NB-2130	Certification of Material
	NB-2311	Materials Requiring Impact Tests (Bolts > 1-inch diam.)
	NB-2333	Bolting Material
	NB-2410	General Requirements (Welding Material)
	NB-2432	Chemical Analysis Tests (Weld Metal)
	NB-2433	Delta Ferrite Determination (Weld Metal)
	NB-2510	Examination of Pressure Retaining Material
	NB-2531	Required Examination (Pressure Retaining Mtl.)/DOE Position
	NB-2581	Required Examination (Bolts, Studs, and Nuts)
	NB-2587	Time of Examination (Bolts, Studs, and Nuts)
	NB-2588	Elimination of Surface Defects (Bolts, Studs, and Nuts)
	NB-2589	Repair by Welding (Bolts, Studs, and Nuts)
	NB-2700	Dimensional Standards

SARP Chapter 2 STRUCTURAL EVALUATION

2.1 Structural Design

2.1.2 Design Criteria

A SARP must identify all of the codes and standards that are used for design. All mechanical loads that affect the design must be identified.

Ref:	NB-1110	Aspects of Construction Covered by these Rules
	NB-1120	Temperature Limits/DOE Position
	NB-3110	Loading Criteria/DOE Position
	NB-3110.4	Design Stress Intensity Values/DOE Position
	NB-3211	Requirements for Acceptability
	NB-3212	Basis for Determining Stresses
	NB-3213	Terms Relating to Stress Analysis

2.3 Mechanical Properties of Materials

All structural materials used in structural evaluation, and their mechanical properties, must be listed.

Ref:	NB-2121	Permitted Material Specifications/DOE Position
	NB-2128	Bolting Material/DOE Position
	NB-2190	Nonpressure-Retaining Material/DOE Position
	NB-3229	Design Stress Values
	NB-3230	Stress Limits for Bolts

2.4 General Standards for all Packages

The following requirements must be addressed in this Section.

Ref:	NB-3214	Stress Analysis
	NB-3215	Derivation of Stress Intensities
	NB-3217	Classification of Stresses
	NB-3220	Stress limits for Other than Bolts
	NB-3227	Special Stress Limits

2.4.1 Chemical and Galvanic Reactions

The following requirements must be addressed in this Section.

Ref:	NB-3121	Corrosion/DOE Position
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2.4.3 Lifting Devices

2.4.4 Tiedown Devices

The following requirements must be addressed in this Section.

Ref: NB-3135 Attachments

2.5 Standards for Type B and Large Quantity Packaging

The following requirements must be addressed in this Section.

Ref: NB-3227 Special Stress Limits
NB-3133 Components Under External Pressure/DOE Position

2.6 Normal Conditions of Transport

The following requirements must be addressed in this Section.

Ref: NB-3110 Loading Criteria/DOE Position
NB-3214 Stress Analysis
NB-3215 Derivation of Stress Intensities
NB-3217 Classification of Stresses
NB-3220 Stress limits for Other than Bolts
NB-3221 Design Loadings
NB-3222 Level A Service Limits
NB-3226 Testing Limits
NB-3227 Special Stress Limits
NB-3231 Design Conditions
NB-3232 Level A Service Limits
NB-3300 Vessel Design

2.6.2 Cold

The SARP must provide evidence that any ferritic-steel bolting material is certified to -40°C (-40°F).

Ref: NB-1120 Temperature Limits/DOE Position

2.7 Hypothetical Accident Conditions

The following requirements must be addressed in this Section.

Ref: NB-3214 Stress Analysis
NB-3215 Derivation of Stress Intensities
NB-3217 Classification of Stresses
NB-3220 Stress limits for Other than Bolts
NB-3225 Level D Service Limits
NB-3228 Applications of Plastic Analysis/DOE Position
NB-3235 Level D Service Limits (Bolts)

SARP Chapter 9 QUALITY ASSURANCE

These requirements should be described in this Chapter.

