TECHNICAL EVALUATION REPORT

QUALITY GROUP CLASSIFICATION OF COMPONENTS AND SYSTEMS (SEP, III-1)

CONNECTICUT YANKEE ATOMIC POWER COMPANY
HADDAM NECK PLANT

NRC DOCKET NO. 50-213

NRC TAC NO. 41594

NRC CONTRACT NO. NRC-03-79-118

FRC PROJECT C5257

FRC ASSIGNMENT 17

FRC TASK 435

Prepared by

Franklin Research Center
20th and Race Street
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Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

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Lead NRC Engineer: M. Boyle

July 22, 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 Haddam Neck Nuclear Power Plant.

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
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 (1)
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 Haddam Neck plant 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.

1. Plant discussed in this report.

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

1. Table of Systems and Components (including updates and revisions) [4], compiled by the NRC, corrected and completed by Connecticut Yankee Atomic Power Company. This table contains the 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, it was completed as well as possible (see Table 4-1).

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] and ASME 1962 Boiler and Pressure Vessel Code, Section VIII, "Unfired Pressure Vessels" [8] and applicable code cases.

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 Consideration

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

Topic	Description
III-7.A	Inservice Inspection, Including Prestressed Concrete Containments with Either Grouted or Ungrouted Tendons
III-7.B	Design Codes, Design Criteria, Load Combinations, 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, a review was performed 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 San Onofre Nuclear Plant are ASA B31.1 (1955) [7] and ASME B&PV Code, Section VIII (1962) [8]. 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 Haddam Neck 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
Safety Injection System
Containment Spray System
Chemical and Volume Control System
Sampling System
Residual Heat Removal System
Component Cooling System
Service Water System
Main Steam System
Feedwater System
Auxiliary Feed System
Containment Purge System
Containment Cooling System
Containment Isolation System
Spent Fuel Pit Cooling 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 Table 4-2 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
Haddam Neck Nuclear Power Plant

Structures, Systems, and Components	Quality Classification		Seismic Classification		Remarks
	Codes and Standards RG 1.26(1)	Codes and Standards Used in Plant Design	RG 1.29	Used in Plant Design	
REACTOR EQUIPMENT					
Fuel Assemblies	NA	--	Category I	Class I	NA(2)
Control Element Assemblies	NA	--	Category I	Class I	NA
Control Element Drive Mechanisms	NA	--	Category I	Class I	NA
Core Support Structure	ASME III Subsection NG	--	Category I	Class I	NA
Reactor Vessels Internals Other Than Above	NA	--	Category I	Class I	NA
REACTOR COOLANT SYSTEM					
Reactor Vessel	ASME III Class 1	--	Category I	Class I	NA
Reactor Vessel Supports	ASME III Subsection NF	--	Category I	Class I	NA
Steam Generators - Tube Side	ASME III Class 1	ASME VIII (1962) and Code Cases 1270N and 1273N	Category I	Class I	NA
Steam Generators - Shell Side	ASME III Class 2	ASME VIII (1962) and Code Cases 1270N and 1273N	Category I	Class I	NA

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 the Summer 1978 Addenda. When Class A, B, or C is listed in this column for a system or component, these components should be designed, fabricated, erected, and tested to quality standards commensurate with the safety function to be performed [1].
2. NA stands for additional information provided in this table that is outside the scope of this report.
* The edition of the code is an assumption because this information was not provided at this time. Confirmation of code edition is required.

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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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Pressurizer	ASME III Class 1	?	Category I	Class I	
Reactor Coolant Pumps (RCP)	ASME III Class 1	ASME VIII (1962)	Category I	Class I	
Reactor Coolant System Piping: Hot and Cold Leg	ASME III Class 1	ASA B31.1 (1955)	Category I	Class I	
Interconnecting Piping of Systems That Form Part of Reactor Coolant Pressure Boundary (RCPB)	ASME III Class 1	ASA B31.1 (1955)	Category I	Class I	
Interconnecting Piping of Systems That Form Part of Reactor Coolant Pressure Boundary	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	
Pressurizer Surge and Spray	ASME III Class 1	?	Category I	Class I	
Piping 3/4 Inch and Smaller Within RCPB	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	
Pressurizer Relief Discharge Piping Upstream of Safety Valves	ASME III Class 1	ASA B31.1 (1955) and Nuclear Code Cases[3]	Category I	Class I	

3. Nuclear code case not specified. This information is required.

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Pressurizer Safety and Relief Valves	ASME III Class 1	?	Category I	Class I	
Power-Operated Relief Valves	ASME III Class 1	?	Category I	Class I	
Block Valves	ASME III Class 1	?	Category I	Class I	
Other Valves Within Quality Group A Portions of RCPB	ASME III Class 1	?	Category I	Class I	
Other Valves Within Quality Group B Portions of RCPB	ASME III Class 2	?	Category I	Class I	
SAFETY INJECTION SYSTEM (EMERGENCY CORE COOLING SYSTEM)					
Refueling Water Storage Tank	ASME III Class 2	?	Category I	Class I	
High and Low Pressure Safety Injection Pumps	ASME III Class 2	ASME VIII (1962)	Category I	Class I	
Boron Injection Tank	ASME III Class 2	?	Category I	Class I	
Accumulators	ASME III Class 2	?	Category I	Class I	

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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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Interconnecting Piping and Valves Required to Perform Safety Injection Function	ASME III Class 2	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	
Boron Injection Recirculation Tank	ASME III Class 3	?	Category I	Class I	
Boron Injection Recirculation Pump	ASME III Class 3	?	Category I	Class I	
Interconnecting Piping and Valves Required to Perform Recirculation Function	ASME III Class 3	?	Category I	Class I	
CONTAINMENT SPRAY SYSTEM					
Pumps	ASME III Class 2	?	Category I	Class I	
Heat Exchanger - Tube Side	ASME III Class 2	?	Category I	Class I	
Heat Exchanger - Shell Side	ASME III Class 3	?	Category I	Class I	
Spray Nozzles	ASME III Class 2	?	Category I	Class I	

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Interconnecting Piping and Valves Required to Perform Spray Function	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	
Spray Chemical Storage Tank	ASME III Class 3	?	Category I	Class I	
Chemical Storage Test Pump	ASME III Class 3	?	Category I	Class I	
Interconnecting Piping and Valves Required to Perform Test Function	ASME III Class 3	?	Category I	Class I	
CHEMICAL AND VOLUME CONTROL SYSTEM					
Regenerative Heat Exchanger	ASME III Class 2	ASME VIII (1962) and Code Cases 1270N and 1273N	Category I	Class I	
Drain Cooler Heat Exchanger - Tube Side	ASME III Class 1	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Drain Cooler Heat Exchanger - Shell Side	ASME III Class 2	ASME VIII (1962)	Category I	Class I	
Reactor Coolant Filter	ASME III Class 2	?	Category I	Class I	

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Volume Control Tank	ASME III Class 2	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Charging Pumps	ASME III Class 2	ASME VIII (1962) and Standards of Hydraulic Institute (1961)	Category I	Class I	
Letdown Orifices	ASME III Class 2	?	Category I	Class I	
Non-Regenerative Heat Exchanger - Tube Side	ASME III Class 2	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Non-Regenerative Heat Exchanger - Shell Side	ASME III Class 3	ASME VIII (1962)	Category I	Class I	
Seal Water Injection Filter	ASME III Class 2	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Seal Water Heat Exchanger - Tube Side	ASME III Class 2	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Seal Water Heat Exchanger - Shell Side	ASME III Class 3	ASME VIII (1962)	Category I	Class I	
Seal Water Filter	ASME III Class 2	ASME VIII (1962)	Category I	Class I	
Boric Acid Tanks	ASME III Class 3	ASME VIII (1962)	Category I	Class I	

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26(1)	Codes and Standards Used in Plant Design	Seismic Classification: RG 1.29	Used in Plant Design	Remarks
Boric Acid Filter	ASME III Class 3	ASME VIII (1962)	Category I	Class I	
Boric Acid Transfer Pumps	ASME III Class 3	?	Category I	Class I	
Boric Acid Blender	ASME III Class 3	ASA B31.1 (1955)(4)	Category I	Class I	
Boric Acid Strainer	ASME III Class 3	ASME VIII (1962)	Category I	Class I	
Piping (Loop 1) Letdown via Regenerative Heat Exchanger and Letdown Valves to and Including Letdown Isolation Valves	ASME III Class 1	ASA B31.1 (1955)	Category I	Class I	
Interconnecting Piping and Valves from Pump Discharge to and Including Valves 399 and 296 to Reactor Coolant System	ASME III Class 1	ASA B31.1 (1955)	Category I	Class I	
Piping and Valves from Pump Discharge to Containment Isolation Valves 399 and 296	ASME III Class 2	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	

4. It seems more likely that a vessel or tank code would have been used in the design of the boric acid blender.

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Piping and Valves from Pump Discharge via Reactor Coolant Pumps and from TV-1847 to Seal Water Heat Exchanger	ASME III Class 2	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	
Piping and Valves Downstream of Letdown Isolation Valves to the Volume Control Tank (VCT) and Other Interconnecting Piping and Valves of the VCT	ASME III Class 2	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	
Mixed Bed Demineralizer	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	--		
Interconnecting Piping and Valves Required to Perform Demineralizer Function	ASME III Class 3	ASA B31.1 (1955)	--		
Boric Acid Tank Connecting Piping and Valves	ASME III Class 3	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	
SAMPLING SYSTEM					
Piping and Valves	ASME III Class 1	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	

Table 4-1 (Cont.)

Structures, Systems, and Components	Quality Classification: Codes and Standards RG 1.26(1)	Codes and Standards Used in Plant Design	Seismic Classification: RG 1.29	Used in Plant Design	Remarks
Piping and Valves	ASME III Class 2	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	
RESIDUAL HEAT REMOVAL SYSTEM					
Residual Heat Removal/ Low Pressure Safety Injection Pumps	ASME III Class 2	ASME VIII (1962)	Category I	Class I	
Heat Exchanger - Tube Side	ASME III Class 2	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Heat Exchanger - Shell Side	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Interconnecting Piping and Valves Required to Perform Residual Heat Removal Function	ASME III Class 2	ASA B31.1 (1955) and Nuclear Code Cases(3)	Category I	Class I	
COMPONENT COOLING SYSTEM					
Pumps	ASME III Class 3	?	Category I	Class I	

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Heat Exchanger - Tube Side	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Heat Exchanger - Shell Side	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Surge Tank	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Interconnecting Piping and Valves Required to Service Quality Groups B and C System Components	ASME III Class 3	ASA B31.1 (1955)	Category I	Class I	
SERVICE WATER SYSTEM					
Pumps	ASME III Class 3	Industry Standards(5)	Category I	Class I	
Strainers	ASME III Class 3	?	Category I	Class I	

5. Standards not provided for review.

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Interconnecting Piping and Valves Required to Service Quality Group C System Components	ASME III Class 3	ASA B31.1 (1955)	Category I	Class I	
MAIN STEAM SYSTEM					
Interconnecting Piping and Valves Comprising Main Steam Lines Extending From the Secondary Side of the Steam Generators up to and Including the Outermost Containment Isolation Valve in Each Main Steam Line and Connected Piping up to and Including the First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	
Relief Valves	ASME III Class 2	ASME VIII (1962)(6)	Category I	Class I	
Safety Valves (16)	ASME III Class 2	ASME VIII (1962)(6)	Category I	Class I	

6. Safety and relief valves are mentioned in Section VIII in reference to capacity requirements, not design requirements. It is more likely that ASA B31.1 and code cases would have been used in the design of safety and relief 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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Piping and Valves (Blow-off) from Steam Generators to and Including Blow-off Valve TV-1312-1 through 4 and 506, 515, 522, and 529. Piping from Valves PICV-1206A, B to Auxiliary Feed Pumps Including Valves SV-1216A, B	ASME III Class 3	ASA B31.1 (1955)	Category I	Class I	
FEEDWATER SYSTEM					
Interconnecting Piping and Valves Comprising Feedwater Lines Extending From the Secondary Side of the Steam Generators up to and Including the Outermost Containment Isolation Valve in Each Feedwater Line and Connected Piping up to and Including the First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
AUXILIARY FEED SYSTEM					
Pumps - Turbine Driven	ASME III Class 3	ASA B31.1 (1955) (7)	Category I	Class I	
Demineralizer Storage Tank	ASME III Class 3	USAS B96.1 (1967)*	Category I	Class I	
Piping and Valves from and Including Valves 156-1 through 156-4, 182 and Main Feed Valves MOV-11, 12, 13, 14, and 135-1 through 135-4 to Steam Generators	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	
Piping and Valves to Suction of Auxiliary Feed System Pumps from Demineralizer Water Storage Tank	ASME III Class 3	ASA B31.1 (1955)	Category I	Class I	
Piping and Valves from Pump Discharge to Valves 156-1 through 156-A and 182	ASME III Class 3	ASA B31.1 (1955)	Category I	Class I	

7. It is noted that pump design is not covered under ASA B31.1. Clarification of this discrepancy is required.

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
CONTAINMENT PURGE SYSTEM					
Interconnecting Piping and Valves That Form an Extension of the Containment Boundary up to and Including the Outermost Containment Isolation Valve	ASME III Class 2	ASA B31.1 (1955)	Category I	Class I	
CONTAINMENT COOLING SYSTEM					
Containment Fan Coolers (Fans and Cooling Coils)	Class B	?	Category I	Class I	NA
System Ductwork and Dampers	Class B	?	Category I	Class I	NA
CONTAINMENT ISOLATION SYSTEM					
Interconnecting Piping and Valves of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to and Including the Outermost Containment Isolation Valve	ASME III Class 1	?	Category I	Class I	
Interconnecting Piping and Valves of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to and Including the Outermost Containment Isolation Valve	ASME III Class 2	?	Category I	Class I	

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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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Interconnecting Piping and Valves of Quality Groups B, C, or D System That Penetrate the Containment From the First Isolation Valve Inside Containment up to and Including the Outermost Containment Isolation Valve	ASME III Class 2	?	Category I	Class I	
SPENT FUEL PIT COOLING SYSTEM					
Spent Fuel Pit Heat Exchanger	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Spent Fuel Pit Pumps	ASME III Class 3	?	Category I	Class I	
Spent Fuel Pit Filter	ASME III Class 3	ASME VIII (1962) and Code Case 1270N	Category I	Class I	
Piping and Valves	ASME III Class 3	ASA B31.1 (1955)	Category I	Class I	
STRUCTURES					
Primary Auxiliary Building (Including Pipe Gallery)	NA	ACI 318 (1963)(8) AISC (6th Edition)	Category I	0.17g	NA

8. ACI stands for American Concrete Institute. AISC stands for American Institute of Steel Construction.

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	Seismic Classification: RG 1.29	Seismic Classification: Used in Plant Design	Remarks
Service Building: Control Room and Switchgear Room Portions Only	NA	ACI 318 (1963)(8) AISC (6th Edition)	Category I	0.17g	NA
New and Spent Fuel Building	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.17g	NA
Waste Disposal Building	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.17g	NA
Diesel Generator Building	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.17g	NA
Service Water Intake (Screenwell House) Pumphouse Discharge Structure	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.17g 0.03g	NA
Refueling Water Storage Tank (RWST) Foundation	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.17g	NA
Demineralized Water Storage Tank Foundation	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.03g	NA
Primary Water Storage Tank (PWST) Foundation	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.03g	NA
Containment	NA	ACI 318 (1963) AISC (6th Edition)	Category I	0.17g	NA

Table 4-2(a)

Quality Group A Components[1]

Code: ASME III-Class 1[2]

Pressure Vessels	Code
Pressurizer (RCS)	?
Drain Cooler Heat Exchanger - Tube Side (CVCS)	ASME VIII (1962) and Code Case 1270N
Piping	
Reactor Coolant System Piping: Hot and Cold Legs (RCS)	ASA B31.1 (1955)
Interconnecting Piping of Systems That Form Part of Reactor Coolant Pressure Boundary (RCS)	ASA B31.1 (1955)
Pressurizer Surge and Spray (RCS)	?
Pressurizer Relief Discharge Piping Upstream of Safety Valves (RCS)	ASA B31.1 (1955) and Nuclear Code Cases[3]
Piping (Loop 1) Letdown via Regenerative Heat Exchanger and Letdown Valves to Letdown Isolation Valves (CVCS)	ASA B31.1 (1955)
Interconnecting Piping from Pump Discharge Via Valves 399 and 296 to Reactor Coolant System (CVCS)	ASA B31.1 (1955)
Sampling System Piping (SS)	ASA B31.1 (1955) and Nuclear Code Cases[3]
Interconnecting Piping of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to the Outermost Containment Isolation Valve (CIS)	?

