50-237

SYSTEMATIC EVALUATION PROGRAM
TOPIC III-1

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ENCLOSURE 1

SYSTEMATIC EVALUATION PROGRAM
TOPIC III-1

DRESDEN UNIT 2

TOPIC: III-1, Classification of Structures, Components and Systems (Seismic and Quality)

I. INTRODUCTION

SEP plants were generally designed and constructed during the time span from the late 1950's to late 1960's. They were designed according to codes and criteria in effect at that time; however, since then, the codes and criteria have been revised to incorporate the results of additional research. Thus, earlier plants may have been designed according to criteria and codes no longer accepted by the NRC.

The purpose of Topic III-1 is the review of the classification of structures, systems and components of as-built plants as compared to current appropriate classifications, codes and standards for seismic and quality groups. The review of seismic classification is being addressed in the seismic topics. Accordingly, this topic was limited to an evaluation of the quality group classification of systems and components.

II. REVIEW CRITERIA

The review criteria are presented in the Appendix of Franklin Technical Evaluation Report - C527-430, "Quality Group Classification of Components and Systems - Dresden 2 Plant."

III. RELATED SAFETY TOPICS AND INTERFACES

The scope of review for this topic was limited to avoid duplication of effort since some aspects of the review were performed under related topics. The related topics and the subject matter are identified below.

III-6	Seismic Design Considerations
III-7.B	Design Codes, Design Criteria, Load Combinations and Reactor Cavity Design Criteria
V-6	Reactor Vessel Integrity
V-8	Steam Generator Integrity

IV. REVIEW GUIDELINES

The review guidelines are presented in Section 3 of Franklin Report - C-5257-430, "Quality Group Classification of Components and Systems - Dresden 2 Plant." Quality Assurance was not reviewed since it is addressed in Topic XVII, "Operational Quality Assurance (QA) Program" and because QA during design and construction is outside of the scope of SEP.

V. EVALUATION

The basic input for this report is Table 4.1 in Section 4 of the Franklin Report. Table 4.1 is a compilation of all systems and components which are required to be classified by Regulatory Guide 1.26 and the original codes and standards used in the plant design. After comparing the original codes with those currently used for licensing new facilities the following areas were identified where the requirements have changed:

1) Fracture Toughness
2) Quality Group Classification

3) Code Stress Limits
4) Radiography Requirements
5) Fatigue Analysis of Piping Systems

An evaluation of each of these areas is presented in Section 5 of the Franklin Report with a detailed discussion included in the Appendix.

We have determined that changes in the following areas have not significantly affected the safety functions of the systems and components reviewed in this report:

1) Quality Group Classification
2) Code Stress Limits
3) Fatigue Analysis of Piping Systems

As noted earlier, we have decided that the area of quality assurance need not be reviewed for this report.

In the remaining two areas we have concluded the following:

1. Fracture Toughness - The current code requires that pressure retaining materials be impact tested. For 6 of 62 components reviewed, sufficient information was available to exempt them from this requirement.

2. Radiography Requirements - For pressure vessels and pump casing, we have concluded the following:

   a. Vessels built to ASME III (1965) Class A or ASME VIII (1965) satisfy current radiography requirements for Class 1 and Class 3 vessels, respectively.

b. Vessels built to ASME III (1965) Class C requirements and currently classified as Class 2 or Class 3 satisfy current radiography requirements for Category A or B joints.

c. Category C joints in current Class 2 vessels built to Class C requirements do not satisfy current radiography requirements.

d. The Recirculation System pump casing does not satisfy current radiography requirements because it is a Class 1 component built to Class C requirements.

For piping and valves, we have concluded that they meet current radiographic requirements provided Code Case N-7 was applied as indicated by the licensee.

Our review has not identified any significant deviations from past codes. However, we were unable to complete our evaluation due to insufficient information for the following:

1. Fracture Toughness - For 56 of 62 components there is insufficient information on materials to complete our review. The licensee should provide the necessary information using the format provided in Tables A4-4 through A4-6 in Appendix A of the Franklin Report. Table 5-1 of the Franklin Report identifies those components for which this information is necessary.

2. Full Radiography Requirements - The licensee should provide the following:

   a. For the following pressure vessels information is necessary regarding the radiographic requirements imposed on the Category C welds: 1) Emergency system isolation condenser, 2) Low pressure coolant injection system heat exchanger, 3) Reactor shutdown cooling system heat exchangers, and 4) Recirculation system pump casing.

   b. The present code requires full radiography for Class 1 and 2 welded joints for piping, valves, and pumps, where as it was not required in past codes. However, Provisions 2 and 3 of Code Case N-7 required full radiography. Confirmation that Code Case N-7 was applied to all Class 1 and 2 piping would resolve this concern.

3. Valves - Provide, on a sample basis for Class 1, 2 and 3 valves, information regarding the design of the valve in order to evaluate if they meet current body shape and pressure - temperature rating requirements.

4. Pumps - The original design code for the Reactor Building Closed Cooling Water System Pumps was not available and the comparisons could not be made. Provide the codes or requirements to which this pump was designed.

5. Storage Tanks - Provide the following:

   a. Confirm that the atmospheric storage tanks meet current compressive stress requirements.

   b. Confirm that the 0 to 15 PSIG storage tanks meet current tensile allowables for biaxial stress field conditions.

   c. The Standby Liquid Control Tank was designed to API 650. The requirements of API 650 are not comparable to present design codes. Therefore, the design and construction of the Standby Liquid Control Tank should be re-evaluated against current criteria.

6. Piping - When considering gross discontinuities of piping systems, two loading cases can prove to be potentially unconservative designs when evaluated to current code requirements. Two examples are given in Section 4.2 of Appendix A of the Franklin Report, in order to assess the potential problems of temperature loading for a large number of cycles and temperature loading for a medium range number of cycles. These examples were based on a temperature drop from 100% power to 0% power of 11°F. This ΔT was obtained in a telephone call between the NRC and the licensee.

   Stresses for both examples indicate no problems exist. Review the methodology and confirm the assumptions used for the above calculations, particularly the temperature drop (11°F) from 100% power to 0% power.

7. The codes and standards given by the licensee for the design of the following components contradict the general use of the given code. Verify for the following components and systems that the design code (including edition) used in our evaluation is correct and clarify why this particular code was invoked for the original design. If the code (including edition) is incorrect, provide the correct code and edition and the comparison of it to the current code in effect.

   a) Core Spray System Spray Header and Spargers - ASME Section III (1965) Class B;
   b) Spargers for High Pressure Coolant Injection - ASME Section III (1965) Class A;
   c) Standby Gas Treatment System Piping - ASME Section III (1965) Class B;
   d) Containment Penetration Piping - ASME Section III (1965) Class B;
   e) Core Spray Pumps - ASME Section III (1965) Class B or C;
   f) Low Pressure Coolant Injection Pumps - ASME Section III (1965) Class B;
   g) Standby Gas Treatment Valves - ASME Section III (1965) Class B;
   h) Containment Penetration Valves - ASME Section III (1965) Class B;
   i) Containment Coolant Subsystem Piping - ASME Section III (1965) Class C; and

TECHNICAL EVALUATION REPORT

QUALITY GROUP CLASSIFICATION OF COMPONENTS AND SYSTEMS

COMMONWEALTH EDISON COMPANY

DRESDEN NUCLEAR POWER STATION UNIT 2

NRC DOCKET NO. 50-237

NRC TAC NO. 41596

NRC CONTRACT NO. NRC-03-79-118

FRC PROJECT C5257

FRC ASSIGNMENT 17

FRC TASK 430

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March 3, 1982

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CONTENTS

FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

Mr. L. Berkowitz contributed to the technical preparation of this report through a subcontract with Innovation Technology, Inc.

1. INTRODUCTION

Systems and components in nuclear power plants should be designed, fabricated, installed, and tested to quality standards that reflect the importance of their safety functions. This is the concern addressed by the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.26 [1], "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," which classifies components into four Quality Groups, A, B, C, and D, and gives the standards applicable to each group.

The systems and components of plants being reviewed as part of the Systematic Evaluation Program (SEP) were designed, fabricated, installed, and tested to standards different from those applied today. This report is the result of work that addresses the safety margins of these systems and components in light of the changes that have taken place in licensing criteria.

The work is part of SEP Topic III-1, "Classification of Structures, Systems, and Components (Seismic and Quality)." NRC has divided this topic into two technical areas: (1) Seismic review, which will be performed by the NRC, and (2) Quality Group review, which this report addresses for the Dresden Nuclear Power Plant, Unit 2.

This report was prepared by the Franklin Research Center (FRC) under NRC Contract No. NRC-03-79-118.

2. SCOPE OF THE EVALUATION

The SEP concerns a review and assessment of the safety of older nuclear plants on the basis of current licensing criteria. Topic III-1 is one of 137 SEP topics. Of the 11 SEP plants, the following 10 are being reviewed:

Plant Name	Docket No.	FRC Task No.
Palisades	50-255	17428
Ginna	50-244	17429
Dresden Unit 2	50-237	17430 (1)
Oyster Creek	50-219	17431
Millstone Unit 1	50-245	17432
San Onofre Unit 1	50-206	17433
Big Rock Point	50-155	17434
Haddam Neck	50-213	17435
Yankee Rowe	50-29	17436
LaCrosse	50-409	17437

Specifically, Topic III-1 entails a review of standards in effect from 1955 to 1965 used in the design of systems and components in older plants, and the 1977 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code as supplemented through the Summer 1978 Addenda [2,3]. The objective of the present evaluation is to assess the ability of systems and components in the Dresden Nuclear Power Plant, Unit 2 to perform their safety functions as judged by current standards. This involves two steps: (1) comparison of current codes and standards with those used in the design, fabrication, installation, and testing of the plant's systems and components to identify significant differences that might affect structural integrity, and (2) assessment of the effect of these differences on the safety margins of the systems and components.

The scope of this evaluation is limited by or to the following:

1. Table of Systems and Components, compiled by the NRC, corrected and completed by Commonwealth Edison Company. This table contains the

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1. Plant discussed in this report.

Quality Group Classification, the current code, and the code used for the listed systems and components when the plant was designed. When the information in the table was incomplete, FRC completed it as well as possible (see Table 4-1) [4].

2. Information in the Final Safety Analysis Report (FSAR) or a similar document [5].

3. NRC Regulatory Guide 1.26, Revision 3 [1].

4. Standard Review Plan 3.2.2 [6].

5. Major older codes and standards: American Standards Association (ASA) B31.1 (1955), "Code for Pressure Piping" [7]; ASME 1965 Boiler and Pressure Vessel Code, Section I, "Rules for Construction of Power Boilers" [8], Section III, "Rules for Construction of Nuclear Vessels" [9], and Section VIII, "Unfired Pressure Vessels" [10]; and applicable Code Cases for ASA B31.1 and ASME VIII.

6. Current code: 1977 ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, to include the General Requirements (articles with "NA" subscript), Subsection NB, NC, and ND, and Appendices, supplemented through the 1978 Summer Addenda [2].

7. Quality Group D components are not considered in this evaluation.

8. Although discussed in this report, quality assurance for design and construction is outside the scope of the SEP.[1]

Also, the following subjects are explicitly excluded because they have been addressed under other SEP topics:

Topic	Description
III-5.A	Effects of Pipe Break on Structures, Systems and Components Inside Containment
III-5.B	Pipe Break Outside Containment
III-6	Seismic Design Considerations
III-7.A	Inservice Inspection, Including Prestressed Concrete Containments with Either Grouted or Ungrouted Tendons

1. Letter from S. Bajwa to S. Carfagno, dated December 10, 1981.

Topic	Description
III-7.B	Design Codes, Design Criteria, Load Combination, and Reactor Cavity Design Criteria
III-7.D	Containment Structural Integrity Tests
III-9	Support Integrity
V-3	Overpressurization Protection
V-6	Reactor Vessel Integrity
V-8	Steam Generator Integrity
IX-6	Fire Protection

3. METHOD OF REVIEW

To accomplish the objective of this evaluation, FRC performed the review as follows:

1. Components from the Table of Systems and Components (Table 4-1) referred to in Section 2 were listed in three tables according to Quality Group. For example, all Quality Group A vessels, piping, valves, pumps, and storage tanks are listed in one table. Table 4-2(a) contains Quality Group A components, Table 4-2(b) Quality Group B components, and Table 4-2(c) Quality Group C components. Within each table, the components are arranged according to type.

2. Major older codes identified in Table 4-1 were compared against the current code. Results of the review are given in Appendix A.

3. The results in Appendix A were used for a comparative analysis which formed the basis for an engineering judgment of the safety margins exhibited by the systems and components by current quality requirements. Details are given in Section 5.

Appendix A lists all the requirements of the current code (the 1977 ASME B&PV Code, Section III with Addenda [2]) and indicates which requirements are considered applicable and significant for structural integrity (designated as "A"), which are not considered significant (designated as "-"), and which are outside the scope of this review (designated as "O"). For each significant requirement in the current code, a similar requirement was sought in the older codes. The major older codes for the Dresden plant are ASA B31.1 (1955) [7] and the 1965 ASME B&PV Code, Sections I, III, and VIII [8, 9, 10]. Differences between significant requirements, such as additions to the older codes, were reviewed, and recommendations were made for assessing their impact on the safety margin of the particular component.

Knowledge of the historical development of the codes and the reasons for the changes was an important element in making effective comparisons. A literature survey, supported by consultation with experts in the field, helped to identify certain changes for special attention, e.g., changes in design criteria, analytical methods, load combinations, quality assurance requirements, fabrication techniques, and testing requirements.

4. QUALITY CLASSIFICATION OF SYSTEMS AND COMPONENTS

Systems and components are Quality Group classified according to the safety functions to be performed. Table 4-1 contains the systems and components for the Dresden plant, the code required for current licensing criteria, based on NRC Regulatory Guide 1.26 [1] and Section 50.55a of the Code of Federal Regulations [3], and the codes and standards used when the systems and components were originally built. The table also contains information regarding the Seismic Classification of the systems and components.

The following systems are listed in Table 4-1 with their respective components:

Reactor Coolant System
Recirculation System
Isolation Condenser
Standby Liquid Control System
Core Spray System
Low Pressure Coolant Injection System
High Pressure Coolant Injection System
Standby Coolant Supply System
Automatic Pressure Relief Subsystem
Standby Gas Treatment System
Safety Valves
Relief Valves
Containment Penetration Valves and Piping
Reactor Coolant Pressure Boundary
Isolation Valves
Control Rod Drive Housing
Control Rod Drive System
Spent Fuel Storage Facility
Reactor Vessel Head Cooling System
Condensate/Feedwater System
Main Steam System
Condensate Storage Tank
Reactor Water Cleanup System
Reactor Shutdown Cooling System
Reactor Building Closed Cooling Water System
Compressed Air System
Standby Diesel Generator System
Service Water System
Structures (for information only, not in the scope of this review).

Table 4-2(a) lists all Quality Group A components, Table 4-2(b) lists all Quality Group B components, and Table 4-2(c) lists all Quality Group C components. Components in Tables 4-2(a), (b), and (c) are grouped as pressure vessels, piping, pumps, valves, and storage tanks. The major code used when the component was built is also provided. Table 4-2(d) provides an index of the abbreviations used for the systems and their definitions.

Additional information on the review procedure for System Quality Group Classification can be obtained from Section 3.2.2 of the Standard Review Plan [6].

Table 4-1

Classification of Structures, Systems, and Components
Dresden Nuclear Power Plant Unit 2

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
REACTOR COOLANT SYSTEM					
Reactor Vessel Including Nozzle Safe Ends	ASME III Class 1	ASME III (1965) Class A	Category I	Class I	NA(3)
Reactor Vessel Support	--	--	Category I	Class I	NA
Reactor Vessel Internals	ASME III Class 1	ASME III (1965) Class A	Category I	Class I	NA
RECIRCULATION SYSTEM					
Piping	ASME III Class 1	ASME I (1965) ASA B31.1 (1955)(4)	Category I	Class I	
Valves	ASME III Class 1	ASME I (1965) ASA B31.1 (1955)(5)	Category I	Class I	
Pumps	ASME III Class 1	ASME III (1965) Class C	Category I	Class I	

1. ASME III stands for the Boiler and Pressure Vessel Code Section III Division I, published by the American Society of Mechanical Engineers, 1977 Edition with Addenda through Summer 1978.
2. When plant design is in accordance with Sections I, III, and VIII of ASME Boiler and Pressure Vessel Code, 1965 Edition with Addenda through Summer 1965 is implied.
3. NA indicates additional information provided in this table that is outside the scope of this report.
4. Plant piping was designed according to ASA B31.1 (1955); piping installation, repair, and replacement was carried out to the guidelines of USAS B31.1 (1967).
5. ASA B31.1 (1955) with Code Cases N-7, N-9, N-10, MSS-SP-66, and MSS-SP-61 provided guidance for design of valves.

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
EMERGENCY SYSTEMS					
Isolation Condenser					
Shell Side	ASME III Class 3	ASME VIII (1965)	Category I	Class I	
Tube Side	ASME III Class 2	ASME III (1965) Class ?	Category I	Class I	
Piping, Fittings, and Valves (Tube Side)	ASME III Class 2	ASME I (1965) ASA B31.1 (1955) (4,5)	Category I	Class I	ASME I to outermost isolation valve and B31.1 from outermost isolation valve to isolation condenser
Standby Liquid Control System					
Piping and Valves	ASME III Class 2	ASA B31.1 (1955) (4,5)	Category I	Class I	
Standby Liquid Control Tank	ASME III Class 2	API-650 (1964)*	Category I	Category I	
Pumps	ASME III Class 2	ASME III (1965) Class C	Category I	Class I	

* Information assumed because it is not available at this time.

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Core Spray System					
Pumps	ASME III Class 2	ASME III (1965)[6] Class B or C	Category I	Class I	
Piping, Fittings, and Valves	ASME III Class 2	ASA B31.1 (1955)[4,5]	Category I	Class I	
Spray Header and Spargers	ASME III Class 2	ASME III (1965)[7] Class B	Category I	Class I	
Low Pressure Coolant Injection/Containment Coolant Subsystem					
Pumps	ASME III Class 2	ASME III (1965)[6] Class B	Category I	Class I	
Piping, Fittings, and Valves	ASME III Class 2	ASA B31.1 (1955)[4,5]	Category I	Class I	
Containment and Suppression Spray Headers	ASME III Class 2	ASA B31.1 (1955)[4,5]	Category I	Class I	
Heat Exchangers-Tube Side	ASME III Class 2	ASME III (1965) Class C	Category I	Class I	
Heat Exchangers - Shell Side	ASME III Class 3	ASME III (1965) Class C	Category I	Class I	

6. Class B is related to containment vessels. It seems more likely that Class C requirements would have been used.
7. It is more likely that ASA B31.1 (1955) would have been used for design purposes than ASME III.

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Containment Coolant Subsystem	ASME III Class 3	ASME III (1965)(7) Class C	Category I	Class I	
High Pressure Coolant Injection					
Pumps	ASME III Class 2	ASME III (1965) Class C	Category I	Class I	
Piping, Fittings, and Valves	ASME III Class 2	ASA B31.1 (1955)(4,5)	Category I	Class I	
Spargers (Feedwater Spargers Used)	ASME III Class 2	ASME III (1965)(7) Class A	Category I	Class I	
Standby Coolant Supply System					
Interconnecting Piping and Associated Valves Between the Service Water System and the Condenser Hotwell	ANSI B31.1 (See remarks)	ASA B31.1 (1955)(4,5)	Non-seismic Category I (OBE)	Class I	If credit is taken for system in ECCS analysis, then ASME III, Class 3 classification and Seismic Category I are applicable
Automatic Pressure Relief Subsystem (ADS)	ASME III Class 1	ASA B31.1 (1955)(4,5)	Category I	Class I	

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1. 6 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1. 9	Seismic Classification: Used in Plant Design	Remarks
STANDBY GAS TREATMENT SYSTEM	ASME III Class 2	ASME III (1965)(6) Class B	Category I	Class I	See FSAR Sec. 5.3.3
Piping, Fittings, and Valves	ASME III Class 2	ASME III (1965)(7) Class B	Category I	Class I	
SAFETY VALVES	ASME III Class 1	ASME III (1965)(8) ASA B31.1 (1955)(9)	Category I	Class I	Discharge piping not evaluated in FSAR
RELIEF VALVES	ASME III Class 1	ASA B31.1 (1955)(9)	Category I	Class I	
CONTAINMENT PENETRATIONS VALVES AND PIPING	ASME III Class 2	ASME III (1965)(7) Class B	Category I	Class I	See FSAR Sec. 5.2.33
REACTOR COOLANT PRESSURE BOUNDARY (RCPB)					
Piping from Reactor Vessel Up to and Including First Isolation Shutoff Valve	ASME III Class 1	ASME I (1965) ASA B31.1 (1955)(4)	Category I	Class I	
ISOLATION VALVES					
Valves Not Identified Under Containment Penetration Valves	ASME III Class 1	ASA B31.1 (1955)(5)	Category I	Class I	

8. It is not clear which specific section of ASME III is referenced here.
9. Safety and relief valves designed in accordance with ASA B31.1 with Code Cases N-2, N-7, N-9, and N-10 taken into consideration.

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Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
CONTROL ROD DRIVE HOUSING	ASME III Class 1	ASA B31.1 (1955)	Category I	Class I	
CONTROL ROD DRIVE SYSTEM	ASME III Class 2	ASME III (1965) Class A	Category I	Class I	
SPENT FUEL STORAGE FACILITIES					
Spent Fuel Pool	ASME III Class 3	--	Category I	Class I	NA (3)
Pump	ASME III Class 3	ASME VIII (1965)	Category I	Class I	
Heat Exchanger	ASME III Class 3	ASME III (1965) Class C	Category I	Class I	
Piping, Fittings, and Valves	ASME III Class 3	ASA B31.1 (1955) (4,5)	Category I	Class I	
Filter	ASME III Class 3	ASME VIII (1965)	Category I	Class I	
REACTOR VESSEL HEAD COOLING SYSTEM					
Piping, Fittings and Valves	ASME III Class 3	ASA B31.1 (1955) (4,5)	Non-seismic Category I (OBE)	-	

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
CONDENSATE/FEEDWATER SYSTEM					
Piping from Outermost Containment Isolation Valve up to and including the Shutoff Valve	ASME III Class 2	ASA B31.1 (1955)[4,5]	Category I	Class II	
Balance of Feedwater System from Shutoff Valve to the Condenser	ANSI B31.1 (See Remarks)	ASA B31.1 (1955)[4,5]	Non-Seismic Category I (OBE)	Class II	Portions of condensate feedwater system required to satisfy reactor vessel reflooding design objectives should be ASME III, Class 3
MAIN STEAM SYSTEM					
Piping from Outermost Containment Isolation Valve up to Turbine Stop and Bypass Valves and Connected Piping up to and including First Valve	ASME III Class 2	ASA B31.1 (1955)[4,5]	Category I	Class II	

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Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
CONDENSATE STORAGE TANK	ASME III Class 3	ASME III (1963) Class C with 1964 Addenda	Category I	Class II	
REACTOR WATER CLEANUP SYSTEM	ASME III Class 3	ASME III (1965) Class C	Non-seismic Category I (OBE)	Class II	
Piping, Fittings, and Valves	ASME III Class 3	ASA B31.1 (1955)[4,5]	Non-Seismic Category I (OBE)	Class II	
REACTOR SHUTDOWN COOLING SYSTEM					
Heat Exchangers - Tube Side	ASME III Class 2	ASME III (1965) Class C	Category I	Class II	
Heat Exchangers - Shell Side	ASME III Class 2	ASME III (1965) Class C	Category I	Class II	
Piping and Valves	ASME III Class 2	ASA B31.1 (1955)[4,5]	Category I	Class II	
REACTOR BUILDING CLOSED COOLING WATER SYSTEM					
Pumps	ASME III Class 3	?	Category I	Class II	

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Used in Plant Design	Remarks
Heat Exchangers	ASME III Class 3	ASME VIII (1965)	Category I	Class II	
Piping, Fittings, and Valves	ASME III Class 3	ASA B31.1 (1955)(4,5)	Category I	Class I	
COMPRESSED AIR SYSTEM					
Piping, Fittings, and Valves	Quality Group D (See remarks)	ASA B31.1 (1955)(4,5)	Non-seismic (See Remarks)	Class II	Portions of air system required to perform safety function should be Category I and Class 3
STANDBY DIESEL GENERATOR SYSTEM					
Piping, Fittings, and Valves	ASME III Class 3	ASA B31.1 (1955)(4,5)	Category I	Class I	FSAR does not identify auxiliary systems required for diesel generator
SERVICE WATER SYSTEM					
Piping, Fittings, and Valves	ASME III Class 3	ASA B31.1 (1955)(4,5)	Category I	Class II	

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26 (1)	Quality Classification: Codes and Standards Used in Plant Design (2)	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
STRUCTURES					
Reactor Building	--	--	Category I	Class I	NA(3)
Drywell, Torus, Vents, and Penetrations (Primary Containment)	ASME III MC	ASME III (1965) Class B	Category I	Class I	NA
Control Room	--	--	Category I	Class I	NA
Stack	--	--	Non-seismic	Class I	NA
Turbine Building	--	--	Non-seismic Category I (OBE)	Class II	NA
Radioactive Waste Building	--	--	Non-seismic Category I (OBE)	Class II	NA
Intake and Discharge (Crib House)	--	--	Category I	Class II	NA

Table 4-2(a)

Quality Group Components (1)

Code: ASME III-Class 1(2)

Pressure Vessels	Code
None	
Piping	
Recirculation System Piping (RCS)	ASME I (1965) (3) ASA B31.1 (1955) (4)
Automatic Pressure Relief Subsystem Piping (ADS)	ASA B31.1 (1955) (4)
Piping from Reactor Vessel up to First Isolation Shutoff Valve (RCPB)	ASME I (1965) (3) ASA B31.1 (1955) (4)
Control Rod Drive Housing (CRDS)	ASA B31.1 (1955)
Pumps	
Recirculation System Pumps (RCS)	ASME III (1965) (3) Class C
Valves	
Recirculation System Valves (RCS)	ASME I (1965) (3) ASA B31.1 (1955) (5)
Automatic Pressure Relief Subsystem Valves (ADS)	ASA B31.1 (1955) (5)

1. Refer to Table 4-2(d) for abbreviations.
2. ASME III-Class 1 stands for Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 1977 Edition, and Addenda through Summer 1978.
3. Plant design is in accordance with Sections I, III, and VIII of ASME Boiler and Pressure Vessel Code, 1965 Edition with Addenda through Summer 1965.
4. Plant piping was designed according to ASA B31.1 (1955). Piping installation, repair, and replacement were carried out according to the guidelines in USAS B31.1 (1967).
5. ASA B31.1 (1955), with Code Cases N-7, N-9, N-10, MSS-SP-66, and MSS-SP-61 provides guidance for design of plant valves.

Table 4-2(a) (Cont.)

Valves (Cont.)	Code
Safety Valves	ASME III (1965)[3,6] Class ? ASA B31.1 (1955)[7]
Relief Valves	ASA B31.1 (1955)[7]
First Isolation Shutoff Valve (RCPB)	ASA B31.1 (1955)[5]
Isolation Valves not Identified under Containment Penetration Valves (IV)	ASA B31.1 (1955)[5]

Storage Tanks (Atmospheric and 0-15 psig)

None

6. It is not clear which specific section of ASME III is referenced here.
7. Safety and relief valves were designed in accordance with ASA B31.1 (1955), with Code Cases N-2, N-7, N-9, and N-10 taken into consideration.

