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EVALUATION OF PRESTRESSED CAST IRON PRESSURE VESSELS FOR COAL GASIFIER, APPENDIX A

ASME Code Considerations for Section VIII
Final Technical Report

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Advanced Energy Systems Division
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U. S. DEPARTMENT OF ENERGY

APPENDIX A

ASME CODE CONSIDERATIONS FOR SECTION VIII

A.1 CURRENT CODE STATUS

The large-scale introduction of PCIV for Coal Gasifiers and/or Thermal Energy Storage (TES) would eventually require compliance with a safety code. The PCIV is a relatively new technology in which not much attention has been placed on development of an applicable section of the ASME Boiler and Pressure Vessel Code. Presently, there is no ASME code directly applicable to the PCIV concept.

The ASME codes for steel vessels (Section III and Section VIII, Division 2) are not directly applicable to prestressing systems and/or cast iron materials. Section IV of the ASME code applies to cast iron vessels but is restricted to low pressures and small volumes. These restrictions do not apply to the PCIV because of the prestressing system and the high compressive strength of cast iron rather than the tensile strength.

Based on this situation, a new draft PCIV code was developed in which parts of Section III, Division 2 and Section VIII, Division 2 were melded into one code. The cast iron design criteria were based on current large casting technology.

A.2 BASIS FOR NEW CODE

Several sections of the ASME code were reviewed and compared for possible application to the PCIV concept.

Since the PCIV concept parallels the Prestressed Concrete Pressure Vessel (PCPV) design (Section III, Division 2), a comparison with this code was made as shown on Tables A-1 through A-4. These tables compare design philosophy, failure modes, structural criteria and specific considerations of the two codes.

Parts of the ASME code (Section III, Division 2) may directly apply to the PCIV concept relative to the prestressing system (Table CB-3421-2) and the

TABLE A-1

DESIGN PHILOSOPHY

	ASME SECTION III DIV 2 (Concrete PV)	PCIV CODE DRAFT
Stress, Strains & Deformations Limited to Ensure a Essentially Elastic Response	X	X
Designed so that as Ultimate Capacity is Approached Response will be Gradual, Observable, Predictable	X	X
Ultimate Capacity is Twice That Required to Resist Maximum Cavity Pressure	X	X
The Design Specification Provides the Loads and Load Combinations	X	X
Load Carrying Elements (TENSION) Are Tendons and Reinforcing Steel	X	Tendons Only

TABLE A-2

FAILURE MODES

	ASME SECTION III DIV 2 (Concrete PV)	PCIV CODE DRAFT
STRESS		
Compressive Fracture (Crushing)	Concrete	Cast Iron
Tensile Fracture	Concrete Reinforcing Steel Tendons Liner	Cast Iron — Tendons Liner
Shear Failure	Concrete Reinforcing Steel Liner	Cast Iron — Liner
Fatigue	Reinforcing Steel Liner	— Liner Cast Iron
Unrestricted Deformation	Reinforcing Steel Tendons Liner	— Tendons Liner
Buckling	Liner	Liner
OTHERS		
Corrosion Low Temperature Embrittlement Residual Weld Stresses Material Compatibility	Reinforcing Steel Tendons Liner	— Tendons Liner

TABLE A-3

STRUCTURAL CRITERIA

	ASME SECTION III DIV 2 (Concrete PV)	PCIV CODE DRAFT
Theories of Failure		
Max Principal Stress	Concrete	Cast Iron
Maximum Shear	Reinforcing Steel	NA
	Tendons	Tendons
	Liner	Liner
Factors of Safety		
Average Primary Compressive Stress	CONCRETE	CAST IRON (Constrained)
construction loads	2.5	3.0
normal loads	3.33	4.0
abnormal loads	3.33	4.0
severe environmental loads	3.33	4.0
extreme environmental loads	1.33	1.33
failure loads	1.10	1.1
Component Stresses		
primary stress	under review	TBD
primary & secondary stress		TBD