1. See Table 4-2(d) for abbreviations.
2. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III Division 1, Subsection NB, 1977 Edition and Addenda through the Summer 1978 Addenda.
3. Nuclear code cases not specified. This information is required.

Table 4-2(a) (Cont.)

Pumps	Code
Reactor Coolant Pumps (RCS)	ASME VIII (1962)
Valves	
Pressurizer Safety and Relief Valves (RCS)	?
Power-Operated Relief Valves (RCS)	?
Block Valves (RCS)	?
Other Valves Within Quality Group A Portions of RCPB (RCS)	?
Letdown Valves and Letdown Isolation Valves in Loop 1 (CVCS)	ASA B31.1 (1955)
Valves from Pump Discharge to and Including Valves 399 and 296 (CVCS)	ASA B31.1 (1955)
Sampling System Valves (SS)	ASA B31.1 (1955) and Nuclear Code Cases[2]
Interconnecting Valves of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to and Including the Outermost Containment Isolation Valve (CIS)	?

Storage Tanks (Atmospheric and 0-15 psig)

None

Table 4-2(b)

Quality Group B Components[1]

Code: ASME III-Class 2[2]

Pressure Vessels	Code
Accumulators (SIS)	?
Containment Spray System Heat Exchanger - Tube Side (CSS)	?
Regenerative Heat Exchanger (CVCS)	ASME VIII (1962) and Code Cases 1270N, 1273N
Drain Cooler Heat Exchanger - Shell Side (CVCS)	ASME VIII (1962)
Reactor Coolant Filter (CVCS)	?
Volume Control Tank (CVCS)	ASME VIII (1962) and Code Case 1270N
Non-Regenerative Heat Exchanger - Tube Side (CVCS)	ASME VIII (1962) and Code Case 1270N
Seal Water Injection Filter (CVCS)	ASME VIII (1962) and Code Case 1270N
Seal Water Heat Exchanger - Tube Side (CVCS)	ASME VIII (1962) and Code Case 1270N
Seal Water Filter (CVCS)	ASME VIII (1962)
Residual Heat Removal Heat Exchanger - Tube Side (RHRS)	ASME VIII (1962) and Code Case 1270N
Piping	
Interconnecting Piping of Systems That Form Part of Reactor Coolant Pressure Boundary (RCS)	ASA B31.1 (1955)
Piping 3/4-Inch and Smaller Within RCPB (RCS)	ASA B31.1 (1955)

1. See Table 4-2(d) for abbreviations.
2. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III Division 1, Subsection NC, 1977 Edition and Addenda through the Summer 1978 Addenda.

Table 4-2(b) (Cont.)

Piping (Cont.)	Code
Interconnecting Piping and Valves Required to Perform Safety Injection Function (SIS)	ASA B31.1 (1955) and Nuclear Code Case[3]
Spray Nozzles (CSS)	?
Interconnecting Piping Required to Perform Spray Function (CSS)	ASA B31.1 (1955)
Letdown Orifices (CVCS)	?
Piping from Pump Discharge to Containment Isolation Valves 399 and 296 (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases [3]
Piping from Pump Discharge via Reactor Coolant Pumps and from TV-1847 to Seal Water Heat Exchanger (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases [3]
Piping Downstream of Letdown Isolation Valves to the Volume Control Tank (VCT) and Other Interconnecting Piping of the VCT (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases[3]
Sampling System Piping (SS)	ASA B31.1 (1955) and Nuclear Code Cases[3]
Interconnecting Piping Required to Perform Residual Heat Removal Function (RHRS)	ASA B31.1 (1955) and Nuclear Code Cases[3]
Interconnecting Piping Comprising Main Steam Lines Extending From the Secondary Side of the Steam Generators up to the Outermost Containment Isolation Valve in Each Main Steam Line and Connected Piping up to First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation (MSS)	ASA B31.1 (1955)

3. Nuclear code cases not specified. This information is required.

Table 4-2(b) (Cont.)

Piping (Cont.)	Code
Interconnecting Piping Comprising Feedwater Lines Extending From the Secondary Side of the Steam Generators up to the Outermost Containment Isolation Valve in Each Feedwater Line and Connected Piping up to the First Valve That is Normally Closed or Capable of Automatic Closure During all Modes of Normal Reactor Operation (FWS)	ASA B31.1 (1955)
Piping from Valves 156-1 through 156-4 and 182, and Main Feed Valves MOV-11, 12, 13, 14, and 135-1 through 135-4 to Steam Generators (AFS)	ASA B31.1 (1955)
Interconnecting Piping That Form an Extension of the Containment Boundary up to the Outermost Containment Isolation Valve (CPS)	ASA B31.1 (1955)
Interconnecting Piping of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to the Outermost Containment Isolation Valve (CIS)	?
Interconnecting Piping of Quality Groups B, C, or D System That Penetrate the Containment From the First Isolation Valve Inside Containment up to the Outermost Containment Isolation Valve (CIS)	?
Pumps	
High and Low Pressure Safety Injection Pumps (SIS)	ASME VIII (1962)
Containment Spray System Pumps (CSS)	?
Charging Pumps (CVCS)	ASME VIII (1962)
Residual Heat Removal/ Low Pressure Safety Injection Pumps (RHRS)	ASME VIII (1962) and Standards of Hydraulic Institute (1961)
Valves	
Other Valves Within Quality Group B Portions of RCPB (RCS)	?

Table 4-2(b) (Cont.)

Valves (Cont.)	Code
Interconnecting Valves Required to Perform Safety Injection Function (SIS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Interconnecting Valves Required to Perform Spray Function (CSS)	ASA B31.1 (1955)
Valves From Pump Discharge to Containment Isolation Valves 399 and 296 (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Valves from Pump Discharge via Reactor Coolant Pumps and from TV-1847 to Seal Water Heat Exchanger (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Valves Downstream of Letdown Isolation Valves to Volume Control Tank (VCT) and Other Valves of the VCT (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Sampling System Valves (SS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Interconnecting Valves Required to Perform Residual Heat Removal Function (RHRS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Interconnecting Valves Comprising Main Steam Lines Extending From the Secondary Side of the Steam Generators up to and Including the Outermost Containment Isolation Valve in Each Main Steam Line and up to the First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation (MSS)	ASA B31.1 (1955)
Relief Valves (MSS)	ASME VIII (1962) (4)
Safety Valves (MSS)	ASME VIII (1962) (4)

4. Safety and relief valves are mentioned in Section VIII in reference to capacity requirements, not design requirements. It is more likely that ASA B31.1 and code cases would have been used for the design of safety and relief valves.

Table 4-2(b) (Cont.)

Valves (Cont.)	Code
Interconnecting Valves Comprising Feedwater Lines Extending From the Secondary Side of the Steam Generators up to and Including the Outermost Containment Isolation Valve in Each Feedwater Line Including The First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation (FWS)	ASA B31.1 (1955)
Valves From and Including Valves 156-1 through 156-4, 182 and Main Feed Valves MOV-11, 12, 13, 14, and 135-1 through 135-4 to Steam Generators (AFS)	ASA B31.1 (1955)
Interconnecting Valves That Form an Extension of the Containment Boundary up to and Including the Outermost Containment Isolation Valve (CPS)	ASA B31.1 (1955)
Interconnecting Valves of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to and Including the Outermost Containment Isolation Valve (CIS)	?
Interconnecting Valves of Quality Groups B, C, or D System That Penetrate the Containment From the First Isolation Valve Inside Containment up to and Including the Outermost Containment Isolation Valve (CIS)	?
Storage Tanks (Atmospheric and 0-15 psig)	
Refueling Water Storage Tanks (SIS)	?
Boron Injection Tank (SIS)	?

Table 4-2(c)

Quality Group C Components[1]

Code: ASME III-Class 3[2]

Pressure Vessels	Code
Containment Spray System Heat Exchanger - Shell Side (CSS)	?
Non-Regenerative Heat Exchanger - Shell Side (CVCS)	ASME VIII (1962)
Seal Water Heat Exchanger - Shell Side (CVCS)	ASME VIII (1962)
Boric Acid Tanks (CVCS)	ASME VIII (1962)
Boric Acid Filter (CVCS)	ASME VIII (1962)
Boric Acid Strainer (CVCS)	ASME VIII (1962)
Mixed Bed Demineralizer (CVCS)	ASME VIII (1962) and Code Case 1270N
Residual Heat Removal System Heat Exchanger - Shell Side (RHRS)	ASME VIII (1962) and Code Case 1270N
Component Cooling System Heat Exchanger - Tube Side (CCS)	ASME VIII (1962) and Code Case 1270N
Component Cooling System Heat Exchanger - Shell Side (CCS)	ASME VIII (1962) and Code Case 1270N
Surge Tank (CCS)	ASME VIII (1962) and Code Case 1270N
Service Water System Strainers (SWS)	?

1. See Table 4.2(d) for abbreviations.
2. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III Division 1, Subsection ND, 1977 Edition and Addenda through the the Summer 1978 Addenda.

Table 4-2(c)

Pressure Vessels (Cont.)	Code
Spent Fuel Pit Heat Exchanger (SPCS)	ASME VIII (1962) and Code Case 1270N
Spent Fuel Pit Filter (SPCS)	ASME VIII (1962) and Code Case 1270N
Piping	
Interconnecting Piping Required to Perform Recirculation Function (SIS)	?
Interconnecting Piping Required to Perform Test Function (CSS)	?
Boric Acid Blender (CVCS)	ASA B31.1 (1955)[3]
Interconnecting Piping Required to Perform Demineralizer Function (CVCS)	ASA B31.1 (1955)
Boric Acid Tank Connecting Piping (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases[4]
Interconnecting Piping Required to Service Quality Groups B and C System Components (CCS)	ASA B31.1 (1955)
Interconnecting Piping Required to Service Quality Group C System Components (SWS)	ASA B31.1 (1955)
Piping from Steam Generators to Blow-off Valve TV-1312-1 through 4 and 506, 515, 522, and 529. Piping from Valves PICV-1206A and B to Auxiliary Feed Pumps (MSS)	ASA B31.1 (1955)
Piping to Suction of Auxiliary Feed System Pumps from Demineralizer Water Storage Tank (AFS)	ASA B31.1 (1955)

3. It seems more likely that a vessel or tank code would have been used in the design of the boric acid blender.
4. Nuclear code cases not specified. This information is required.

Table 4-2(c)

Piping (Cont.)	Code
Piping from Pump Discharge to Valves 156-1 through 156-A and 182 (AFS)	ASA B31.1 (1955)
Spent Fuel Pit Cooling System Piping (SFPCS)	ASA B31.1 (1955)
Pumps	
Boron Injection Recirculation Pump (SIS)	?
Chemical Storage Test Pump (CSS)	?
Boric Acid Transfer Pumps (CCS)	?
Component Cooling System Pumps (CCS)	?
Service Water System Pumps (SWS)	Industry Standards (5)
Pumps - Turbine Driven (AFS)	ASA B31.1 (1955) (6)
Spent Fuel Pit Pumps (SFPCS)	?
Valves	
Interconnecting Valves Required to Perform Recirculation Function (SIS)	?
Interconnecting Valves Required to Perform Test Function (CSS)	?
Interconnecting Valves Required to Perform Demineralizer Function (CVCS)	ASA B31.1 (1955)
Boric Acid Tank Connecting Valves (CVCS)	ASA B31.1 (1955) and Nuclear Code Cases (3)
Interconnecting Valves Required to Service Quality Groups B and C System Components (CCS)	ASA B31.1 (1955)

5. Standards not provided for review.
6. It is noted that pump design is not covered under ASA B31.1.

Table 4-2(c)

Valves (Cont.)	Code
Interconnecting Valves Required to Service Quality Group C System Components (SWS)	ASA B31.1 (1955)
Valves (Blow-off) from Steam Generators to and Including Blow-off Valve TV-1312-1 through 4 and 56, 515, 522, and 529. Valves PICV-1206A and B to Auxiliary Feed Pumps Including Valves SV-1216A and B (MSS)	ASA B31.1 (1955)
Valves to Suction of Auxiliary Feed System from Demineralizer Water Storage Tank (AFS)	ASA B31.1 (1955)
Valves from Pump Discharge to Valves 156-1 through 156-A and 182 (AFS)	ASA B31.1 (1955)
Spent Fuel Pit Cooling System Valves (SFPCS)	ASA B31.1 (1955)
Storage Tanks (Atmosphere and 0-15 psig)	
Boron Injection Recirculation Tank (SIS)	?
Spray Chemical Storage Tank (CSS)	?
Demineralizer Storage Tank (AFS)	USAS B96.1 (1967)[7]

7. The edition of the code is an assumption because this information was not provided at this time. Confirmation of code edition is required.

Table 4-2(d)

Index of Abbreviations for Systems

Abbreviation	Definition
AFS	Auxiliary Feed System
CCS	Component Cooling System
CIS	Containment Isolation System
CPS	Containment Purge System
CSS	Containment Spray System
CVCS	Chemical and Volume Control System
FWS	Feedwater System
MSS	Main Steam System
RCS	Reactor Coolant System
RHRS	Residual Heat Removal System
SFPCS	Spent Fuel Pit Cooling System
SIS	Safety Injection System
SS	Sampling 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 Haddam Neck 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 if it is necessary or not to impact-test the material used for each specific component of the Haddam Neck 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 9, 10, and 11.