Table 4-2(b)

Quality Group B Components (1)

Code: ASME III-Class 2 (2)

Pressure Vessel	Code
Emergency System Isolation Condenser-Tube Side (IC)	ASME III (1965) (3) Class ?
Low Pressure Coolant Injection System Heat Exchangers - Tube Side (LPCI)	ASME III (1965) (3) Class C
Control Rod Drive System (CRDS)	ASME III (1965) (3) Class A
Reactor Shutdown Cooling System Heat Exchangers - Tube and Shell Sides (RSCS)	ASME III (1965) (3) Class C
Piping	
Emergency System Isolation Condenser Piping (IC)	ASME I (1965) (3) ASA B31.1 (1955) (4)
Piping for Standby Liquid Control System (SLCS)	ASA B31.1 (1955) (4)
Core Spray System Piping (CSS)	ASA B31.1 (1955) (4)
Core Spray System Spray Header and Spargers (CSS)	ASME III (1965) (3,5) Class B
Low Pressure Coolant Injection System Piping (LPCI)	ASA B31.1 (1955) (4)

1. Refer to Table 4-2(d) for abbreviations.
2. ASME III-Class 2 stands for Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC, 1977 Edition, and Addenda through Summer 1978.
3. Plant design is in accordance with Sections I, III, and VIII of ASME Boiler and Pressure Vessel Code, 1965 Edition with Addenda through Summer 1965.
4. Plant piping was designed according to ASA B31.1 (1955). Piping installation, repair, and replacement were carried out according to guidelines in USAS B31.1 (1967).
5. Class B is related to containment vessels. It seems more likely that Class C [9] (for pumps) or ASA B31.1 (for piping and valves) requirements would have been used.

Table 4-2(b) (Cont.)

Piping (Cont.)	Code
Containment and Suppression Spray Headers (LPCI)	ASA B31.1 (1955) (4)
High Pressure Coolant Injection System Piping (HPCI)	ASA B31.1 (1955) (4)
Spargers for High Pressure Coolant Injection (HPCI)	ASME III (1965) (3,5) Class A
Standby Gas Treatment System Piping (SGTS)	ASME III (1965) (3,5) Class B
Containment Penetration Piping (CS)	ASME III (1965) (3,5) Class B
Piping from Outermost Containment Isolation Valve up to the Shutoff Valve (C/FWS)	ASA B31.1 (1955) (4)
Piping from Outermost Containment Isolation Valve up to the Turbine Stop and Bypass Valves and Connected Piping up to the First Valve (MSS)	ASA B31.1 (1955) (4)
Reactor Shutdown Cooling System Piping (RSCS)	ASA B31.1 (1955) (4)
Pumps	
Standby Liquid Control System Pumps (SLCS)	ASME III (1965) (3) Class C
Core Spray System Pumps (CSS)	ASME III (1965) (3,5) Class B or C
Low Pressure Coolant Injection Pumps (LPCI)	ASME III (1965) (3,5) Class B
High Pressure Coolant Injection Pumps (HPCI)	ASME III (1965) (3) Class C

Table 4-2(b) (Cont.)

Valves	Code
Emergency System Isolation Valves (IC)	ASA B31.1 (1955) (6)
Standby Liquid Control System Valves (SLCS)	ASA B31.1 (1955) (6)
Core Spray System Valves (CSS)	ASA B31.1 (1955) (6)
Low Pressure Coolant Injection System Valves (LPCI)	ASA B31.1 (1955) (6)
High Pressure Coolant Injection System Valves (HPCI)	ASA B31.1 (1955) (6)
Standby Gas Treatment System Valves (SGTS)	ASME III (1965) (3,5) Class B
Containment Penetration Valves (CS)	ASME III (1965) (3,5) Class B
Shutoff Valve in Condensate/Feedwater System (C/FWS)	ASA B31.1 (1955) (6)
Valves from the Outermost Containment Isolation Valve up to the Turbine Stop and Bypass Valves Including the First Valve (MSS)	ASA B31.1 (1955) (6)
Reactor Shutdown Cooling System Valves (RSCS)	ASA B31.1 (1955) (6)
Storage Tanks (Atmospheric and 0-15 psig)	
Standby Liquid Control Tank (SLCS)	API-650 (1964) (7)

6. ASA B31.1 (1955), with Code Cases N-7, N-9, N-10, MSS-SP-66, and MSS-SP-61, provides guidance for design of plant valves.

7. Information regarding this edition of the Code is an assumption because the information is not available at this time.

Table 4-2(c)

Quality Group C Components (1)

Code: ASME III-Class 3 (2)

Pressure Vessel	Code
Emergency System Isolation Condenser - Shell Side (IC)	ASME VIII (1965) (3)
Low Pressure Coolant Injection/ Containment Coolant Subsystem Heat Exchangers - Shell Side (LPCI)	ASME III (1965) (3) Class C
Spent Fuel Storage Heat Exchangers (SFSF)	ASME III (1965) (3) Class C
Spent Fuel Storage Filters (SFSF)	ASME VIII (1965) (3)
Reactor Building Closed Cooling Water Heat Exchangers (CCWS)	ASME VIII (1965) (3)
Piping	
Containment Coolant Subsystem Piping (LPCI)	ASME III (1965) (3,4) Class C
Piping Between Service Water System and the Condenser Hotwell (SCSS)	ASA B31.1 (1955) (5)
Piping Associated with Spent Fuel Storage Facility (SFSF)	ASA B31.1 (1955) (5)

1. Refer to Table 4-2(d) for abbreviations.
2. ASME III-Class 3 stands for Boiler and Pressure Vessel Code, Section III, Division 1, Subsection ND, 1977 Edition, and Addenda through Summer 1978.
3. Plant design is in accordance with Sections I, III, and VIII of ASME Boiler and Pressure Vessel Code, 1965 Edition, with Addenda through Summer 1965.
4. It is more likely that ASA B31.1 (1955) would have been used for design purposes than ASME III.
5. Plant piping was designed according to ASA B31.1 (1955). Piping installation, repair, and replacement were carried out according to guidelines in USAS B31.1 (1967).

Table 4-2(c) (Cont.)

Piping (Cont.)	Code
Reactor Vessel Head Cooling System Piping (RVHCS)	ASA B31.1 (1955)(5)
Balance of Feedwater System From Shutoff Valve to the Condenser (C/FWS)	ASA B31.1 (1955)(5)
Reactor Water Cleanup System Piping (RWCS)	ASA B31.1 (1955)(5)
Reactor Building Closed Cooling Water System Piping (CCWS)	ASA B31.1 (1955)(5)
Compressed Air System Piping (CAS)	ASA B31.1 (1955)(5)
Standby Diesel Generator System Piping (SDGS)	ASA B31.1 (1955)(5)
Service Water System Piping (SWS)	ASA B31.1 (1955)(5)
Pumps	
Pumps for Spent Fuel Storage Facility (SFSF)	ASME VIII (1965)(3)
Pumps for Reactor Building Closed Cooling Water System (CCWS)	?
Valves	
Containment Coolant Subsystem Valves (LPCI)	ASME III (1965)(3,4) Class C
Associated Valves Between Service Water System and Condenser Hotwell (SCSS)	ASA B31.1 (1955)(6)
Valves for Spent Fuel Storage Facility (SFSF)	ASA B31.1 (1955)(6)
Reactor Vessel Head Cooling System Valves (RVHCS)	ASA B31.1 (1955)(6)
Valves in Balance of Feedwater System (C/FWS)	ASA B31.1 (1955)(6)
Reactor Water Cleanup System Valves (RWCS)	ASA B31.1 (1955)(6)
Reactor Building Closed Cooling Water System Valves (CCWS)	ASA B31.1 (1955)(6)

6. ASA B31.1 (1955), with Code Cases N-7, N-9, N-10, MSS-SP-66, and MSS-SP-61, provides guidance for design of plant valves.

Table 4-2(c) (Cont.)

	Code
Valves (Cont.)	
Compressed Air System Valves (CAS)	ASA B31.1 (1955)[6]
Standby Diesel Generator System Valves (SDGS)	ASA B31.1 (1955)[6]
Service Water System Valves (SWS)	ASA B31.1 (1955)[6]
Storage Tanks (Atmospheric and 0-15 psig)	
Condensate Storage Tank (C/FWS)	ASME III (1963) Class C with 1964 Addenda

Table 4-2(d)

Index of Abbreviations of Systems

Abbreviations	Definitions
ADS	Automatic Pressure Relief Subsystem
CAS	Compressed Air System
CCWS	Reactor Bldg. Closed Cooling Water System
CRDH	Control Rod Drive Housing
CRDS	Control Rod Drive System
CS	Containment System
CSS	Core Spray System
C/FWS	Condensate/Feedwater Systems
HPCI	High Pressure Coolant Injection System
IC	Isolation Condenser
IV	Isolation Valve
LPCI	Low Pressure Coolant Injection System
MSS	Main Steam System
RCPB	Reactor Coolant Pressure Boundary
RCS	Recirculation System
RSCS	Reactor Shutdown Cooling System
RVHCS	Reactor Vessel Head Cooling System
RWCS	Reactor Water Cleanup System
SCSS	Standby Coolant Supply System
SDGS	Standby Diesel Generator System
SFSF	Spent Fuel Storage Facility
SGTS	Standby Gas Treatment System
SLCS	Standby Liquid Control System
SWS	Service Water System

5. EVALUATION OF SPECIFIC COMPONENTS

5.1 GENERAL REQUIREMENTS

The purpose of this section is to evaluate, for the specific components of the Dresden Nuclear Power Plant, how the general code requirements of the current code affect the safety margin to which these components were originally designed.

General code requirements are those requirements that apply to all the components discussed in this report (i.e., piping, pressure vessels, valves, pumps, and tanks). The following topics were identified in Section 4.1 of Appendix A to be general requirements that have changed from older codes to the current code: fracture toughness, quality assurance,[1] quality group classification, and code stress limits. They will be discussed herein.

5.1.1 Fracture Toughness

As indicated in Section 4.1.1 of Appendix A, the current code [2] requires that pressure-retaining material be impact tested, but there are exemptions from this requirement. Tables A4-4 through A4-6, developed in Appendix A, are used as a guideline in evaluating whether it is necessary to impact test the material used for each specific component of the Dresden Nuclear Power Plant. The results of this evaluation are compiled in Table 5-1. Data on nil ductility transition temperature (T_{NDT}) of the different materials can be found in References 11, 12, and 13. Of the 62 components reviewed in Table 5-1:

- o six components (10%) do not require impact testing
- o the type of stainless steel used (most probably austenitic) was not specified for 9 components (15%)
- o the material used was not specified for 43 components (69%)
- o additional data are required to assess 4 components (69%).

1. Quality assurance is outside the scope of the SEP according to the letter from S. Bajwa to S. Carfagno dated December 10, 1981.

Table 5-1

Review of Fracture Toughness Requirements
Dresden Nuclear Power Plant Unit 2

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
RECIRCULATION SYSTEM					
Recirculation System Piping	Class A	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Recirculation System Valves	Class A	Not Given			Not discussed in FSAR
Recirculation System Pumps	Class A	Not Given			Not discussed in FSAR
EMERGENCY SYSTEMS					
Isolation Condenser					
Shell Side	Class C	Not Given			Not discussed in FSAR
Tube Side	Class B	Not Given			Not discussed in FSAR
Interconnecting Piping and Valves between Reactor Core Cooling and Isolation Condenser	Class B	Not Given			Not discussed in FSAR

1. Refer to Tables A4-4 through A4-6 of Appendix A for explanation of exemptions.

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
Standby Liquid Control System					
Pumps	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Tank	Class B	Not Given			Not discussed in FSAR
Piping and Valves	Class B	Not Given			Not discussed in FSAR
Core Spray System					
Pumps -					
Casing	Class B	Cast Steel	Insufficient Data		No information on T_{NDT} available
Impeller	Class B	Bronze	No	8f	See FSAR Table 6.2.3
Shaft	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Piping from the Suppression Chamber to the Outer Isolation Valve	Class B	Carbon Steel	Insufficient Data		Sizes and steel type not given
Piping from Outer Isolation Valve into the Reactor	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel

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Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
Spray Spargers and Spray Nozzles	Class B	Stainless Steel 304	No	8e	
Low Pressure Coolant Injection/Containment Coolant Subsystem					
Pump -					
Casing	Class B	Cast Steel	Insufficient Data		No information on T_{NDT} available
Impeller	Class B	Bronze	No	8f	See FSAR Table 6.2.4
Shaft	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Piping from Isolation Valve to Reactor System	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Containment and Suppression Spray Headers	Class B	Not Given			Not discussed in FSAR
Heat Exchangers - Tube Side	Class B	Not Given			Not discussed in FSAR
Shell Side	Class C	Not Given			Not discussed in FSAR
Containment Coolant Subsystem	Class C	Not Given			Not discussed in FSAR

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
High Pressure Coolant Injection					
Pumps	Class B	Not Given			Not discussed in FSAR
Piping, Fittings, and Valves	Class B	Not Given			Not discussed in FSAR
Spargers (Feedwater Spargers Used)	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Standby Coolant Supply System					
Pipings, Fittings and Valves	Class C	Not Given			Not discussed in FSAR
Automatic Pressure Relief Subsystem	Class A	Not Given			Not discussed in FSAR
STANDBY GAS TREATMENT SYSTEM	Class B	Not Given			Not discussed in FSAR
Pipings, Fittings and Valves	Class B	Not Given			Not discussed in FSAR
SAFETY VALVES	Class A	Not Given			Not discussed in FSAR
RELIEF VALVES	Class A	Not Given			Not discussed in FSAR

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
CONTAINMENT PENETRATIONS					
Hydraulic Lines to the Control Rod Drives	Class B	Stainless Steel	Insufficient Data		Probably austenitic stainless steel
Valves	Class B	Not Given			Not discussed in FSAR
REACTOR COOLANT PRESSURE BOUNDARY					
Piping, Fittings, and Valves	Class A	Not Given			Not discussed in FSAR
ISOLATION VALVES	Class A	Not Given			Not discussed in FSAR
CONTROL ROD DRIVE HOUSING	Class A	Not Given			Not discussed in FSAR
CONTROL ROD DRIVE SYSTEM					
Velocity Limiter	Class B	Stainless Steel Casting	Insufficient Data		Probably austenitic stainless steel
Guide Tubes	Class B	Stainless Steel Type 304	No	8e	
SPENT FUEL STORAGE FACILITIES					
Spent Fuel Pool	Class C	Stainless Steel Lining-3/16 inch thick	No	8a	

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
Pump	Class C	Not Given			Not discussed in FSAR
Heat Exchanger	Class C	Not Given			Not discussed in FSAR
Piping, Fittings, and Valves	Class C	Not Given			Not discussed in FSAR
Filter	Class C	Stainless Steel Mesh	No	8a	
REACTOR VESSEL HEAD COOLING SYSTEM	Class C	Not Given			Not discussed in FSAR
Piping, Fittings, and Valves	Class C	Not Given			Not discussed in FSAR
CONDENSATE/FEEDWATER SYSTEM					
Piping from Outermost Containment Isolation Valve up to and including the Shutoff Valve	Class B	Not Given			Not discussed in FSAR
Piping from Shutoff Valves to the Condenser	Class C	Not Given			Not discussed in FSAR

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
MAIN STEAM SYSTEM					
Piping from Outermost Containment Isolation Valve up to Turbine Stop and Bypass Valves and Connected Piping up to and including First Valve	Class B	Carbon Steel	Insufficient Data		Size of pipe and steel type not given
CONDENSATE STORAGE TANK	Class C	Not Given			Not discussed in FSAR
REACTOR WATER CLEANUP SYSTEM	Class C	Not Given			Not discussed in FSAR
Piping, Fittings, and Valves	Class C	Not Given			Not discussed in FSAR
REACTOR SHUTDOWN COOLING SYSTEM					
Heat Exchangers - Tube Side	Class B	Not Given			Not mentioned in FSAR
Heat Exchangers - Shell Side	Class B	Not Given			Not mentioned in FSAR
Piping, Fittings, and Valves	Class B	Not Given			Not mentioned in FSAR
REACTOR BUILDING CLOSED COOLING WATER SYSTEM					
Pumps	Class C	Not Given			Not discussed in FSAR

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption(1)	Remarks
Heat Exchangers	Class C	Not Given			Not discussed in FSAR
Piping	Class C	Not Given			Not discussed in FSAR
Valves	Class C	Not Given			Not discussed in FSAR
COMPRESSED AIR SYSTEM					
Piping, Fittings, and Valves	Class D (See remarks)	Not Given			Not discussed in FSAR Portions required to perform safety functions should be Class 3
STANDBY DIESEL GENERATOR SYSTEM					
Piping, Fittings, and Valves	Class C	Not Given			Not discussed in
SERVICE WATER SYSTEM					
Piping, Fittings, and Valves	Class C	Not Given			Not discussed in FSAR

5.1.2 Quality Assurance(1)

The quality assurance requirements for the design and construction of Class 1, Class 2, and Class 3 components as per the current code [2] are outlined in Section 4.1.2 of Appendix A. Most of these requirements were not considered in past codes [7, 8, 9, 10]. Nevertheless, quality assurance was considered in the Dresden Nuclear Power Plant, as illustrated in Appendix E of the Final Safety Analysis Report [5].

5.1.3 Quality Group Classification

As indicated in Section 4.1.3 of Appendix A under the title "Quality Group Classification," classification of components was not considered in the old piping code [7] or in the ASME B&PV Code, Sections I and VIII, 1965 Edition [8,10].

The ASME B&PV Code, Section III, 1965 Edition [9] classified pressure vessels as Class A, B, or C. Class A is equivalent to Class 1 of the current code [2]. Class B is concerned with containment vessels, which are outside the scope of this report. Class C may currently be classified as Class 2 or 3 of the current code.

Note in Table 4-2(b) that current Class 2 pressure vessels were constructed to Class C requirements except for the control rod drive system, which was designed to Class A, and the emergency system isolation condenser - tube side, for which the class used for designing is not known (it is logical to assume Class C). In Table 4-2(c), all current Class 3 pressure vessels were constructed to Class C [9] or ASME B&PV Code, Section VIII [10] requirements. Class 2 pressure vessels constructed to Class C requirements should be evaluated against current Class 2 requirements, especially for radiography requirements. See discussion on full radiography requirements in Section 5.2 of this report.

5.1.4 Code Stress Limits

Methods of calculating stress limits have changed in two major respects: the use of different strength theories and the additional consideration of service levels C and D as possible loading conditions with different stress limits.

Design based on the old piping code [7] and ASME B&PV Code, Section VIII [10] is more conservative, but less exact, than design based on the maximum shear stress theory of failure and stress limits given in the current code [2] for Class 1 components. The theory of failure used in ASME B&PV Code, Section III, 1965 Edition [9] for Class A pressure vessels is similar to that of the current code. The current code for Class 2 and Class 3 components uses the same theory of failure as past codes.

Consideration of service level D, although not required in past codes, is included in the Dresden FSAR [5]. The stress allowable set in the FSAR for this service level is conservative compared to the current stress limit, as shown on page 12.1-7 of the FSAR.

Although discussed in the previous paragraph, the seismic portion of this topic is outside the scope of this report. Seismic review of the systems and components is performed by the NRC.

5.2 PRESSURE VESSELS

As discussed in Appendix A, Section 4.3, major differences between current requirements [2] and old requirements [9, 10] for the construction of pressure vessels appear in four areas: fracture toughness, quality group classification, design, and full radiography requirements.

Fracture toughness is discussed in Section 5.1.1 of this report. Quality group classification is discussed in Section 5.1.3. The basic difference in design requirements concerns stress limits and consideration of service level C and D loading conditions. This topic is addressed in Section 5.1.4 of this report.

Full radiography requirements for pressure vessels are discussed in Section 4.3 of Appendix A. The conclusion to be drawn from this discussion is that, in general, past full radiography requirements for vessels were more conservative than current requirements, with the exception of Category C welds of vessels currently classified Class 2 which were designed to Class C [9] requirements. For this exception, the current full radiography requirements are more restrictive than past requirements. Information regarding the radiography requirements imposed on the welds of the following vessels should be provided: emergency system isolation condenser - tube side, low pressure coolant injection system heat exchanger - tube side, and reactor shutdown cooling system heat exchangers - tube and shell sides. This information should be compared with the current requirements given in Section 4.3 of Appendix A. Information is missing regarding the class used in designing the emergency isolation condenser - tube side.

5.3 PIPING

In addition to the general requirements previously discussed, the following items are considered when designing Class 1 piping for fatigue stresses based on the current code [2] that were not considered or were considered differently in the past code [7]:

- o gross discontinuities in the piping systems are accounted for
- o loading due to the thermal gradient through the thickness of the pipe
- o indices used in calculating secondary stresses are equal to or less than twice the corresponding stress intensification factors in the past code.

The last two items pose no problem as far as the structural integrity of the system and are discussed in detail in Section 4.2 of Appendix A.

When considering gross discontinuities of piping systems, two loading cases can prove to be potentially unconservative designs when evaluated to current code requirements. Two examples are given in Section 4.2 of Appendix A in order to assess the potential problems of temperature loading for a large number of cycles and temperature loading for a medium range number of cycles. These examples are based on Palisades specifications [14]. Stresses for both examples indicate that no problem exists.

From Table 4.2.1 of the FSAR [5], it can be seen that the thermal and loading cycles given for the Dresden plant are similar to those given in the examples of Appendix A. Data concerning the drop in temperature from 100% power to 0% power were not given in the FSAR. Assuming that the drop in temperature is 100°F (see Section 3.4.1.4 of NUREG-0123 [15]), the previous conclusion given in examples in Appendix A also applies to the Dresden plant. The Licensee has informally indicated [16] that the temperature drop is 11°F. Confirmation and documentation regarding this value are required.

Piping designed only to Section I of the ASME B&PV Code [8] should be evaluated for the thermal stress and cyclic loading requirements as discussed in Section 4.2 of Appendix A. Information regarding the thermal stress and cyclic loading imposed on the isolation condenser piping systems up to the outermost isolation valve should be provided (see remarks on page 9).

For Class 2 and Class 3 piping systems, the requirements of past and current codes are very similar.

Full radiography requirements for piping, valves, and pumps are discussed in Section 4.2 of Appendix A. The conclusion to be drawn from this discussion is that, currently, full radiography is required for Class 1 and Class 2 welded joints, whereas it was not required in the past code [7]. However, Provisions 2 and 3 of Code Case N-7 to Reference 7 required full radiography for circumferential and longitudinal welds. If these provisions of the code case were applied, then current requirements are met. Using Table 4-1, the Licensee should provide information indicating if Provisions 2 and 3 of Code Case N-7 were invoked, bearing in mind that this code case is only applicable to austenitic stainless steel. Code Case N-7 is invoked for many of the valves listed in Table 4-1. The same type of information is needed for piping systems.

Some piping systems at the Dresden plant were designed to ASME B&PV Code Section I (1965) [8] in conjunction with the piping code [7]. Section I requires full radiography for circumferential and longitudinal welds. Therefore, the piping systems designed to this code comply with current full radiography requirements.

The Licensee has indicated that the following piping systems were designed to codes not usually related to piping design: core spray system spray header and spargers, spargers for high pressure coolant injection, standby gas treatment system piping, containment penetration piping,[1] and containment coolant subsystem piping. Clarification of this information is requested.

5.4 PUMPS

Class 1 recirculation system pumps were designed to ASME B&PV Code Section III Class C, 1965 Edition [9] as indicated in Table 4-2(a). Table 4-2(b) shows that Class 2 pumps are designed according to Section III of the 1965 ASME Code [9]. Table 4-2(c) shows that Class 3 pumps are designed to Section VIII of the 1965 ASME Code [10].

Pumps designed to Section III or VIII should be checked for requirements outlined in the Pressure Vessel Section (Section 5.2). Recirculation pump casing which belongs to Class C Category of ASME B&PV Code Section III, 1965 Edition [9] does not experience pressure and temperature transients; therefore, it is not necessary to design it by Class A of ASME Section III, 1965 Edition [9] as mentioned in the FSAR [5]. However, it is essential to fully radiograph Category C welded joints on the pump casing.

Items to be reviewed regarding pumps are general requirements and full radiography requirements, discussed in Sections 4.1 and 4.2, respectively, of this report.

Information on the radiography requirements imposed on the welds of the Class 1 and 2 pumps listed in Table 4-2(a) and (b) should be provided and compared with current requirements given in Section 4.2 of Appendix A.

Of seven pumps reviewed in this report, six were designed to ASME B&PV Code Section III or VIII. No information on the code used in designing the reactor building closed cooling water system pump was provided. The Licensee indicated that the core spray system pump and the low pressure coolant injection pump were designed according to Class B requirements. However, since Class B is related to containment design, it seems more likely that Class C requirements were used (see Section 5.1.3 of this report).

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1. Penetrations can be designed according to Section III Class B, but not piping or valves.

5.5 VALVES

Major differences between current requirements [2] and past requirements [7] for valves are discussed in Section 4.5 of Appendix A.

Class 1 valves designed in accordance with past requirements should be adequate when judged by current standards except for:

1. fracture toughness requirements
2. stress limits might not be satisfied for valves that differ significantly from the body shapes described in the current code
3. stress limits for service level C might not be satisfied
4. full radiography requirements (Class 1 and Class 2).

The following recommendations should be followed in order to evaluate the adequacy of Class 1 valves (see Table 4-2(a)) in the Dresden plant:

1. See Table 5-1 for the fracture toughness requirements evaluation.
2. Compare actual body shape of valves with body shape rules of Section NB-3544 [2]. If significantly different, the Licensee should provide calculations based on alternative rules in order to prove the adequacy of the valve.
3. Show that valve has been subjected to service level C conditions and no replacement was necessary. If this is true, the previous item need not be investigated.

The following recommendation should be followed in order to evaluate Class 2 and 3 valves:

The pressure-temperature rating of Class 2 and 3 valves in the Dresden plant (see Tables 4-2(b) and 4-2(c)) should be compared with current pressure-temperature ratings [17].

Full radiography requirements for piping, valves, and pumps are discussed in Section 4.2 of Appendix A. The conclusion to be drawn from this discussion is that, currently, full radiography is required for Class 1 and Class 2 welded joints, whereas it was not required in the past code [7]. However, Provisions 2 and 3 of Code Case N-7 to Reference 7 required full radiography for circumferential and longitudinal welds. If these provisions of the code case were applied, then current requirements are met.

According to the information provided in Table 4-1, Code Case N-7 was invoked for most Class 1 and Class 2 valves. A confirmation that Code Case N-7 was used, bearing in mind that this code case is only applicable to austenitic stainless steel, would indicate that current radiography requirements were met for Class 1 and Class 2 valves.

The Licensee indicated that the following valves were designed to codes that are not usually related to valve design: safety valves, standby gas treatment system valves, containment penetration valves, and containment coolant subsystem valves. Clarifiction on this information is requested. Information on the radiography requirements imposed on the welds of previously mentioned valves should be provided.