TABLE A-4

SPECIFIC CONSIDERATIONS

	ASME SECTION III DIV 2 (Concrete PV)	PCIV CODE DRAFT
Effect of Deflections on Plant Functional Performance	X	X
Foundation Settlement	X	X
Creep and/or Shrinkage	X	X
Steel Relaxation	X	X
Irradiation Effects on Material Properties	X	NA
Thermal Effects on Material Properties	X	X
Moisture Effects on Materials	X	X
Construction Equipment Loads	X	X
Prestressing Procedures	X	X
Tendon Failure or Degradation	X	X
Pressurized Cracks & Gaps	X	X

liner limits (Table CI-3700-1). In addition the basic philosophy on the allowable design stresses for gray cast iron is analogous to concrete so long as the cast iron is restrained as in the concrete vessel. Thin cast iron walls under uniaxial load are limited by shear strength limits. The concrete vessels are not as restricted by shear because of the reinforcing steel and the thick wall sections. Presently, a more conservative safety factor of 3.0 is applied to cast iron against 2.5 for the concrete (Table CI-3421-1).

The draft PCIV code uses the same design philosophy as Section VIII, Division 2, as far as inspection, safety, design and operating conditions are concerned. This PCIV code represents non-nuclear, fired pressure vessels. The vessel is also limited to a maximum of 650°F (343°C) in the cast iron. The reader should be aware that the design criteria for the cast iron are based on a limited amount of test data. These criteria must be substantiated by an adequate materials verification program, which is briefly described in the recommendation section of this appendix.

A.2.1 GRAY CAST IRON COMPONENTS

The gray cast iron design criterion represents the major difference in the application of the existing ASME code. The primary stress in the ASME code is limited by the "design stress intensity" ... S_m factor used for ferritic carbon and low alloy steels. These stress intensities are based on the smaller of the following conditions:

- 2/3 of yield strength or,
- 1/3 of ultimate tensile strength

This same procedure is used for both tensile and compressive stress conditions. The maximum shear stress theory is employed for the combined stress condition. For the three-dimensional tensile stress condition, the algebraic sum of the three principal stresses ($\sigma_1 + \sigma_2 + \sigma_3$), shall not exceed four times the tabulated value of S_m. The above mentioned method cannot be used for the cast iron for the following reasons:

- there is no definite yield strength and Young's modulus is stress dependent.
- the compressive strength is higher (about 3 to 4 times) than the tensile strength. The maximum shear stress theory is therefore not applicable. Therefore the ASME code (Section III and Section VIII) should not be applied in its present condition, to highly stressed cast iron structures.

Because of the compressive strength/tensile strength ratio for cast iron, the hypothesis of maximum principal stresses should be used rather than the maximum shear stress hypothesis. The maximum principal stress hypothesis is based independently on maximum tensile strength and maximum compressive strength.

In addition to the above mentioned considerations, the design criteria for cast iron were developed based on the following assumptions:

- Minimum failure stress in shear is assumed to be 1.4 times the minimum ultimate tensile strength.
- Construction service limits include both basic construction and/or unpressurized loading conditions. These limits are permitted to be ∿30% higher than normal conditions based on a limited number of on/off loading cycles.
- Bending stresses are permitted to be 50% higher than the membrane tensile stress.
- Due to uniaxial compressive loading of columns unsupported laterally - two sets of design criteria have been developed:

  (a) Constrained Cast Iron Components - these represent designs where components are supported such that cracking may be tolerated so long as adequate consideration of large cracking is precluded. This configuration somewhat parallels the concrete code relative to thickness and three-dimensional compressive stress conditions.

  (b) Unconstrained Cast Iron Components - these represent designs where any postulated crack/crack pattern can be shown to be unacceptable. This configuration would be prototypic of thin wall (1" - 2") ribbed sections. This configuration is limited by the shear stress limits defined on Table CI-3421-1 of the draft PCIV code.