Of 87 items reviewed in Table 5-1:

- o Thirty-six items (41%) do not require impact testing
- o Material used was not specified for 39 components (45%)
- o More data are required in order to assess 12 components (14%).

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

Table 5-1
Review of Fracture Toughness Requirements
Haddam Neck Nuclear Power Plant

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption (1)	Remarks
REACTOR COOLANT SYSTEM					
Pressurizer	Class A	Carbon Steel (Thickness - 5-7/16 in)	Insufficient Data		No information on T_{NDT} available
Reactor Coolant Pumps Casing	Class A	A-351, Gr CF8M	No	8e	
Reactor Coolant System: Hot and Cold Leg	Class A	SA-430, Type 316	No	8e	
Interconnecting Piping of Systems That Form Part of Reactor Coolant Pressure Boundary (RCPB)	Class A	Not Given			Not discussed in FSAR
Interconnecting Piping of Systems That Form Part of Reactor Coolant Pressure Boundary	Class B	Not Given			Not discussed in FSAR
Pressurizer Surge and Spray	Class A	Not Given			Not discussed in FSAR
Piping 3/4 Inch and Smaller Within RCPB	Class B	Not Given			Not discussed in FSAR
Pressurizer Relief Discharge Piping Upstream of Safety Valves	Class A	Not Given			Not discussed in FSAR

1. Refer to Table 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
Pressurizer Safety and Relief Valves	Class A	Not Given			Not discussed in FSAR
Power-Operated Relief Valves	Class A	Not Given			Not discussed in FSAR
Block Valves	Class A	Not Given			Not discussed in FSAR
Other Valves Within Quality Group A Portions of RCPB	Class A	Stainless Steel	Insufficient Data		Probably Austenitic Stainless Steel
Other Valves Within Quality Group B Portions of RCPB	Class B	Not Given			Not discussed in FSAR
SAFETY INJECTION SYSTEM (EMERGENCY CORE COOLING SYSTEM)					
Refueling Water Storage Tank	Class B	Aluminum	No	8f	
High and Low Pressure Safety Injection Pumps	Class B	Stainless Steel	Insufficient Data		Probably Austenitic Stainless Steel
Boron Injection Tank	Class B	Austenitic Stainless Steel	No	8e	
Accumulators	Class B	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
Interconnecting Piping and Valves Required to Perform Safety Injection Function	Class B	Austenitic Stainless Steel	No	8e	
Boron Injection Recirculation Tank	Class C	Not Given			Not discussed in FSAR
Boron Injection Recirculation Pump	Class C	Not Given			Not discussed in FSAR
Interconnecting Piping and Valves Required to Perform Recirculation Function	Class C	Not Given			Not discussed in FSAR
CONTAINMENT SPRAY SYSTEM					
Pumps	Class B	Not Given			Not discussed in FSAR
Heat Exchanger - Tube Side	Class B	Not Given			Not discussed in FSAR
Heat Exchanger - Shell Side	Class C	Not Given			Not discussed in FSAR
Spray Nozzles	Class B	Not Given			Not discussed in FSAR
Interconnecting Piping and Valves Required to Perform Spray Function	Class B	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
Spray Chemical Storage Tank	Class C	Not Given			Not discussed in FSAR
Chemical Storage Test Pump	Class C	Not Given			Not discussed in FSAR
Interconnecting Piping and Valves Required to Perform Test Function	Class C	Not Given			Not discussed in FSAR
CHEMICAL AND VOLUME CONTROL SYSTEM					
Regenerative Heat Exchanger	Class B	Austenitic Stainless Steel	No	8e	
Drain Cooler Heat Exchanger - Tube Side	Class A	Austenitic Stainless Steel	No	8e	
Drain Cooler Heat Exchanger - Shell Side	Class B	Carbon Steel	Insufficient Data		Material thickness not given
Reactor Coolant Filter	Class B	Not Given			Not discussed in FSAR
Volume Control Tank	Class B	Austenitic Stainless Steel	No	8e	
Charging Pumps	Class B	Austenitic Stainless Steel	No	8e	

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption (1)	Remarks
Letdown Orifices	Class B	Austenitic Stainless Steel	No	8e	
Non-Regenerative Heat Exchanger - Tube Side	Class B	Austenitic Stainless Steel	No	8e	
Non-Regenerative Heat Exchanger - Shell Side	Class C	Carbon Steel	Insufficient Data		Material thickness not given
Seal Water Injection Filter	Class B	Austenitic Stainless Steel	No	8e	
Seal Water Heat Exchanger - Tube Side	Class B	Austenitic Stainless Steel	No	8e	
Seal Water Heat Exchanger - Shell Side	Class C	Carbon Steel	Insufficient Data		Material thickness not given
Seal Water Filter	Class B	Austenitic Stainless Steel	No	8e	
Boric Acid Tanks	Class C	Austenitic Stainless Steel	No	8e	
Boric Acid Filter	Class C	Austenitic Stainless Steel	No	8e	
Boric Acid Transfer Pumps	Class C	Austenitic Stainless Steel	No	8e	
Boric Acid Blender	Class C	Austenitic Stainless Steel	No	8e	
Boric Acid Strainer	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
Piping (Loop 1) Letdown via Regenerative Heat Exchanger and Letdown Valves to and Including Letdown Isolation Valves	Class A	Austenitic Stainless Steel	No	8e	
Interconnecting Piping and Valves from Pump Discharge to and Including Valves 399 and 296 to Reactor Coolant System	Class A	Austenitic Stainless Steel	No	8e	
Piping and Valves from Pump Discharge to Containment Isolation Valves 399 and 296	Class B	Austenitic Stainless Steel	No	8e	
Piping and Valves from Pump Discharge via Reactor Coolant Pumps and from TV-1847 to Seal Water Heat Exchanger	Class B	Austenitic Stainless Steel	No	8e	
Piping and Valves Downstream of Letdown Isolation Valves to the Volume Control Tank (VCT) and Other Interconnecting Piping and Valves of the VCT	Class B	Austenitic Stainless Ste	No	8e	

Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption (1)	Remarks
Mixed Bed Demineralizer	Class C	Austenitic Stainless Steel	No	8e	
Interconnecting Piping and Valves Required to Perform Demineralizer Function	Class C	Austenitic Stainless Steel	No	8e	
Boric Acid Tank Connecting Piping and Valves	Class C	Austenitic Stainless Steel	No	8e	
SAMPLING SYSTEM					
Piping and Valves	Class A	Austenitic Stainless Steel	No	8e	
Piping and Valves	Class B	Austenitic Stainless Steel	No	8e	
RESIDUAL HEAT REMOVAL SYSTEM					
Residual Heat Removal/ Low Pressure Safety Injection Pumps	Class B	Austenitic Stainless Steel	No	8e	
Heat Exchanger - Tube Side	Class B	Austenitic Stainless Steel	No	8e	
Heat Exchanger - Shell Side	Class C	Carbon Steel	Insufficient Data		Material thickness not given

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Table 5-1 (Cont.)

Structures, Systems, and Components	Quality Group Classification	Material	Impact Test Required?	Reason for Exemption (1)	Remarks
Interconnecting Piping and Valves Required to Perform Residual Heat Removal Function	Class B	Austenitic Stainless Steel	No	8e	
COMPONENT COOLING SYSTEM					
Pumps	Class C	Cast Iron	Insufficient Data		Sizes and steel type not given
Heat Exchanger - Tube Side	Class C	Admiralty Brass	No	8f	
Heat Exchanger - Shell Side	Class C	Carbon Steel	Insufficient Data		Sizes and steel type not given
Surge Tank	Class C	Carbon Steel	Insufficient Data		Sizes and steel type not given
Interconnecting Piping and Valves Required to Service Quality Groups B and C System Components	Class C	Carbon Steel	Insufficient Data		Sizes and steel type not given
SERVICE WATER SYSTEM					
Pumps	Class C	Not Given			Not discussed in FSAR
Strainers	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
Interconnecting Piping and Valves Required to Service Quality Group C System Components	Class C	Not Given			Not discussed in FSAR
MAIN STEAM SYSTEM					
Inconnecting Piping and Valves Comprising Main Steam Lines Extending From the Secondary Side of the Steam Generator up to and Including the Outermost Containment Isolation Valve in Each Main Steam Line and Connected Piping up to and Including the First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation	Class B	Carbon Steel	Insufficient Data		No information on T_{NDT} available
Relief Valves	Class B	Not Given			Not discussed in FSAR
Safety Valves (16)	Class B	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
Piping and Valves (Blow-off) from Steam Generators to and Including Blow-off Valve TV-1312-1 through 4 and 506, 515, 522, and 529. Piping from Valves PICV-1206A, B to Auxiliary Feed Pumps Including Valves SV-1216A, B	Class C	Not Given			Not discussed in FSAR
FEEDWATER SYSTEM					
Interconnecting Piping and Valves Comprising Feedwater Lines Extending From the Secondary Side of the Steam Generators up to and Including the Outermost Containment Isolation Valves in Each Feedwater Line and Connected Piping up to and Including the First Valve That is Normally Closed or Capable of Automatic Closure During All Modes of Normal Reactor Operation	Class B	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
AUXILIARY FEED SYSTEM					
Pumps - Turbine Driven	Class C	Not Given			Not discussed in FSAR
Demineralizer Storage Tank	Class C	Not Given			Not discussed in FSAR
Piping and Valves from and Including Valves 156-1 through 156-4, 182 and Main Feed Valves MOV-11, 12, 13, 14, and 135-1 through 135-4 to Steam Generators	Class B	Not Given			Not discussed in FSAR
Piping and Valves to Suction of Auxiliary Feed System Pumps from Demineralizer Water Storage Tank	Class C	Not Given			Not discussed in FSAR
Piping and Valves from Pump Discharge to Valves 156-1 through 156-A and 182	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
CONTAINMENT PURGE SYSTEM					
Interconnecting Piping and Valves That Form an Extension of the Containment Boundary up to and Including the Outermost Containment Isolation Valve	Class B	Not Given			Not discussed in FSAR
CONTAINMENT ISOLATION SYSTEM					
Interconnecting Piping and Valves of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to and Including the Outermost Containment Isolation Valve	Class A	Not Given			Not discussed in FSAR
Interconnecting Piping and Valves of the Reactor Coolant Pressure Boundary That Penetrate the Containment up to and Including the Outermost Containment Isolation Valve	Class B	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
Interconnecting Piping Valves of Quality Groups B, C, or D System That Penetrate the Containment From the First Isolation Valve Inside Containment up to and Including the Outermost Containment Isolation Valve	Class B	Not Given			Not discussed in FSAR
SPENT FUEL PIT COOLING SYSTEM					
Spent Fuel Pit Heat Exchanger	Class C	Inconel	No	8f	
Spent Fuel Pit Pumps	Class C	Austenitic Stainless Steel	No	8e	
Spent Fuel Pit Filter	Class C	Austenitic Stainless Steel	No	8e	
Piping and Valves	Class C	Austenitic Stainless Steel	No	8e	

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, 14]. Quality assurance requirements for the design, and construction, fabrication, and installation of components at the Haddam Neck Plant are addressed in Section 13 of the FSAR [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, Section VIII, 1962 Edition [8].

The ASME B&PV Code Section VIII [8] in conjunction with Code Case 1270N classifies vessels in two different categories, primary vessels and secondary vessels. Primary vessels were defined as vessels which contain reactor coolant and are equivalent to current Class 1 vessels. Secondary vessels do not contain reactor coolant and are not subject to irradiation and are equivalent to current Class 2 and 3 vessels.

Note in Table 4-2(a) that the drain cooler heat exchanger-tube side, currently classified as a Class 1 pressure vessel, was designed to Section VIII [8] with Code Case 1270N invoked. The design code used for the pressurizer has not been provided. Note in Table 4-2(b) that current Class 2 pressure vessels were constructed to ASME B&PV Code Section VIII [8] with Code Case 1270N invoked, except for accumulators, containment spray system heat exchangers-tube side, and the reactor coolant filter, for which the design code was not provided. Code Case 1270N was not invoked for the drain cooler heat exchanger-shell side.

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

Similarly, in Table 4-2(c), all current Class 3 pressure vessels were designed to ASME Section VIII [8]. Code Case 1270N was invoked for the mixed bed demineralizer, residual heat removal system heat exchanger-shell side, component cooling system heat exchanger-shell and tube sides, surge tank, spent fuel pit heat exchanger, and spent fuel pit filter. Codes used in designing containment spray system heat exchanger-shell side and service water system strainers have not been provided. Currently classified Class 1, 2, and 3 pressure vessels, if previously classified as secondary vessels, should be evaluated against current radiography requirements (see discussion on full radiography in Section 5.2 of this report). Class 1 pressure vessels should be evaluated against current fatigue analysis requirements (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 the ASME B&PV Code, Section VIII [8], was based on the maximum normal stress theory of failure as compared to design based on the maximum shear stress theory of failure of the current code [2] for Class 1 components. The maximum shear stress theory currently used is advantageous for analysis because it is less conservative and it facilitates a more precise fatigue analysis. The current code for Class 2 and Class 3 components uses the same theory of failure as past codes.

Consideration of stress limits for equivalents of service levels C and D is not mentioned in the Haddam Neck FSAR [5].

Although discussed in the previous paragraph, the seismic portion of this topic is outside the scope of this report. The seismic review of 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 [8] 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 is that, in general, past full radiography requirements were dependent on material of construction, total plate thickness of the vessels, code cases invoked for design purpose, and whether or not the vessel contained lethal radioactive substances. Section VIII (1962) required that all joints whose material thickness exceeded 1-1/2 inches be fully radiographed. All longitudinal and circumferential welded joints with material thickness less than 1-1/2 inches should be fully radiographed as described in Paragraphs UCS-57, VHA-33, and UCL-35 of Reference 8.

Presently classified Class 1 vessels were referred to as primary vessels (containing radioactive lethal substances) when constructed to Section VIII (1962) [8] and Code Case 1270N. All longitudinal and circumferential welded joints of primary vessels were fully radiographed when designed to Section VIII [8] with Code Cases 1270N and 1273N invoked. Information regarding the radiography requirements imposed on drain cooler heat exchanger-tube side and the pressurizer should be provided for review against current radiography requirements (see Table 4-2(a)). A primary vessel (Code Case 1270N) designed to Section VIII (1962) requirements with Code Case 1273N invoked would meet current full radiography requirements.

Fatigue analysis was not required for vessels built according to Section VIII. All vessels currently classified as Class 1 should be evaluated for current fatigue analysis requirements. Discussion on current fatigue analysis requirements is provided in Section 5.4 of this report. For the pressurizer and drain cooler heat exchanger-tube side, the Licensee should provide the following:

a. proof that the five conditions outlined in Section 5.4 of this report were met and, therefore, analysis for cyclic loading is not required, or

b. if the five conditions were not met, calculations showing compliance with the current requirements for analysis for cyclic loading as described in Section NB-3222.4 of Reference 2.