5.6 STORAGE TANKS

As discussed in Section 4.7 of Appendix A, atmospheric storage tanks designed to the 1965 Edition of ASME B&PV Code, Section III Class C or Section VIII, should be checked to see if the current compressive stress requirements are met. Class C atmospheric storage tanks currently classified as Class 2 should be checked against current quality assurance requirements.(1)

As also discussed in Section 4.7 of Appendix A, 0 to 15 psig storage tanks designed to Class C requirements may not satisfy current tensile allowables for the biaxial stress field. Zero to 15 psig Class C storage tanks currently classified as Class 2 may not satisfy current quality assurance requirements.(1)

Storage tanks designed to the American Petroleum Institute API-650, 1964 Edition [18] should be investigated to determine if they meet current requirements.

The condensate storage tank and standby liquid control tank are reviewed in this report. The condensate storage tank was designed to ASME B&PV Code,

1. Although discussed in this report, quality assurance is outside the scope of the SEP according to the letter from S. Bajwa to S. Carfagno dated December 10, 1981.

Section III (1963), Class C with 1964 Addenda and the standby liquid control tank was designed to API-650 (1964). Stress allowables for the tank walls were lower in API-650 than in current standards. Stress allowables for the roof satisfy current standards. The use of A-7 plate material permitted by API-650 is no longer accepted by the current code. Calculations on the standby liquid control tank should be provided in order to determine whether they satisfy current standards.

6. CONCLUSIONS AND RECOMMENDATIONS

A comparison of the standards in effect during the design and construction of the Dresden Nuclear Power Plant against current standards indicates differences in the following areas: fracture toughness requirements, quality assurance requirements,[1] quality group classification, code stress limits, full radiography requirements, and fatigue analysis of piping systems.

Although the requirements for code stress limits and fatigue analysis of piping systems have changed throughout the historical development of the current code, the changes in these areas have not significantly affected the safety functions of the systems and components reviewed in this report.

Recommendations are given in Section 5 of this report with regard to the necessity for additional information to permit an adequate assessment of the impact of the new or changed requirements of the current code [2] on the safety functions of the systems and components reviewed in this report.

A summary of conclusions and recommendations is as follows:

1. Fracture toughness - 62 components were reviewed in Table 5-1 to determine if impact testing was required. From the information in this table, it is found that 10% of the components do not require impact testing, 15% of the components require confirmation that austenitic stainless steel was the material used, 69% of the components did not specify the material used, and 4% of the components require more data in order to be assessed. The missing information should be provided by the Licensee and, using Tables A4-4 through A4-6 in Appendix A, an evaluation should be made for each component to indicate if impact testing is required or exempted.

2. Full radiography requirements - information should be provided regarding the radiography requirements implemented for (i) Class 2 pressure vessels, (ii) Class 1 and 2 piping and valves, and (iii) Class 1 and 2 pumps. Confirm that Code Case N-7 of B31.1 was invoked for valves. Indicate whenever Code Case N-7 was invoked for piping. Vessels and pumps designed to Class A requirements [9] and current

1. Although discussed in this report, quality assurance is outside the scope of the SEP according to the letter from S. Bajwa to S. Carfagno dated December 10, 1981.

Class 3 vessels, piping, pumps, and valves meet current full radiography requirements. Tables 4-2(a), 4-2(b), and 4-2(c) should be used in providing the required information.

3. Quality group classification - Class A [9] vessels are equivalent to current Class 1 vessels. Class C vessels may currently be classified as Class 2 or 3. In the Dresden Nuclear Power Plant, recirculation system pump casing, currently classified as a Class 1 vessel, was designed to Class C requirements. Radiography requirements imposed on the welds of these pumps should be provided and compared to current Class 1 requirements.

4. Valves - in addition to the impact testing and full radiography requirements previously discussed, information should be provided by the Licensee, on a sample basis, regarding the design of valves in order to evaluate if they meet current body shape and pressure-temperature rating requirements as discussed in Section 5.5 of this report.

5. Pumps - pumps designed to standards other than ASME B&PV Code Sections III or VIII, 1965 Edition should be checked to determine whether they meet current standards. Seven pumps were reviewed in this report. Information on the code used in designing the reactor building closed cooling water system pump was not provided.

6. Storage tanks - (i) atmospheric storage tanks should be checked to determine whether they meet current compressive stress requirements; (ii) 0 to 15 psig storage tanks should be checked to determine whether they meet current tensile allowables for biaxial stress field condition; (iii) storage tanks designed to API-650 (1964) [18] (standby liquid control tank) should be investigated to determine whether they satisfy current stress allowables and material standards. Calculations for the two storage tanks discussed in this report should be provided.

7. Missing information - (i) information missing from Tables 4-2(a), 4-2(b), and 4-2(c) of this report regarding the code or code class used in designing 3 of 70 components should be provided; (ii) assumptions on code editions that were made in order to complete Table 4-1 should be confirmed; (iii) information provided regarding the temperature drop (11°F) from 100% power to 0% power should be confirmed and documented; (iv) clarification should be provided of the codes used in the design of valves, piping, and pumps in cases where the codes indicated by the Licensee are not applicable to the referenced components (see Sections 5.3, 5.4, and 5.5 for list).

7. REFERENCES

1. NRC Regulatory Guide 1.26
   "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants"
   Revision 3, February 1976

2. American Society of Mechanical Engineers
   "Boiler and Pressure Vessel Code," Section III, Division 1
   New York: 1977 Edition and addenda through Summer 1978

3. Title 10 of the Code of Federal Regulations
   Section 50.55a, "Codes and Standards"
   Revised January 1, 1981

4. RIDS Accession No. 8107020158, docket date: 81/06/26, contains letter from T. J. Rausch (Commonwealth Edison) to D. M. Crutchfield and one attachment; Telephone memorandum A. Gonzalez (FRC) to A. Wang (NRC) dated October 19, 1981; information provided to A. Wang (NRC) via telephone conversation November 30, 1981 by Commonwealth Edison representatives

5. Final Safety Analysis Report for Commonwealth Edison Company, Dresden Nuclear Power Station Unit 2 (3 Volumes)
   Docketed USAEC, January 10, 1966
   Docket No. 50-237.

6. NRC Standard Review Plan
   Section 3.2.2, "System Quality Group Classification"
   Office of Nuclear Reactor Regulation
   NUREG-75/087

7. American Standards Association
   "Code for Pressure Piping"
   Published by the American Society of Mechanical Engineers, 1955
   ASA B31.1-1955

8. American Society of Mechanical Engineers
   Boiler and Pressure Vessel Code, Section I, "Rules for Construction of Power Boilers"
   1965 Edition

9. American Society of Mechanical Engineers
   Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Vessels"
   1965

10. American Society of Mechanical Engineers
Boiler and Pressure Vessel Code, Section VIII, "Unfired Pressure Vessels"
1965

11. Snaider, R. P., Hodge, J. M., Levin, H. A., and Zudans, J. J.
"Potential for Low Fracture Toughness and Lamellar Tearing on PWR Steam Generator and Reactor Coolant Pump Support"
NUREG-0577, Published for Comment, October 1979

12. Electric Power Research Institute
"Nuclear Pressure Vessel Steel Data Base"
Prepared by Fracture Control Corporation
Palo Alto, CA: December 1978
NP-933, Research Project 886-1

13. American Society for Metals
"Metals Handbook"
Metals Park, Ohio: Ninth Edition, 1979

14. Final Safety Analysis Report for Consumers Power Company, Palisades Plant (3 Volumes)
Docketed USAEC, November 5, 1968
Docket No. 50-255

15. "Standard Technical Specifications for General Electric Boiling Water Reactors"
Office of Nuclear Reactor Regulation, Rev. 3, 1980
NUREG-0123

16. A. Gonzalez (FRC)
Telephone memorandum to A. Wang (NRC)
January 19, 1982

17. American National Standards Institute
"Steel Valves"
American Society of Mechanical Engineers, 1977
ANSI B16.34-1977

18. American Petroleum Institute
"Welded Steel Tanks for Oil Storage"
Second Edition, April 1964
API-650

APPENDIX A

REVIEW OF CODES AND STANDARDS
APPLICABLE TO OYSTER CREEK, MILLSTONE, AND DRESDEN PLANTS

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CONTENTS

1. INTRODUCTION

The purpose of this appendix is to compare the code currently used in the design, fabrication, erection, and testing of systems and components for nuclear power plants against the codes and standards used in the design of plants being reviewed under the Systematic Evaluation Program (SEP). The current code is the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code (B&PV), Section III, 1977 Edition as supplemented by the Summer 1978 Addenda [1, 2]. The three major older codes being compared against the current code are the B&PV Code, Section III, 1965 Edition [3]; the "Code for Pressure Piping," American Standard Association B31.1, 1955 Edition [4]; and B&PV Code, Section VIII, 1965 Edition [5].

Table A1-1 groups the SEP plants according to the major codes used to design them. In order to take advantage of the similarities in each group, this appendix applies only to the Group I plants: Palisades, Ginna, Millstone Unit 1, Dresden Unit 2, and Oyster Creek.

The B&PV Code, Section I, 1965 Edition [5] is also discussed in this appendix at it applies to Oyster Creek, Millstone Unit 1, and Dresden Unit 2.

The older requirements are evaluated to identify differences from the current code requirements and to assess the impact of these differences on the structural integrity of the systems and components. The current code requirements are discussed in Section 2. The major identified differences are discussed in Section 4.

The scope of this comparison is limited to quality classification of systems and components as discussed in Regulatory Guide 1.26 [6] and Section 3.2.2 of the Standard Review Plan [7]. The reactor vessel, steam generators, and supports are outside the scope of this appendix, as is the seismic classification of systems and components. All these subjects are addressed in other SEP topics. Quality assurance has also been determined to be outside the scope of this comparison, but has been included for informational purposes only.(1)

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1. Letter from S. Bajwa to S. Carfagno dated December 10, 1981.

Table A1-1

Major Codes and Standards Used in Design of Systems and Components of SEP Plants

Plant	Commercial Operation	Major Codes
Group I (1969-1971)		
Palisades	Dec. 1971	1. ASME III (1965)
Millstone 1	March 1971	2. ASA B31.1 (1955) and Code Cases
Ginna	July 1970	3. ASME VIII (1965) and Code Cases
Dresden 2	July 1970	4. ASME I (1965) (Oyster Creek, Millstone 1, Dresden 2)
Oyster Creek	Dec. 1969	
Group II (1968)		
LaCrosse	Nov. 1969	1. ASME I & VIII (1962) and Code Cases
San Onofre	Jan. 1968	2. ASA B31.1 (1955) and Code Cases
Haddam Neck	Jan. 1968	
Group III (1961-1963)		
Big Rock Point	March 1963	1. ASME I & VIII (1959) and Code Cases
		2. ASA B31.1 (1955) and Code Cases
Yankee Rowe	July 1961	1. ASME I & VIII (1956) and Code Cases
		2. ASA B31.1 (1955) and Code Cases

2. SUMMARY OF RESULTS OF CODE COMPARISON

2.1 GENERAL

The current code requirements for the construction of nuclear power plant components [1] are outlined in Table A2-1. For each article or subarticle, the applicability to Code Class 1, 2, or 3, corresponding to Quality Class A, B, or C, respectively, is noted. Requirements considered especially significant from the viewpoint of pressure boundary integrity are indicated by an "A" in the "Significant" column. The basis for selecting significant items is discussed in Section 5 of this appendix.

2.2 PIPING

Table A2-2 presents a comparison of the current and past code requirements for the materials, design, fabrication, examination, and testing of piping systems and components for nuclear power plants. The past code for piping is the B31.1 (1955) power piping code. The ASME I (1965) [5] power boiler code may have been invoked for piping between the BWR vessel and the first set of shutoff and check valves in the line. A comparison of significant past and current piping requirements may be found in Sections 4.1 and 4.2 of this appendix.

2.3 PRESSURE VESSELS

Tables A2-3 and A2-4 compare the current and past code requirements for the materials, design, fabrication, examination, and testing of pressure vessels for nuclear power plants. Table A2-3 compares the current code against ASME III (1965). Table A2-4 compares the current code against ASME VIII (1965).

Note that past Class A vessels were built in accordance with ASME III (1965), which would be equivalent to the current Class 1 classification.

Past Class B vessels were defined as containment vessels, which are outside the scope of this review.

Table A2-1

Current Code Requirements [1]

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Remarks
NA-1000	SCOPE OF SECTION III	A	A	A	-	
NA-2000	CLASSIFICATION OF COMPONENTS	A	A	A	A	
NA-3000	RESPONSIBILITIES AND DUTIES	A	A	A	-	
NA-4000	QUALITY ASSURANCE					
NA-4100	Quality Assurance Requirements	A	A	NA	A	
NA-5000	INSPECTION					
NA-5100	General Requirements for Authorized Inspection Agencies and Inspectors	A	A	A	A	
NA-5200	Duties of Inspectors	A	A	A	A	
NA-6000	QUALITY CONTROL SYSTEMS FOR CLASS 3 CONSTRUCTION					
NA-6100	General Requirements	NA	NA	A	A	
NA-6200	Organization and Responsibilities	NA	NA	A	A	
NA-6300	Control of Operations	NA	NA	A	A	
NA-6400	Records and Forms	NA	NA	A	A	
NA-8000	CERTIFICATES OF AUTHORIZATION, NAMEPLATES, STAMPING, AND REPORTS	A	A	A	-	
1000	INTRODUCTION					
1100	Scope	A	A	A	A	
2000	MATERIAL					
2100	General	A	A	A	A	
2200	Material Test Coupons and Specimens for Ferritic Steel Materials	A	A	A	-	

A Addressed in the Code for the specified class or considered significant for this review.
- Not considered significant for this review.
O Outside the scope of this review.
NA Not applicable to this review or not addressed in the Code for the specified class.
* Article number in current Code will be preceded by NB for Class 1 component, NC for Class 2 component, and ND for Class 3 component.

Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Remarks
2300	Fracture Toughness Requirement for Material	A	A	A	A	
2400	Welding and Brazing	A	A	A	A	
2500	Examination and Repair of Pressure Retaining Materials	A	A	A	-	
2600	Material Manufacturers' Quality System Program	A	A	A	A	
2700	Dimensional Standard	A	A	A	-	
3000	DESIGN					
3100	General	A	A	A	A	
3200	Design by Analysis (Cl. 1); Alternate Design Rules for Vessels (Cl. 2)	A	A	NA	A	
3300	Vessel Design	A	A	A	A	
3400	Pump Design	A	A	A	A	
3500	Valve Design	A	A	A	A	
3600	Piping Design	A	A	A	A	
3700	Electrical and Mechanical Penetration Assemblies	NA	A	A	A	
3800	Design of Atmospheric Storage Tanks	NA	A	A	A	
3900	0-15 psi (0-103 kPa) Storage Tank Design	NA	A	A	A	
4000	FABRICATION AND INSTALLATION					
4100	General	A	A	A	-	
4200	Forming, Fitting, and Aligning	A	A	A	-	
4300	Welding Qualifications	A	A	A	A	
4400	Rules Governing Making, Examining, and Repairing Welds	A	A	A	-	
4500	Brazing	A	A	A	-	
4600	Heat Treatment	A	A	A	-	

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Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Remarks
4700	Mechanical Joints	A	A	A	-	
4800	Expansion Joints	NA	A	A	-	
5000	EXAMINATION					
5100	General Requirements	A	A	A	A	
5200	Required Examination of Welds (Cl. 1); Examination of Welds (Cl. 2 and Cl. 3)	A	A	A	A	
5300	Acceptance Standard	A	A	A	A	
5400	Final Examination of Items (Cl. 1); Spot Examination of Welded Joints (Cl. 3)	A	NA	A	A	
5500	Qualifications of Nondestructive Examination Personnel	A	A	A	A	
5600		NA	NA	NA	-	
5700	Examination Requirement of Expansion Joints	NA	A	A	-	
6000	TESTING					
6100	General	A	A	A	-	
6200	Hydrostatic	A	A	A	-	
6300	Pneumatic	A	A	A	-	
6400	Pressure Test Gages	A	A	A	-	
6500	Atmospheric and 0-15 psig Storage Tanks	NA	A	A	-	
6600	Hydrostatic Testing of Vessels Designed to NC-3200	NA	A	NA	-	
6700	Pneumatic Testing of Vessels Designed to NC-3200	NA	A	NA	-	
6800						
6900	Proof Tests to Establish Design Pressure	NA	A	A	-	

Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi- ficant	Remarks
7000	PROTECTION AGAINST OVERPRESSURE					
7100	General	A	A	A	-	
7200	Definitions Applicable to Overpressure Protection Devices	A	A	A	-	
7300	Overpressure Protection Report (Cl. 1); Analysis (Cl. 2)	A	A	NA	-	
7400	Relieving Capacity Requirements and Acceptable Types of Overpressure Protection Devices	A	A	A	-	
7500	Set Pressures of Pressure Relief Devices	A	A	A	-	
7600	Operating Design Requirements for Pressure Relief Valves	A	A	A	-	
7700	Requirements for Nonreclosing Pressure Relief Devices	A	A	A	-	
7800	Certification Requirements	A	A	A	-	
7900	Marking, Stamping, and Reports	A	A	A	-	
8000	NAMEPLATES, STAMPING, AND REPORTS					
8100	General	A	A	A	-	
	MANDATORY APPENDICES					
I	Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves	A	A	A	A	
II	Experimental Stress Analysis	A	A	A	-	
III	Basis for Establishing Design Stress Intensity Values and Allowable Stress Values	A	A	A	A	

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Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Remarks
IV	Approval of New Materials Under the ASME Boiler and Pressure Vessel Code for Section III Application	A	A	A	-	
V	Certificate Holder's Data Report Forms and Application Forms for Certificates of Authorization for Use of Code Symbol Stamps	A	A	A	-	
VI	Rounded Indications Charts	A	A	A	-	
VII	Charts for Determining Shell Thickness of Cylindrical and Spherical Components Under External Pressure	A	A	A	-	
XI	Rules for Bolted Flange Connections for Class 2 and 3 Components and Class MC Vessels	NA	A	A	-	
XII	Design Considerations for Bolted Flange Connections	A	A	A	A	
XIII	Design Based on Stress Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	-	
XIV	Design Based on Fatigue Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	-	
XVI	Nondestructive Examination Methods Applicable to Core Support Structures	A	A	A	O	
XVII	Design of Linear Type Supports by Linear Elastic and Plastic Analysis	A	A	A	O	

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Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Remarks
	NONMANDATORY APPENDICES					
A		A	NA	NA	–	
B	Owner's Design Specification	A	A	A	–	
C	Certificate Holder's Stress Report	A	NA	NA	–	
D	Nonmandatory Preheat Procedures	A	A	A	–	
E	Minimum Bolt Cross-Sectional Area	A	NA	NA	–	
F	Rules for Evaluation of Level D Service Limits	A	A	A	A	
G	Protection Against Nonductile Failure	A	A	A	A	
H	Capacity Conversions for Class 3 Safety Valves	NA	NA	A	–	
J	Owner's Design Specifications for Core Support Structure	A	NA	NA	O	
K	Recommended Maximum Deviations and Tolerances for Component Supports	A	A	A	O	

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Table A2-2

Comparison of B31.1 (1955) [4] Against ASME Section III (1977) [1]

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in B31.1 (1955)	Remarks
NA-1000	SCOPE OF SECTION III	A	A	A	–	–	
NA-2000	CLASSIFICATION OF COMPONENTS	A	A	A	A	Not Addressed	
NA-3000	RESPONSIBILITIES AND DUTIES	A	A	A	–	–	
NA-4000	QUALITY ASSURANCE						
NA-4100	Quality Assurance Requirements	A	A	NA	A	Not Addressed	
NA-5000	INSPECTION						
NA-5100	General Requirements for Authorized Inspection Agencies and Inspectors	A	A	A	A	Not Addressed	
NA-5200	Duties of Inspectors	A	A	A	A	Not Addressed	
NA-6000	QUALITY CONTROL SYSTEMS FOR CLASS 3 CONSTRUCTION						
NA-6100	General Requirements	NA	NA	A	A	Not Addressed	
NA-6200	Organization and Responsibilities	NA	NA	A	A	Not Addressed	
NA-6300	Control of Operations	NA	NA	A	A	Not Addressed	
NA-6400	Records and Forms	NA	NA	A	A	Not Addressed	
NA-8000	CERTIFICATES OF AUTHORIZATION, NAMEPLATES, STAMPING, AND REPORTS	A	A	A	–	–	

A Addressed in the Code for the specified class or considered significant for this review.
– Not considered significant for this review.
O Outside the scope of this review.
NA Not applicable to this review or not addressed in the Code for the specified class.
* Article number in current Code will be preceded by NB for Class 1 component, NC for Class 2 component, and ND for Class 3 component.

Table A2-2 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in B31.1 (1955)	Remarks
1000	INTRODUCTION						
1100	Scope	A	A	A	A	101, Table 2a, Note 2	
2000	MATERIAL						
2100	General	A	A	A	A	105, Table 1, Sect. 7	See Sect. 6
2200	Material Test Coupons and Specimens for Ferritic Steel Materials	A	A	A	–	–	
2300	Fracture Toughness Requirement for Material	A	A	A	A	Not Addressed	
2400	Welding and Brazing	A	A	A	A	Sect. 6: Chapter 4 and Appendices	
2500	Examination and Repair of Pressure Retaining Materials	A	A	A	–	–	
2600	Material Manufacturers' Quality System Program	A	A	A	A	Not Addressed	
2700	Dimensional Standard	A	A	A	–	–	
3000	DESIGN						
3100	General	A	A	A	A	Not Addressed	
3200	Design by Analysis (Cl. 1); Alternate Design Rules for Vessels (Cl. 2)	A	A	NA	A	NA	
3300	Vessel Design	A	A	A	A	NA	
3400	Pump Design	A	A	A	A	NA	
3500	Valve Design	A	A	A	A	107,108,124, 129,134,139	
3600	Piping Design	A	A	A	A	Sect. 1	
3700	Electrical and Mechanical Penetration Assemblies	NA	A	A	A	NA	
3800	Design of Atmospheric Storage Tanks	NA	A	A	A	NA	
3900	0-15 psi (0-103 kPa) Storage Tank Design	NA	A	A	A	NA	

Table A2-2 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in B31.1 (1955)	Remarks
4000	FABRICATION AND INSTALLATION					Sect. 6	
4100	General	A	A	A	–	Not Addressed	
4200	Forming, Fitting, and Aligning	A	A	A	–	–	
4300	Welding Qualifications	A	A	A	–	Appendix A to Sect. 6	
4400	Rules Governing Making, Examining, and Repairing Welds	A	A	A	–	–	
4500	Brazing	A	A	A	–	–	
4600	Heat Treatment	A	A	A	–	–	
4700	Mechanical Joints	A	A	A	–	Chapter 2 of Sect. 6	
4800	Expansion Joints	NA	A	A	–	Not Addressed	
5000	EXAMINATION						
5100	General Requirements	A	A	A	A	Not Addressed	
5200	Required Examination of Welds (Cl. 1); Examination of Welds (Cl. 2 and Cl. 3)	A	A	A	A	Not Addressed	
5300	Acceptance Standard	A	A	A	A	Not Addressed	
5400	Final Examination of Items (Cl. 1); Spot Examination of Welded Joints (Cl. 3)	A	NA	A	A	Not Addressed	
5500	Qualifications of Nondestructive Examination Personnel	A	A	A	A	Not Addressed	
5600		NA	NA	NA	–	–	
5700	Examination Requirements of Expansion Joints	NA	A	A	–	–	
6000	TESTING						
6100	General	A	A	A	–	–	
6200	Hydrostatic	A	A	A	–	–	
6300	Pneumatic	A	A	A	–	–	

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Table A2-2 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in B31.1 (1955)	Remarks
6400	Pressure Test Gages	A	A	A	–	–	
6500	Atmospheric and 0-15 psig Storage Tanks	NA	A	A	–	–	
6600	Hydrostatic Testing of Vessels Designed to NC-3200	NA	A	NA	–	–	
6700	Pneumatic Testing of Vessels Designed to NC-3200	NA	A	NA	–	–	
6800						–	
6900	Proof Tests to Establish Design Pressure	NA	A	A	–	NA	
7000	PROTECTION AGAINST OVERPRESSURE						
7100	General	A	A	A	–	NA	
7200	Definitions Applicable to Overpressure Protection Devices	A	A	A	–	NA	
7300	Overpressure Protection Report (Cl. 1); Analysis (Cl. 2)	A	A	NA	–	NA	
7400	Relieving Capacity Requirements and Acceptable Types of Overpressure Protection Devices	A	A	A	–	NA	
7500	Set Pressures of Pressure Relief Devices	A	A	A	–	NA	
7600	Operating Design Requirements for Pressure Relief Valves	A	A	A	–	NA	
7700	Requirements for Nonreclosing Pressure Relief Devices	A	A	A	–	NA	
7800	Certification Requirements	A	A	A	–	NA	
7900	Marking, Stamping, and Reports	A	A	A	–	NA	
8000	NAMEPLATES, STAMPING, AND REPORTS						
8100	General	A	A	A	–	–	

Table A2-2 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in B31.1 (1955)	Remarks
	MANDATORY APPENDICES						
I	Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves	A	A	A	A	Tables 1 and 2, Sect. 1	
II	Experimental Stress Analysis	A	A	A	-	-	
III	Basis for Establishing Design Stress Intensity Values and Allowable Stress Values	A	A	A	A	Not Addressed	
IV	Approval of New Materials Under the ASME Boiler and Pressure Vessel Code for Section III Application	A	A	A	-	-	
V	Certificate Holder's Data Report Forms and Application Forms for Certificates of Authorization for Use of Code Symbol Stamps	A	A	A	-	-	
VI	Rounded Indications Charts	A	A	A	-	-	
VII	Charts for Determining Shell Thickness of Cylindrical and Spherical Components Under External Pressure	A	A	A	-	122	
XI	Rules for Bolted Flange Connections for Class 2 and 3 Components and Class MC Vessels	NA	A	A	-	106,111,138, 143	
XII	Design Considerations for Bolted Flange Connections	A	A	A	A	-	
XIII	Design Based on Stress Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	-	Not Addressed	
XIV	Design Based on Fatigue Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	-	NA	

Table A2-2 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in B31.1 (1955)	Remarks
XVI	Nondestructive Examination Methods Applicable to Core Support Structures	A	A	A	O	NA	
XVII	Design of Linear Type Supports by Linear Elastic and Plastic Analysis	A	A	A	O	NA	
	NONMANDATORY APPENDICES						
A		A	NA	NA	-	-	
B	Owner's Design Specification	A	A	A	-	-	
C	Certificate Holder's Stress Report	A	NA	NA	-	-	
D	Nonmandatory Preheat Procedures	A	A	A	-	-	
E	Minimum Bolt Cross-Sectional Area	A	NA	NA	-	-	
F	Rules for Evaluation of Level D Service Limits	A	A	A	A		
G	Protection Against Nonductile Failure	A	A	A	A		
H	Capacity Conversions for Class 3 Safety Valves	NA	NA	A	-	-	
J	Owner's Design Specifications for Core Support Structure	A	NA	NA	O	NA	
K	Recommended Maximum Deviations and Tolerances for Component Supports	A	A	A	O	NA	

Table A2-3

Comparison of ASME B&PV Code Section III
1965 Edition [3] Against the 1977 Edition [1]

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME B&PV Sect. III (1965)	Remarks
NA-1000	SCOPE OF SECTION III	A	A	A	-	N-110	
NA-2000	CLASSIFICATION OF COMPONENTS	A	A	A	A	N-130	
NA-3000	RESPONSIBILITIES AND DUTIES	A	A	A	-	N-140	
NA-4000	QUALITY ASSURANCE						
NA-4100	Quality Assurance Requirements	A	A	NA	A	Appendix VII	
NA-5000	INSPECTION					Articles 6, 14	
NA-5100	General Requirements for Authorized Inspection Agencies and Inspectors	A	A	A	A	N-610	
NA-5200	Duties of Inspectors	A	A	A	A	N-610	
NA-6000	QUALITY CONTROL SYSTEMS FOR CLASS 3 CONSTRUCTION						
NA-6100	General Requirements	NA	NA	A	A	Not Addressed	
NA-6200	Organization and Responsibilities	NA	NA	A	A	Not Addressed	
NA-6300	Control of Operations	NA	NA	A	A	Not Addressed	
NA-6400	Records and Forms	NA	NA	A	A	Not Addressed	
NA-8000	CERTIFICATES OF AUTHORIZATION, NAMEPLATES, STAMPING, AND REPORTS	A	A	A	-	-	

A Addressed in the Code for the specified class or considered significant for this review.
\- Not considered significant for this review.
O Outside the scope of this review.
NA Not applicable to this review or not addressed in the Code for the specified class.
* Article number in current Code will be preceded by NB for Class 1 component, NC for Class 2 component, and ND for Class 3 component.