Ref: NB-2130 Certification of Material
NB-2600 Material Manufacturers' Quality System Programs
NB-2610 Documentation and Maintenance of QSP
NB-4322 Maintenance and Certification of Records

**DOE POSITIONS AND REQUIREMENTS: ASME CODE, SECTION III,
SUBSECTION NB**

NB-1120 Temperature Limits

The allowable temperature limits of the Code are from -29 to +427°C (-20 to +800°F). The maximum allowable temperature given in the Code may be lower than 427°C (800°F) for some ferritic bolting materials.

The DOE will consider the use of the high-temperature design rules in Code Case N-47 for containment vessels with temperatures that exceed 427°C (800°F). The Code minimum temperature limit can be extended to -40°C (-40°F) for austenitic stainless steels, but must be

verified for ferritic-steel bolting.

NB-2121 Permitted Material Specifications

The pressure-retaining material must conform to one of the austenitic stainless steel specifications listed in Section II, Part D, Subpart 1, Table 2A.

The DOE will consider the use of non-Code materials for containment vessels if they are qualified by criteria equivalent to those applied to Code materials:

- Procurement according to an authoritative material specification such as ASTM, AMS, MIL, or SAE.
- Quantitative proof of the material's suitability for both the maximum and minimum service temperatures.
- Certification of materials and fabrication equivalent to the requirements of NB-4120.
- Nondestructive examination (NDE) equivalent to the requirements of NB-2500.

NB-2128 Bolting Material

The material for bolts and studs must conform to one of the steel specifications listed in Section II, Part D, Subpart 1, Table 4.

The DOE position is that non-Code materials may be acceptable for bolts and studs if they are qualified by criteria equivalent to those applied to Code materials described by the DOE position for NB-2121. In addition, both Code and non-Code bolting materials should satisfy the following requisites to ensure quality:

- Procurement of the material or finished bolts from a vendor who is qualified in accordance with a quality assurance plan.
- Quantitative proof that the bolts are not counterfeit, including confirmation of chemical and mechanical properties.

NB-2190 Nonpressure-Retaining Material

Nonpressure-retaining structural attachments shall meet the requirements of NF-2000.

The DOE will consider attachments made from a structural material other than those listed in NF-2000 if they are compatible with the containment vessel material and satisfy the applicable requirements in 10 CFR 71.

NB-2530 Examination and Repair of Plate

NB-2531 Required Examination

All plates for vessels must be examined by the straight-beam ultrasonic method in accordance with NB-2532.1.

The DOE will consider exemption of this examination of plates for vessels that are equal to or less than 4.76 mm (3/16 of an inch) thick.

ARTICLE NB-3000 DESIGN

NB-3100 General Design

NB-3110 Loading Criteria

The regulations in 10 CFR §71.41(a) specify that a package (consisting of a containment vessel plus other components) must be evaluated and qualified by testing or by another acceptable method. The DOE position is that the other acceptable method is analysis. If analysis is employed, the following rules apply:

- The design mechanical loadings for the containment vessel includes
- internal and external pressure,

- impact loads,
- weight of components and contents,
- superimposed loads,
- vibrations,
- reactions of supports and tie-downs,
- temperature effects.

In addition, the mechanical loads specified in 10 CFR §71.45(b), Tiedown lugs; §71.71, Normal Conditions of Transport; and §71.73, Hypothetical Accident Conditions must be included. Section 2.1.2, Design Criteria, must state that the containment vessel is designed to the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 10 CFR 71, and DOE Order 5480.3.

NB-3112.4 Design Stress Intensity Values

Design stress intensity values are in Section II, Part D, Subpart 1, Tables 2A and 4.

The DOE will consider the use of the high-temperature design rules in Code Case N-47 for containment vessels in which temperatures exceed 427°C (800°F). The Code minimum temperature limit can be extended to -40°C (-40°F) for austenitic stainless steels, but must be verified for ferritic steel bolting.

NB-3120 Special Considerations

NB-3121 Corrosion

Material subject to thinning by corrosion, erosion, mechanical abrasion, or other environmental effects must have additional thickness added to the required minimum thickness of the base metal.