Vessels built according to Section VIII [8] with Code Case 1270N invoked and formerly classified as secondary vessels (not containing radioactive letha_ substances) are currently categorized as Class 2 and 3 vessels. All longitudinal and circumferential welded joints of secondary vessels with material thickness exceeding 1-1/2 inches were fully radiographed when designed to Section VIII [8]. All longitudinal and circumferential welded joints with material thickness less than 1-1/2 inches should be fully radiographed as described in Paragraphs UCS-57, VHA-33, and UCL-35 of Reference 8.

Information regarding the radiography requirements imposed on the all Class 2 and 3 vessels should be provided for review against current radiography requirements.

5.3 PIPING

In addition to the general requirements previously discussed, the following items are considered in the design of Class 1 piping for fatigue stresses based on the current code [2] but 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 is considered
- 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 is concerned 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. From Figure 7.2-1 of the FSAR [5], the drop in average reactor coolant temperature is 29.3°F for 100% to 0% power variation. Stress calculations for the Haddam Neck plant that are similar to two examples given in Section 4.2 of Appendix A for the Palisades plant [12] will indicate that no problem exists for medium and large numbers of cyclic loads.

Specific code cases invoked for piping systems designed to ASA B31.1 (1955) [7] should be specified in Table 4-1. This information is required in order to perform a more comprehensive assessment of the piping systems. Discussion of code cases used in conjunction with ASA B31.1 (1955) is provided in Section 4.2 of the appendix. In general, piping designed to ASA B31.1 (1955) [7] with Code Case N-1[(1)] invoked had safety requirements imposed for loss of radioactive fluid. If Code Case N-7[(1)] was invoked for piping made from austenitic stainless steel, full radiography requirements and allowable stress values up to a temperature of 650°F would meet current requirements. Code Case N-9[(1)] provided guidelines for centrifugally cast austenitic steel for nuclear service and required fully radiographed welded joints. Code Case N-10[(1)] permitted the use of cast austenitic butt-welded fittings for nuclear service and required full radiography. Stress allowables for Code Cases N-9 and N-10 meet current stress allowables for a temperature range up to 650°F.

For Class 1 and 2 piping systems designed to ASA B31.1 (1955), information on the radiography requirements imposed should be provided in order to determine if the systems meet the current requirements.

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1. Mechanical Engineering, August 1962 (Code Cases N-1, N-7), December 1960 and October 1964 (N-9), and April 1960 (N-10).

5.4 PUMPS

Table 4-2(a) shows that Class 1 pumps (recirculation system pumps) were designed to ASME VIII [8]. Table 4-2(b) shows that Class 2 pumps were designed to ASME VIII [8], except the containment spray system pumps, for which no design code was specified. Table 4-2(c) shows that the turbine-driven pumps were designed to ASA B31.1 (1955) [7]. It is noted that pump design is not covered under the piping code; therefore, clarification of this discrepancy should be provided by the Licensee. No information was provided regarding design codes used for the remaining pumps listed in Table 4-2(c). The Licensee should provide additional design information with reference to the current requirements imposed on these pumps.

Items to be reviewed regarding pumps are general requirements as discussed in Section 5.1 of this report and full radiography requirements discussed in Section 5.2 of this report, and the fatigue analysis discussed herein. Information on the radiography requirements imposed on the welds of Class 1 and 2 pumps listed in Tables 4-2(a) and 4-2(b) should be provided and compared with current requirements given in Section 4.2 of Appendix A.

The recirculation system pumps are currently classified as Class 1 pumps. Class 1 requirements specify fatigue analysis if a set of conditions are not met (see NB-3222-4(d) of Reference 2).

If any one of the following conditions is not met, the recirculation system pumps should be analyzed for cyclic loads:

(1) Pressure Fluctuations: the specified full range of pressure fluctuations during normal service does not exceed:

$(1/3)\ (\text{Design Pressure})\ (S_a/S_m)$

where:

S_a = alternating stress from fatigue curves corresponding to the number of pressure fluctuations

S_m = allowable stress intensity at the service temperature

(2) Atmospheric to Service Pressure Cycle

$N_2 \leq N(3S_m)$

where:

N_2 = the maximum number of atmospheric to service pressure cycles

$N(3S_m)$ = number of cycles from design fatigue curve for $S_a = 3S_m$

(3) Temperature differences between adjacent points, i.e., two points along the meridian of a vessel, nozzle, or flange closer than $2(Rt)^{(1/2)}$ where R is the mean radius and t is the mean thickness between the two points:

$\Delta T_i \leq S_a/(2E\alpha)$ (i = 1,2)

where:

ΔT_i = temperature differences between two adjacent points

i = 1: startup and shutdown

i = 2: normal service

E = modulus of elasticity at mean temperature between points

α = instantaneous coefficient of expansion, mean value (see Table I-5.0 of Reference 2)

S_a = alternating stress from design fatigue curve corresponding to the number of startups and shutdowns, N_1, and the number of significant temperature difference fluctuations during normal service, N_2. A significant number of temperature fluctuations are greater than $S/(2E\alpha)$ where S is the endurance limit, i.e., the value of S_a from the fatigue curve at 10^6 cycles.

(4) Temperature difference - dissimilar materials - see paragraph NB-3222.4(d)(4) of Reference 2

(5) Mechanical loads - stresses due to mechanical load fluctuations (excluding pressure) such as pipe loads on nozzles less than the value of S_a from the design fatigue curve corresponding to the number of load fluctuations.

The Licensee should provide the following:

a. proof that the five conditions previously outlined were met; therefore, analysis for cyclic loading is not required, or

b. if the five conditions were not met, calculations showing compliance with the current requirements for analysis for cyclic loading as described in Section NB-3222.4 of Reference 2.

Of the twelve pumps reviewed in this report, four were designed to ASME VIII. Information is needed on the pumps that were not designed to ASME B&PV Code, in order to determine if they meet current standards: codes, code classes, editions, code cases, design calculations, and radiography requirements should be provided. Information on the radiography requirements imposed on Class 1 and 2 pumps should be provided in order to determine whether they meet the current requirements.

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 [2, 13]
3. stress limits for service level C might 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 Haddam Neck 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 the 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 Haddam Neck plant (see Table 4-2(b) and 4-2(c)) should be compared with the current pressure-temperature rating [13].

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, Code Case N-1 in combination with codes cases N-7, N-9, or N-10 [1] to Reference 7 required full radiography for circumferential and longitudinal welds. If these code cases were applied, then current full radiography requirements are met. Using Table 4-1, the Licensee should provide information indicating which code cases were invoked.

5.6 STORAGE TANKS

As discussed in Section 4.7 of Appendix A, atmospheric storage tanks designed to USAS B96.1 (1967) [14] for welded aluminum alloy field-erected storage tanks should be evaluated to determine if the current design requirements are met. Welded aluminum alloy tank shells are currently permitted for Class 3 storage tanks only. Shells designed to USAS B96.1 specifications may be overstressed by as much as 20% above the current allowables. Calculations and specifications for the demineralizer storage tank which is designed to USAS B96.1 (1967) and currently classified as a Class 3 storage tank should be provided to determine whether they meet current standards.

Information on codes, calculations, and specifications used for the design of the following tanks should be provided: refueling water storage tank, boron injection tank, boron injection recirculation tank, and spray chemical storage tank.

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1. Mechanical Engineering, August 1962 (Code Case N-1, N-7), December 1960 and October 1964 (N-9), and April 1960 (N-10).

6. CONCLUSIONS AND RECOMMENDATIONS

A comparison of the design standards in effect during the design and construction of the Haddam Neck 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 Class 1 piping systems, pressure vessels, and pumps.

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. In many instances, information provided by the Licensee in the table of quality group classification of systems and components and the FSAR is not sufficient or clear enough to enable FRC to make a proper judgment on 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 - Eighty-seven items in Table 5-1 were reviewed to determine if impact testing was required. From the information in this table, it can be concluded:

   o Thirty-six items (41%) do not require impact testing

   o Material used was not specified for 39 components (45%)

   o More data are required in order to assess 12 components (14%).

2. Full radiography requirements - Information should be provided on the radiography requirements imposed on Class 1 vessels not designed as

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

primary vessels (Code Case 1270N) and for which Code Case 1273N was not invoked. Information on the radiography requirements imposed on Class 2 and 3 vessels for which Code Case 1273N was not invoked and with welded joint thicknesses less than 1-1/2 in should be provided. Piping systems designed to ASA B31.1 [7] and Code Case N-1, in combination with Code Cases N-7, N-9, and N-10, meet current full radiography requirements. Information on the radiography requirements imposed on Class 1 and 2 piping and valves designed only to ASA B31.1 (1955) should be provided in order to determine if these components meet current radiography requirements. Information on the radiography requirements imposed on Class 1 and 2 pumps should be provided in order to determine whether the pumps meet current radiography requirements. Tables 4-2(a), (b), and (c) should be used in providing the required information.

3. Pressure vessels - Information regarding the radiography requirements imposed on all Class 1, 2, and 3 pressure vessels is required. Additional data on the materials of construction are needed for the fracture toughness evaluation. Proof of compliance with current fatigue analysis requirements for Class 1 vessels (Table 4-2(a)) should be provided as per the discussion in Section 5.4 of this report.

4. Piping - In addition to the impact testing and full radiography requirements previously discussed, information on the code cases invoked for the piping system designed to ASA B31.1 (1955) [7] should be provided.

5. 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.

6. Pumps - Of the 12 pumps reviewed in this report, four were designed to Section VIII of the ASME B&PV Code. Information is needed on the eight remaining pumps in order to evaluate if the current requirements are met. Codes, code classes, editions, codes cases, design calculations, and radiography requirements should be provided for these pumps in the Haddam Neck plant. Proof of compliance with current fatigue analysis requirements, as discussed in Section 5.4 of this report, for current Class 1 pumps (the recirculation system pumps) should be provided. Information on the radiography requirements imposed on Class 1 and 2 pumps should be provided.

7. Storage tanks - (i) Calculations and specifications for the demineralizer storage tank designed to USAS B96.1 (1967) [14] should be provided in order to determine whether they meet current standards;

(ii) information on codes, calculations, and specifications for the four remaining tanks reviewed in this report should be provided in order to determine if they meet current standards.

8. Missing information - The following information, which is incomplete or missing from Table 4-1 or Tables 4-2(a), (b), and (c) of this report, should be provided:

   i. Information on codes, class, and code cases used in the design of 56 out of 114 components (Table 4-2)

   ii. Any specifications or calculations used in designing pumps, valves, and tanks that may assist in conducting this evaluation

   iii. Confirmation of assumptions made regarding code editions (Table 4-1)

   iv. Clarification or additional information on notes 3, 4, 6, and 7 in Table 4-1.

7. REFERENCES

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

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. Letter to D. L. Ziemann (NRC) from W. G. Counsil (CYAPCO), with Table of Systems and Components, dated September 28, 1979; Note to A. Gonzalez (FRC) from M. Boyle (NRC) with additional information on Table of Systems and Components, dated April 19, 1982; Request for Additional Information from C. J. Crane (FRC) to S. Bajwa (NRC) dated April 28, 1982; Telephone Memorandum from A. Gonzalez (FRC) to M. Boyle (NRC) dated June 10, 1982

5. Final Safety Analysis Report for Haddam Neck Plant
   (2 Volumes)
   Docketed USAEC, July 22, 1966
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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 VIII
   "Unfired Pressure Vessels"
   1962

9. 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 Supports"
Published for Comment, October 1979
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10. 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

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

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

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

14. "USA Standard Specification for Welded Aluminum-Alloy Field-Erected Storage Tanks"
United States of America Standards Institute, February 1967
USAS B96.1-1967

APPENDIX A

REVIEW OF CODES AND STANDARDS
APPLICABLE TO LACROSSE, SAN ONOFRE, AND HADDAM NECK 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(1) being compared against the current code are the B&PV Code, Section VIII, 1962 Edition [3] for vessels and the "Code for Pressure Piping," American Standard Association B31.1, 1955 Edition [4] and/or the B&PV Code, Section I, 1962 Edition [5] for piping.

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 II plants: LaCrosse, San Onofre, and Haddam Neck plants.

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

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1. Together with Code Cases 1270N, 1271N, 1272N, and 1273N for vessels and/or Code Cases N-1, N-2, N-4, N-7, N-9, N-10, N-11, and N-12 for piping, when invoked.

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.[2]

2. 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 1270N, 1271N, 1272N, 1273N, 1273N-4, 1274N, and 1275N
San Onofre	Jan. 1968	2. ASA B31.1 (1955) and Code Cases N-1, N-2, N-4, N-7, N-9, N-10, N-11, and N-12
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 codes for piping are the B31.1 (1955) power piping code and Section I of ASME B&PV Code (1962) [5], "Power Boilers," for piping between the reactor vessel up to and including the valve or valves required by ASME I. 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

Table A2-3 compares the current code [1] requirements for the materials, design, fabrication, examination, and testing of pressure vessels for nuclear power plants against ASME B&VP Code Section VIII (1962) [3].

A comparison of significant past and current pressure vessel requirements may be found in Section 4.3 of this appendix.

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 VIII [3], which is discussed in Sections 2.3 and 4.3 of this appendix, and possibly 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 may have been designed to the ASME Boiler and Pressure Vessel Code, Section VIII, 1962 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.

Table A2-1

Current Code Requirements [1]

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	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	-	

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	–	

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Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	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	

Table A2-1 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	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	

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	Significant	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	[illegible]	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	Signi-ficant	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	-	-	

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	Significant	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 VIII (1962) [3] with ASME III (1977) [1]

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi- ficant	Corresponding Article in ASME VIII (1962)	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-90(c) & UG-93	
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-115 through UG-120	
1000	INTRODUCTION						
1100	Scope	A	A	A	A	U-1	

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 VIII (1962)	Remarks
2000	MATERIAL						
2100	General	A	A	A	A	UG-5	
2200	Material Test Coupons and Specimens for Ferritic Steel Materials	A	A	A	-		
2300	Fracture Toughness Requirement for Material	A	A	A	A	UG-84	
2400	Welding and Brazing	A	A	A	A	UW & UB	
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, UG-16 through UG-55	
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	
						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 A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME VIII (1962)	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 (m)	
5400	Final Examination of Items (Cl. 1); Spot Examination of Welded Joints (Cl. 3)	A	NA	A	A	UG-99(g), UW-50	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. UG-91 gives requirements for qualification of inspectors, but not NDE personnel
5500	Qualifications of Nondestructive Examination Personnel	A	A	A	A	NA	
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	-		

Table A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Signi-ficant	Corresponding Article in ASME VIII (1962)	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 A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME VIII (1962)	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 A2-3 (Cont.)

Article* or Subarticle	Description	Class 1	Class 2	Class 3	Significant	Corresponding Article in ASME VIII (1962)	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		

3. CONCLUSIONS AND RECOMMENDATIONS

Nuclear components and systems for SEP "Group II" plants may have been designed in accordance with the following codes:[1]

1. ASME I (1962) - piping and valves
2. ASME VIII (1962, 1974) - vessels
3. ASME III (1963) - vessels
4. B31.1 (1955) - piping and valves
5. TEMA (1959) - heat exchangers
6. ASA B16.5 (1961, 1953) - steel pipe flanges and flanged fittings
7. Hydraulic Institute Standards (1965) - pumps
8. USAS B96.1 (1967) - aluminum field erected storage tanks
9. API 650 (1964) - welded steel tanks for oil storage
10. B16.10 (1957) - valves and B16.9 (1958) - fittings
11. USAS B31.1 (1967), ANSI B31.1 (1973), USAS B31.7 (1968 Draft), Draft ASME Code for Pumps and Valves for Nuclear Power (1968).