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Table A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME B&PV Sect. III (1965)	Remarks
1000	INTRODUCTION					Art. 2, 11, 21	See Note 1
1100	Scope	A	A	A	A	N-210, N-2110	
2000	MATERIAL					Articles 3, 12	
2100	General	A	A	A	A	N-310	
2200	Material Test Coupons and Specimens for Ferritic Steel Materials	A	A	A	A	-	
2300	Fracture Toughness Requirement for Material	A	A	A	A	N-330	
2400	Welding and Brazing	A	A	A	A	Not Addressed	
2500	Examination and Repair of Pressure Retaining Materials	A	A	A		N-320	
2600	Material Manufacturers' Quality System Program	A	A	A	A	N-614	
2700	Dimensional Standard	A	A	A	-	-	
3000	DESIGN					Articles 4, 13	
3100	General	A	A	A	A	N-440	Only Class 1
3200	Design by Analysis (Cl. 1); Alternate Design Rules for Vessels (Cl. 2)	A	A	NA	A	N-430	Only Cl. 1, See Note 2
3300	Vessel Design	A	A	A	A	Articles 4, 13	
3400	Pump Design	A	A	A	A	Not Addressed	
3500	Valve Design	A	A	A	A	Not Addressed	
3600	Piping Design	A	A	A	A	N-150/Mostly Not Addressed	
3700	Electrical and Mechanical Penetration Assemblies	NA	A	A	A	Not Addressed	
3800	Design of Atmospheric Storage Tanks	NA	A	A	A	Not Addressed	
3900	0-15 psi (0-103 kPa) Storage Tank Design	NA	A	A	A	Not Addressed	

Notes:
1. For requirements of Class 3 vessel, reference is made to Section VIII of the Code.
2. Use Table I-1.0 (1977 Edition) when designing pressure vessels by Alternative Design Analysis (NC-3200).

Table A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME B&PV Sect. III (1965)	Remarks
4000	FABRICATION AND INSTALLATION					Article 5	Only Class 1
4100	General	A	A	A	A	N-510	Only Class 1
4200	Forming, Fitting, and Aligning	A	A	A	-	-	
4300	Welding Qualifications	A	A	A	A	N-520, N-540	Only Class 1
4400	Rules Governing Making, Examining, and Repairing Welds	A	A	A	-	-	
4500	Brazing	A	A	A	-	-	
4600	Heat Treatment	A	A	A	-	N-530	Only Class 1
4700	Mechanical Joints	A	A	A	-	Not Addressed	
4800	Expansion Joints	NA	A	A	-	Not Addressed	
5000	EXAMINATION					Articles 6, 14	Only Class 1, 2
5100	General Requirements	A	A	A	A	N-610	Only Class 1
5200	Required Examination of Welds (Cl. 1); Examination of Welds (Cl.2 and Cl. 3)	A	A	A	A	N-620	
5300	Acceptance Standard	A	A	A	A	N-626.5, N-627.7	Only Class 1
5400	Final Examination of Items (Cl. 1); Spot Examination of Welded Joints (Cl. 3)	A	NA	A	A	N-620	Only Class 1
5500	Qualifications of Nondestructive Examination Personnel	A	A	A	A	Not Addressed	
5600		NA	NA	NA	-	-	
5700	Examination Requirements of Expansion Joints	NA	A	A	-	-	
6000	TESTING					Article 7	
6100	General	A	A	A	-	-	
6200	Hydrostatic	A	A	A	-	-	
6300	Pneumatic	A	A	A	-	-	
6400	Pressure Test Gages	A	A	A	-	-	
6500	Atmospheric and 0-15 psig Storage Tanks	NA	A	A	-	-	

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Table A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME B&PV Sect. III (1965)	Remarks
6600	Hydrostatic Testing of Vessels Designed to NC-3200	NA	A	NA	–	–	
6700	Pneumatic Testing of Vessels Designed to NC-3200	NA	A	NA	–	–	
6800						–	
6900	Proof Tests to Establish Design Pressure	NA	A	A	A	Not Addressed for Class A or B	See Table A2-4 for Class C
7000	PROTECTION AGAINST OVERPRESSURE						
7100	General	A	A	A	–	NA	
7200	Definitions Applicable to Overpressure Protection Devices	A	A	A	–	NA	
7300	Overpressure Protection Report (Cl. 1); Analysis (Cl. 2)	A	A	NA	–	NA	
7400	Relieving Capacity Requirements and Acceptable Types of Overpressure Protection Devices	A	A	A	–	NA	
7500	Set Pressures of Pressure Relief Devices	A	A	A	–	NA	
7600	Operating Design Requirements for Pressure Relief Valves	A	A	A	–	NA	
7700	Requirements for Nonreclosing Pressure Relief Devices	A	A	A	–	NA	
7800	Certification Requirements	A	A	A	–	NA	
7900	Marking, Stamping, and Reports	A	A	A	–	NA	
8000	NAMEPLATES, STAMPING, AND REPORTS					Articles 8, 15	
8100	General	A	A	A	–	–	

Table A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME B&PV Sect. III (1965)	Remarks
	MANDATORY APPENDICES						
I	Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves	A	A	A	A	Article 4	Table N-421
II	Experimental Stress Analysis	A	A	A	-	-	
III	Basis for Establishing Design Stress Intensity Values and Allowable Stress Values	A	A	A	A	Appendix II	
IV	Approval of New Materials Under the ASME Boiler and Pressure Vessel Code for Section III Application	A	A	A	-	-	
V	Certificate Holder's Data Report Forms and Application Forms for Certificates of Authorization for Use of Code Symbol Stamps	A	A	A	-	-	
VI	Rounded Indications Charts	A	A	A	-	-	
VII	Charts for Determining Shell Thickness of Cylindrical and Spherical Components Under External Pressure	A	A	A	-	Article I-1 of Appendix I, N-431	
XI	Rules for Bolted Flange Connections for Class 2 and 3 Components and Class MC Vessels	NA	A	A	-	Article I-12 of Appendix I, N-471, Table N-422	
XII	Design Considerations for Bolted Flange Connections	A	A	A	A	Article I-12 of Appendix I, N-471	
XIII	Design Based on Stress Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	-	Article I-10 of Appendix I, N-430	
XIV	Design Based on Fatigue Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	-	Article I-10 of Appendix I, N-430	
XVI	Nondestructive Examination Methods Applicable to Core Support Structures	A	A	A	O	NA	
XVII	Design of Linear Type Supports by Linear Elastic and Plastic Analysis	A	A	A	O	NA	

Table A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME B&PV Sect. III (1965)	Remarks
	NONMANDATORY APPENDICES						
A		A	NA	NA	–	–	
B	Owner's Design Specification	A	A	A	–	–	
C	Certificate Holder's Stress Report	A	NA	NA	–	–	
D	Nonmandatory Preheat Procedures	A	A	A	–	–	Appendix III
E	Minimum Bolt Cross-Sectional Area	A	NA	NA	–	–	
F	Rules for Evaluation of Level D Service Limits	A	A	A	A	Not Addressed	
G	Protection Against Nonductile Failire	A	A	A	A	Article N-330	Only Class 1
H	Capacity Conversions for Class 3 Safety Valves	NA	NA	A	–	–	
J	Owner's Design Specifications for Core Support Structure	A	NA	NA	O	NA	
K	Recommended Maximum Deviations and Tolerances for Component Supports	A	A	A	O	NA	

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Table A2-4

Comparison of ASME VIII (1965) [5] with ASME III (1977) [1]

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME VIII (1965)	Remarks
NA-1000	SCOPE OF SECTION III	A	A	A	–		
NA-2000	CLASSIFICATION OF COMPONENTS	A	A	A	A	NA	
NA-3000	RESPONSIBILITIES AND DUTIES	A	A	A	–		
NA-4000	QUALITY ASSURANCE						
NA-4100	Quality Assurance Requirements	A	A	NA	A	NA	
NA-5000	INSPECTION						
NA-5100	General Requirements for Authorized Inspection Agencies and Inspectors	A	A	A	A	UG-90	
NA-5200	Duties of Inspectors	A	A	A	A	UG-91	
NA-6000	QUALITY CONTROL SYSTEMS FOR CLASS 3 CONSTRUCTION						
NA-6100	General Requirements	NA	NA	A	A	NA	
NA-6200	Organization and Responsibilities	NA	NA	A	A	NA	
NA-6300	Control of Operations	NA	NA	A	A	NA	
NA-6400	Records and Forms	NA	NA	A	A	NA	
NA-8000	CERTIFICATES OF AUTHORIZATION, NAMEPLATES, STAMPING, AND REPORTS	A	A	A	–	UG-116	
1000	INTRODUCTION						
1100	Scope	A	A	A	A	U-1	
2000	MATERIAL						
2100	General	A	A	A	A	UG-5	
2200	Material Test Coupons and Specimens for Ferritic Steel Materials	A	A	A	–		

A Addressed in the Code for the specified class or considered significant for this review.
– Not considered significant for this review.
O Outside the scope of this review.
NA Not applicable to this review or not addressed in the Code for the specified class.
* Article number in current Code will be preceded by NB for Class 1 component, NC for Class 2 component, and ND for Class 3 component.

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Table A2-4 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME VIII (1965)	Remarks
2300	Fracture Toughness Requirement for Material	A	A	A	A	UG-84	
2400	Welding and Brazing	A	A	A	A	UW	
2500	Examination and Repair of Pressure Retaining Materials	A	A	A	-		
2600	Material Manufacturers' Quality System Program	A	A	A	A	UG-93	
2700	Dimensional Standard	A	A	A	-		
3000	DESIGN						
3100	General	A	A	A	A	NA	
3200	Design by Analysis (Cl. 1); Alternate Design Rules for Vessels (Cl. 2)	A	A	NA	A		
3300	Vessel Design	A	A	A	A	UW-8, UF-12	
3400	Pump Design	A	A	A	A	NA	
3500	Valve Design	A	A	A	A	NA	
3600	Piping Design	A	A	A	A	NA	
3700	Electrical and Mechanical Penetration Assemblies	NA	A	A	A	NA	
3800	Design of Atmospheric Storage Tanks	NA	A	A	A	NA	
3900	0-15 psi (0-103 kPa) Storage Tank Design	NA	A	A	A	NA	
4000	FABRICATION AND INSTALLATION						
4100	General	A	A	A	A	UG-75	
4200	Forming, Fitting, and Aligning	A	A	A	-		
4300	Welding Qualifications	A	A	A	A	UW-28, UW-29	
4400	Rules Governing Making, Examining, and Repairing Welds	A	A	A	-		
4500	Brazing	A	A	A	-		
4600	Heat Treatment	A	A	A	-		

Table A2-4 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME VIII (1965)	Remarks
4700	Mechanical Joints	A	A	A	-	UR-19	
4800	Expansion Joints	NA	A	A	-	NA	
5000	EXAMINATION						
5100	General Requirements	A	A	A	A	UG-90	
5200	Required Examination of Welds (Cl. 1); Examination of Welds (Cl. 2 and Cl. 3)	A	A	A	A	UW-46	
5300	Acceptance Standard	A	A	A	A	UW-51 (i)	
5400	Final Examination of Items (Cl. 1); Spot Examination of Welded Joints (Cl. 3)	A	NA	A	A	NA	UG-99(g) requires inspection after hydrostatic but does not specify liquid penetrant or magnetic particle inspection; UW-50 requires LPE or magnetic particle inspection before pneumatic testing.
5500	Qualifications of Nondestructive Examination Personnel	A	A	A	A	NA	UG-91 gives requirements for qualification of inspectors, but not NDE personnel
5600		NA	NA	NA	-	-	
5700	Examination Requirements of Expansion Joints	NA	A	A	-	-	
6000	TESTING						
6100	General	A	A	A	-		
6200	Hydrostatic	A	A	A	-		
6300	Pneumatic	A	A	A	-		

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Table A2-4 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME VIII (1965)	Remarks
6400	Pressure Test Gages	A	A	A	–		
6500	Atmospheric and 0-15 psig Storage Tanks	NA	A	A	–		
6600	Hydrostatic Testing of Vessels Designed to NC-3200	NA	A	NA	–		
6800	Pneumatic Testing of Vessels Designed to NC-3200	NA	A	NA	–		
6800							
6900	Proof Tests to Establish Design Pressure	NA	A	A	A	UG-101	
7000	PROTECTION AGAINST OVERPRESSURE						
7100	General	A	A	A	–		
7200	Definitions Applicable to Overpressure Protection Devices	A	A	A	–		
7300	Overpressure Protection Report (Cl. 1); Analysis (Cl. 2)	A	A	NA	–		
7400	Relieving Capacity Requirements and Acceptable Types of Overpressure Protection Devices	A	A	A	–		
7500	Set Pressures of Pressure Relief Devices	A	A	A	–		
7600	Operating Design Requirements for Pressure Relief Valves	A	A	A	–		
7700	Requirements for Nonreclosing Pressure Relief Devices	A	A	A	–		
7800	Certification Requirements	A	A	A	–		
7900	Marking, Stamping, and Reports	A	A	A	–		
8000	NAMEPLATES, STAMPING, AND REPORTS						
8100	General	A	A	A	–		

Table A2-4 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME VIII (1965)	Remarks
	MANDATORY APPENDICES						
I	Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves	A	A	A	A	Subsection C	Fatigue Curves not included in Sect. VIII
II	Experimental Stress Analysis	A	A	A	–		
III	Basis for Establishing Design Stress Intensity Values and Allowable Stress Values	A	A	A	A	Appendices P&Q	
IV	Approval of New Materials Under the ASME Boiler and Pressure Vessel Code for Section III Application	A	A	A	–		
V	Certificate Holder's Data Report Forms and Application Forms for Certificates of Authorization for Use of Code Symbol Stamps	A	A	A	–		
VI	Rounded Indications Charts	A	A	A	–		
VII	Charts for Determining Shell Thickness of Cylindrical and Spherical Components Under External Pressure	A	A	A	–	UG-28 & Appendix V	
XI	Rules for Bolted Flange Connections for Class 2 and 3 Components and Class MC Vessels	NA	A	A	–	Appendix II	
XII	Design Considerations for Bolted Flange Connections	A	A	A	A	NA	
XIII	Design Based on Stress Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	–		
XIV	Design Based on Fatigue Analysis for Vessels Designed in Accordance with NC-3200	NA	A	NA	–		

Table A2-4 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME VIII (1965)	Remarks
XVI	Nondestructive Examination Methods Applicable to Core Support Structures	A	A	A	O		
XVII	Design of Linear Type Supports by Linear Elastic and Plastic Analysis	A	A	A	O		
	NONMANDATORY APPENDICES						
A		A	NA	NA	-		
B	Owner's Design Specification	A	A	A	-		
C	Certificate Holder's Stress Report	A	NA	NA	-		
D	Nonmandatory Preheat Procedures	A	A	A	-		
E	Minimum Bolt Cross-Section Area	A	NA	NA	-		
F	Rules for Evaluation of Level D Service Limits	A	A	A	A	NA	
G	Protection Against Nonductile Failure	A	A	A	A	NA	
H	Capacity Conversions for Class 3 Safety Valves	NA	NA	A	-		
J	Owner's Design Specifications for Core Support Structure	A	NA	NA	O		
K	Recommended Maximum Deviations and Tolerances for Component Supports	A	A	A	O		

Past Class C vessels were built in accordance with the requirements of ASME VIII (1965), except for inspection and the longitudinal (Category A) and circumferential (Category B) welding requirements noted in Section 4.3. Past Class C vessels could be classified in accordance with current requirements [1] as either Class 2 (Quality Group B) or Class 3 (Quality Group C).

2.4 PUMPS

See Section 4.4 of this appendix.

2.5 VALVES

See Section 4.5 of this appendix.

2.6 HEAT EXCHANGERS

Heat exchangers were usually designed to the ASME Boiler and Pressure Vessel Code, Section III, 1965 Edition [3], and Section VIII [5], which are discussed in Sections 2.3 and 4.3 of this appendix, and to the Standards of the Tubular Exchanger Manufacturers Association (TEMA), 1959 Edition [8]. Discussions regarding TEMA may be found in Section 4.6 of this appendix.

2.7 STORAGE TANKS

Storage tanks that must withstand pressures above atmospheric were usually designed to the ASME Boiler and Pressure Vessel Code, Section III, 1965 Edition [3], which is discussed in Sections 2.3 and 4.3 of this appendix. Aluminum tanks might have been designed to "USA Standard Specification for Welded Aluminum-Alloy Field-Erected Storage Tanks," USAS B96.1-1967 [9]. Storage tanks were also designed to the American Petroleum Institute (API) Standard 650 [10], 1964 Edition. USAS B96.1 and API-650 are discussed in Section 4.7 of this appendix.

3. CONCLUSIONS AND RECOMMENDATIONS

Nuclear components and systems for SEP "Group I" plants were designed in accordance with the following codes:

1. ASME III (1965) - Class A or Class C vessels
2. ASME VIII (1965) - Vessels
3. B31.1 (1955) and ASME I (1965) - Piping and Valves
4. TEMA (1959) - Heat Exchangers
5. ASA B16.5 (1961) - Steel Pipe Flanges and Flanged Fittings
6. Hydraulic Institute Standards (1965) - Pumps
7. USAS B96.1 (1967) - Aluminum Field Erected Storage Tanks
8. API 650 (1964) - Welded Steel Tanks for Oil Storage

Current requirements are contained in the following:

9. ASME III (1977) - Div. 1 Nuclear Components
10. ANSI B16.34 (1977) - Steel Valves

The following broad conclusions can be made regarding components built to past codes and evaluated against current requirements:

1. components currently classified as Class 3 would satisfy basic current requirements

2. components currently classified as Class 1 or Class 2 may possibly not satisfy current fracture toughness and full radiography requirements

3. piping currently classified as Class 1 would satisfy current requirements except possibly high cycle fatigue, fracture toughness, and full radiography requirements. Piping currently classified as Class 2 may not satisfy current fracture toughness and full radiography requirements.

The following is recommended:

1. Component materials should be evaluated for fracture toughness as described in Section 4.1.1 of this Appendix.

2. Standard class rated valves should be carefully checked against current pressure-temperature ratings.

3. Atmospheric and 0 to 15 psig storage tanks should be carefully reviewed against current requirements.

4. Unless Code Case N-7 to B31.1 has been invoked, Class 1 and 2 piping should be checked to see if full radiography of welded joints was specified.

4. COMPARISON OF SIGNIFICANT CURRENT CODE REQUIREMENTS AND PAST REQUIREMENTS

4.1 GENERAL REQUIREMENTS

Section 4.1 compares the significant general requirements of the current code [1] with past requirements. In addition, where feasible, an approach is formulated which facilitates the review of nuclear components and systems designed and built in accordance with past requirements to be evaluated from the viewpoint of current requirements. The general requirements discussed herein are fracture toughness, quality assurance, quality group classification, and code stress limits.

4.1.1 Fracture Toughness Requirements

Class 1 Components

The current code requires that pressure-retaining materials for Class 1 components shall be impact tested to determine T_{NDT}* by the drop weight test and RT_{NDT}* by the Charpy V-Notch test, except for materials whose nominal thickness is 7/8 in or less; bolts 1 in or less; bars with nominal sectional area 1 sq in or less; pipes, fittings, pumps, and valves with nominal pipe size 6 in or less; austenitic stainless steels; and non-ferrous materials. Drop weight tests are not required for martensitic high alloy chromium (Series 4xx) and precipitation-hardening steels listed in Appendix I [1e]; however, other requirements of NB-2332 [1b] do apply.

Class 2 Components

Pressure-retaining materials for Class 2 components are required to be impact tested with exceptions as outlined for Class 1 components. Also exempted are commonly used plate, forging, and casting materials listed in Table NC-2311(a)-1 of Reference 1c when used in Class 2 components whose lowest service temperature (LST)* exceeds the tabulated nil ductility transition temperature (T_{NDT}) by at least the thickness-dependent value A,

* See Table A4-1 for definitions of commonly used terms and symbols.

determined from the curve in Figure NC-2311(a)-1 from Reference 1c. For convenience, the table and the figure are reproduced as Table A4-2 and Figure A4-1, respectively. Materials for components whose LST exceeds 150°F are also exempt from impact testing.

Drop weight tests are not required for martensitic high alloy (Series 4xx) and precipitation-hardening steels listed in Appendix I of Reference 1e. Charpy V-Notch testing or alternative testing as described in NC-2331 [1c] applies for these steels in all thicknesses. For nominal wall thicknesses greater than 2.5 in, the required C_v values shall be 40 mils lateral expansion.

Table A4-1

Definition of Commonly Used Fracture Toughness Terms and Symbols

Symbol	Definition
T_{NDT}	A temperature at or above the nil ductility temperature as determined by a "break, no-break" drop weight test in accordance with ASTM E208. (The nil ductility temperature is that temperature above which cleavage fracture can be initiated only after appreciable plastic flow at the base of the notch and below which cleavage will be initiated with little evidence of notch ductility.) T_{NDT} is 10°F below the temperature at which at least two specimens show no-break performance.
RT_{NDT}	The higher of T_{NDT} or (T_{cv} - 60°F).
T_{cv}	A temperature above T_{NDT} at which three specimens made and tested in accordance with SA-370 Charpy V-Notch testing exhibit at least 35 mils lateral expansion and not less than 50 ft-lb absorbed energy.
LST	Lowest Service Temperature: the minimum temperature of the fluid retained by the component or the calculated minimum metal temperature expected during normal operation whenever the pressure within the component exceeds 20% of the preoperational system hydrostatic test pressure.

Table A4-2

TABLE NC-2311(a)-1
EXEMPTIONS FROM IMPACT TESTING UNDER NC-2311(a)-8

Material[1]	Material Condition[2]	T_{NDT},[3] deg. F
SA-537-Class 1	N	−30
SA-516-Grade 70	Q & T	−10
SA-516-Grade 70	N	0
SA-508-Class 1	Q & T	+10
SA-533-Grade B	Q & T	+10
SA-299[4]	N	+20
SA-216, Grades WCB, WCC	Q & T	+30
SA-36 (Plate)	HR	+40
SA-508-Class 2	Q & T	+40

NOTES:

(1) These materials are exempt from toughness testing when A or LST — T_{NDT} is above the curve in Fig. NC-2311(a)-1, for the thickness as defined in NC-2331 or NC-2332.

(2) Material Condition letters refer to:
N - Normalize
Q & T - Quench and Temper
HR - Hot Rolled

(3) These values for T_{NDT} were established from data on heavy section steel (thickness greater than 2½ in.). Values for sections less than 2½ in. thick are held constant until additional data is obtained.

(4) Materials made to a fine grain melting practice.

Figure A4-1

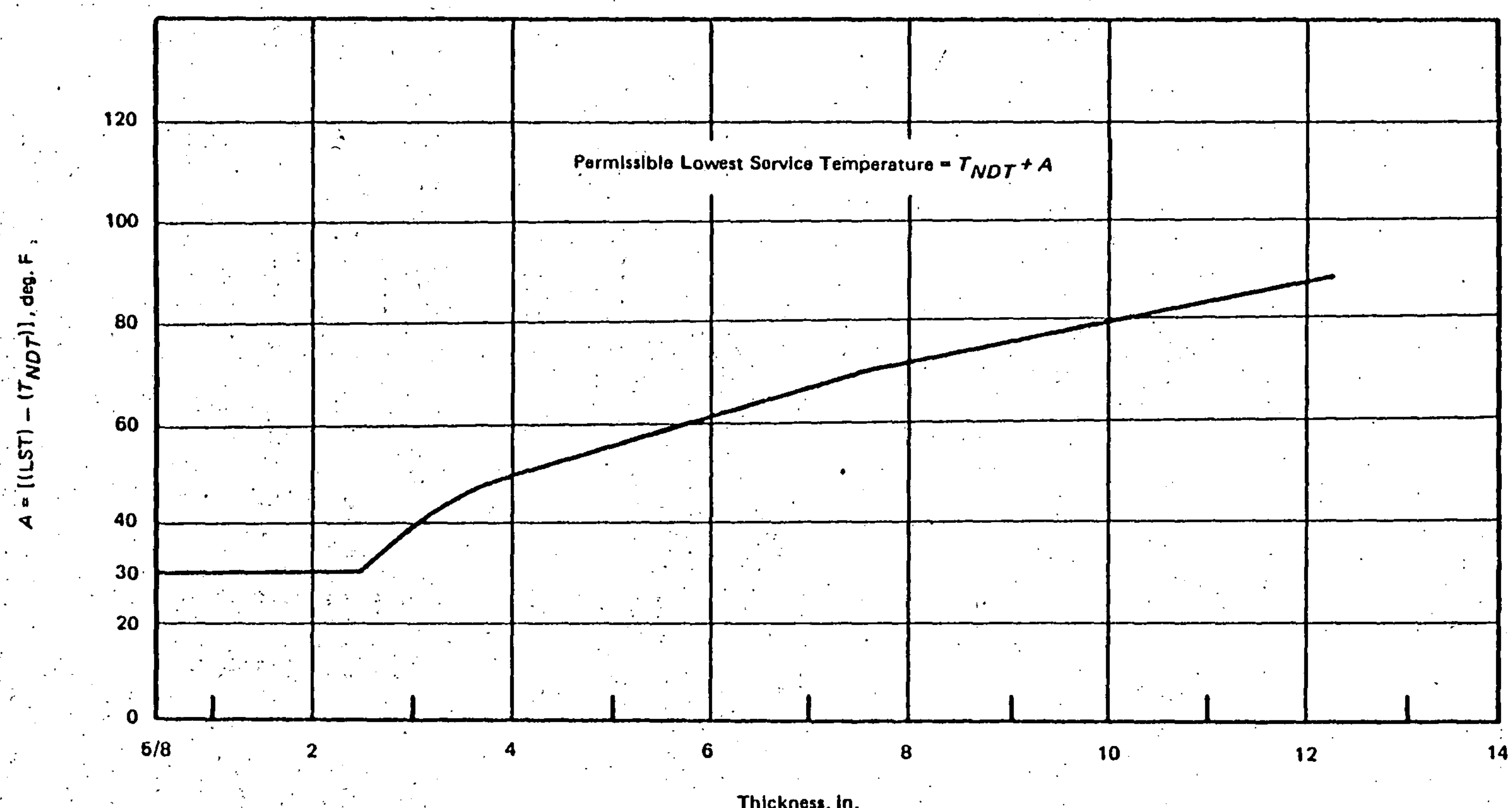

FIG. NC-2311(a)-1 DETERMINATION OF PERMISSIBLE LOWEST SERVICE TEMPERATURE

Class 3 Components

Pressure-retaining materials for Class 3 components are required to be tested, except as outlined for Class 1 components and the materials listed in Table ND-2311-1 [1d] in the thicknesses shown when the LST for the component is at or above the tabulated temperature. For convenience, Table ND-2311-1 has been reproduced as Table A4-3. In addition, materials for components for which the LST exceeds 100°F are exempt from impact testing.