In addition, 10 CFR §71.43(d) requires that there be no significant chemical, galvanic, or contact reactions among the components or between the components and contents.

NB-3133 Components Under External Pressure

This paragraph provides rules for determining stresses in shells and tubes under external pressure.

Regulations that specify mechanical loadings due to external pressure are contained in 10 CFR §71.71(c)(4) & (9) and §71.73(c)(4) or (5).

NB-3221 Design Loadings

The loading condition described in NB-3221 is considered part of the Normal Conditions of Transport given in 10 CFR §71.71. The stress intensity limits for this condition are listed in Fig. NB-3221-1. In general, the Design Loadings consist of the design internal pressure, the weight of the components and contents, and temperature effects associated with the thermal behavior of the contents.

NB-3222 Level A Service Limits

This mechanical loading condition is also part of the Normal Conditions of Transport, and the stress intensity limits are given in Fig. NB-3222-1. This paragraph also contains rules to determine if the containment vessel requires an analysis for cyclic operation.

NB-3225 Level D Service Limits

This mechanical loading condition is associated with the Hypothetical Accident Conditions in 10 CFR §71.73. Rules to evaluate these mechanical loadings are given in Appendix F of the ASME Code.

NB-3228 Applications of Plastic Analysis

The DOE position is that plastic analysis is not permitted.

NB-4320 Welding Qualifications, Records, and Identifying Stamps

NB-4321 Required Qualifications

The applicant is responsible for developing the procedures and conducting the welding qualification tests required by this paragraph and Section IX of the ASME Code. Section III, Subsection NCA, paragraph NCA-3131 provides additional information when welding services are subcontracted.

NB-4322 Maintenance and Certification of Records

The applicant is responsible for maintaining the records that relate to the welding qualification. This paragraph contains requirements for these records.

NB-6000 TESTING

NB-6100 General Requirements

NB-6110 Pressure Testing of Components

All containment vessels shall be pressure tested. The preferred method is hydrostatic testing with water. Pneumatic testing may be used in certain circumstances as indicated in NB-6112. Gaskets are exempted from the pressure test.

SUMMARY

This guide presents lists of the ASME Code paragraphs that are applicable to the design, fabrication, examination, and testing of Category I containment vessels that are used to transport high-level radioactive materials. Because this guide is intended to be helpful to those who are preparing a SARP, the lists follow the outline recommended for a SARP in the NRC Regulatory Guide 7.9. The guide also presents DOE positions related to certain Code requirements that may be ambiguous with respect to the design and fabrication of containment vessels that are used for the transport of high-level radioactive materials.

This guide refers to 91 paragraphs from Section III, Subsection NB of the Code that apply to these containment vessels. Although the number of paragraphs is extensive, it represents only a small fraction of the total requirements found in the Code. Section III of the Code is intended for the construction of nuclear reactor pressure vessel systems; consequently, it must consider components other than pressure vessels. These components include pipes, valves, pumps, as well as attachments to the reactor pressure vessel for internal and external structures. In addition, the Code must consider a wide range of ferritic and austenitic steels in wrought, forged, and cast form. Therefore, when applied to the relatively simple containment pressure vessels considered in this guide, the applicable Code rules are far less formidable.

REFERENCES

American Society of Mechanical Engineers, *1992 ASME Boiler and Pressure Vessel Code*, "Section III, Rules for Construction of Nuclear Power Plant Components, Division 1, Subsection NB: Class 1 Components," The American Society of Mechanical Engineers, New York, 1992.

Office of the Federal Register, *Title 10, Code of Federal Regulations*, Part 71-Packaging and Transportation of Radioactive Material, U.S. Government Printing Office, Washington, DC, January 1, 1994.

U.S. Department of Energy, "Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings, Rev. 1," DOE/DP-0049, Office of Security Evaluation, U.S. Department of Energy, Germantown, MD, October 1988.

U.S. Department of Energy, "Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes," DOE Order 5480.3, Washington, DC, 1985.

U.S. Nuclear Regulatory Commission, "Regulatory Guide 7.9, Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material," U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, DC, Revision 1, 1980.