Current requirements are contained in the following:

12. ASME III (1977) - Div. 1 nuclear components
13. 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, except for full radiography requirements for welded vessel joints less than 1-1/2 in thick for some materials as noted in Section 4.3 of this appendix.

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

3. Piping currently classified as Class 1 satisfies 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.

4. Vessels and pumps currently classified as Class 1 may not satisfy current fatigue analysis requirements.

5. Vessels previously classified as "primary vessels" by Code Case 1270N would currently be categorized as Class 1 vessels. Vessels previously classified as "secondary vessels" by Code Case 1270N may currently be regarded as Class 2 or Class 3 vessels.

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1. Modified for nuclear components by code cases for vessels and piping when invoked.

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-1 together with either N-2, N-7, N-9, or N-10 has been invoked when designing to B31.1 requirements, Class 1 and 2 piping should be checked to see if full radiography of welded joints was specified.

5. Past full radiography past requirements for Class 2 and Class 3 welded vessel joints less than 1 1/2 in thick should be reviewed in light of Section 4.3 of this appendix.

6. Currently classified Class 1 vessels and pumps should be evaluated for fatigue analysis requirements.

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.

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.

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.

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.

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.

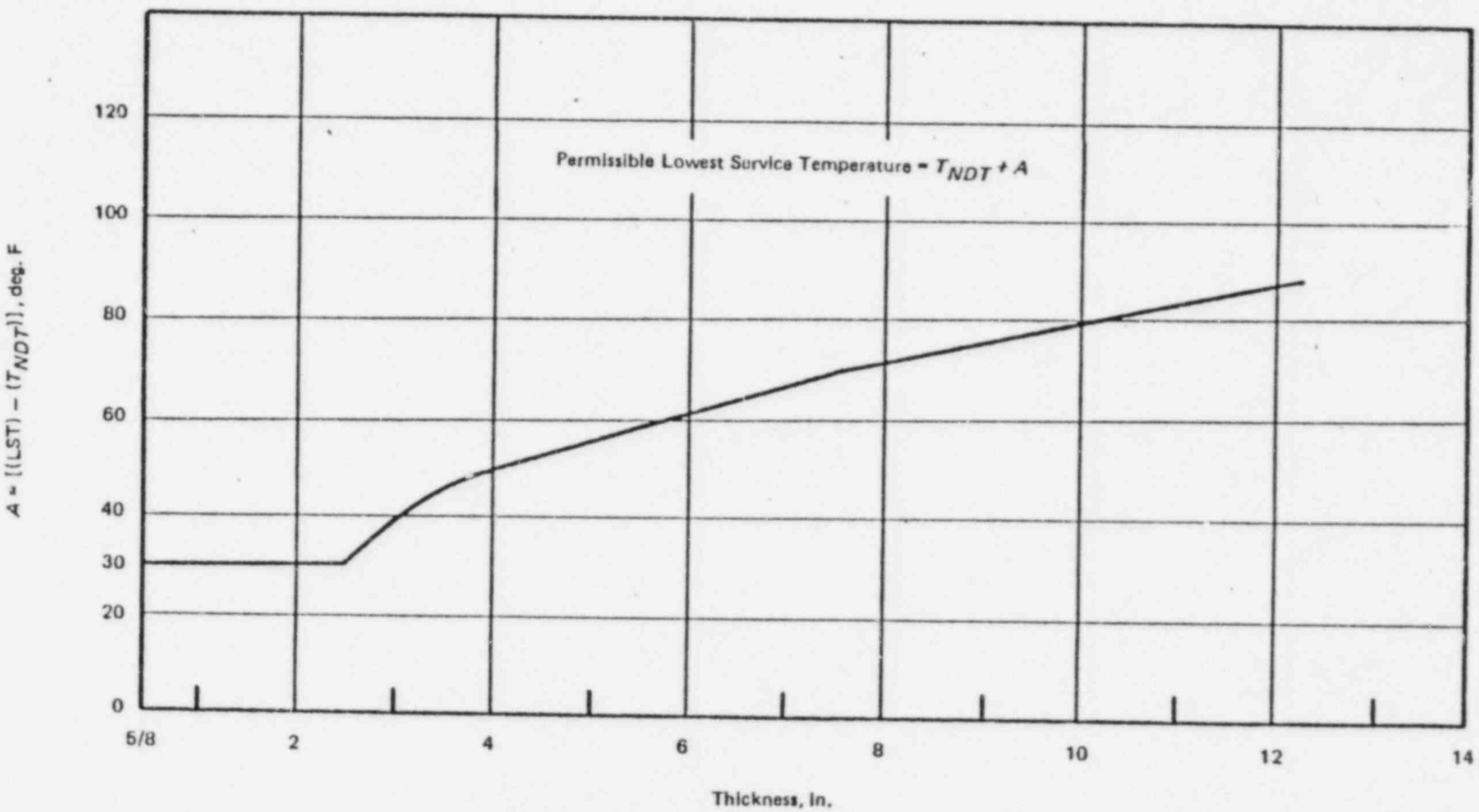

FIG. NC-2311(a)-1 DETERMINATION OF PERMISSIBLE LOWEST SERVICE TEMPERATURE

Figure A4-1

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 A4-6

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 tougnness 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.

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.

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.

---

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.

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

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.

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:

*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.

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 not 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.

Quality Group C (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 are 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 and ASME I (1962) do not designate quality classes for piping or valves. 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.

Piping built to ASME I (1962 Edition) and for which Code Class 1270N was invoked would currently be designated as Class 1 piping.

Piping built to B31.1 (1955) for which Code Case N-1 was invoked would be classified in one of the two following categories:

1. Nuclear piping designed to contain a fluid "whose loss from the system could result in a radiation hazard either to the plant personnel or to the general public"

2. Conventional steam and service non-nuclear piping.

Nuclear piping can currently be designated as Class 1 or Class 2. Code Cases N-7, N-9, and N-10, when invoked for nuclear piping, together with ASA B31.1 requirements, have been evaluated in Section 4.2 of this appendix to determine whether piping built to these requirements codes satisfies current Class 1 or Class 2 requirements.

Past ASME B&VP Code Sections I and VIII, 1962 editions, did not classify vessels for nuclear service. Code Case 1270N, when invoked, did classify vessels for nuclear service as follows:

a. Reactor vessel (outside scope of this study)

b. Primary vessels, other than reactor and containment vessels designed to contain reactor coolant

c. Secondary vessels which do not contain reactor coolant or are otherwise subject to irradiation

d. Containment vessels (outside scope of this study)

Note that a vessel previously designated as a primary vessel under Code Case 1270N would currently be designated as a Class 1 vessel. A vessel previously designated as a secondary vessel could be designated as a Class 2 or Class 3 vessel under current rules.

Secondary vessels currently designated as Class 2 or Class 3 should be carefully reviewed for possible non-compliance with current full radiography requirements.

4.1.4 Code Stress Limits

Strength Theories

Past codes [3, 4, 5], 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.

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

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

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

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

Example: 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 $\sigma/2$. 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:

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

---

1. Except for Class 2 vessels designed in accordance with the alternative rules of NC-3200.

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.

Stress Categories

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. Primary Stresses

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

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

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 1e 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]

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

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)

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

Stress Category	Limit of Stress Intensity		
(a) Expansion Stress Intensity P_e (not for vessels)	Tabulated 3 S_m	YS $\leq$2 YS	UTS $\leq$ 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.

---

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.

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.

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

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

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).

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,

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

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).

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.

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).

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.

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.

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:

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. The B31.1 (1955) piping code and the ASME Boiler and Pressure Vessel Code, Sections I and VIII (1962) are 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.

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2. Computed value of stress assuming elastic behavior.

3. The current code for Class 1 components considers primary as well as secondary stresses and peak stress categories. The B31.1 (1955) power piping and ASME I (1962) power boiler codes do not consider peak stresses.

4. The current code for Class 2 and 3 vessels considers primary stresses for size selection, as does ASME VIII (1962).(1) The current code for Class 2 and 3 piping considers primary and secondary stresses, as does the past B31.1 (1955) piping code.

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.

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

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.

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1. B31.1 (1955) only; ASME I (1962) 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 $S_h \leq 0.9(1/4\ \text{UTS})$ gives $S_A \leq f\ (1.5(\text{UTS})/4)0.9$.

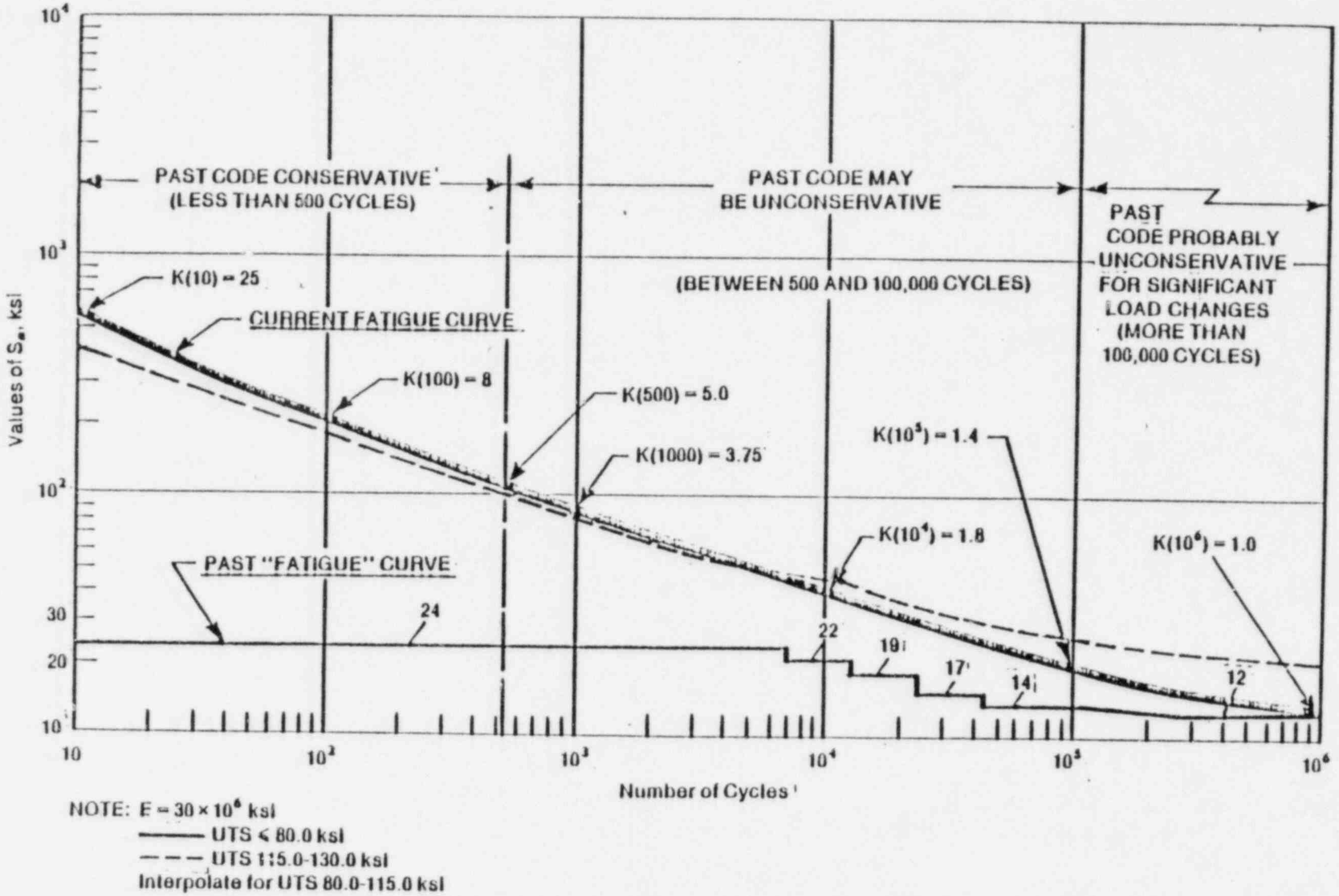

Figure A4-2. Design Fatigue Curves for Carbon, Low Alloy, and High Tensile Steels (For Metal Temperatures Not Exceeding 700°F) (Reference 4e)

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:

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

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

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

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

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

$\nu = 0.3$

$E\alpha$ = 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.

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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 (1962).

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

Piping Products and Joints	(Not Applicable for $D_o/t > 100$) Internal Pressure			Moment Loading[8]			Thermal Loading		
	B_1	C_1	K_1	B_2	C_2	K_2	C_3	C_3'	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 $\delta/t \leq 0.1$]	0.5	1.1	1.2[1]	1.0	1.0	1.8	1.0	0.5	1.7
(c) as welded $t \leq 3/16$ 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[4]									
(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 $t \leq 3/16$ 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	$\frac{2R-r}{2(R-r)}$[9]	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	[8]	[8]	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 $0.08 D_o$, and acceptable value of K_1 may be obtained by multiplying the tabulated values of K_1 by the factor F_{1b}:

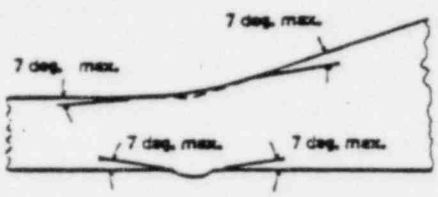
$$F_{1b} = 1 + \frac{M S_y}{P D_o / 2t}$$

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 surface 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.