The evaluation of materials based on past codes for which fracture toughness requirements may not have been specified or limited is facilitated by the survey forms shown as Tables A4-4, A4-5, and A4-6 for Class 1, Class 2, and Class 3 components or systems, respectively.

Example

Tables A4-2 through A4-6 and Figure A4-1 will be used to evaluate the resistance to brittle fracture of components whose design is based on past codes for which impact testing may not have been required. The following is an example of how the tables and the figure will be used.

Consider the 42-in primary pipe line between the reactor vessel and steam generator in the Palisades plant. These pipes were fabricated from 3.75-in-thick ASTM 516, Grade 70 plate with a rolled bond 1/4-in nominal cladding of 304L stainless steel. The design temperature is 650°F. The safety injection system is designed to cool the primary system to 130°F in 24 hours with a maximum pressure of 270 psig as noted in Reference 11. The LST is taken as 130°F. From Table A4-3, T_{NDT} = 0°F for SA-516 Grade 70. From Figure A4-1, A = 48° for material 3.75 in thick:

$$(LST - T_{NDT}) = 130° - 0° = 130°F > 48°F = A$$

so that this material, if it were a Class 2 or 3 component, would be exempt from impact testing. The fact that the primary coolant piping is Class 1 would not exempt it from impact testing based on present code requirements. However, the fact that the LST exceeds the T_{NDT} by more than 150% of A allows us to conclude that the primary coolant piping material used in the construction of the Palisades plant is adequate, provided that exposure to radiation does not induce an increase of the T_{NDT} sufficient to require the fracture mechanics approach outlined in Appendix G [4e]. In this regard, note that paragraph NB-2332(b) [1b] indicates that if the LST exceeds the reference nil ductility transition temperature (RT_{NDT}) by 100°F, then the fracture mechanics approach of Appendix G is not required. In this example:

$$(LST - T_{NDT}) = 130°F > 100°F$$

so that the material for the Palisades primary coolant piping is considered adequate.

Table A4-3

TABLE ND-2311-1
EXEMPTIONS FROM IMPACT TESTING UNDER ND-2311(a)(8)

Material	Material Condition[1]	Lowest Service Temperature for the Thickness Shown Over 5/8 in. to 3/4 in., incl. (Over 16 mm to 19 mm, incl.)	Over 3/4 in. to 1 in., incl. (Over 19 mm to 25 mm, incl.)	Over 1 in. to 1½ in., incl. (Over 25 mm to 38 mm, incl.)	Over 1½ in. to 2½ in., incl. (Over 38 mm to 64 mm, incl.)
SA-516 Grade 70	N	-30 F (-34 C)	-20 F (-29 C)	0 F (-18 C)	0 F (-18 C)
SA-537 Class 1	N	-40 F (-40 C)	-30 F (-34 C)	-30 F (-34 C)	-30 F (-34 C)
SA-516 Grade 70	Q & T	(2)	(2)	(2)	-10 F (-23 C)
SA-508 Class 1	Q & T	(2)	(2)	(2)	10 F (-12 C)
SA-508 Class 2	Q & T	(2)	(2)	(2)	40 F (4 C)
SA-533 Grade B[3] Class 1	Q & T	(2)	(2)	(2)	10 F (-12 C)
SA-216 Grades WCB, WCC	Q & T	(2)	(2)	(2)	30 F (-1 C)
SA-299[3]	N	(2)	(2)	(2)	20 F (-7 C)

NOTES:
(1) Material Condition letters refer to:
N — Normalize
Q & T — Quench and Temper
(2) The lowest service temperature shown in the column "Over 1½ in. to 2½ in." may be used for these thicknesses.
(3) Material made to a fine grain melting practice.

Table A4-4

Evaluation for Fracture Toughness of Pressure-Retaining Material for Class 1 Component/System
__________ Nuclear Power Plant

FSAR Page__________

I. Component/System Data

1. Description of Component/System:
2. Material Description and Thickness: P No.________
3. Design Temperature:______°F
4. Design Pressure:_______psi
5. Lowest Service Temperature[1] (LST):________°F
6. Pressure at LST: _______psi
7. Fracture Toughness Requirement? Yes___ No___

II. Evaluation

____8. Material is exempt[2,3] from impact testing because:

____ (a) Nominal thickness 5/8 in or less
____ (b) Bolts 1 in or thinner
____ (c) Bars with nominal 1 sq in cross section or less
____ (d) Pipes, fittings, pumps, and valves, nominal pipe size of 6-in diameter or smaller

NOTES:

1. Lowest Service Temperature (LST) is the minimum temperature of the fluid retained by the component or, alternatively, the calculated minimum metal temperature whenever the pressure within the component exceeds 20% of the preoperational system hydrostatic test pressure [1].

2. Welding material used to join materials with P Nos. 1, 3, 4, 5, 6, 7, 9, and 11, which are exempt from impact testing because of 8(a) through 8(f), is likewise exempt from impact testing. However, exemption 9 does not exempt either the weld metal (NB-2430) or the welding procedure qualification (NB-4335) from impact testing. See paragraph NB-2431 of Reference 1b.

3. The current code does not exempt Class 1 components from impact testing on the basis of tabulated T_{NDT} and A values as it does Class 2 components. Item 9 is not an exemption listed in paragraph NB-2311 but a conservative adaptation of NC-2311(a)(8) for Class 2 components to facilitate the SEP review.

Table A4-4 (Cont.)

____ (e) Austenitic stainless steel
____ (f) Non-ferrous material

9. Fracture toughness of material[3]

____ appears
____ does not appear

to be adequate on the basis of the following evaluation:

(a) for material other than bolting and up to 2-1/2 in thick:

T_{NDT} = ______ °F
(See Table NC-2311(a)-1)
(___ Other reference used[4]: ____________________)
and,
($LST - T_{NDT}$) = _______ °F _______ which exceeds 90°F
_______ which does not exceed 90°F

(b) for material other than bolting in excess of 2-1/2 in thick:

RT_{NDT} = ______ °F
(Reference used[4]: ________________________)
and,
($LST - RT_{NDT}$) = _______ °F _______ which exceeds 120°F
_______ which does not exceed 120°F

10. For bolting material in excess of 1-in diameter, reference data[4] ________________:

____ has been available
____ has not been available
and found to
____ satisfy
____ not satisfy
the requirements of NB-2333 [4(b)]

____11. Fracture toughness cannot be evaluated because of insufficient information.

____12. Material is not exempt from impact testing.

NOTE:

4. When using references other than the current code to obtain T_{NDT} and RT_{NDT}, be sure that the data have been obtained from specimens whose condition matches the material being evaluated (e.g., normalized or quenched and tempered) and that have designation such as "SA-516 Gr. 70".

Table A4-4 (Cont.)

III. Conclusions

____ Fracture toughness appears to be adequate.

____ Adequacy of fracture toughness not established; request supplemental test data and supporting documents.

____ Welding material is ____ is not ____ exempt from impact testing on the basis of foregoing data and Note 2.

Table A4-5

Evaluation for Fracture Toughness of Pressure-Retaining
Material for Class 2 Component/System
_______ Nuclear Power Plant

FSAR Page ____

I. Component/System Data

1. Description of Component/System:
2. Material Description and Thickness: P No. ____
3. Design Temperature:_______°F
4. Design Pressure:______ psi
5. Lowest Service Temperature (1) (LST):_____°F
6. Pressure at LST:______ psi
7. Fracture Toughness Requirement? Yes___ No___

II. Evaluation

____ 8. Material is exempt (2) from impact testing because:

____ (a) Nominal thickness 5/8 in or less
____ (b) Bolts 1 in or thinner
____ (c) Bars with nominal 1 sq in cross section or less
____ (d) Pipes, fittings, pumps, and valves, nominal pipe size of 6-in diameter or smaller
____ (e) Austenitic stainless steel
____ (f) Non-ferrous material

NOTES:

1. Lowest Service Temperature (LST) is the minimum temperature of the fluid retained by the component or, alternatively, the calculated minimum metal temperature whenever the pressure within the component exceeds 20% of the preoperational system hydrostatic test pressure [1].

2. Welding material used to join materials with P Nos. 1, 3, 4, 5, 6, 7, 9, and 11, which are exempt from impact testing because of 8(a) through 8(f), or 8(h), is likewise exempt from testing. However, 8(g) exemption does not exempt either the weld metal (NC-2430) or the weld procedure qualification (NC-4335) from impact testing. See paragraph NC-2431 of Reference 1c.

Table A4-5 (Cont.)

____ (g) LST of material listed in Table NC-2311(a)-1 (see Table A4-2) exceeds T_{NDT} by at least "A" (A depends on thickness).[2]

LST______°F (from FSAR)

T_{NDT} ______ °F (Table NC-2311(a)-1, Summer 1977 Addenda)

A ________°F (Figure NC-2311(a)-1, Summer 1977 Addenda) (Reproduced on p.)

LST - T_{NDT} = _____°F is ____ is not ____ greater than A.

____ (h) LST exceeds 150°F.

____ 9. Fracture toughness cannot be evaluated because of insufficient information.

___ 10. Material is not exempt from impact testing.

III. Conclusions

___ Fracture toughness appears to be adequate.

___ Adequacy of fracture toughness not established; request supplemental test data and supporting documents.

___ Welding material is ____ is not ____ exempt from impact testing on the basis of foregoing data and Note 2.

Table A.4-6

Evaluation for Fracture Toughness of Pressure-Retaining Material for Class 3 Component/System

_______ Nuclear Power Plant

FSAR Page ____

I. Component/System Data

1. Description of Component/System:
2. Material Description and Thickness: P No. ____
3. Design Temperature:_______°F
4. Design Pressure:______ psi
5. Lowest Service Temperature(1) (LST):______°F
6. Pressure at LST:______ psi
7. Fracture Toughness Requirement? Yes___ No___

II. Evaluation

____ 8. Material is exempt(2) from impact testing because:

____ (a) Nominal thickness 5/8 in or less
____ (b) Bolts 1 in or thinner
____ (c) Bars with nominal 1 sq in cross section or less
____ (d) Pipes, fittings, pumps, and valves, nominal pipe size of 6-in diameter or smaller
____ (e) Austenitic stainless steel
____ (f) Non-ferrous material

NOTES:

1. Lowest Service Temperature (LST) is the minimum temperature of the fluid retained by the component or, alternatively, the calculated minimum metal temperature whenever the pressure within the component exceeds 20% of the preoperational system hydrostatic test pressure [1].

2. Welding material used to join materials with P Nos. 1, 3, 4, 5, 6, 7, 9, and 11, which are exempt from impact testing because of 8(a) through 8(f), or 8(h), is likewise exempt from testing. However, exemption 8(g) does not exempt either the weld metal (NC-2430) or the weld procedure qualification (NC-4335) from impact testing. See paragraph NC-2431 of Reference 1d.

Table A4-6 (Cont.)

____ (g) LST equals or exceeds T_{NDT} in Table NC-2311(a)-1 for the material and thickness being evaluated.(2)

____ (h) LST exceeds 100°F.

____ 9. Fracture toughness cannot be evaluated because of insufficient information.

____ 10. Material is not exempt from impact testing.

III. Conclusions

____ Fracture toughness appears to be adequate.

____ Adequacy of fracture toughness not established; request supplemental test data and supporting documents.

____ Welding material is ____ is not ____ exempt from impact testing on the basis of foregoing data and Note 2.

4.1.2 Quality Assurance Requirements[1]

The current code [1] requires that activities in connection with the design and construction[2] of ASME III nuclear power plant components and systems be performed in accordance with a quality assurance program that provides adequate confidence in compliance with the rules of Section III. The program is to be planned, documented, controlled, managed, and evaluated in accordance with Article NCA-4000[3] for Class 1 and 2 items, and in accordance with NCA-4135[3] and NCA-8122[3] for Class 3 items. The quality assurance program is to be established and documented prior to the issuance of a Certificate of Authorization by the American Society of Mechanical Engineers after the program has been evaluated and accepted by the society.

For Class 1 and 2 items, the program is to be documented in detail in a quality assurance manual which should include policies, procedures, and instructions which demonstrate provisions for:

a. an organization with sufficient authority, freedom, and independence from cost and schedule considerations to:

    1. identify quality problems

    2. initiate, recommend, or provide solutions

    3. verify implementation of solutions

    4. limit and control further work on nonconforming items until proper disposition, and with direct access to appropriate levels of management to assure proper execution of the program

b. indoctrination and training of qualified personnel

c. notification of the authorized inspection agency of significant changes in the program

---

1. Quality assurance requirements have been determined to be outside the scope of SEP Topic III-1 according to the letter from S. Bajwa to S. Carfagno dated December 10, 1981. This discussion is provided as general information.
2. Construction under Division 1 includes materials, design, fabrication, examination, testing, installation, inspection, and certification.
3. See Summer 1977 and Summer 1978 Addenda to ASME III (1977) General Requirements.

d. control of the design to assure compliance with the design specification of Section III

e. design review and checking by individuals or groups other than those who performed the original design

f. documentation for procurement of materials and subcontracted services requiring compliance with Section III

g. document control with provisions for review of changes

h. identification and traceability of materials

i. the control of construction processes

j. examination, testing, and inspections verifying the quality of work by persons independent from supervisors immediately responsible for the work being inspected, and using measuring and test equipment calibrated against measurement standards traceable to national standards (where such standards exist) at intervals sufficient to maintain accuracy within necessary limits

k. proper handling, storage, shipping, and preservation of materials and components

l. identification of items with suitable marking to indicate the status of examinations and tests, including conformance or non-conformance to the examination and test requirements

m. prompt identification and corrective action of significant conditions adverse to quality, with documented measures to preclude repetition

n. maintenance of quality assurance records as specified in NCA-4134.17 of Reference 1, including maintaining for the life of the plant as a minimum, the following: a permanent record file, certified design and construction specifications, drawings and reports, data reports, certified stress reports, certified as built drawings, material test reports, non-destructive examination reports, and test treatment reports

o. a comprehensive system of planned and periodic audits with documentation of results, follow-up action, and re-audit of deficient areas.

Class 3 items are to be designed and constructed in accordance with the quality control requirements of NCA-4135 of Reference 1, which include:

a. an organization chart which reflects the actual organization

b. a quality control system suitable to the complexity of the work and size of the organization

c. persons who perform quality control functions with sufficient responsiblity, authority, and independence to implement the quality control system, identify problems, and initiate, recommend, and provide solutions.

The quality control system for Class 3 construction is evaluated for compliance with the requirements of Section III [1] by the authorized inspection agency and either a representative of the American Society of Mechanical Engineers or the jurisdictional authority at the construction site as required by NCA-8122. If the jurisdictional authority also performs duties as an authorized inspection agency, a representative of the National Board of Boiler and Pressure Vessel Inspectors or a representative of the facility will participate in the evaluation.

If jurisdictional laws do not require inspection or permit inspection personnel to participate in the evaluation of the quality control system, then the evaluation will be performed by a representative of the National Board or the Society.

Past codes did not provide for a quality assurance program for Class 1 and 2 construction, nor for a quality assurance system for Class 3 construction, as required by the current code. Although an integrated program or system was not required by past codes, many quality assurance features were required.

Although the program or system was not specifically required, nevertheless, construction organizations typically did operate under "in-house" quality assurance programs which provided for the inspection, testing, and surveillance of components and construction activities.

Design organizations did not typically operate under an integrated program. Two nuclear plants were reviewed by the author as part of the design adequacy task of the Reactor Safety Study.* Approximately 20% of the items reviewed for one plant either did not fully comply with the FSAR criteria or were not adequately documented for assessment. Similarly, 40% of the items examined for the other plants could not demonstrate full compliance with FSAR criteria.

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*Appendix X to the "Reactor Safety Study - An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," WASH-1400, USAEC, Draft August 1974.

It is recommended that the quality assurance program used in both the design and construction phases for each SEP plant Class 1 and 2 item should be compared with the current requirements previously outlined. If the comparison shows a weak or non-existent program with design and/or construction phases, then the operating history of the plant should be examined to determine the frequency and origin of incidents in which the pressure boundary has been breached. If subsequent repairs or replacement of the breached boundary have not provided a permanent fix, then it is reasonable to conclude that a design deficiency exists. The following would then be recommended:

1. a design review of the deficient area with design change recommendations

2. a technical audit to determine design adequacy of selected Class 1 and Class 2 items for the complete plant.

4.1.3 Quality Group Classifications [6]

Nuclear power plant components are currently classified as Class 1, 2, 3, MC, or CS. Class MC and CS are for metal containment vessels and core support structures and are outside the scope of this study. Current classification standards are as follows:

Quality Group A (Class 1)

A component of the reactor coolant pressure boundary is currently designated as a Class 1 component.

Quality Group B (Class 2)

Components are currently designated as Class 2 provided that:

1. They are not part of the reactor coolant pressure boundary, but part of:

   a. emergency core cooling systems, post-accident heat removal systems, post-accident fission product removal

   b. reactor shutdown or residual heat removal systems

c. BWR main steam components described in Reference 2:

main steam line from second isolation valve to turbine stop valve

main steam line branch lines to first valve

main turbine bypass line to bypass valve

first valve in branch lines connected to either main steam lines or turbine bypass lines

d. PWR steam generator steam and feedwater systems up to and including outermost containment isolation valves and connected piping up to and including the first valve that is normally closed or capable of automatic closure during normal reactor operation

e. systems connected to the reactor coolant pressure boundary <u>not</u> capable of being isolated from the boundary by two valves normally closed or capable of automatic closure during normal reactor operation.

2. They are part of the reactor coolant pressure boundary, but are not designated as Class 1 because either the component is not needed for safe shutdown of the reactor in the event of an accident or the component can be isolated by two valves as described in footnote (2) of Section 50.55a of Reference 2.

<u>Quality Group C</u> (Class 3)

Class 3 components are not part of the reactor coolant pressure boundary, nor designated Class 2, but are part of:

1. cooling water and auxiliary feedwater systems important to safety, such as emergency core cooling or post-accident heat removal

2. cooling water and seal water systems that are designed for functioning of components important to safety, such as cooling water systems for reactor coolant pumps, diesels, and control room

3. systems connected to the reactor coolant pressure boundary that <u>are</u> capable of being isolated from the boundary by two valves normally closed or capable of automatic closure during normal operation

4. systems not previously defined, other than radioactive waste management systems that contain or may contain radioactive material, and whose postulated failure would potentially result in off-site doses that exceed 0.5 rem.

Comparison with Past Codes

The past B31.1 (1955) piping code does not designate quality classes for piping or valves.[1] Comparison of the component classification designations in the FSAR with the standards previously described for each SEP plant is required before a comparison with current code requirements can be initiated.

The past pressure vessel code, ASME III (1965), designates Class A vessels which are essentially equivalent to currently designated Class 1 vessel. Class B vessels designated in accordance with the past code would currently be classified as MC vessels, which are outside the scope of this review. Previously designated Class C or ASME Section VIII vessels may be currently classified as Class 2 or Class 3 vessels. Vessels previously classified as Class C but currently classified as Class 2 should be evaluated carefully against current Class 2 requirements such as the quality assurance program.

4.1.4 Code Stress Limits

Strength Theories

Past codes [4,5], except ASME III (1965) for Class A vessels, have been based on the assumption that inelastic behavior begins when the maximum principal stress reaches the yield point of the material, S_Y. It has been commonly accepted that both the maximum shear stress theory (Tresca criterion) and the maximum distortion energy theory (Mises criterion) are much better than the maximum principal stress assumption in predicting yielding and fatigue failure in ductile metals. Although most experiments show that the Mises criterion is more accurate than the maximum shear stress theory, the present code [1] uses the maximum shear stress theory of strength for Class 1 components because (1) it is more conservative, (2) it is easier to apply, and (3) it facilitates fatigue analysis. Class 2[1] and Class 3 components continue to be designed in accordance with the maximum principal stress assumption.

1. Code Case N-1 classifies piping into two categories: nuclear piping, designed to contain a fluid whose loss from the system could result in a radiation hazard to either the plant personnel or the general public; and conventional steam and service non-nuclear piping.
2. Except for Class 2 vessels designed in accordance with the alternative rules of NC-3200.

If the principal stresses at a point are $\sigma_1 > \sigma_2 > \sigma_3$, then yielding occurs

when:

$$T_{max} = (1/2)\ (\sigma_1 - \sigma_3) = (1/2)\ S_Y$$

according to the maximum shear stress theory. For convenience, the present code uses the term "stress intensity," which is defined as:

$2T_{max}$ = the largest algebraic difference between any of two of the three principal stresses.

<u>Example</u>: Consider a thin-walled cylindrical pressure vessel or pipe, away from any discontinuities and subjected to an internal pressure, p, which induces a hoop stress σ and an axial stress $1/2\sigma$. The three principal stresses in descending magnitude would be:

$$\sigma_1 = \sigma$$
$$\sigma_2 = (1/2)\sigma$$
$$\sigma_3 = -p$$

According to the current code, the "stress intensity" is:

$$(\sigma_1 - \sigma_3) = (\sigma + p)$$

which together with the stress limit controls the design. According to past codes, the design would be controlled by the maximum stress together with the stress limits used in the past codes.

<u>Stress Categories</u>

The current code recognizes the advances in computer-aided structural analysis capability which enable a more comprehensive and detailed determination of stress and strain fields, in both the elastic and plastic states due to thermal as well as mechanical loads, gross structural discontinuities, and local structural discontinuities such as small holes and fillet radii. Accordingly, the current code recognizes various stress categories defined in NB-3213 of Reference 1b and briefly summarized as follows:[1]

1. <u>Primary Stresses</u>

   Any normal or shear stress induced by an imposed load which is necessary to satisfy equilibrium between the external and internal

1. See Figure NB-3222-1 [1b].

forces and moments. A primary stress is not self-limiting. The existence of primary stresses in excess of the yield strength across the thickness of the material will result in failure due to gross distortion or rupture, inhibited only by the strain hardening characteristics of the material. Primary stresses are further categorized as:

a. General Membrane Stress. The average primary stress across a solid section excluding the effects of gross and local discontinuities. The six stress components associated with a primary general membrane stress are symbolized by P_m.

b. Local Membrane Stress. The average stress across any solid section induced by a combination of mechanical loading and gross discontinuity which may produce excessive distortion when transferring the load from one portion of the structure to another, e.g., in the crotch region of a piping tee due to internal pressure. The stress components associated with a primary local membrane stress are symbolized by P_L.

c. Bending Stress. That component of a primary stress which is proportional to the distance from the centroid of a solid section, excluding effects of gross and local structural discontinuities, e.g., the bending stress across the thickness of the central region of a flat head of a vessel due to internal pressure. The stress components associated with a primary bending stress are symbolized by P_b.

2. Secondary Stresses

Secondary stress is a normal or shear stress induced by an imposed strain field necessary to satisfy compatibility and continuity requirements within the structure. Secondary stresses are "self-equilibrating" and limited by local yielding and minor distortions so that failure due to secondary stresses induced by the application of one load will not occur. Secondary stresses are further categorized as follows:

a. Secondary Expansion Stresses. Induced by the constraint of free end displacements due to gross structural discontinuities, such as the stresses in a piping element of hot piping system whose ends are constrained; does not apply to vessels. The stress components of the expansion stress are symbolized by P_e.

b. Secondary Membrane and Bending Stress. Occurring at gross structural discontinuities and caused by mechanical loads, pressure, or differential thermal expansion, symbolized by Q.

3. Peak Stresses

Peak stresses are induced by local discontinuities such as notches or thermal loads in which the expansion is completely suppressed, such as the local thermal expansion coefficient of the austenitic steel cladding of a carbon steel component.

Code Stress Limits for Material Other Than Bolting Class 1 Components

Current code stress limits depend on the code class and service levels being considered. Design stress intensity values, S_m, for Class 1 components are given in Tables I-1.1 and I-1.2 of Appendix I of Reference le for ferritic and austenitic steels, respectively. For materials other than bolting, the design stress intensity value S_m is essentially the lower of 1/3 (UTS) or 2/3 (YS) at design temperature for ferritic steels.(1) For austenitic steels, S_m is the lower of 1/3 (UTS) or 0.9 YS at design temperature or 2/3 (YS) at room temperature.(2)

Assuming that S_m is essentially the lower of 1/3 (UTS) or 2/3 (YS), then the stress limits for the various service level loads and stress category combinations for materials other than bolting may be summarized as follows:

1. Design Condition (See Figure NB-3221-1 [1b])

Stress Category	Limit of Stress Intensity		
Primary Stresses	Tabulated	YS	UTS
P_m	S_m	$\leq$ 2/3 (YS)	$\leq$ 1/3 (UTS)
P_L	1.5 S_m	$\leq$ YS	$\leq$ 1/2 (UTS)
$P_L + P_b$	1.5 S_m	$\leq$ YS	$\leq$ 1/2 (UTS)

1. See III-2110(a) of Reference le.
2. See III-2110(b) of Reference le.

2. Level A and B Service (Operating and Upset Conditions)
(See Fig. NB-3222-1 [1b])

Stress Category	Limit of Stress Intensity		
	Tabulated	YS	UTS
(a) Expansion Stress Intensity P_e (not for vessels)	3 S_m	$\leq$2 YS	$\leq$ UTS
(b) Primary and Secondary $P_L + P_b + P_e + Q$	3 S_m (1)	$\leq$2 YS	$\leq$ UTS
(c) Peak Stresses(2) $P_L + P_b + P_e + Q + F$	S_a (3) (See fatigue curves, Fig. I-9.0, Reference 1e)		

3. Level A and B Service Limits for Cyclic Operation (NB-3222.4)

Unless the analysis for cyclic service is not required by NB-3222.4(d)(1) through NB-3222-4(d)(6) [1], the ability of the component to withstand cylic service without fatigue failure shall be demonstrated by satisfying the requirements of NB-3222.4(e) as follows:

a. Determine the stress difference and the alternating stress intensity, Sa, for each condition of normal service.

b. Use stress concentration factors to account for local structural discontinuities, as determined by theoretical, experimental, photoelastic, or numerical stress analysis techniques. Experimental methods shall comply with Appendix II-1600, except for high strength alloy steel bolting, for which NB-3232.3(c) shall apply. The fatigue strength reduction factor shall not exceed 5, except for crack-like defects and for specified piping geometries given in NB-3680.

c. Design fatigue curves in Figure I-9.0 for the various materials shall be used to determined the number of cycles N_i for a given alternating stress value $(S_{alt})_i$. The alternating stress determined from the analysis should be multiplied by the ratio of the modulus of elasticity given on the design fatigue curve divided by the modulus of elasticity used in the analysis before entering the design fatigue curve.

---

1. 3 S_m may be exceeded provided the conditions of NB-3228.3 are satisfied.
2. For cyclic operation.
3. 2 S_a for full range of fluctuation.

d. Cumulative usage for multiple stress cycles is be determined from

$U = \text{Sum of } (M_i/N_i)$

where M_i is the expected number of cycles associated with $(S_{alt})_i$ and N_i is the corresponding number of cycles from the design fatigue curve. The cumulative usage factor U shall not exceed 1.