An example of the stress limits selected in this investigation are shown below:

- Tensile strength (confined): $f_{cit} = \sigma_{ci}/4$ for primary stresses;
- Compressive strength (confined): $f_{cic} = \sigma_{cuc}/3$ for primary stresses;

where

σ_{ci} = Specified minimum tensile strength of cast iron

σ_{cuc} = Specified minimum compressive strength of cast iron

The above stress limits are slightly more conservative (.33 against $.40\sigma_{cua}$) than the limits of ASME code for the Prestressed Concrete Pressure Vessel (PCPV). This approach was used because the wall thickness of the PCIV will not lead to a truely three-dimensional compressive stress state as found in thick wall section in the PCPV. Other specific stress limits are shown on Table CI-3421-1 and CI-3421-2 of the attached draft PCIV code.

A.2.2 PRESTRESSING STEEL

In the basic PCIV concept high strength steel cables with low relaxation properties axially and circumferentially hold the cast iron body segments in place. These cables provide the principal load carrying elements of the PCIV. Similar systems have been employed in the PCPV concept. Therefore, Section III, Division 2 (code for Concrete Reactor Vessels and Containment), design criteria have been applied to the PCIV design. Current ASME and ASTM standards can be used to maintain high quality control of the prestressing steel specified in the PCIV concept.

Circumferential prestressing (wire wrap) is a relatively new method and may require some additional control to insure that high quality prestressing is maintained.

Low stress relaxation steel is required to meet the design conditions of the PCIV concept. Therefore, adequate controls must be employed to insure that the prestressing steels meet the specified requirements. Stress relaxation data

as a function of temperature are required to insure that the specific materials meet the design conditions. In addition the temperature control in the region of the prestressing tendons is a limiting condition. Presently, Section III, Division 2 requires that the prestressing tendons be limited to 140°F (60°C). Similar conditions and restriction have been adapted on the PCIV design. Stress limits for the prestressing steels are located on Table CI-3421-3 of the draft PCIV code.

A.2.3 VESSEL LINER

The reference application includes a steel liner as the leak tight pressure boundary. The purpose of the liner is two-fold in that it provides a leak tight boundary and provides corrosion protection of the cast iron and prestressing steel tendons. The requirements of such a liner are dependent on the design, application and operating conditions.

The liner is not to be interpreted as the primary pressure retaining structure. The prestressing steel tendons are the primary pressure retaining structure. This liner is used to attach internal vessel insulation and nozzles for penetrations. Buckling of the liner is the primary concern of the designer. Liner anchor studs are used to prevent this buckling and limit liner distortion. Liner analysis to determine liner stud spacing presents a rather difficult problem. Some techniques are available and have been used for the design calculations but some additional verification of these techniques may be required. The temperature difference at the interface of liner and cast iron is also responsible for possible buckling of the liner. Limiting of this temperature difference is necessary to prevent buckling of the liner.

A liner is employed in the PCPV concept but is installed in a very different manner. The PCPV liner installation concept provides an earier method in which the liner welds can be Post-Weld Heat Treated (PWHT). The PCIV liner is to be welded as the PCIV is being constructed. If carbon steel is to be used for the liner, the liner welds must be PWHT during construction. Liner weld PWHT methods must be considered when selecting the liner materials. The reference

design uses a 304L stainless steel liner which is not required to be PWHT.

Based on the PCPV experience with liners, the design criteria from Section III, Division 2, have been adopted as the basis for the PCIV draft code. The stress and strain limits for the liner may be found on Table CI-3700-1 of the Draft PCIV code.

A.4 CODE CONSIDERATIONS FOR SECTION II PART A

A review of Section II, Part A (Ferrous Materials Specification), was conducted to determine the applicability of this section of the ASME Boiler and Pressure Vessel Code to the PCIV concept. Generally, this section of the code contains an adequate amount of specifications to control and evaluate the quality of the material used in the vessel. ASTM specifications were adopted or modified for the PCIV whenever ASME specifications were not applicable. Additional specifications are necessary to adequately control the qualify of the large gray cast iron segments.