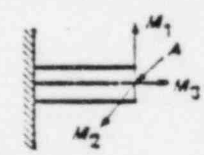
(4) R = curved pipe or elbow radius, in.
r = mean radius of cross section, in.
$= (D_o - t)/2$, where t = nominal wall thickness

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

Straight Through Pipe

M_i = moment at Point A

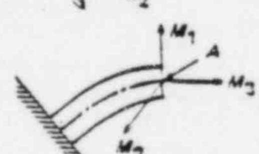
$M_i = \sqrt{M_1^2 + M_2^2 + M_3^2}$



Curved Pipe or Welding Elbow

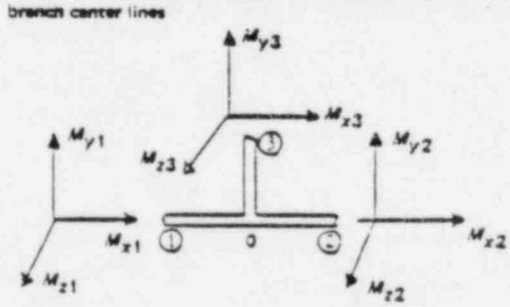
M_i = moment at Point A

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



Branch Pipe

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



For M_b

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

For M_r

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

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

If M_{i1} and M_{i2} have the same algebraic sign, then $M_{ir} = 0$. If M_{i1} and M_{i2} have different algebraic signs, then M_{ir} is the smaller of M_{i1} or M_{i2} 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) $$B_{2b}\frac{M_b}{Z_b} + B_{2r}\frac{M_r}{Z_r}$$

Equations (10) & (12) $$C_{2b}\frac{M_b}{Z_b} + C_{2r}\frac{M_r}{Z_r}$$

Equation (11) $$C_{2b}K_{2b}\frac{M_b}{Z_b} + C_{2r}K_{2r}\frac{M_r}{Z_r}$$

where

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

$$Z_r = \pi R_m^2 T_r$$

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) $B_{2b} = 0.75\,C_{2b}$ but not less than 1.0
$B_{2r} = 0.75\,C_{2r}$ but not less than 1.0
$C_{2b} = 3(R_m/T_r)^{2/3}\,(r'_m/R_m)^{1/2}\,(T'_b/T_r)\,(r'_m/r_p)$, 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
$K_{2b} = 1.0$
$C_{2r} = 0.8\,(R_m/T_r)^{2/3}\,(r'_m/R_m)$, but not less than 1.0
$K_{2r} = 2.0$
The product of $C_{2r}K_{2r}$ shall be a minimum of 3.0

(8) $C_1 = \dfrac{1.95}{h_1^{2/3}}$, but not less than 1.5; $B_1 = 0.75\,C_1$

$h_1 = \dfrac{tR}{r^2}$, where t = nominal pipe wall thickness
R = bend radius of curved pipe or elbow
r = mean pipe radius
$= (D_o - t)/2$

(9) $B_{1b} = B_{1r} = 0.75\,C_{1b}$

$C_{1b} = C_{1r} = 0.67\,(R_m/T_r)^{1/3}$, but not less than 2.0

R_m = mean radius of designated run pipe

T_r = nominal wall thickness of designated run pipe

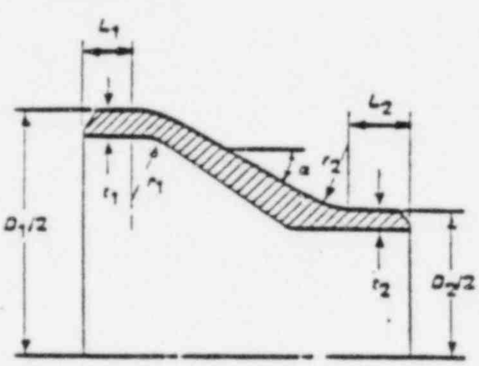
$K_{1b} = K_{1r} = 1.0$

(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 $r_2 \geq 0.1D_1$

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

$$C_2 = 1 + 0.36\,\alpha^{0.4}(D_n/t_n)^{0.4}(D_2/D_1 - 0.5)$$

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 $r_2 < 0.1D_1$

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

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

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 δ_1/t_1, $\delta_2/t_2 < 0.1$:

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

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

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 $C_2 = 1.9\ i$, 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

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

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

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

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

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

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

$$S_p = \frac{1}{4}(0.9)\ \lambda_1 K_1 C_1\ (UTS) + 0.65f\ \lambda_{2i} K_2\ (UTS) + \frac{1}{(1-\nu)} E\alpha|\Delta T_2| + K_3 \frac{E\alpha}{2(1-\nu)} |\Delta T_1| \qquad (1a)$$

for ferritic steels.

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

$$S_p = \frac{0.9}{5} \lambda_1\ (UTS)\ K_1 C_1 + 0.63f\ \lambda_{2i}\ K_2\ (UTS) + \frac{1}{(1-\nu)} E\alpha|\Delta T_2| + K_3 \frac{E\alpha}{2(1-\nu)} |\Delta T_1| \qquad (1b)$$

for austenitic steels.

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

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

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

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:

$$S_p = 0.23\ \lambda_1\ (UTS)\ K_1 C_1 + 0.85 f\ \lambda_{2i}\ K_2\ (UTS) + 0.291\ |\Delta T_2| + 0.145\ K_3\ |\Delta T_1| \qquad (1a)$$

for ferritic steels

$$S_p = 0.18\ \lambda_1\ (UTS)\ K_1 C_1 + 0.82 f\ \lambda_{2i}\ K_2\ (UTS) + 0.380\ |\Delta T_2| + 0.190\ K_3\ |\Delta T_1| \qquad (1b)$$

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 10 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 11, so that:

Service Cycle - 1 $\quad n_1 = 15{,}000 \quad$ 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

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

$$r = 23.13$$

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

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 ksi (ASTM 516 - 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 ± 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 $\lambda_{2i} = \dfrac{\Delta T_i}{[(T_o)_{max} - 70°]}$

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

ΔT of Service Cycle 1 = 62°F ΔT 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 $\quad n_1 = 15{,}000 \quad f = 0.8 \quad \lambda_{21} = 0.12$

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

$$S_p = 0.644\ K_1 C_1 + 59.5\ f\ K_2 \lambda_{21} + 0.291 |\Delta T_2| + 0.145\ K_3 |\Delta T_1| = 18.7 \text{ ksi}$$

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

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

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

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

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

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

$N_2 > 10^6$ (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)	k_{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 valves k_{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 (1962) Requirements

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

a. ASME I (1962)
b. ASME I (1962) and B31.1 (1955).

If requirement (a) was invoked, expansion stress limits due to cyclic thermal loading are not specifically imposed. However, ASME I (1962) 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 (1962) criteria should furnish details as to how thermal stresses were considered.

If requirement (b) was invoked, then paragraph 102(b) of Section I [4] requires that valves, fittings, and piping for boilers as prescribed in Section 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 Section I.

Nuclear Code Cases N-1, N-2, N-4, N-7, N-9, N-10, N-11, and N-12,(1) when invoked, impose requirements as follows:

1. Code Case N-1 requires that nuclear piping (for which loss of fluid could result in a radiation hazard) may be designed to B31.1 (1955) supplemented by the requirements of case interpretations identified by the prefix "N."

2. Code Case N-2 requires that valves used in nuclear power systems:

   a. be of materials recognized by ASA B31.1-1955 and conform to a recognized standard (e.g., ASA B16.5).

   b. meet physical and inspection requirements of Code Case N-10.

   c. have a positive sealing or some provision for stem and bonnet leakoff control.

   d. screwed end valves (in which the thread provides the only seal) are not permitted.

3. Code Case N-4 permits the temperature limit of 100°F for hydrostatic media to be exceeded.

4. Code Case N-7 permits the use of nuclear piping made from austenitic stainless steels, provided that:

   a. materials conform to one of the following ASTM specifications: A376, A358, A312, and A430 for piping; ASTM-A403 for welded fittings; or ASTM-182 for forgings.

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1. Mechanical Engineering, August 1962 (Code Case N-1, N-7), December 1960 and October 1964 (N-9), April 1960 (N-10), July 1961 (N-2), December 1960 (N-4), and November 1961 (N-11 and N-12).

b. full radiography of longitudinal and circumferential welds is performed; however, fluid penetrant methods are permitted when size or configuration precludes full radiography, or for services at or near atmospheric temperatures up to 212°F provided that piping is tested at 1.5 times the maximum allowable working pressure.

c. allowable stress values are used as shown in the following table:

Allowable Stress Values

Temperature (F°)	Steel Type									
	304H	304	304L	361H	316	316L	321H 347H 348H	321 347 348	309	310
-20 to 100	18750	18750	17500	18750	18750	17500	18750	18750	18750	18750
200	16650	16650	15300	18750	18750	16250	18750	18750	18750	18750
300	15000	15000	13100	17900	17900	14500	17000	17000	17300	18500
400	13650	13650	11000	17500	17500	12000	15800	15800	16700	18200
500	12500	12500	9700	17200	17200	11000	15200	15200	16600	17700
600	11600	11600	9000	17100	17100	10150	14900	14900	16500	17200
650	11200	11200	8750	17050	17050	9800	14850	14850	16450	16900
700	10800	10800	8500	17000	17000	9450	14800	14800	16400	16600
750	10400	10400	8300	16900	16900	9100	14700	14700	16200	16250
800	10000	10000	8100	16750	16750	8800	14550	14550	15700	15700
850	9700	9700		16500	16500		14300	14300	14900	14900
900	9400	9400		16000	16000		14100	14100	13800	13800
950	9100	9100		15100	15100		13850	13850	12500	12500
1000	8800	8800		14000	14000		13500	13500	10500	11000
1050	8500			12200			13100		8500	7100
1100	7500			10400			10300		6500	5000
1150	5750			8500			7600		5000	3600
1200	4500			6800			5000		3800	2500
1250	3250			5300			3300		2900	1450
1300	2450			4000			2200		2300	750
1350	1800			2700			1500		1750	450
1400	1400			2000			1200		1300	350
1450	1000			1500			900		900	250
1500	750			1000			750		750	200

d. reheat treating at 1950°F for 1 hour per inch of thickness for pipe sections subject to cold or hot formings followed by fluid penetrant testing of all accessible surfaces was performed.

3. Code Case N-9 allows the use of centrifugally cast austenitic steel pipe for nuclear service provided that specified chemical and mechanical properties are satisfied: inside and outside surfaces shall (1) be machine finished to 250 micro-inch RMS or 225 micro-inch AA or finer; (2) be pressure tested at 1.5 times the rated pressure and fluid penetrant inspected; (3) be fully radiographed; (4) meet the requirements of ASTM E-71 for Class 2 quality casting; and (5) be reheat treated at 1950°F for hot formed sections.

Stress allowables should be in accordance with the following table:*

Maximum Allowable Stress Values in Tension, psi

	ASTM A451 Grade		
	CPFS	CPF8M	CPF8C
Spec. Min. Tensile	70000	70000	70000
Temperature (°F)			
-20 to 100	17500	17500	17500
200	15700	16900	17000
300	14250	16500	15600
400	13100	16300	14200
500	12200	15900	13000
600	11700	15350	12200
650	11500	15000	11900
700	11300	14700	11700
750	11100	14350	11600
800	10900	14000	11500
850	10650	13500	11350
900	10400	13000	11200
950	10100	12350	11100
1000	9850	11700	11100
1050	9600	10600	10900

Note: These stress values are based an a casting quality factor of 1.00.

4. Code Case N-10 permits the use of cast austenitic steel butt welding fittings for nuclear service provided that ASTM Specifications A-351 and ASA B16.9 are augmented by the following requirements:

   a. specified chemistry and mechanical properties shall be satisfied

   b. fittings shall be finished to 250 micro-inch RMS or 225 micro-inch AA or finer

   c. fittings shall be tested at 1.5 times the rated pressure

   d. fittings shall be inspected by the fluid penetrant method and be fully radiographed in satisfaction of the ASTM E-71 requirements for Class 2 quality castings

   e. fittings shall be heat treated at 1950°F followed by rapid cooling in air or a liquid medium

   f. Stress allowables shall be in accordance with the following table:

* Values are applicable only after October 1964.

Maximum Allowable Stess Values in Tension, psi

	ASTM A351 Grade				
	CF8	CF8M	CF8C	CH20	CK20
Spec. Min. Tensile	70000	70000	70000	70000	65000
Temperature (F°)					
-20 to 100	17500	17500	17500	17500	16250
200	15700	16900	17000	16100	15300
300	14250	16500	15600	15150	14900
400	13100	16300	14200	14600	14600
500	12200	15900	13000	14550	14450
600	11700	15350	12200	14450	14450
650	11500	15000	11900	14400	14400
700	11300	14700	11700	14350	14350
750	11100	14350	11600	14300	14300
800	10900	14000	11500	14150	14150
850	10650	13500	11350	13900	13900
900	10400	13000	11200	13500	13500
950	10100	12350	11100	12500	12500
1000	9850	11700	11000	10500	11000
1050	9600	10600	10900	8500	9750

5. Code Case N-11 indicates that any sound means of providing for thermal expansion may be used and the following requirements must be met:

   a. Must meet requirements of Section 6, Chapter 3 of ASA B31.1-1955.

   b. Material recognized by ASA B31.1-1955.

   c. If sliding or swivel type, have a positive seal or leakoff control.

   d. Provide for thermal expansion due to rapid temperature fluctuations.

6. Code Case N-12 provides a procedure for qualifying new materials for use in nuclear piping systems. The following subjects are discussed: ASTM identification, alternate identification, creep and stress rupture data, physical properties, heat treatment, hardness measurements, impact strength and transition temperature, radiation and temperature effects, microstructure variations, availability, weldability, and test results.

The following is concluded:

1. If ASME I (1962) was used, the Licensee should furnish information regarding how expansion thermal stresses were determined. This

information should be reviewed against current fatigue requirements, especially for services with more than 500 cycles. Fracture toughness should be reviewed against current requirements. See Section 4.1.1.

2. If ASME I (1962) and B31.1 (1955) were used, the calculations for fatigue evaluation should be reviewed, especially for services with more than 500 cycles. Fracture toughness should be reviewed against current requirements. See Section 4.1.1.

3. Piping built to B31.1 (1955) and the code cases should be reviewed for satisfaction of current fracture toughness requirements. See Section 4.1.1.

4. When Code Cases N-1 plus either N-2, N-7, N-9, or N-10 were invoked, current full radiography requirements would be satisfied.

5. When Code Cases N-1 plus either N-7, N-9, or N-10 were invoked, current stress allowables would be satisfied for a temperature range up to 650°F.

<u>Comparison With USAS B31.1.0-1967 Requirements</u>

USAS B31.1-1967 [13] is essentially the same as the power piping portions of ASA B31.1-1955. The comparison of ASA B31.1-1955 requirements with current requirements would also apply to USAS B31.1-1967 requirements.

<u>Comparison With ANSI B31.1 (1973) Requirements</u>

The ANSI B31.1 (1973) [14] power piping code requirements applicable to this review are essentially the same as the 1955 Code except that the Summer 1973 Addendum modifies the stress intensification i factors for butt welds and fillet welds and introduces new factors for 30° taper transition, concentric reducers, and branch connections. Comparison between these factors and half the C_2 factors (but not less than 1) from ASME III (1977) as shown in Table A4-8 of this appendix indicates that the i factors are conservative when compared to current values.

ANSI B31.1 (1973) also introduces an equivalent full temperature cycle formula for variable temperature cycle service. A fatigue evaluation accounting for local discontinuities is not required by either the 1973 power piping code or B31.1 (1955). The fatigue evaluation example and conclusions based on a comparison between the 1955 power piping code and current requirements (see Section 4.2 of this appendix) are also applicable to a comparison of the 1973 power piping code with current requirements.

Comparison With USAS B31.7 (1968-Draft) Requirements

The following items in the USAS B31.7 1968 Draft Code for "Nuclear Power Piping" [15] are similar to items in the current code:

1. Piping systems are designed to Class I, II, or III requirements, as given in Subsections 1, 2, or 3 of B31.7 (1968).

2. The shear theory of failure with its associated stress intensity concepts and limits for primary, secondary, and peak stress categories for Class I piping are the same.