4. Level C (Emergency Conditions)
(See Fig. NB-3224-1 [1b])

Stress Category	Limit	Type of Analysis
Primary Stresses		
P_m (pressure and mechanical)	1.2 S_m or YS(1)	Elastic
P_m (pressure - only for ferritic material)	1.1 S_m or 0.9 YS(1)	Elastic
P_L	1.8 S_m or 1.5 YS(1) 0.8 (collapse load)	Elastic Limit
$P_L + P_b$	1.8 S_m or 1.5 YS(1) 0.8 (collapse load) 4.8 S_m	Elastic Limit Triaxial Stresses(2)
Secondary/Peak		Evaluation not required

Bolting Material Stress Limits - Class 1 Components (NB-3230)

Design Conditions

Pressure-retaining bolts are designed in accordance with the procedures of Appendix E [1e], which account for gasket materials and design as well as bolting material stress allowables given in Table I-1.3 of Reference 1e, which are based on the lower of:

1/3 (YS) at room temperature
1/3 (YS) at design temperature (up to 800°F).

---

1. Whichever is greater.
2. Based on sum of primary principal stresses.

Level A, B, and C Service Limits (NB-3232)

Actual stresses in bolts produced by a combination of preload, pressure, and differential thermal expansion may exceed the allowables given in Table I-1.3 as indicated below:

a. Average stress (neglecting stress concentrations) shall not exceed 2 times the Table I-1.3 [1e] values,

$$(S_b)_{avg} \leq \frac{2}{3}(YS)$$

b. Maximum stress at bolt periphery (or maximum stress intensity if tightening method induces torsion) due to direct tension and bending shall not exceed 3 times the value given in Table I-1.3 [1e],

$$(S_b)_{max} \leq (YS)$$

Fatigue Analysis of Bolts

Fatigue analysis of bolts is required unless all the conditions of NB-3222.41(d) [1] are satisfied. Suitability for cyclic service of bolts shall be determined as described in NB-3222.4(e) and as follows (NB-3232.3):

a. Use the design fatigue curve of Figure I-9.4 [1] using the appropriate fatigue strength reduction factor described in NB-3232.3(c) for bolting having less than 100 ksi tensile strength.

b. For high strength alloy bolts, use Figure I-9.4, provided that (1) the nominal stress due to tension and bending does not exceed 2.7 S_m for the upper curve or 3.0 S_m for the lower curve, (2) the minimum thread root radius is not less than 0.003 inches, and (3) the ratio of the shank fillet radius to the shank diameter is not less than 0.060.

c. For bolting having less than 100 ksi tensile strength, use a fatigue strength reduction factor of 4.0 unless a smaller factor can be justified by analysis or test. For high strength alloy bolts, use a fatigue strength reduction factor not less than 4.0.

Code Stress Limits - Class 2 and Class 3 Components

Design Allowable Stress Values

Design allowable stress values are given in Table I-7.0[1] for Class 2 and Class 3 and in Table I-8.0 for Class 3 component materials. These design allowable stress values are limits on maximum normal stresses rather than the stress intensity values for Class 1 components.

1. Ferritic Steel Non-Bolting Materials

Design allowable stress S for Class 2 and 3 components as detailed in III-3200 [1e] for ferritic steel non-bolting materials is the lowest of:

1/4 (UTS at room temperature)
1/4 (UTS at temperature)
2/3 (YS at room temperature)
2/3 (YS at temperature).

2. Austenitic Steel Non-Bolting Materials

The stress allowable for austenitic steels is the lowest of:

1/4 (UTS at room temperature)
1/4 (UTS at temperature)
2/3 (YS at room temperature)
0.9 (YS at room temperature).

3. Bolting Materials

Design stress allowables for bolting materials are based on the same criteria as for non-bolting materials, except that for heat-treated bolting materials, the allowable shall be the lower of:

1/5 (UTS at room temperature)
1/4 (YS at room temperature).

---

1. Except for Class 2 vessels designed in accordance with the alternative design rules of NC-3200, where stress intensity limits are based on Table I-1.0, i.e., the same as for Class 1 components.

Level D (Faulted Condition) (Appendix F of Reference 1e)

The rules for evaluating level D service conditions are contained in Appendix F of Reference 1e. Only limits on primary stresses are prescribed; thermal stresses are not considered. When compressive stresses are present, component stability must be assured. The potential for unstable crack growth should also be considered.

Component design limits on primary stress intensities for level D conditions depend on whether the system has been analyzed elastically or inelastically.

Elastic System Analysis

For an elastic system analysis, the component design limits for level D conditions permit plastic deformations based on loads or stresses determined by:

a. Elastic Analysis: in which the computed primary stress appears to exceed the YS by as much as 60% but remains within 70% of the UTS, except for piping in which the pressure does not exceed two times the design pressure, in which case the primary stress computed by Equation 9 of NB-3652 should not exceeed $3S_m$ (2 x YS).

b. Collapse Load Analysis: in which the level D loads do not exceed 90% of the collapse load determined by either a lower bound limit[1] analysis (which assumes an elastic-perfectly plastic material), a plastic analysis which accounts for the strain-hardening characteristics of the material, or by experiment.

c. Stress Ratio Analysis: which is a pseudo-elastic analysis method utilizing the techniques and curves given in Appendix A-9000 [1e], in which the apparent stress[2] is limited to the lesser of 3 S_m or 0.7 S_n except when the methods of A-9000 [1e] permit higher limits when the type of stress field is taken into account.

Inelastic System Analysis

When a system is analyzed inelastically, the level D primary stress or load limits for components permit plastic deformation depending on the component analysis method as follows:

---

1. A load which is in equilibrium with a system of stresses which satisfies equilibrium everywhere, but nowhere exceeds the YS at or below the collapse load.
2. Computed value of stress assuming elastic behavior.

a. Elastic Analysis: in which the computed primary stress intensity is limited to the greater of 0.7 UTS or YS + ((UTS - YS)/3).

b. Collapse Load Analysis: in which the load is limited to 90% of the collapse load. The collapse load may be determined by one of the three methods previously described.

c. Stress Ratio Analysis: as described previously.

d. Plastic Instability Analysis: in which a plasticity analysis is used to determine the load, P_I for which the deformation increases without bound. The load P is limited to 0.7 P_I or YS + (S_I - YS)/3 where S_I is the true effective stress associated with plastic instability.

e. Strain Limit Load Analysis: in which the load P is limited as described in (d) but not to exceed P_S associated with a specified strain limit.

f. Inelastic Analysis: in which primary stress is limited as in (a).

Comparison with Past Codes

The fundamental differences between current and past codes with regard to stress limits are summarized as follows:

1. The current code for Class 1 items is based on the maximum shear stress theory of failure. ASME III (1965) is based on the same theory for Class A (equivalent to Class 1) vessels. B31.1 (1955) piping code is based on maximum normal stress theory of failure.

2. The current code for Class 2 and 3 items is based on the same theory of failure as past codes.

3. The current code for Class 1 items considers primary as well as secondary stresses and peak stress categories, as does ASME III (1965). B31.1 (1955) power piping code does not consider peak stresses. ASME I (1965) considers (for piping) primary membrane stresses due to pressure only, except for mitered bends where the required thickness for a straight pipe is multiplied by a factor, (k - 0.5)/(k - 1.0), where k is the ratio between the radius of the bend (from center of curvature to center of pipe) to the inside radius of the pipe.

4. The current code for Class 2 and 3 vessels considers primary stresses for size selection, as does ASME III (1965).[1] The current code for Class 2 and 3 piping considers primary and secondary stresses, as does the past piping code.

1. Unless the vessel is designed in accordance with the alternative NB-3200 rules which are based on primary, secondary, and peak stresses.

5. The current code gives stress limits for the design condition as well as for service levels A and B which are equivalent to past code requirements.

6. The current code gives stress limits which permit large deformations in the region of discontinuity that may require repair for service level C and overall gross deformations that may require replacement for service level D. The equivalent of service levels C and D was not specifically considered by past codes. The FSAR, however, does consider a design basis accident which would be the equivalent of service level D and the stress limits given in the FSAR may be conservative, when compared to current stress limits. Stress limits for the equivalent of service levels C and D should be examined and evaluated based on the information given in the FSAR for the plant being evaluated.

4.1.5 Welding Requirements

Welding materials must currently satisfy the qualification requirements of Section IX of the ASME B&PV Code as well as the mechanical property and chemical analysis test requirements of NB/NC/ND-2430 [1].

A determination of delta ferrite shall be performed for A-No. 8 weld material (see QW-442 of ASME IX) except for SFA-5.4, Type No. 16-8-2 and filler metal to be used for weld metal cladding. A-No.8 weld material would typically be used to join chrome-nickel austenitic stainless steels such as SA-312 Grade TP 316. The minimum acceptable delta ferrite shall be 5FN and results shall be included in the certified material test report.

Full radiographic examination of vessel welds is currently required, depending on thickness of materials joined, weld joint category (see NB/NC/ND-3351 [1]) and code class as discussed in Section 4.3 of this Appendix.

Full radiographic examination for piping, pumps, and valves based on current and past codes, depends on weld joint category, pipe size, and code class as discussed in Section 4.2 of this Appendix.

It is concluded that past welding requirements for vessels were more severe than current requirements, but past code requirements for piping, pumps, and valves were not as severe as current requirements for Class 1 and 2 components.

It is recommended that the FSAR be carefully examined for radiography requirements for pipes, pumps, and valves which would currently be classified as Class 1 or 2. It is also recommended that welded components and systems in SEP plants made from austenitic stainless steel be spot-checked to determine evidence of hot short cracking in the weld region unless evidence of the use of A-No.8 welding rod with at least 5FN delta ferrite can be provided.

4.1.6 Design Considerations for Bolted Flange Connections

Appendix XII of the current code [1] provides supplementary information to prevent leakage in bolted flange connections with unusual features such as a very large diameter or under unusual conditions such as high pressure, high temperature, or severe temperature gradients. Appendix XII permits analysis of the joint which considers changes in bolt elongation, flange deformation, and gasket load that can take place upon pressurization and that may indicate a required bolt preload greater than 1.5 times the design value. This practice is permitted provided that excessive flange distortion and gross crushing of the gasket is prevented. Bolt relaxation under high temperatures should also be investigated. Methods for assuring adequate bolt tightening for large diameter bolts are discussed in Appendix XII.

Past codes did not consider special situations as described above. The current considerations of Appendix XII may be useful in evaluating problem connections.

4.2 PIPING

The current Class 1 piping design requirements are given in NB-3600 of Reference 1b. The fundamental differences between current and past requirements are that:

1. The current code explicitly considers and evaluates the margin against fatigue damage by a formulation for peak stress which accounts for local as well as gross discontinuities. The secondary stress indices C_i in the current code are equivalent in principal to the stress intensification factor i of the past code [4]. The current code magnifies gross discontinuity stress by multiplying C_i by a local stress index K_i. The past code[1] considers the effect of cyclic loading by reducing the allowable expansion stress by a factor f which varies between 1.0 for less than 7,000 cycles and 0.5 for more than 250,000 cycles.

   Figure A4-2 shows a plot of the allowable expansion stress based on the past code and labelled past "fatigue" curve superimposed against the design fatigue curves for carbon, low alloy, and high tensile steels (Fig. I-9.1 of Reference 1e) of the present codes, labelled current fatigue curve. The past "fatigue" curve is based on a 70 ksi ultimate tensile strength (UTS) material whose allowable stress range, S_A,[2] is f (1.5)(UTS)/(4) (0.9) where 0.9 accounts for the efficiency of a welded joint, and f depends on the number of cycles as shown in Table A4-7. The figure also indicates a value K (cycles), which is the ratio of the present over the past fatigue allowable alternating stress for a given number of cycles. K varies between K(10) = 25 and the K (1,000,000) = 1.0. Notice that K is the allowable local stress index for a design which is based on the past code and being evaluated in light of the present code, all other things being equal. Assuming that for most piping systems the maximum local stress index is not likely to be higher than 5, but higher than 1.4, we conclude from Figure A4-2 that piping systems designed in accordance with the past and the present code:

   a. are conservative for services with less than 500 cycles

   b. possibly are unconservative for services with cycles greater than 500 but less than 100,000

   c. are probably unconservative for services with more than 100,000 cycles and significant load changes.

---

1. B31.1 (1955) only; ASME I (1965) does not explicitly consider cyclic loads.
2. $S_A = f\,(1.25\,S_c + 0.25\,S_h)$. Using S_c approximately equal to S_h and $S_h \le 0.9(1/4\text{ UTS})$ gives $S_A \le f\,(1.5(\text{UTS})/4)0.9$.

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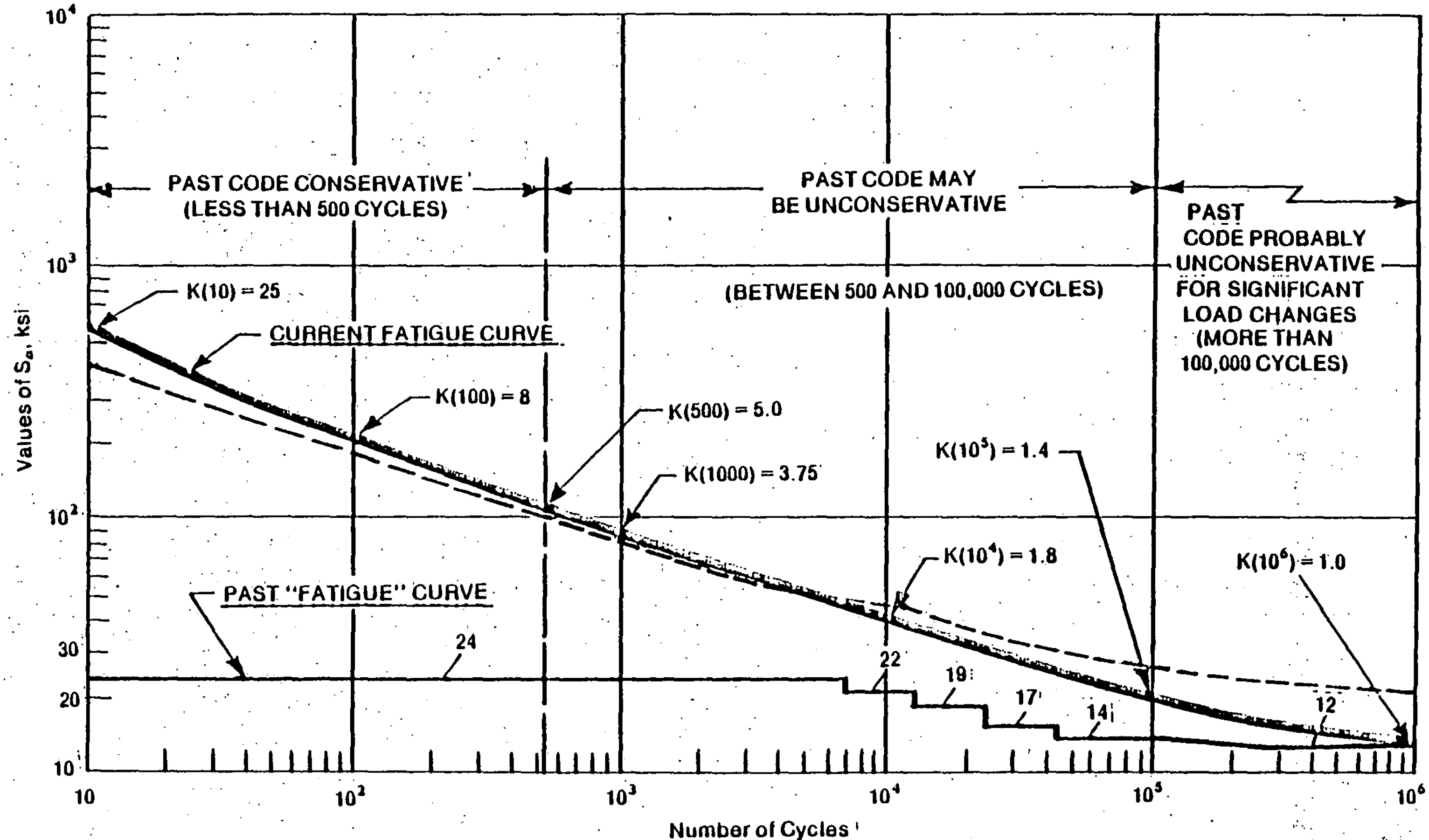


NOTE: $E = 30 \times 10^6$ ksi
UTS < 80.0 ksi
UTS 115.0-130.0 ksi
Interpolate for UTS 80.0-115.0 ksi

Figure A4-2. Design Fatigue Curves for Carbon, Low Alloy, and High Tensile Steels (For Metal Temperatures Not Exceeding 700°F) (Reference 4e)

2. The current code considers the influence of thermal gradients through the thickness of piping elements, together with the effects of the range of pressure and moments due to changes in service temperature and pressure, when determining the peak stress intensity S_p.

3. The current secondary stress indices C_i are either equal or less than twice the corresponding stress intensification factor i of the past code. This implies that expansion stress computations based on the past code are conservative from the viewpoint of margin against excessive distortion.

NB-3653.2 gives a simplified expression for S_p which conservatively estimates the sum of primary and secondary and peak stresses as follows:

$$S_p = K_1 C_1 \frac{P_o D_o}{2t} + K_2 C_2 \frac{D_o}{2I} M_i$$

$$+ \frac{1}{2(1-\nu)} K_3 E\alpha \left|\Delta T_1\right|$$

$$+ K_3 C_3 E_{ab} \times \left|\alpha_a T_a - \alpha_b T_b\right|$$

$$+ \frac{1}{(1-\nu)} E\alpha \left|\Delta T_2\right| \tag{1}$$

where:

K_1, K_2, K_3 = local stress indices

ΔT_1 = linear portion of thermal gradient through the thickness

ΔT_2 = non-linear portion of thermal gradient through the thickness

M_i = resultant range of moment due to service changes in temperature $|\Delta T_i|$ or mechanical loads such as earthquake

C_1, C_2, C_3 = secondary stress indices

P_o = range of service pressure

ν = 0.3

$E\alpha$ = modulus of elasticity times the mean coefficients of thermal expansion

D_o = outside diameter of the pipe

t = nominal wall thickness

I = sectional moment of inertia

$T_a(T_b)$ = range of average temperature on side a(b) of gross structural or material discontinuity.

Values of stress indices for the various piping elements are given in Table NB-3682.2-1 of Reference 1b and reproduced as Table A4-8. For the purpose of the discussion which follows,[1] the fourth term in the expression for S_p is neglected since it is atypical.

The past piping code [4] sets limits on the first two terms in the expression for S_p which will be derived herewith. Equation 13 of Section 6 of Reference 4, neglecting contributions due to torsion, is given by:

$$S_E = i \frac{M_b}{Z} \leq S_A$$

where:

M_b = resultant moment due to change in temperature from the minimum operating temperature (usually taken as erection temperature 70°F as noted in Section 619(b) Section 6 of Reference 4 to the maximum normal operating temperature plus movements of pipe ends attached to equipment.) Note that $M_i = \lambda_{2i} \cdot M_b$ (approx) where:

$$\lambda_{2i} = \frac{\Delta T_i}{[(T_o) - 70°F]}$$

Z = section modulus of pipe = $(I)/(D_o/2)$

i = stress intensification factor given in Figure 2 in Section 6 of Reference 4 for various piping elements.

Substituting the expression for Z in S_E, we obtain:

$$S_E = i \frac{D_o}{2I} M_b$$

Comparison of the stress intensification factors, i, given in Section 6, Figure 2 [4] with the stress indices C_2 given in Table NB-3682.2-1 reveals that C_2 is approximately 1.9 x i.

---

1. This discussion can be used to compare current requirements with piping designed to B31.1 (1955). It is not applicable to piping designed to ASME I (1965).

Note further that the limit on S_c is:

$$S_A = f(1.25\ S_c + 0.25\ S_h)$$

where:

S_c = allowable stress in cold condition

S_h = allowable stress in hot condition

f = stress-range reduction factor to account for cyclic conditions as given in Table A4-7.

Table A4-7

Stress Reduction Factor - f

No. of Full Temperature Cycles over Expected Life	Stress Reduction Factor, f
7,000 and less	1.0
14,000 and less	0.9
22,000 and less	0.8
45,000 and less	0.7
100,000 and less	0.6
250,000 and less	0.5

Note that for ferritic steels, both S_c and S_h approximately equal 0.9* (1/4 UTS) such that:

$$S_A = 1.5\ f(0.9)\ \frac{UTS}{4} = 0.34\ f(UTS)$$

(ferritic steel)

For austenitic steels, S_h is approximately equal to $\frac{4}{5}\ S_c$ so that:

$$S_A = f\left[\frac{5}{4}\left(\frac{UTS}{4}\right) + \frac{1}{4}\left(\frac{4}{5}\right)\left(\frac{UTS}{4}\right)\right](0.9)$$

$$S_A = 0.33\ f\ (UTS)$$

(austenitic steel)

* The factor of 0.9 is used to account for a butt-welded joint efficiency.

TABLE NB-3682.2-1
STRESS INDICES FOR USE WITH EQUATIONS IN NB-3650

(Not Applicable for $D_o/t>100$)

Piping Products and Joints	Internal Pressure B_1	Internal Pressure C_1	Internal Pressure K_1	Moment Loading[5] B_2	Moment Loading[5] C_2	Moment Loading[5] K_2	Thermal Loading C_3	Thermal Loading C_3	Thermal Loading K_3
Straight pipe, remote from welds or other discontinuities	0.5	1.0	1.0[1]	1.0	1.0	1.0	1.0	...	1.0
Girth butt weld between straight pipe or between pipe and butt welding components[2,12]									
(a) flush	0.5	1.0	1.1[1]	1.0	1.0	1.1	1.0	0.5	1.1
(b) as welded $t>3/16$ in. [and $\delta/t\leq0.1$]	0.5	1.1	1.2[1]	1.0	1.0	1.8	1.0	0.5	1.7
(c) as welded $t\leq3/16$ in. [or $\delta/t>0.1$]	0.5	1.1	1.2[1]	1.0	1.4	2.5	1.0	0.5	1.7
Girth fillet weld to socket weld fittings, slip on flanges, or socket welding flanges	0.75	2.0	3.0	1.5	2.1	2.0	1.8	1.0	3.0
Longitudinal butt welds in straight pipe[2]									
(a) flush	0.5	1.0	1.1[1]	1.0	1.0	1.1	1.0	...	1.1
(b) as welded $t>3/16$ in.	0.5	1.1	1.2[1]	1.0	1.2	1.3	1.0	...	1.2
(c) as welded $t\leq3/16$ in.	0.5	1.4	2.5[1]	1.0	1.2	1.3	1.0	...	1.2
Tapered transition joints per NB-4425 and Fig. NB-4233-1[2,6,12]									
(a) flush or no girth weld closer than $\sqrt{rt}$	0.5	[6]	1.2	1.0	[6]	1.1	[6]	1.0	1.1
(b) as welded	0.5	[6]	1.2	1.0	[6]	1.8	[6]	1.0	1.7
Branch connections per NB-3643[3,11]	1.0	2.0	1.7	[7]	[7]	[7]	1.8	1.0	1.7
Curved pipe or butt welding elbows per ANSI B16.9, ANSI B16.28 or MSS SP48[10,11]	1.0	$\frac{2R-r}{2(R-r)}$[4]	1.0[1]	[8]	[8]	1.0	1.0	0.5	1.0
Butt-welding-tees per ANSI B16.9 or MSS SP48[10,11]	1.0	1.5	4.0	[9]	[9]	1.0	1.0	0.5	1.0
Butt-welding reducers per ANSI B16.9 or MSS SP48[10,11]	1.0	[13]	[14]	1.0	[13]	[14]	1.0	0.5	1.0

NOTES:

(1) (a) The values of K_1 shown for these components are applicable for components with out of roundness not greater than $0.08t$, where out of roundness is defined as $D_{max}-D_{min}$, and

D_{max} = maximum outside diameter of cross section, in.
D_{min} = minimum outside diameter of cross section, in.
t = nominal wall thickness, in.

(b) If the cross section is out of round such that the cross section is approximately elliptical, an acceptable value of K_1 may be obtained by multiplying the tabulated values of K_1 by the factor F_{1a}:

$$F_{1a}=1+\frac{D_{max}-D_{min}}{t}\left[\frac{1.5}{1+0.455\left(\frac{D_o}{t}\right)^3\frac{p}{E}}\right]$$

where D_o = nominal outside diameter, in.
p = internal pressure, psi (use maximum value of pressure in the load cycle under consideration)
E = modulus of elasticity of material at room temperature, psi

Other symbols are defined in (a).

(c) If $D_{max}-D_{min}$ is not greater than $0.08D_o$, and acceptable value of K_1 may be obtained by multiplying the tabulated values of K_1 by the factor F_{1b}:

$$F_{1b}=1+\frac{M\,S_y}{P\,D_o/2t}$$

where M = 2 for ferritic steels and nonferrous materials except nickel-chrome-iron alloys and nickel-iron-chrome alloys
M = 2.7 for austenitic steels, nickel-chromium-iron alloys, and nickel-iron-chromium alloys
S_y = yield strength at design temperature, psi (Tables I-2.0)
P = Design Pressure, psi

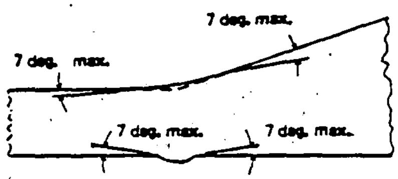
D_o and t are defined in (a) and (b).

(2) Welds in accordance with the requirements of this Subsection.

(a) *Flush welds* are defined as those welds which have been ground on both interior and exterior surface to remove weld irregularities and abrupt changes in contour due to misalignment. Thickness of weld reinforcement (total inside and outside) shall not exceed $0.1t$. No concavity on the root side is permitted. The finished contour shall nowhere have a slope (angle measured from tangent to

Table A4-8 (Cont.)

surfaces of pipe or, on tapered transition side of weld, to the nominal transition surface) greater than 7 deg., see sketch below.



(b) *As-welded* is defined as welds not meeting the special requirements for *flush welds*. At the intersection of a longitudinal butt weld in straight pipe with a girth butt weld or girth fillet weld.

$$B_1 = 0.5 \text{ and } B_2 = 1.0$$

The C_1, K_1, C_2, K_2, and K_3 indices shall be the product of the respective indices for the longitudinal weld and girth weld. For example, at the intersection of an *as-welded* girth butt weld with an *as-welded* longitudinal butt weld, C_1 is 1.1X1.1=1.21. C_2 for a girth fillet weld intersecting a longitudinal weld shall be taken as 2.0.

(3) The stress indices given are applicable only to branch connections in straight pipe with branch axis normal to the pipe surface and which meet the dimensional requirements and limitations of NB-3686 and Fig. NB-3686.1-1.

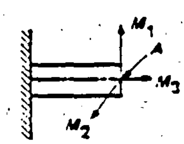
(4) R = curved pipe or elbow radius, in.
r = mean radius of cross section, in.
= $(D_o - t)/2$, where t = nominal wall thickness

(5) The values of moment, M_t, shall be obtained from an analysis of the piping system in accordance with NB-3672. M_t is defined as the range of moment loading applied during the specified operating cycle.

Straight Through Pipe

M_t = moment at Point A

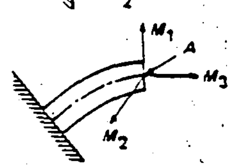
$M_t = \sqrt{M_1^2 + M_2^2 + M_3^2}$



Curved Pipe or Welding Elbow

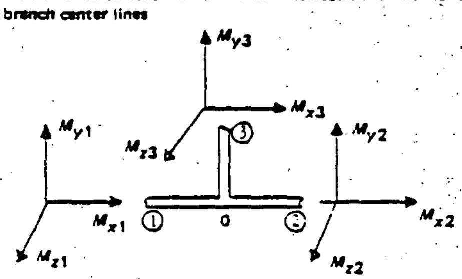
M_t = moment at Point A

$M_t = \sqrt{M_1^2 + M_2^2 + M_3^2}$



Branch Pipe

Moments calculated for point at intersection of run and branch center lines



For M_b

$$M_b = \sqrt{M^2_{x3} + M^2_{y3} + M^2_{z3}} = \text{resultant moment on branch}$$

For M_r

$$M_r = \sqrt{M^2_{zr} + M^2_{yr} + M^2_{zr}} = \text{resultant moment on run}$$

where M_{xr}, M_{yr} and M_{zr} are determined as follows:

If M_{i_1} and M_{i_2} have the same algebraic sign, then M_{ir}=0. If M_{i_1} and M_{i_2} have different algebraic signs, then M_{ir} is the smaller of M_{i_1} or M_{i_2} where $i = x, y, z$.

For branch connections of tees, the M_i term of Equations (9), (10), (11), or (12) shall be replaced by the following pairs of terms:

Equation (9) $\quad B_{1b}\dfrac{M_b}{Z_b} + B_{1r}\dfrac{M_r}{Z_r}$

Equations (10) & (12) $\quad C_{1b}\dfrac{M_b}{Z_b} + C_{1r}\dfrac{M_r}{Z_r}$

Equation (11) $\quad C_{1b}K_{1b}\dfrac{M_b}{Z_b} + C_{1r}K_{1r}\dfrac{M_r}{Z_r}$

where

$$Z_b = \pi(r'_m)^2 T'_b$$

$$Z_r = \pi Rm^2 Tr$$

For branch connections per NB-3643 see Footnote 3 above
r'_m, T'_b, R_m, and T_r are defined in Fig. NB-3686.1-1
For butt-welding tees per ANSI B16.9 or MS SP 48:
r'_m = mean radius of designated branch pipe
T'_b = nominal wall thickness of designated branch pipe
R_m = mean radius of designated run pipe
T_r = nominal wall thickness of designated run pipe

(6) Indices are applicable to tapered transition joints with a girth butt weld at the thin end of the transition.
$C_1 = 1.3 + 0.003\,(D_o/t) + 1.5\,(\delta/t)$
but not greater than 2.0
$C_2 = 1.4 + 0.004\,(D_o/t) + 3.0\,(\delta/t)$
but not greater than 2.1
$C_3 = 1.2 + 0.008\,(D_o/t)$

(7) $B_{1b} = 0.75\,C_{1b}$ but not less than 1.0
$B_{1r} = 0.75\,C_{1r}$ but not less than 1.0
$C_{1b} = 3(R_m/T_r)^{2/3}\,(r'_m/R_m)^{1/2}\,(T'_b/T_r)\,(r'_m/r_p)$, but not less than 1.5
R_m, T_r, r'_m, T'_b, and r_p are defined in Fig. NB-3686.1-1
$K_{1b} = 1.0$
$C_{1r} = 0.8\,(R_m/T_r)^{2/3}\,(r'_m/R_m)$, but not less than 1.0
$K_{1r} = 2.0$
The product of $C_{1r}K_{1r}$ shall be a minimum of 3.0

(8) $C_2 = \dfrac{1.95}{b_1^{2/3}}$, but not less than 1.5; $B_2 = 0.75\,C_2$

$b_1 = \dfrac{tR}{r^2}$, where t = nominal pipe wall thickness
R = bend radius of curved pipe or elbow
r = mean pipe radius
= $(D_o - t)/2$

(9) $B_{2b} = B_{2r} = 0.75\,C_{2b}$

$C_{2b} = C_{2r} = 0.67\,(R_m/T_r)^{2/3}$, but not less than 2.0

R_m = mean radius of designated run pipe

T_r = nominal wall thickness of designated run pipe

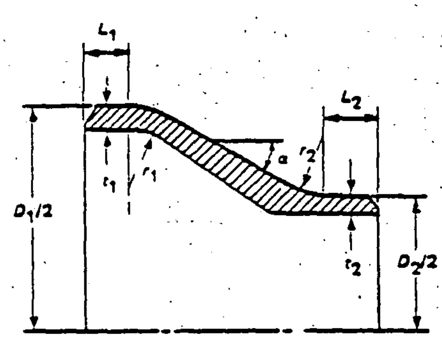
$K_{2b} = K_{2r} = 1.0$

(10) The K indices given for fittings per ANSI B16.9, ANSI B16.28, or MSS SP48 apply only to seamless fittings with no connections, attachments, or other extraneous stress raisers on the bodies thereof. For fittings with longitudinal butt welds, the K indices shown shall be multiplied by the 1.1, for *flush welds* as defined in Note 2; by 1.3 for welds not meeting the requirements for *flush welds*.

(11) The stress indices given predict stresses which occur in the body of a fitting. It is not required to take the product of stress indices for two piping products such as a tee and a reducer, or a tee and a girth butt weld when welded together except for the case of curved pipe or butt welding elbows welded together or joined by a piece of straight pipe the length of which is less than 1 pipe diameter. For this specific case the stress index for the curved pipe or butt welding elbow must be multiplied by that for the girth butt weld. Excluded from this multiplication are the B_1 and C'_1 indices. Their value is to be: $B_1 = 1.0$, $C'_1 = 0.50$.

(12) δ is defined as the maximum permissible mismatch as shown in Fig. NB-4233-1. A value of δ less than 3/32 in. may be used provided the smaller mismatch is specified for fabrication. For *flush welds*, defined in footnote (2), δ may be taken as zero.

(13) *(a)* Nomenclature



t_1 = nominal wall thickness, large end
t_2 = nominal wall thickness, small end
D_1 = nominal outside diameter, large end
D_2 = nominal outside diameter, small end
α = cone angle, deg.

(b) The indices given in (c) and (d) apply if the following conditions are met.

(1) Cone angle, α, does not exceed 60 deg. and the reducer is concentric.

(2) The wall thickness is not less than t_{1m} throughout the body of the reducer, except in and immediately adjacent to the cylindrical portion on the small end, where the thickness shall not be less than t_{2m}. Wall thicknesses t_{1m} and t_{2m} are to be obtained by Equation (1), NB-3641.1.

(c) Reducers in which r_1 and $r_2 \geq 0.1 D_1$

$$C_1 = 1 + 0.0058\,\alpha\sqrt{D_n/t_n}$$

$$C_2 = 1 + 0.38\,\alpha^{4}(D_n/t_n)^{0.4}(D_2/D_1 - 0.5)$$

where D_n/t_n is the larger of D_1/t_1 and D_2/t_2.

(d) Reducers in which r_1 and/or $r_2 < 0.1 D_1$

$$C_1 = 1 + 0.00465\,\alpha^{1.285}(D_n/t_n)^{0.39}$$

$$C_2 = 1 + 0.0185\,\alpha\sqrt{D_n/t_n}$$

where D_n/t_n is the larger of D_1/t_1 and D_2/t_2.

(14) The K indices given in (a), (b), and (c) apply for reducers attached to the connecting pipe with *flush* or *as-welded* girth welds as defined in footnote (2). Note that the connecting girth weld must also be checked separately for compliance.

(a) For reducers connected to pipe with *flush* girth butt welds:

$$K_1 = 1.1 - 0.1\,\frac{L_m}{\sqrt{D_m t_m}}, \text{ but not less than } 1.0$$

$$K_2 = 1.1 - 0.1\,\frac{L_m}{\sqrt{D_m t_m}}, \text{ but not less than } 1.0$$

where $L_m/\sqrt{D_m t_m}$ is the smaller of $L_1/\sqrt{D_1 t_1}$ and $L_2/\sqrt{D_2 t_2}$.

(b) For reducers connected to pipe with *as-welded* girth butt welds where $t_1, t_2 > 3/16$ in. and $\delta_1/t_1, \delta_2/t_2 \leq 0.1$:

$$K_1 = 1.2 - 0.2\,\frac{L_m}{\sqrt{D_m t_m}}, \text{ but not less than } 1.0$$

$$K_2 = 1.8 - 0.8\,\frac{L_m}{\sqrt{D_m t_m}}, \text{ but not less than } 1.0$$

where $L_m/\sqrt{D_m t_m}$ is the smaller of $L_1/\sqrt{D_1 t_1}$ and $L_2/\sqrt{D_2 t_2}$.

(c) For reducers connected to pipe with *as-welded* girth butt welds, where t_1 or $t_2 \leq 3/16$ in. or δ_1/t_1 or $\delta_2/t_2 > 0.1$:

$$K_1 = 1.2 - 0.2\,\frac{L_m}{\sqrt{D_m t_m}}, \text{ but not less than } 1.0$$

$$K_2 = 2.5 - 1.5\,\frac{L_m}{\sqrt{D_m t_m}}, \text{ but not less than } 1.0$$

where $L_m/\sqrt{D_m t_m}$ is the smaller of $L_1/\sqrt{D_1 t_1}$ and $L_2/\sqrt{D_2 t_2}$.

Noting that $M_i = \lambda_i M_b$ and conservatively assuming that a nuclear power plant designed in accordance with past codes is such that $S_E = S_A$ and recalling that $C_2 \doteq 1.9\ i$, the second term in the expression for S_p becomes:

$$K_2 C_2 \frac{D_o}{2I} M_i = \lambda_{2i}\ K_2\ 1.9 \left(i \frac{D_o}{2I} M_b \right)$$

$$= 1.9\ S_A\ (\lambda_{2i}\ K_2) = \quad 0.65f\ \lambda_{2i}\ K_2\ (UTS) \qquad (2a)$$

for ferritic steels

$$0.63f\ \lambda_{2i}\ K_2\ (UTS) \qquad (2b)$$

for austenitic steels

Past piping codes determine pipe thickness in accordance with the formula[1]

$$t_m = \frac{PD_o}{2(S_h + 0.4P)} + C \qquad \text{(Equation 1, Section 1 of Reference 4),}$$

where:

P = design pressure

D_o = outside pipe diameter

C = allowance for corrosion

S_h = allowable stress at temperature

t_m = minimum pipe wall thickness

When C is small compared to the thickness and 0.4P is small compared to S, the minimum thickness is approximated by

$$t_m \doteq \frac{PD_o}{2S}$$

Since the actual pipe thickness, t, is not less than t_m, we have

$$\frac{PD_o}{2t} \leq S_h = \begin{cases} \frac{1}{4}\ (UTS)(0.9) & \text{ferritic steel} \\ \frac{1}{5}\ (UTS)(0.9) & \text{austenitic steel} \end{cases}$$

1. Based on y = 0.4 for ferritic materials below 900°F.

Assuming that the range of service pressure P_o is a fraction λ_i of the design pressure, we have

$$\frac{P_o D_o}{2t} = \frac{\lambda_i P D_o}{2t} \leq \lambda S_h = \begin{array}{l} 1/4\ \lambda_i (UTS)(0.9) \text{ ferritic steels} \\ 1/5\ \lambda_i (UTS)(0.9) \text{ austenitic steels} \end{array}$$

so that the first term in the expression for S_p may be put in the form

$$K_1 C_1 \left(\frac{P_o D_o}{2t} \right) = \begin{array}{ll} \frac{1}{4} \lambda_1 \ (UTS)\ K_1 C_1 \ (0.9) \text{ ferritic steel} & (3a) \\ \frac{1}{5} \lambda_1 \ (UTS)\ K_1 C_1 \ (0.9) \text{ austenitic steel} & (3b) \end{array}$$

Substituting Equations 2a and 3a on Equation 1 and neglecting the fourth term in Equation 1, we obtain:

$$S_p = \frac{1}{4} (0.9) \lambda_1 K_1 C_1 \ (UTS) + 0.65 f \ \lambda_{2i} K_2 \ (UTS)$$

$$+ \frac{1}{(1-\nu)} E\alpha |\Delta T_2| + K_3 \frac{E\alpha}{2(1-\nu)} |\Delta T_1| \qquad (1a)$$

for ferritic steels.

Similarly substituting Equations 2b and 3b in Equation 1 and neglecting the fourth term in Equation 1, we obtain:

$$S_p = \frac{0.9}{5} \lambda_1 \ (UTS)\ K_1 C_1 + 0.63 f \ \lambda_{2i} \ K_2 \ (UTS)$$

$$+ \frac{1}{(1-\nu)} E\alpha |\Delta T_2| + K_3 \frac{E\alpha}{2(1-\nu)} |\Delta T_1| \qquad (1b)$$

for austenitic steels.

These expressions can be further simplified by noting from Tables I-5.0 and I-6.0 [1e] (Winter 1978 Addenda) that:

$$\frac{E\alpha}{(1-\nu)} = \frac{27.9 \times 10^3 \times 7.3 \times 10^{-6}}{0.7} = 0.291 \frac{ksi}{°F} \text{ for ferritic steels}$$

$$\frac{E\alpha}{(1-\nu)} = \frac{28.3 \times 10^3 \times 9.4 \times 10^{-6}}{0.7} = 0.380 \frac{ksi}{°F} \text{ for austenitic steels}$$

Substituting appropriately in Equations 1a and 1b and multiplying the second term by 1.3 to account for movements of pipe ends attached to equipment, we have:

$$S_p = 0.23\ \lambda_1\ (UTS)\ K_1C_1 + 0.85f\ \lambda_{2i}\ K_2\ (UTS)$$

$$+ 0.291\ |\Delta T_2| + 0.145\ K_3\ |\Delta T_1| \qquad (1a)$$

for ferritic steels

$$S_p = 0.18\ \lambda_1\ (UTS)\ K_1C_1 + 0.82f\ \lambda_{2i}\ K_2\ (UTS)$$

$$+ 0.380\ |\Delta T_2| + 0.190\ K_3\ |\Delta T_1| \qquad (1b)$$

for austenitic steels

where:

λ_1 = (range of service pressure)/(design pressure) = $\frac{P_o}{P}$

UTS = ultimate tensile strength of material at 70°F

f = stress-reduction factor (see Table A4-7)

λ_{2i} = [Change in temperature for ith service cycle] divided by [maximum operating temperature - 70°F]

$= |\Delta T_i| \ / \ |(T_o)_{max} - 70°F|$

$K_1, C_1, K_2, |\Delta T_2|, K_3, |\Delta T_1|$ = previously defined.

The alternating stress intensity, S_{alt}, is one half of the peak stress intensity, S_p; that is:

$$S_{alt} = \frac{1}{2} S_p$$

For a given value of alternating stress corresponding to actual n_i service cycles, the number of such cycles N_i allowed may be found from the applicable design fatigue curve, Figure I-9.0 [1e]. The usage factor for the given n_i service cycles is defined as:

$$U_i = \frac{n_i}{N_i}$$

The cumulative usage factor, $U = \Sigma U_i$ shall not exceed 1.0 as required by NB-3222.4(e)(5) of Reference 1b.

Equations 1a and 1b may be used to evaluate Class 1 piping designed in accordance with past code requirements from the viewpoint of present code requirements. Some examples will be used to illustrate use of the formulae.

Example 1

Consider the 42-in ID primary coolant piping between the reactor vessel and steam generator for the Palisades plant [11]. These pipes were fabricated from 3-3/4-in thick ASTM 516, Gr. 70 plate with a rolled band 1/4-in nominal cladding of 304L stainless steel. A review of transient conditions given in Section 4.2.2 of Reference 11 indicates the following step power change service cycles:

1. 15,000 cycles of 10% full load step power changes increasing from 10% to 90% of full power and decreasing from 100% to 20% of full power

2. 500 reactor trips from 100% power.

Examination of Figure 4-8 of Reference 11 shows the reactor coolant temperature as a straight line function of NSSS power. Considering the hot temperature function, note that this full power T = 594°F and at 0% power T = 532°F. This indicates that the temperature change associated with the reactor trips is 62°F. For each ΔT, we shall assume that $\Delta T_1 = 0.75\ \Delta T$ and $\Delta T_2 = 0.25\ \Delta T$. A more accurate determination of ΔT_1 and ΔT_2 may be obtained from Reference 12, so that:

Service Cycle - 1 $\qquad n_1 = 15{,}000 \qquad$ ΔT of Service Cycle 1 = 62°F

$$\Delta T_1 = 0.75 \times 62 = 46.5°F$$

$$f = 0.8$$

$$\Delta T_2 = 0.25 \times 6.2 = 15.5°F$$

Service Cycle - 2 $n_2 = 500$ ΔT of Service Cycle 2 = 62°F

$$\Delta T_1 = 0.75 \times 62 = 46.5°F$$

$f = 1.0$

$$\Delta T_2 = 0.25 \times 62 = 15.5°F$$

Elbow

Consider an elbow in which the bend radius R is 5 times the pipe diameter 2r

$$2r = 42.5 + 3.75 = 46.25$$

$$r = 23.13$$

$$R = 5 \times 46.25 = 231.25, \quad 2R = 462.5$$

From Table A4-8 for curved pipe or a butt welding elbow

$$K_1 = 1.0$$

$$C_1 = (2R - r)/[2(R - r)]$$

$$= (462.5 - 23.13)/[2 \times (231.25 - 23.13)]$$

$$= 1.06$$

$$K_2 = 1.0, \quad K_3 = 1.0$$

Longitudinal Butt Weld-Straight Pipe

A longitudinal butt weld flush in a straight pipe would be a more critical element to investigate since for this element:

$$K_1 = 1.1, \quad C_1 = 1.0, \quad K_2 = 1.1, \quad K_3 = 1.1$$

Branch Connections

A branched connection which may possibly have been used to connect the 12-in Schedule 140 316 stainless steel surge line from pressurizer to the hot leg would have stress indices as follows:

$$K_2 = 2.0, \quad K_3 = 1.7, \quad K_1 = 2.2, \quad C_1 = 1.5$$

and obviously would be most critical. These K_1 and C_1 values are taken from the Summer of 1979 Addenda [1].

Determination of Usage Factors

$$UTS = 70 \text{ ksi} \quad (\text{ASTM } 516 - \text{Gr. } 70)$$

For the i^{th} service cycle:

$$(S_p)_i = 0.23\lambda_1 \times 70 \times K_1C_1 + 0.85 \times 70 f K_2\lambda_{2i}$$

$$+ 0.291|\Delta T_2| + 0.145 K_3|\Delta T_1|$$

Assuming that the pressurizer maintains pressure within $\pm$ 50 psi during these service cycles, then:

$$\lambda_1 = \frac{100}{2500} = 0.04 \text{ so that}$$

$$(S_p)_i = 0.644 K_1C_1 + 59.5 \lambda_{2i} f K_2 + 0.291|\Delta T_2| + 0.145 K_3|\Delta T_1|$$

Determination of λ_{2i} for each service cycle $\qquad \lambda_{2i} = \dfrac{\Delta T_i}{[(T_o)_{max} - 70°]}$

$(T_o)_{max}$ = maximum operating temperature = 594°F

ΔT of Service Cycle 1 = 62°F $\quad \Delta T$ of Service Cycle 2 = 62°F

$$\lambda_{21} = 62/(594 - 70) = 0.12$$

$$\lambda_{22} = 62/(594 - 70) = 0.12$$

finally $(S_{alt})_i = \frac{1}{2} (S_p)_i$

A summary of the results for each of the two service cycles as it affects the usage of the three elements is given in Tables A4-9 through A4-11. It is apparent from the usage factors calculated in these tables that cumulative damage from cycles 1 and 2 is negligible.

Table A4-9

Usage Factors Due to Thermal Gradient Through Thickness

Example: Hot Leg of Palisades Primary Coolant Piping

Piping Element: Elbow

$$K_1 = 1.0, \quad C_1 = 1.06, \quad K_2 = 1.0, \quad K_3 = 1.0$$

Service Cycle - 1 $\quad n_1 = 15{,}000 \quad f = 0.8 \quad \lambda_{21} = 0.12$

$$\Delta T_2 = 15.5°F \qquad \Delta T_1 = 46.5°F$$

$$S_p = 0.644\ K_1 C_1 + 59.5\ f\ K_2 \lambda_{2i} + 0.291|\Delta T_2| + 0.145\ K_3 |\Delta T_1| = 18.7 \text{ ksi}$$

$$S_{alt} = \frac{1}{2} S_p = 9.3 \text{ ksi}$$

$$N_1 > 10^6 \quad \text{(See Figure A4-2)} \quad U_1 = \frac{n_1}{N_1} = 0.02$$

Service Cycle - 2 $\quad n_2 = 500 \quad f = 1.0 \quad \lambda_{22} = 0.12$

$$\Delta T_2 = 15.5°F \qquad \Delta T_1 = 46.5\ °F$$

$$S_p = 0.644\ K_1 C_1 + 59.5\ f\ K_2 \lambda_{22} + 0.291|\Delta T_2| + 0.145\ K_3 |\Delta T_1| = 19.1 \text{ ksi}$$

$$S_{alt} = \frac{1}{2} S_p = 9.5 \text{ ksi}$$

$$N_2 > 10^6 \quad \text{(See Figure A4-2)} \quad U_2 = \frac{n_2}{N_2} = 0$$

$$U_1 + U_2 = 0.02$$

Table A4-10

Usage Factors Due to Thermal Gradient Through Thickness

Example: Hot Leg of Palisades Primary Coolant Piping

Piping Element: Longitudinal Butt Weld-Straight Pipe

$K_1 = 1.1, \quad C_1 = 1.0, \quad K_2 = 1.1, \quad K_3 = 1.1$

Service Cycle - 1 $\quad n_1 = 15{,}000 \quad f = 0.8 \quad \lambda_{21} = 0.12$

$\Delta T_2 = 15.5°F \quad \Delta T_1 = 46.5°F$

$$S_p = 0.644\ K_1C_1 + 59.5\ f\ K_2\lambda_{21} + 0.291|\Delta T_2| + 0.145\ K_3|\Delta T_1| = 18.9 \text{ ksi}$$

$$S_{alt} = \frac{1}{2} S_p = 9.5 \text{ ksi}$$

$N_1 > 10^6$ (See Figure A4-2) $\quad U_1 = \frac{n_1}{N_1} = 0.02$

Service Cycle - 2 $\quad n_2 = 500 \quad f = 1.0 \quad \lambda_{22} = 0.12$

$\Delta T_2 = 15.5°F \quad \Delta T_1 = 46.5°F$

$$S_p = 0.644\ K_1C_1 + 59.5\ f\ K_2\lambda_{22} + 0.291|\Delta T_2| + 0.145\ K_3|\Delta T_1| = 20.5 \text{ ksi}$$

$$S_{alt} = \frac{1}{2} S_p = 10.2 \text{ ksi}$$

$N_2 > 10^6$ (See Figure A4-2) $\quad \frac{U_2}{N_2} = 0$

$$U_1 + U_2 = 0.02$$

Table A4-11

Usage Factors Due to Thermal Gradient Through Thickness

Example: Hot Leg of Palisades Primary Coolant Piping

Piping Element: Branch Connection (K_1 and C_1 from Summer 1979 Addenda [1])

$K_1 = 2.2, \quad C_1 = 1.5, \quad K_2 = 2.0, \quad K_3 = 1.7$

Service Cycle - 1 $\quad n_1 = 15{,}000 \quad f = 0.8 \quad \lambda_{21} = 0.12$

$\Delta T_2 = 15.5°F \quad \Delta T_1 = 46.5°F$

$$S_p = 0.644\ K_1C_1 + 59.5\ f\ K_2\lambda_{2i} + 0.291|\Delta T_2| + 0.145\ K_3|\Delta T_1| = 29.5\text{ ksi}$$

$$S_{alt} = \frac{1}{2}S_p = 14.8\text{ ksi}$$

$N_1 > 10^6$ (See Figure A4-2) $\quad U_1 = \frac{n_1}{N_1} = 0.02$

Service Cycle - 2 $\quad n_2 = 500 \quad f = 1.0 \quad \lambda_{22} = 0.12$

$\Delta T_2 = 15.5°F \quad \Delta T_1 = 46.5°F$

$$S_p = 0.644\ K_1C_1 + 59.5\ f\ K_2\lambda_{22} + 0.291|\Delta T_2| + 0.145\ K_3|\Delta T_1| = 25.2\text{ ksi}$$

$$S_{alt} = \frac{1}{2}S_p = 12.6\text{ ksi}$$

$N_2 = 10^6$ (See Figure A4-2) $\quad U_2 = \frac{n_2}{N_2} = 0.0005$

$$U_1 + U_2 = 0.0205$$

Example 2

The same Palisades primary coolant piping will be considered as in Example 1, except that only a branch connection will be considered for service cycles in which there is a more significant change in average metal temperature as follows:

Service Cycle $i-n_i$	ΔT_i (°F)	λ_{2i} $(\lvert\Delta T_i\rvert/(524))$
1-15,000 (10% to 100% full power)	59°	0.113
2-15,000 (50% to 100% full power)	31°	0.059
3-15,000 (10% to 90% full power)	55°	0.105
4-15,000 (100% to 20% full power)	49°	0.094

Comparing the above values λ_{2i} with the value of 0.12 obtained in Example 1, the usage factors associated with the above four additional cycles are negligible.

Comparison With ASME I (1965) Requirements

Piping from a BWR reactor vessel up to and including the first isolation valve external to the drywell could have been designed and built to the following requirements:

a. ASME I (1965)
b. ASME I (1965) and B31.1 (1955).

If requirement (a) was invoked, expansion stress limits due to cyclic thermal loading are not specifically imposed. However, ASME I (1965) does require consideration of loads other than working pressure or static head, which "increases the average stress by more than 10% of the allowable working stress." For example, the allowable working stress for welded alloy steel SA-250-T1 at 600°F is 11,700 psi. Expansion stresses would typically be in excess of 1170 psi and should be considered. Licensees that designed their piping based on ASME I (1965) criteria should furnish details as to how thermal stresses were considered.

If requirement (b) was invoked, then paragraph 102(b) of Section 1 [4] requires that valves, fittings, and piping for boilers as prescribed in ASME I are within the scope of B31.1, but provisions of ASME I shall govern where they exceed corresponding requirements of B31.1. Accordingly, piping built to requirement (b) would have to satisfy the specified expansion stress limits of B31.1 due to cyclic thermal loads as well as the full radiography requirements for all longitudinal and circumferential fusion welded butt joints of ASME I.