3. The formula for peak stress intensity range for Class I piping is the same, and local and secondary stress indices are used in both codes.

4. Both codes require full radiography for circumferential and longitudinal butt welds for Class I and II piping.

Differences between the USAS B31.7 1968 Draft Code and current requirements are summarized as follows:

1. Stress indices in USAS B31.7 (reproduced in the table "USAS B31.7 (1968 Draft) Stress Indices") may in some cases be lower than those currently required. For example, for B_1 the stress index for a girth fillet weld-to-socket weld fitting is currently 0.75 (Table A4-8) compared to 0.5 in B31.7.

2. Fracture toughness (impact testing) requirements are not specified in the older code.

3. Stress limits for the equivalent service levels C and D (emergency and faulted) conditions are not specified.

In conclusion, piping built to the B31.7 code [15] should be reviewed for the differences noted above and evaluated against current requirements.

Welding Requirements

Full radiography of welded joints in piping, pumps, and valves as stipulated in past [4, 5] and current codes [1, 16] depends on weld joint

Table - USAS B31.7 (1968 Draft) Stress Indices

TABLE D-201. STRESS INDICES FOR USE WITH EQUATIONS 9, 10, AND 11 OF DIVISION 1-705

Component	Internal Pressure			Moment Loading(5)			Thermal Loading	
	B_1	C_1	K_1	B_2	C_2	K_2	C_3	K_3
Straight pipe, remote from welds or other discontinuities	0.5	1.0	1.0(1)	1.0	1.0	1.0	0	1.0
Girth butt weld between straight pipe or between pipe and butt-welding components(2)								
(a) flush	0.5	1.0	1.1(1)	1.0	1.0	1.1	0	1.1
(b) as welded	0.5	1.1	1.2(1)	1.0	1.0	1.8	0	1.7
Girth fillet weld to socket weld fittings, slip-on flanges, or socket-welding flanges(2)	0.5	2.0	3.0	1.0	1.5	2.0	1.8	3.0
Longitudinal butt welds in straight pipe(2)								
(a) flush	0.5	1.0	1.1(1)	1.0	1.0	1.1	0	1.1
(b) as welded	0.5	1.1	1.2(1)	1.0	1.2	1.3	0	1.2
Tapered transition joints per Subpar. 1-727.4.2(c) and Fig. 1-727.3.1	0.5	1.4	1.5	1.0	1.2	1.8	0	1.5
Branch connections per Subdiv. 1-704.3(3)	1.0	2.0	1.7	(7)	(7)	1.0	1.8	1.7
Curved pipe or butt-welding elbows per USAS B16.9, USAS B16.28, or MSS SP48(10)	1.0	$\frac{2R-r}{2(R-r)}$(4)	1.0(1)	(8)	(8)	1.0	0	1.0
Butt-welding tees per USAS B16.9 or MSS SP48(10)	1.0	1.5	4.0	(9)	(9)	1.0	1.0	1.0
Butt-welding reducers per USAS B16.9 or MSS SP48(10)	1.0	1.5	4.0	1.0	1.3	1.0	0	1.0

(1) The values of K_1 shown for these components are applicable for components with circular cross section. If the cross section is out-of-round such that the cross-section shape is approximately elliptical, the value of K_1 may be obtained by the equation:

$$K_1 = 1 + \frac{D_{max} - D_{min}}{t}\left[\frac{1.5}{1 + 0.455\left(\frac{D_o}{t}\right)^3 \frac{P}{E}}\right]$$

where D_{max} = maximum outside diameter of cross section, in.

D_{min} = minimum outside diameter of cross section, in.

t = nominal wall thickness, in.

D_o = nominal outside diameter, in.

P = internal pressure, psi

E = modulus of elasticity of component material, psi.

If the cross section contains flat spots or peaks, particularly at or near longitudinal welds in the component, the designer shall make a suitable theoretical or experimental analysis (Appendix I) to determine the stresses as such irregularities

(2) Welds in accordance with the requirements of this Code for Class I piping. In addition, "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 shall not exceed one-half of the values tabulated in Par. 1-724-4.2(d). No concavity on the root side is permitted. The finished contour shall nowhere have a slope (angle measured from tangent to surface of pipe) greater than 7 degrees. "As welded" is defined as welds not meeting the special requirements for "flush welds".

(3) The values given are limited to branch connections in straight pipe and to connections with (a) d/D not over 1/2, (b) D/t not over 100, and (c) branch pipe normal to the surface of the run pipe, d = nominal outside diameter of branch pipe, D = nominal outside diameter of run pipe, t = nominal thickness of run pipe.

(4) R = curved pipe or elbow radius, in.

r = mean radius of cross section, in.

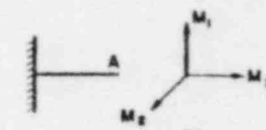
$= (D_o - t)/2$, where t = nominal wall thickness.

(5) The values of the moment M_i shall be obtained from an analysis of the piping system in accordance with Div. 1-719. M_i is defined as the range of moment loading applied during the specified operating cycle.

Straight Through Components

M_i = moment at Point A

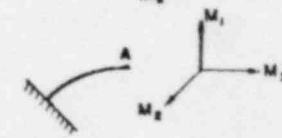
$M_i = \sqrt{M_1^2 + M_2^2 + M_3^2}$



Curved Pipe or Welding Elbow

M_i = moment at Point A

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



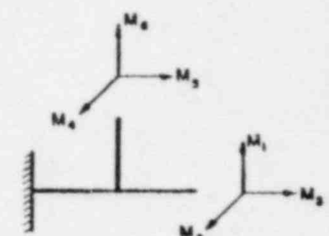
Branch Components

Moments calculated for point at intersection of run and branch centerlines

M_i = larger of:

(a) $\sqrt{(M_1 + M_6)^2 + (M_2 + M_4)^2 + (M_3 + M_5)^2}$

or (b) $\sqrt{M_4^2 + M_5^2 + M_6^2}$



(6) The K_2 indices for tapered transition joints are for such joints where a girth butt weld is made at the thin end of the taper.

(7) $C_2 = \frac{1.8}{h_1^{2/3}}$, but not less than 2.0 ; $B_2 = 0.75\ C_2$

$h_1 = \frac{3t}{r}$, where t = nominal run pipe wall thickness

r = mean run pipe radius

$= (D_o - t)/2$.

(8) $C_2 = \frac{1.95}{h_2^{2/3}}$, but not less than 1.5 ; $B_2 = 0.75\ C_2$

$h_2 = \frac{tR}{r^2}$, where t = nominal pipe wall thickness

R = bend radius of curved pipe or elbow

r = mean pipe radius

$= (D_o - t)/2$.

(9) $C_2 = \frac{1.8}{h_3^{2/3}}$, but not less than 2.0 ; $B_2 = 0.75\ C_2$

$h_3 = \frac{4.4t}{r}$, where t = nominal run pipe wall thickness

r = mean run pipe radius

$= (D_o - t)/2$.

(10) The C and K indices given for fittings per USAS B16.9, USAS 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.

category, pipe size, and code class as shown in the table, "Full Radiography Code Requirements for Welded Joints in Piping, Pumps, and Valves."

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.

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

Description of Welded Joint	Current Codes: ASME III (1977) Class 1	ASME III (1977) Class 2	ASME III (1977) Class 3	ANSI B16.34 (1977) Class Standard	ANSI B16.34 (1977) Class Special	Past Codes[1, 2] ASA B31.1 (1955) & ASME I (1962)
A. Longitudinal	Yes	Yes	No[3]	No	Yes	No [2]
B. Circumferential	Yes	Yes	No	No	Yes	No [2]
C. Flange connection	Yes	Yes[4]	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. Applicable also to B31.1 (1967) and B31.1 (1973). B31.7 (1968) requires full radiography for circumferential and longitudinal butt welds for Class I and II piping.
2. 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 (1962) requirements.
3. Except when specified by material specification for piping in excess of 2 in nominal diameter.
4. When either member thickness exceeds 3/16 in.

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) ASME III (1962) ASME VIII (1974)
III	ASME VIII* (1959, 1956)

4.3.1 ASME VIII (1962)

The current code requirements [1] and the past ASME VIII (1962) [3] code differences are summarized as follows:

Fracture Toughness - Class A Vessels

Except for containment vessels, which are covered by Code Case 1272N and outside the scope of this study, impact test requirements for primary vessels (the equivalent of Class 1 vessels) and secondary vessels (the equivalent of current Class 2 or Class 3 vessels) designed and built to ASME VIII (1962) were significantly less severe than current requirements as noted by the following comparison table:

Description	Past(1) Requirements	Current Requirements
Maximum Temperature of Impact Testing When Required	LST	o Class 1 - LST-60°F o Class 2 - LST o Class 3 - LST
LST Above Which Impact Testing Not Required	-20°F	o Class 1 - None o Class 2 - See Figure A4-1 o Class 3 - 100°F

*Plus nuclear code cases.

1. See UCS-66(d), UHA-51, and UG-84 of Reference 3.

Description	Past Requirements	Current Requirements
Specimen Notch Type	U or Keyhole	V
Minimum Absorbed Energy	5 to 15 ft-lb depending on specimen type	o Class 1 - 50 ft-lb o Class 2 and 3 - Not specified for thickness less than 2-1/2 in; 50 ft-lb for thickness greater than 2-1/2 in
Minimum Lateral	Not specified	o Class 1 - 35 mils o Class 2 and 3 - 20 to 40 mils, depending on thickness

It is apparent from the comparison table that current fracture toughness requirements are significantly more severe than past requirements when impact testing is necessary. Use of Tables A4-4, A4-5, and A4-6 will aid in evaluating material toughness of vessels built to the past code.

Design Requirements

Vessels built to ASME VIII (1962) were not classified with regard to quality class. Code Case 1270N, when invoked, classified nuclear vessels within the scope of tnis study as follows:

Vessel Type	Current Classification
Reactor Vessel (outside scope)	
Primary	Class 1
Secondary	Class 2 or Class 3
Containment Vessel (outside scope)	

Code Case 1271N deals with modifications to Section I and Section VIII rules for safety requirements for devices such as pop-type safety or relief valves, direct reading pressure gages, inspection openings, gage glasses, water columns, gage cocks, and rupture disks. In general, the code case eliminates the requirements for these devices or provides for the safe containment and disposal of the effluent of such devices if they are installed and activated by an accident. Safety devices other than relief valves are considered outside the scope of this study. Section 4.5 of this appendix reviews the structural integrity requirements of valves; operational requirements were considered outside the scope of this study.

Code Case 1272N dealing with containment vessels and intermediate containment vessels (outside the scope of this study) may nevertheless have been invoked for SEP pressure vessels. The provisions of 1272N are briefly summarized as follows:

1. Stress relieving of containment vessels not inside a heated enclosure is not required provided the vessel material shall conform to ASTM specifications SA-300 and SA-350 for plates and forgings, respectively. In addition, these materials shall meet the impact test requirements of paragraph VG-84 at LST -30°F but not less than -84°F. In addition, the thickness of shell and head shall not exceed the thickness for which stress relieving is required by UCS-56, except that for P-1 materials stress relieving is not required for thickness of 1-1/4 in to 1-1/2 in, provided a preheat of 200°F is used during welding.

2. Stress relieving for intermediate containment vessels not containing radioactive materials is not required except as may be required by Section VIII.

3. The mandatory minimum corrosion allowance provisions of UCS-25 for compressed air service, steam service, or water service are not applicable to containment and intermediate containment vessels.

Code Case 1273N, when invoked, imposed the following additional requirements on primary (Class 1) vessels built to ASME VIII (1962):

1. Thicknesses shall be no less than that required by the code formulae.

2. Stresses due to thermal loads combined with pressure loads cannot exceed 1.5 times allowable working stress, that is 1.5XS.

3. The maximum allowable bolt design stress may be based on the properties of the heat-treated metal for operating metal temperatures 100°F or more, below the tempering temperature, provided the allowable stress does not exceed 1/3 YS at the tempering temperature and the operating metal temperature does not exceed 800°F.

4. Creep and stress rupture properties must be considered for long-term exposure at temperatures that will assure adequate safety.

5. a. Compensation shall be made for all openings regardless of diameter.

   b. When compensation is totally in the nozzle, the nozzle should be attached by a full penetration weld.

   c. Thermal stresses and external pipe reactions should be considered.

   d. Full penetration welds should be used wherever possible, except where not practicable, such as at closely spaced openings.

6. All welds are to be fully radiographed except where not practicable, such as at closely spaced openings.

7. Although no specific rules are provided for corrosion, radiation effects, transient thermal stresses, mechanical shock, and vibration loads, these factors should be considered to obtain desired vessel life.

8. Particular consideration should be given to quality of materials, fabrication, and inspection.

9. Cladding thickness in not to be included in code design formulae.

Special ruling 4[1] of the Code Case 1273N discusses attachment of nozzles in primary vessels using partial penetration welds. Additional requirements imposed on primary (Class 1) vessels built to ASME VIII (1962) are:

1. Partial penetration welds are allowed only for attachments on which there are substantially no piping reactions, such as control rod housings, pressurizer heater attachments, and openings for instrumentation for which there no thermal stresses greater than expected in the vessel itself.

2. All compensation shall be integral with the part of the vessel penetrated.

3. Partial penetration welds shall be of sufficient size to develop the full strength of the attachments.

4. Full radiography shall be carried out on all the welds.

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.

Stress limits for vessels which would currently be classified as Class 2 or 3 are essentially the same as for 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.

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1. Mechanical Engineering, February 1961.

Secondary vessels which would currently be classified as Class 2 or Class 3 vessels should be evaluated against current Class 2 or Class 3 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.

Fatigue Requirements for Pressure Vessels

Class 1 vessels designed to the current code are required to be analyzed for cyclic loads unless they can be shown to be exempt from analysis for cyclic service by demonstrating compliance with all the conditions of NB-3222.4(d) of Reference 1b as follows:

(1) Pressure Fluctuations: the specified full range of pressure fluctuations during normal service does not exceed:

$(1/3)$ (Design Pressure) (S_a/S_m)

where:

S_a = alternating stress from fatigue curves corresponding to the number of pressure fluctuations

S_m = allowable stress intensity at the service temperature

(2) Atmospheric to Service Pressure Cycle

$N_2 \leq N(3S_m)$

where:

N_2 = the maximum number of atmospheric to service pressure cycles

$N(3S_m)$ = number of cycles from design fatigue curve for $S_a = 3S_m$

(3) Temperature differences between adjacent points, i.e., two points along the meridian of a vessel, nozzle, or flange closer than $2(Rt)^{(1/2)}$ where R is the mean radius and t is the mean thickness between the two points:

$\Delta T_i \leq S_a/(2E\alpha)$ (i = 1,2)

where:

ΔT_i = temperature differences between two adjacent points

i = 1: startup and shutdown

i = 2: normal service

E = modulus of elasticity at mean temperature between points

α = instantaneous coefficient of expansion, mean value (see Table I-5.0 of Reference 1e)

S_a = alternating stress from design fatigue curve corresponding to the number of startups and shutdowns, N_1, and the number of significant temperature difference fluctuations during normal service, N_2. A significant number of temperature fluctuations are greater than $S/(2E\alpha)$ where S is the endurance limit, i.e., the value of S_a from the fatigue curve at 10^6 cycles.