Welding Requirements

Full radiography of welded joints in piping, pumps, and valves as stipulated in past [4] and current codes [1,13] depends on weld joint category, pipe size, and code class as shown in the following table:

Full Radiography Code Requirements
for Welded Joints in Piping, Pumps, and Valves

Description of Welded Joint	Current Codes: ASME III (1977) Class 1	2	3	ANSI B16.34 (1977) Class Standard	Special	Past Codes(1) ASA B31.1 (1955) & ASME I (1965)
A. Longitudinal	Yes	Yes	No (2)	No	Yes	No (1)
B. Circumferential	Yes	Yes	No	No	Yes	No (1)
C. Flange connection	Yes	Yes (3)	No	No	Yes	No
D. Branch and piping connections to pipes, pumps, and valves of nominal pipe size exceeding 4" as follows						
(1) Butt-welded	Yes	Yes	No	No	Yes	No
(2) Corner-welded full penetration	Yes	Yes	No	No	Yes	No
(3) Full penetration	Yes	Yes	No	No	Yes	No

1. Full radiography of butt-welded joints may be specified under B31.1 (1955) but it is not mandatory. Full radiography is required for all longitudinal and circumferential fusion welded butt joints for pipes built to ASME I (1965) requirements.
2. Except when specified by material specification for piping in excess of 2 in nominal diameter.
3. When either member thickness exceeds 3/16 in.

In conclusion, full radiography was not required by the past code, but it is a current requirement for Class 1 and Class 2 welded joints for piping, pumps, and valves. It is recommended that welded Class 1 and Class 2 components and systems be checked to learn what radiography requirements were enforced.

4.3 PRESSURE VESSELS

The past code requirements for pressure vessels are given in one or more of the following ASME Boiler and Pressure Vessel Codes depending on the SEP nuclear plant group as defined in Table A1-1.

Group	Pressure Vessel Code
I	ASME III (1965) ASME VIII* (1965)
II	ASME VIII* (1962)
III	ASME VIII* (1956, 1959)

The current code requirements [1] and the past ASME III (1965) code are essentially the same with regard to significant items with the following exceptions:

Fracture Toughness - Class A Vessels

The current code, except for exempt materials as noted in Section 4.1, requires greater toughness than the past code. A comparison of current and past Charpy V-Notch acceptance levels at temperatures at least 60°F below the temperature at which the vessel is to be pressure tested is as follows:

	Past	Current
Minimum Absorbed Energy	15 to 35 ft-lb depending on yield strength	50 ft-lb
Mimimum Lateral Expansion	Not specified	35 mils

*Plus nuclear code cases.

It is recommended that past Class A vessels should be evaluated from the viewpoint of current Class 1 fracture toughness requirements as outlined in Section 4.1.

Fracture Toughness - Class B Vessels (Outside Scope)

The impact test requirements for Class B vessel materials built in accordance with Subsection B of ASME III (1965) are the same as for Class A vessel materials, except that the maximum test temperature should be at least 30°F lower than the lowest service metal temperature (LST). The current code permits Charpy V-Notch testing at temperatures up to the lowest service metal temperature. The acceptance standard for the C_v test of the current code, however, requires a lateral expansion between 20 and 40 mils and sets no absorbed energy requirement. The current code provides for exemptions from impact testing. Where the exemption does not apply, drop weight testing for materials exceeding 2.5-in thickness shall demonstrate a nil ductility transition temperature below the LST by 30°F for 2.5-in thick material, and increasing to 87°F for 12-in thick material as show in Figure A4-2.

Class B vessel materials built according to the past code and evaluated in accordance with the current fracture toughness requirements:

1. would satisfy current requirements provided the material thickness is less than 2.5 in

2. may not satisfy current requirements for thicknesses in excess of 3 in (exclusive of cladding) for those materials not otherwise exempt from impact testing as noted in Section 4.1.

Fracture Toughness - Class C Vessels

Materials for Class C vessels built in accordance with ASME III (1965) were required to satisfy impact testing provisions of ASME VIII (1965) [5]. Paragraph VCS-66(c) of Reference 5 exempts materials whose LST is -20°F or greater. Apparently, impact testing was intended primarily for outdoor vessels. The current code exempts materials for vessels whose LST exceeds

100°F. Therefore, all Class C vessels built in accordance with the past code should be evaluated in accordance with Section 4.1 Class 3[1] criteria to determine if current Class 3 requirements would be satisfied.

Design Requirements

Class A vessels designed in accordance with ASME III (1965) are based on an analysis which determines the stress distribution in the vessel. Stresses were combined, categorized, and limited in the same manner as is currently required for Class 1 design condition as well as the equivalence of service levels A and B, i.e., for expected operating and upset conditions which the vessel must withstand without substaining damage requiring repair. The basis for establishing design stress intensity values, S_m, as noted in Appendix II [3] as well as the basis for establishing fatigue curves is the same as current code requirements. In conclusion, Class A vessels designed in accordance with ASME III (1965) would satisfy current Class 1 vessel requirements for the design condition as well as service levels A and B.

Class A vessels were not, however, required to withstand loading conditions which may produce large deformations in the areas of gross structural discontinuities (service level C) or conditions which may produce gross general deformations (service level D) requiring removal of the vessel from service for repair.

The past codes do not specifically consider loading conditions, other than design, operating, and test. The FSARs for specific SEP plants may, however, consider the equivalent of emergency and faulted conditions. A discussion of the evaluation of the FSAR stress limits for these loads against current limits is presented in Section 4.1.4 of this appendix.

Class B vessels, as defined by ASME III (1965), are containment vessels, which are outside the scope of this study.

Class C vessels are designed in accordance with ASME VIII (1965) except that:

1. Class C vessels currently designated as Class 1 or Class 2 should be evaluated against Section 4.1 Class 1 or Class 2 criteria.

1. the exemptions from inspection defined in U-1(g) of Reference 5 are not applicable

2. longitudinal and circumferential welds for those Class C vessels which are or may be connected to the reactor coolant or moderator system during operation and Class C chambers in a multi-chamber vessel having at least one Class A chamber shall be full penetration welds and shall be fully radiographed, and shall satisfy the requirements of N-462.1 and N-462.2 of Reference 3 for Category A and B joints, respectively.

Stress limits for Class C vessels which would currently be classified as Class 3 vessels are essentially the same as for Class 3 vessels designed in accordance with the current code. The past code allowable normal stress was the lower of 1/4 (UTS) or 0.625 (YS) compared with a current allowable of the lower of 1/4 (UTS) or 0.677 (YS). The past code is at least as conservative as the current code.

The current code does set limits on combinations of primary membrane and bending stress at 3/2 S = YS.

Class C vessels which would currently be classified as Class 1 or Class 2 vessels should be evaluated against current Class 1 or Class 2 code requirements, with special attention being given to current radiography requirements.

Evaluation of past vessels for the equivalent of service levels C and D for stress limits set in the FSAR should be compared to current stress limits for these service levels.

Example

The Palisades FSAR classifies the pressurizer as a Class A vessel and defines the stress limit for the design basis accident (equivalent of service level D) as 10% above YS based on an equivalent elastic stress. Current requirements permit computed stress levels to exceed the YS by as much as 20% for an elastic analysis. We conclude that Class A Palisades vessels satisfy current requirements for level D loads.

Welding Requirements

The following table provides a comparison between current and past code requirements when radiographic examination of butt-welded joints is mandatory. The values given are thickness limits above which full radiographic examination of butt-welded joints is mandatory.

From the table, it can be seen that:

1. Vessels built to ASME III (1965) Class C requirements and currently classified as Class 2 or Class 3 would more than satisfy the current radiography requirements for joints of Category A or B. (Refer to NB-3351, NC-3351, and ND-3351 for definitions [1].)

2. Joints of Category C (Refer to NB-3351, NC-3351, and ND-3351 for definitions [1]) in a Class C vessel currently classified as Class 2 would have been examined in accordance with ASME VIII (1965) requirements, which do not satisfy current Class 2 requirements.

3. Vessels built to ASME III (1965) Class A or ASME VIII (1965) would satisfy current requirements for Class 1 and Class 3 vessels, respectively.

It is concluded that current Category C joints in Class 2 vessels built to past Class C requirements do not satisfy current radiography requirements.

4.4 PUMPS

Pumps furnished under the requirements of the Hydraulic Institute Standards [14] were designed to satisfy functional requirements. Integrity of the pressure boundary was not covered by this standard. The design of the pump pressure boundary should be evaluated in accordance with the current requirements of NB/NC/ND-3400 [1].

See Sections 4.1.5 and 4.2 of this Appendix for discussion of pump welding requirements.

4.5 VALVES

Class 1 valves current design requirements are given in Subarticle NB-3500 of Reference 1b. All Class 1 valve materials must meet the fracture toughness requirements of NB-2332. All Class 1 listed pressure rated valves should have a minimum body wall thickness as determined by ANSI B16.34 [13],

P-No. Material Classification	Current Code Requirements Code Class 1	2	3	Past Code Requirements ASME B&PV Sect. III (1965) Class A	Class C[1]	ASME VIII (1965)[6]
1	0[2]	3/16 in	1 1/4 in	0[2,4]	0[2,5]	1 1/4 in
3	0	3/16	3/4	0	0	3/4
4	0	3/16	5/8	0	0	5/8
5	0	3/16	0	0	0	0
7	0	3/16	5/8	0	0	See Note 3
8	0	3/16	1 1/2	0	0	See Note 3
9	0	3/16	See Note 3	0	0	5/8
10	0	3/16	5/8	0	0	0
11	0	3/16	5/8	0	0	See Note 3

1. ASME B&PV Code Section III, 1965 Edition, Class C may currently be classified as Class 2 or 3 of the current code.
2. All thicknesses require full radiography when "0" is indicated.
3. Requirements not specified for this P-No.
4. These requirements are for full penetration welded joints of Categories A, B, or C (N-463 [3]).
5. These requirements are for full penetration welded joints of Categories A or B (N-2113 [3]). Butt-welded joints of other categories shall satisfy the requirements of ASME B&PV Code Section VIII, 1965 edition.
6. Vessels containing lethal substances shall have welded joints for materials of all thicknesses fully radiographed.

except that the inside diameter, d_m, will be the larger of the basic valve body inside diameters in the region near the welding ends. Class 1 valves may be designed in accordance with either the standard design rules of NB-3530 through NB-3550 or the alternative design rules of NB-3512.2. Alternative design rules require either computer analysis or experimental stress analysis procedures.

Listed pressure rated Class 1 valves should be hydrostatically tested to assure integrity of the pressure boundary (leakage through the stem packing is not a cause for rejection) at not less than 1.5 times the 100°F rating rounded off to the next higher 25-psi increment as required by Reference 13, except that valves with a primary pressure rating of less than Class 150 will be subjected to the required test pressure for Class 150 rated valves.

Class 1 valves may be subjected to normal duty within the cyclic load limits of NB-3550; otherwise the valve may have to be designed in accordance with the alternative design rules for severe duty applications.

Class 1 valves are to be designed for service levels A, B, C, and D with stress limits of NB-3525 through NB-3527 [1b]. Stress limits for level B loads are based on 110% of operating limits. Level C pressures are limited to 120% of operating limits. Pipe reaction stresses for level C loads are limited to 1.8 S_m for the valve body material at 500°F, with S taken at 1.2 YS for the pipe at 500°F. Primary and secondary stresses for level C loads are based on $C_p = 1.5$, $Q_T = 0$, and limited to 2.25 S_m. Level D loads may be evaluated in accordance with Appendix F [1e].

A design report for Class 1 valves will be prepared in accordance with the requirements of NB-3560 [1b].

Class 1 valves designed in accordance with the standard rules must satisfy the body shape rules of NB-3544 which are intended to limit the local stress index to a maximum of 2.0. Primary and secondary stress intensities may then be calculated by the formulas given in NB-3545.1 and NB-3545.2 [1b], respectively, and subject to the stress limits described in Section 4.1.1 for Class 1 items. Fatigue evaluation is performed by the rules and formulas of NB-3545.3.

Comparison With Past Requirements

The past code [4] required that steel valves for power piping systems:

1. be recommended for the intended service by the manufacturer
2. be made from code materials suitable for the pressure and temperature
3. have a minimum body metal thickness as required for ASA B16.5 fittings [15]
4. shall be hydrostatically tested as required by Reference 15, i.e., 1.5 times the 100°F rating rounded off to the next higher 25-psi increment, using water not above 125°F, with no leakage through the shell.

Note that the minimum body thickness of valves based on the current code would be based on ANSI B16.34 [13].

As an example, consider a 2500-lb valve designed in accordance with the past code [15]. Body thickness would be based on Table 33 [15]. Comparison with current requirements may be obtained from Table 3 [13] as shown in the following table:

Minimum Wall Thickness Based on Past and Current Codes

Nominal Pipe Size (in)	Inside Diameter (in)	2500-lb Class Minimum Wall Thickness Past Code Table 33 [15]	2500-lb Class Minimum Wall Thickness Current Code Table 3 [13]
4	2.88	1.09	1.09
5	3.63	1.34	1.34
6	4.38	1.59	1.59
8	5.75	2.06	2.06
10	7.25	2.59	2.59
12	8.63	3.03	3.03

Notice that past valves would satisfy current thickness requirements.

It is concluded that Class 1 valves designed in accordance with past requirements would satisfy current requirements with the following possible exceptions:

1. Fracture toughness requirements may not be satisfied. Evaluate as recommended by Section 4.1 of this appendix.

2. Valves may not satisfy the primary, secondary and peak stress combination limits if body shape differs significantly from the rules of NB-3544 [1b].

3. Valves may not satisfy the primary plus secondary stress limit for service level C.

It is recommended that SEP Class 1 valves be evaluated on a case-by-case basis as follows:

1. Use fracture toughness evaluation forms given in Section 4.1 of this appendix.

2. Compare actual body shape with body shape rules of NB-3544 [1b]. If not significantly different, the valve would be considered adequate. If significant differences are found, the Licensee should be asked to provide calculations and an evaluation based on alternative rules for the valve in question, unless it can be shown that the valve has been subjected to level C conditions and did not have to be replaced.

Class 2 and 3 valves are currently designed to the requirements of subarticle NC-3500 [1c] and ND-3500 [1d], respectively. Class 2 valves satisfying the standard design rules comply with the standard class requirements of ANSI B16.34 except that valves with flanged and butt welded ends may be designated as Class 75 in sizes larger than 24-in nominal pipe size provided that NC-3512.1(a) is satisfied. Valves with flanged ends in sizes larger than 24-in nominal pipe size may be used provided that NC-3512.1(b) is satisfied. A shell hydrostatic test satisfying ANSI B16.34 is required. Class 2 and 3 valve stress limits for service limits A, B, C, and D are as given in Table A4-12.

Class 2 and 3 valves with butt welding or socket welding ends conforming to the requirements of NC-3661 and ND-3661 should satisfy the special class requirements of ANSI B16.34 except that:

a. the nondestructive examination (NDE) requirements of ANSI B16.34, special class, shall be applied to all sizes in accordance with NC-2500 for Class 2 valves and ND-2500 for Class 3 valves.

b. stress limits for service levels B, C, and D shall be as shown in Table A4-12.

Table A4-12

Level B, C, and D Service Limits
for Class 2 and 3 Valves

TABLE NC-3521-1
LEVEL B, C, AND D SERVICE LIMITS

Service Limit	Stress Limits[1-4]	P_{max}[5]
Level B	$\sigma_m \leq 1.1\ S$ $(\sigma_m \text{ or } \sigma_L)+\sigma_b \leq 1.65\ S$	1.1
Level C	$\sigma_m \leq 1.5\ S$ $(\sigma_m \text{ or } \sigma_L)+\sigma_b \leq 1.8\ S$	1.2
Level D	$\sigma_m \leq 2.0\ S$ $(\sigma_m \text{ or } \sigma_L)+\sigma_b \leq 2.4\ S$	1.5

NOTES:
(1) A casting quality factor of 1 shall be assumed in satisfying these stress limits.
(2) These requirements for the acceptability of valve design are not intended to assure the functional adequacy of the valve.
(3) Design requirements listed in this table are not applicable to valve disks, stems, seat rings, or other parts of the valves which are contained within the confines of the body and bonnet.
(4) These rules do not apply to safety relief valves.
(5) The maximum pressure shall not exceed the tabulated factors listed under P_{max} times the Design Pressure or times the rated pressure at the applicable service temperature.

c. openings for auxiliary connections shall satisfy ANSI B16.34 and the reinforcement requirements of NC-3300 and ND-3300.

Comparison With Past Requirements

Class 2 and Class 3 valves designed by past code requirements would have the required minimum body thickness but may not comply with pressure-temperature ratings of B16.34, which depend on material group and a rational formulation as compared to the empirical basis of B16.5.

It is recommended that the pressure-temperature rating of Class 2 and 3 SEP valves be compared with the current pressure-temperature rating of B16.34. For example, the isolation valves of engineered safeguard system of the Palisades plant would be considered Quality Group B (Class 2) components by current standards. These valves are 150 lb rated valves designed to withstand 210 psig at 300°F by Table 2 of the past standard ASA B16.5 for flanged fittings. The current standard ANSI B16.34 gives an allowable pressure at 300°F which depends on the material group as shown in Table A4-13.

It is apparent from Table A4-13 that the engineered safeguard isolation valves for the Palisades plant would satisfy the current standard provided that the valve material was in one of the tabulated material groups other than 1.12, 2.1, or 2.3.

4.6 HEAT EXCHANGERS

Heat exchangers are currently designed and constructed in accordance with the rules of ASME B&PV Code Section III, 1977 Edition [1]. The design requirements for the pressure boundaries of the heat exchanger are found in the following sections of the current code:

	Section
Shell Side	3300
Tube Side	3600
Tube Sheet	3300
Shell Flange	3200 (Class 1); Appendix XI (Class 2 and 3)

Heat exchangers designed to ASME III (1965) or ASME VIII (1965) are compared as pressure vessels with current requirements in Section 4.3 of this Appendix.

Table A4-13

Allowable Working Pressure[1] for a 150 lb Standard Class Valve at 300°F

Material Group	Allowable Pressure (psig)
1.1	230
1.2	230
1.3	230
1.4	210
1.5	230
1.6	215
1.7	230
1.8	215
1.9	230
1.10	230
1.11	230
1.12	205
1.13	230
1.14	230
2.1	205
2.2	215
2.3	175
2.4	210
2.5	225
2.6	220
2.7	220

1. Based on ANSI B16.34 (1977)

Heat exchangers designed to the standards of the Tubular Exchanger Manufacturers Association (TEMA) 1959 Edition [8] require that "the individual vessels shall comply with the ASME Code for Unfired Pressure Vessels." TEMA Class R heat exchangers are for the more severe requirements of petroleum and chemical processing applications. TEMA Class C heat exchangers are for the moderate requirements of commercial and general process applications.

The TEMA standards give design rules which "supplement and define the code for heat exchanger applications." Allowable stress values, identical with Tables UCS-23 and UCS-27 of the 1959 edition of the ASME Code for Unfired Pressure Vessels, are reproduced in TEMA as Table D-8 for carbon and low alloy steels and as Table D-8W for carbon and low alloy pipe and tubes of welded manufacture; the stress values are one-fourth the specified minimum tensile strength multiplied by a quality factor of 0.92.

Group I heat exchangers designed to TEMA (1959) would be governed by the code requirements of ASME VIII (1965). Comparison of ASME VIII (1965) with current requirements is as follows:

1. Class 1 heat exchangers shell flanges would have to be designed by computer analysis to determine primary, secondary, and peak stress intensities, rather than design formulas as previously used.

2. Materials for Class 1, 2, and 3 heat exchangers must comply with current fracture toughness requirements outlined in Section 4.1.1 of this Appendix.

3. Radiography requirements for vessels designed and constructed to ASME III (1965) or ASME VIII (1965) are compared with current requirements in Section 4.3 of this Appendix.

4.7 STORAGE TANKS

Storage tanks may currently be classified as Class 2 or Class 3 and are designed in accordance with the rules of NC/ND-3900 [1] for atmospheric tanks or 0 to 15 psi tanks, respectively. Atmospheric tanks may be within building structures or above grade, exposed to atmospheric conditions. Storage tanks of 0 to 15 psi design are normally located above ground within building structures.

Atmospheric Storage Tanks

Atmospheric storage tanks are currently required to satisfy the general design requirements of NC/ND-3100 and the vessel design requirements of NC/ND-3300 except that a stress report is not required. Stress limits on the maximum normal stress for Service Levels A, B, C, D is as shown in Table A4-12. Minimum size of fillet welds should satisfy NC/ND-4246.6, i.e., 3/16 in for 3/16-in thick plate, and at least 1/3 of thinner plate thickness for plates greater than 3/16 in but not less than 3/16 in.

Nominal thickness of shell plates should be at least 3/16 in for tanks of nominal diameter less than 50 ft or 1/4 in for tanks of 50 to 120 ft nominal diameter, but not greater than 1 1/2-in thick.

Roofs shall be designed to carry dead load plus a uniform load of at least 25 psf for outside tanks or at least 10 psf for inside tanks. Minimum roof plate thickness is 3/16 in plus corrosion allowance. Allowable stresses are summarized as follows:

a. tension - for rolled steel, net section: 20 ksi; full penetration groove welds in thinner plate area: 18 ksi.

b. compression - 20 ksi where lateral deflection is prevented, or as determined from column formulas of NC/ND-3852.6(b)(3).

c. bending - 22 ksi in tension and compression for rolled shapes satisfying the shape requirement of NC/ND-3852.6(c)(1); 20 ksi in tension and compression for unsymmetric members laterally supported at intervals no greater than 13 times the compression shape width; and for other rolled shapes, built-up members, and plate girders: 20 ksi in tension and compression as determined by the buckling formulas of NC/ND-3852.6(c)(4).

d. shearing - 13.6 ksi in fillet, plug, slot, and partial penetration groove welds across throat area, 13 ksi on the gross area of beam webs where the aspect ratio (h/t) is less than 60 or:

$$\frac{19.5}{1 + \frac{(h/t)^2}{7200}}$$

0 to 15 psi Storage Tanks

Storage tanks which may contain gases or liquids with vapor pressure above the liquid not exceeding 15 psig are currently designed in accordance with the requirements of NC/ND-3920. Maximum tensile stress in the outside tank walls is as given in Table I-7.0 of Reference 1e if both meridional and latitudinal forces are in tension, or this value multiplied by the tensile stress factor N (less than 1.0) determined from the Biaxial Stress Chart, Fig. NC/ND-39222.1-1 [1] if one of these forces is compressive. Maximum compressive stress in the outside wall shall be determined by the rules of NC/ND 3922.3 [1]. Maximum allowable stress values for structural members shall be as determined from NC/ND-3923. The 0 to 15 psi storage tank shall be designed in accordance with the detailed rules of NC/ND-3930.

Comparison with Past Code Requirements

Storage tanks in Group I SEP plants were designed either in accordance with A/E specifications, USAS B96.1 (1967) [9], API-650 (1964) [10], ASME III (1965) Class C, or ASME VIII (1965). Stress allowables for ASME III (1965) Class C vessels are as given in ASME VIII (1965). Examination of the ASME VIII (1965) allowable stress valves for carbon and low alloy plate steels indicates that the values do not exceed 20 ksi except for SA-353 Grade A and B, with allowable stresses of 22.5 and 23.75 ksi, respectively. ASME VIII (1965) does not consider biaxial stress fields with associated reduction in tensile allowables. Stress allowables for roofs in Reference 10 are the same as for current atmospheric storage tanks.

A comparison of API-650 (1964) roof design requirements, including stress allowables, shows agreement with current requirements; shell material and tensile stress allowables may, however, not satisfy current requirements. The past code allows the use of A-7 plate material not currently listed as an acceptable material. The past code permits an allowable tensile shell stress 21,000 psi times the joint efficiency. Assuming spot radiography of a double welded butt vertical shell joint made from A-283 Grade C or A-36 plate material, the allowable stress would be 17,850 psi based on 0.85 joint efficiency, which exceeds the current 12,600 psi allowable.

USAS B96.1 (1967) for welded aluminum alloy field-erected storage tanks cannot be used for Class 2 storage tanks since aluminum alloy is not a permitted Class 2 material as listed in Table I-7.0 [1]. However, allumimum alloy can be used for Class 3 storage tanks since aluminum alloys are listed in Table I-8.4, which is currently used for aluminum shell design, and in Tables ND-3852.7-2 through ND-3852.7-6 for aluminum roof design. A comparison of allowables based on past and current codes is shown in the following table:

Structures (Type of Stress)	Aluminum Material (Temper)	Specified Min. Strength TS/YS	Allowable Stress (1) Past (USAS B96.1)	Allowable Stress (1) Current (ASME III (1977))
Shell (Tension)	5050 (0)	18.0 ksi/6.0 ksi	4.8 ksi	4.0 ksi
Shell (Tension)	6061 (T4,T6)	24.0 ksi/ -	7.2 ksi	6.0 ksi
Bolts (Tension)	6061 (T6)	-	18.0 ksi	18.0 ksi
Roof Support (Axial Compression, $L/r \leq 10$)	6061 (T6)	-	19.0	19.0
Roof Support (Axial Compression $10 \leq L/r \leq 67$)	6061 (T6)	-	20.4-0.135 L/r	20.4-0.113 L/r

From this table, it can be concluded that:

1. shells designed to USAS B96.1 (1967) may be overstressed by as much as 20% compared to current allowables

2. bolts designed to USAS B96.1 (1967) satisfy current requirements

3. roof supports with slenderness ratios up to 10 satisfy current requirements

4. roof supports with slenderness ratios between 10 and 67 more than satisfy current compression allowables by as much as 13%.

Therefore, aluminum alloy storage tanks built to USAS B96.1 (1967), when evaluated against current requirements:

1. At temperatures to 100°F.

1. may not satisfy materials requirements in Table I-7.0 if the tank is a Class 2 component

2. may be unconservatively designed when compared to current stress allowables, by as much as 20% for the shell.

In conclusion,

1. Tanks designed to A/E specification should be carefully compared to current code requirements

2. Atmospheric tanks designed to ASME III (1965) Class C are likely to satisfy current requirements with regard to allowable tensile stress, but may not satisfy current compression stress requirements. Class C atmospheric tanks currently classified as Code Class 2 may not satisfy the current quality assurance requirements as discussed in Section 4.1.2 of this Appendix.

3. 0 to 15 psig tanks designed to ASME III (1965) Class C requirements may not satisfy current tensile allowables for biaxial stress fields in which one of the stress components is compression. These tanks should be examined carefully in light of current requirements. Class C (0 to 15 psig) tanks currently classified as Code Class 2 may not satisfy the current quality assurance requirements discussed in Section 4.1.2 of this Appendix.

4. Atmospheric storage tank roofs designed to API-650 (1964) satisfy current stress allowables.

5. Atmospheric welded steel storage tanks designed to API-650 (1964) may not satisfy current requirements with regard to:

   a. use of A-7 plate material not currently acceptable

   b. shell tensile stresses may exceed current code allowables

6. Atmospheric storage tanks designed to USAS B96.1 (1967) may not satisfy current requirements.

5. BASIS FOR SELECTING REQUIREMENTS MOST SIGNIFICANT TO COMPONENT INTEGRITY

The selection of code requirements most significant to component integrity has been based on the experience of the author and colleagues in industry, government, and academia. Codes pertaining to the design and construction of nuclear power plants have been modified and expanded. The changes reflect new "state of the art" knowledge, new techniques of fabrication, examination, testing, and methods of achieving quality that have been "filtered" and accepted by the technical community. It is the author's view that current codes represent a consensus of what is best for achieving both economy of construction and public safety. Accordingly, changes in stress limits, full radiography requirements, and fatigue evaluation for piping, as well as more conservative requirements for fracture toughness, have been given special attention.

6. REFERENCES

1. American Society of Mechanical Engineers
   Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components"
   New York: 1977 Edition with Addenda through Summer 1978

   a. Division 1 and Division 2 General Requirements
   b. Division 1, Subsection NB, Class 1 Components
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   d. Division 1, Subsection ND, Class 3 Components
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