(4) Temperature difference - dissimilar materials - see paragraph NB-3222.4(d)(4) of Reference 1b

(5) Mechanical loads - stresses due to mechanical load fluctuations (excluding pressure) such as pipe loads on nozzles less than the value of S_a from the design fatigue curve corresponding to the number of load fluctuations.

Fatigue evaluation was not required for Section VIII vessels. It is recommended that Section VIII vessels which would be currently categorized as Class 1 (e.g., pressurizer) be reviewed to see if the pressure fluctuation and atmospheric to service pressure cycles, conditions (1) and (2), are satisfied. The information needed to see if conditions (1) and (2) are satisfied should be available from the FSAR or other source. It is also possible to see if condition (3) is satisfied by assuming that the temperature difference between two adjacent points at vessel inlet, outlet, and feedwater nozzles is equal to the fluid temperature transients given in the FSAR. Note that fluid temperature transients would be an upper bound on metal temperature differences between adjacent points. Accordingly, satisfaction of condition (3) based on fluid temperature transients implies actual satisfaction of condition (3).

Non-satisfaction on fluid temperature transients does not necessarily imply actual non-satisfaction of condition (3) based on actual metal temperature differences which can be determined on the basis of thermal analysis. The following is recommended:

(1) Determine if the limit on pressure fluctuation as defined by condition (1) is satisfied based on FSAR information or other source.

(2) Determine if the limit on the number of atmospheric to service pressure cycles as defined by condition (2) is satisfied based on FSAR information or other source.

(3) Determine if temperature difference limits for startup and shutdown and normal service as defined by condition (3), but using fluid temperature transients are satisfied based on FSAR information or other source.

If steps (1) and (2) show non-satisfaction of conditions (1) and/or (2), the vessel is not exempt from fatigue evaluation and the licensee should be requested to furnish same for review by NRC.

If steps (1), (2), and (3) show satisfaction of conditions (1), (2), and (3), the licensee should be asked to either demonstrate compliance with conditions (4) and (5) or furnish fatigue evaluation for review by NRC.

If steps (1) and (2) show satisfaction of conditions (1) and (2) but non-satisfaction of condition (3), the licensee should be asked to furnisn evidence of compliance of conditions (3) based on metal temperature differences determined by analysis, as well as satisfaction of conditions (4) and (5), or furnish fatigue evaluation for review by NRC.

Vessels built to ASME VIII and currently classified as Class 2 or Class 3 do not currently require evaluation for cyclic load conditions.

Welding Requirements

The table on the following page, "Weld Joint Thickness Requiring Full Radiography," 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 following table, "Weld Thicknesses Requiring Full Radiography," it can be seen that:

1. Vessels built to ASME VIII (1962) requirements only and currently classified as Class 1, 2, or 3 vessels may not satisfy the current radiography requirements.

2. Primary vessels built to ASME VIII (1962) requirements may satisfy current requirements for Class 1 vessels, provided that Code Cases 1270N and 1273N were invoked.

3. Secondary vessels built to ASME VIII (1962) requirements and currently classified as Class 2 or Class 3 may not satisfy the current radiography requirements for butt-welded joints of thickness less than 1 1/2 inch.

4. Currently classified Class 1 vessels built to Reference 3 and 1273N-4 satisfy the current radiography requirements.

It is concluded that vessels built to past requirements may not satisfy current radiography requirements, depending on materials and whether or not Code Cases 1270N and 1273N were invoked.

Weld Joint Thicknesses Requiring Full Radiography

P-No. Material Classification	Current Code Requirements Code Class 1	2	3	Past Code Requirements ASME VIII (1962)[1]
1	0[2]	3/16 in	1 1/4 in	o All joints whose material thickness exceeds 1 1/2-in
3	0	3/16	3/4	
4	0	3/16	5/8	
5	0	3/16	0	o Lesser thicknesses for carbon and low alloy steels, high alloy steels, and clad plate steels as specified in paragraphs UCS-57, UHA-33, UCL-35 of Reference 3 which follow.
7	0	3/16	5/8	
8	0	3/16	1 1/2	
9	0	3/16	See Note 3	
10	0	3/16	5/8	
11	0	3/16	5/8	

1. Vessels containing lethal substances shall have welded joints for materials of all thicknesses fully radiographed.
2. All thicknesses require full radiography when "0" is indicated.
3. Requirements not specified for this P-No.

Carbon and Low Alloy Steels (UCS-57 Radiographic Examination)

"In addition to the requirements in Par. UW-11, complete radiographic examination is required for each butt-welded joint in vessel built of steel complying with Specifications SA-202, SA-203, SA-204, SA-212, SA-225, SA-299, SA-302 and SA-387 Grades A, B and C at which the plate thickness exceeds 1 in. and for each butt-welded joint in vessels built of steel complying with specifications SA-333 Grade 4, SA-350 Grade LF4, SA-353, SA-357, SA-387, Grades D and E, and SA-410 for all plate thickness. (See Par. UCSD-19.)"

High Alloy Steels (UHA-33 Radiographic Examination)

"(a) The requirements for radiographing prescribed to Pars. UW-11, UW-51, UW-52 shall apply in high-alloy vessels, except as provided in (b). (See Par. UHA-21).

(b) Butt-welded joints in vessels constructed of materials conforming to Type 405 welded with straight chromium electrodes, and to Types 410 and 430 welded with any electrode, shall be radiographed in all thicknesses. Butt-welded joints in vessels constructed of Type 405 materials or of Type 410 with carbon content not to exceed 0.08 percent, welded with electrodes that produce an austentic chromium-nickel weld deposit or a non-hardening nickel chromium-iron deposit shall be radiographed when the plate thickness at the welded joint exceeds 1-1/2 in. The final radiographs of all straight chromium ferritic welds including major repairs to these welds shall be made after stress-relieving has been performed.

(c) Butt-welded joints in vessels constructed of austenitic chromium-nickel stainless steels which are radiographed because of the thickness requirements of Par. UW-11, or for lesser thicknesses where the joint efficiency reflects the credit for radiographic examination of Table UW-12, shall be radiographed following post-heating if such is performed."

Clad Steels (UCL-35 Radiographic Examination)

"(a) General Vessels or parts of vessels constructed of clad plate and those having applied corrosion-resistant linings shall be radiographed when required by the rules in Pars. UW-11, and UCS-57. The plate thickness specified under these rules shall be the total plate thickness for clad construction and the base plate thickness for applied-lining construction.

(b) Base Plate Weld with Strip Covering. When the base-plate weld in clad or lined construction is protected by a covering strip or sheet of corrosion-resistant material applied over the weld in the base plate to complete the cladding or lining, any radiographic examination required by the rules of Pars. UW-11 and UCS-57 may be made on the completed weld in the base plate before the covering is attached.

(c) Base Plate Weld Protected by Alloy Weld. When a layer or corrosion-resistant weld metal is used to protect the weld in the base plate from corrosion, radiographic examinations required by the rules in Pars. UW-11 and UCS-57 shall be made as follows after the joint, including the corrosion-resistant layer, is completed:

(1) On any clad construction in which the total thickness of clad plate is used in the design calculation;

(2) On lined construction, and on clad construction in which the base plate thickness only is used in the design calculations, except as otherwise permitted in (d).

(d) The required radiographic examination may be made on the completed weld in the base plate before the corrosion-resistant alloy cover weld is deposited provided all of the following requirements are met:

(1) The thickness of the base plate at the welded joint is not less than that required by the design calculations (See Par. UG-16(c));

(2) The weld reinforcement is removed down to the surface which is to be covered, leaving it flush with the adjacent base plate, reasonably smooth, and free from undercutting;

(3) The corrosion-resistant alloy weld deposit is not air-hardening;

(4) The completed corrosion-resistant weld deposit is examined by spot-radiography as provided in Par UW-52. Such spot-radiographic exa ination is to be made only for the detection of possible cracks."

4.3.2 <u>ASME III (1963)</u>

The current code requirements [1] and the past ASME III (1963) [17] code are essentially the same with regard to significant items with the following exceptions:

<u>Fracture Toughness - Class A Vessels</u>

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
Minimum Lateral Expansion	Not specified	35 mils

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 (1963) 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 (1963) were required to satisfy impact testing provisions of ASME VIII (1962) [3]. Paragraph VCS-66(c) of Reference 3 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 (1963) 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 [17] as well as the basis for establishing fatigue curves is the same as current code requirements. Class A vessels designed in accordance with ASME III (1963) [17] provided the compensation limits that are sufficient compared to ones provided by Reference 1. In conclusion, Class A vessels designed in accordance with ASME III (1963) 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 (1963), are containment vessels, which are outside the scope of this study.

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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.

Class C vessels are designed in accordance with ASME VIII (1962) except that the exemptions from inspection defined in U-1(g) of Reference 3 are not applicable.

Welding Requirements

The table on the following page provides a comparison between current and past codes, ASME III (1963) [17] and ASME VIII (1974) [18], 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 following table, "Weld Joint Thicknesses Requiring Full Radiography in Pressure Vessels," it can be seen that:

1. Vessels built to ASME III (1963) 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 examined in accordance with ASME VIII (1974) requirements do not satisfy current Class 2 requirements.

3. Vessels built to ASME III (1963) Class A or ASME VIII (1974) 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.

Weld Joint Thicknesses Requiring Full Radiography in Pressure Vessels

P-No. and Grade No. Material Classification	Current Code Requirements Code Class 1	2	3	Past Code Requirements ASME B&PV Sect. III (1963) Class A	Class C [1]	ASME VIII (1974) [6]
1 Gr. 1, 2, 3	0 [2]	3/16 in	1 1/4 in	0 [2,4]	0 [2,5]	1 1/4 in
3 Gr. 1, 2, 3	0	3/16	3/4	0	0	3/4
4 Gr. 1, 2	0	3/16	5/8	0	0	5/8
5 Gr. 1, 2	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 Note 7
10	0	3/16	5/8	0	0	3/4 Note 8
11	0	3/16	5/8	0	0	See Note 3

1. ASME B&PV Code Section III, 1963 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 [17]).
5. These requirements are for full penetration welded joints of Categories A or B (N-2113 [17]). Butt-welded joints of other categories shall satisfy the requirements of ASME B&PV Code Section VIII, 1962 edition.
6. Vessels containing lethal substances shall have welded joints for materials of all thicknesses fully radiographed.
7. Applicable for P-Nos. 9A, 9B and Group No. 1.
8. Applicable for P-Nos. and Group Nos. 10A, Gr. 1, 10A Gr. 6. Weld joint thickness of 5/8 in is applicable for P-Nos. and Group Nos. 10B Gr. 2 and 10C Gr. 3.

4.4 PUMPS

Pumps furnished under the requirements of the Hydraulic Institute Standards [19] 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. The discussion in Section 4.3 of this appendix, under the subheading, "Fatigue Requirements for Pressure Vessels," also applies to Class 1 pumps.

Comparison with Requirements from Draft ASME Code for Pumps and Valves for Nuclear Power

Pumps and valves designed and constructed in accordance with the requirements of the Draft ASME Code for Pumps and Valves for Nuclear Power, 1968 [20] would have been classified as Class I, Class II, or Class III in accordance with the requirements of Section A, B, or C, respectively.

Class I valves and pumps would be designed to the same stress allowables and fatigue limits as currently required [1]. Welding of longitudinal and girth welds and cast products would be 100% radiographed as currently required. Fracture toughness requirements, however, were not as stringent as those currently required. Paragraph 313.4 of Reference 20, "Steel Material for Low Temperature Conditions," does require that such material subjected to metal temperatures below 30°F during operation or testing be evaluated and selected to ensure adequate fracture toughness. Appendix E [20] included in the 197[illegible] Addenda calls for Charpy V-notch impact testing if required by the design specifications. Energy absorption is limited to the values given in Table N-421 of the ASME B&PV Code, Section III. Lateral expansion must be reported although no limits are set. These modified fracture toughness requirements are not as stringent as those currently required.

Design requirements for valves are compatible with current requirements. However, Class I pump design requirements were not as detailed in the past Code as they are in the current Code.

Section B of the past Code deals with Class II pumps and valves and does require full radiography of welds and cast material. However, design rules are not explicit. The past code states "that any design method which has been demonstrated to be satisfactory for specified design conditions may be used."

Section C of the past Code deals with Class III pumps and valves; the requirement permits visual examination of welds unless pipe size is 4 in or greater, in which case random magnetic particle or liquid penetrant examination is required.

In summary, Class I valves designed to the past Code would meet current requirements except possibly current fracture toughness requirements. Class I pumps designed to the past Code, however, should be evaluated against the current design rules.

Class II and Class III pumps and valves should be evaluated to determine if current design rules are satisfied.

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 [16], 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 16, 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.

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.

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

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 [21]

4. shall be hydrostatically tested as required by Reference 19, 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 [16].

As an example, consider a 2500-lb valve designed in accordance with the past code [15]. Body thickness would be based on Table 33 [21]. Comparison with current requirements may be obtained from Table 3 [16] 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 [21]	Current Code Table 3 [16]
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.

Table A4-12

<u>Level B, C, and D Service Limits for Class 2 and 3 Valves</u>

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.

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.

Design requirements for Class 1 valves constructed to the Draft ASME Code for Pumps and Valves for Nuclear Power [20] are in compliance with requirements for current Class 1 valves, except for fracture toughness requirements (see discussion in Section 4.4 of this appendix).

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.

ASA B16.9 (1958) [22] provides overall dimensions, tolerances, and markings for wrought carbon-steel and alloy-steel factory-made welding fittings. It refers to ASA B31.1 for design requirements.

ASA B16.10 (1957) [23] provides face-to-face and end-to-end dimensions for ferrous valves of various types and ferrous butt-welding end valves.

ASA B16.9 and ASA B16.10 do not provide design guidance for valve or fittings. Valves and fittings built to these standards should be evaluated against the current requirements [1, 16].

AWWA C504 (1958) [24] classifies valves in different groups based on shutoff pressure and maximum pipe line velocity. Details on body and flange dimensions for cast and fabricated valves are given for different groups. Valves built to these standards should be evaluated against the current requirements [2, 16].

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 VIII (1962) are compared as pressure vessels with current requirements in Section 4.3 of this appendix.

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

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) [16].

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 II heat exchangers designed to TEMA (1959) would be governed by the code requirements of ASME VIII (1962). Comparison of ASME VIII (1962) 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 VIII (1962) 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 II SEP plants were designed either in accordance with A/E specifications, USAS B96.1 (1967) [9], API-650 (1964) [10], or ASME VIII (1962) [3]. Examination of the ASME VIII (1962) allowable stress values 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 (1962) 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, aluminum 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

1. At temperatures to 100°F.

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. 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 VIII (1962) are likely to satisfy current requirements with regard to allowable tensile stress, but may not satisfy current compression stress requirements.
3. 0 to 15 psig tanks designed to ASME VIII (1962) 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.

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.

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