A specification and/or test methods are required to determine the maximum allowable compressive stress in gray cast iron. The maximum allowable compressive stress level is required to substantiate the present design criteria and identify a test method that would provide a basis for quality measurement. This specification would also provide a means to correlate test specimen strength properties to large casting section properties.

The liner specifications provide adequate control of material quality with little or no modifications to the ASME or ASTM specifications. Material certification and testing methods are consistent with current specifications.

ASTM specifications are used to control the material quality of the prestressing steel for the PCIV. Some minor modifications of these specifications may be necessary to insure an adequate amount of stress relaxation property data is made available to the designer. Stress relaxation data as a function of temperature represent a critical aspect for applications above the 140 °F region.

Development and incorporation of the suggested modifications would require an appropriate materials testing program. From this program the critical aspects for controlling material quality would be identified.

A.5 CODE CONSIDERATIONS FOR SECTION V

As assessment of Section V (Non-Destructive Examination) of the ASME Boiler and Pressure Vessel Code was made to determine the applicability of these

specifications to the PCIV concept. The geometric and assembly method constraints of the PCIV determine the applicability of certain NDE techniques. This fact does not preclude obtaining Section VIII type quality control methods or standards. This fact only limits the flexibility of the designer to specify a certain inspection method. Some modifications of the ultrasonic inspection method may be required depending on future development of inspection criteria (i.e., defect size, and/or rejection size) for gray cast iron.

Radiographic inspection appears to be an unlikely technique for the three basic components of the PCIV concept. The liner welds cannot be radiographed because of lack of clearance during field fabrication of the vessel. This method is not applicable to the cast iron or prestressing steel.

Ultrasonic inspection of the gray cast iron body segments appears to be the only technique applicable for determining internal voids or defects. Some development is required to determine the optimum inspection methods and controlling parameters. Internal damping of the ultrasonic waves in the cast iron requires a modification of the inspection technique. Ultrasonic may be used for the liner welds depending on geometric considerations.

Liquid penetrant inspection will be used as the primary inspection method of liner welds. This represents the only area of application for the PCIV concept. No modifications of this inspection technique are anticipated.

Minor surface defects on the cast iron segments would be detected using the magnetic particle inspection method. The application of this method will be limited to only highly stressed regions. Other inspection methods are less cumbersome to use for detecting the same defect.

Visual inspection for detecting surface defects of all three main components is applicable. Prestressing steel (tendon and/or strands) is more amenable to visual inspection than to the other methods mentioned above.

Modifications of the basic inspection techniques should be carefully evaluated and developed in order to maintain high quality standards.

SUBSECTION CI

PRESTRESSED CAST IRON PRESSURE VESSELS

PREFACE TO PROPOSED SECTION VIII, DIVISION 3

This document has been prepared by Westinghouse Advanced Energy Systems Division under the sponsorship of the U.S. Department of Energy (Contract No. ET-78-C-01-3013). The objective of this document was to develop a draft code for prestressed cast iron vessels patterned after existing ASME codes.

This draft code represents preliminary information which has not been reviewed or approved by the American Society of Mechanical Engineers organization. The design criteria for the gray cast iron segments are based upon present technology and on allowable stresses governed by essentially elastic conditions. This gray cast iron criteria must be substantiated via an adequate materials verification test program.

The basic materials for this document were provided by two existing ASME Boiler and Pressure Vessel codes; the Section III, Division 2 — Code for Concrete Reactor Vessels and Containments and the Section VIII, Division 2 — Alternative Rules.

These two documents were combined into a single document entitled PROPOSED STANDARD — Code for Prestressed Cast Iron Pressure Vessels. This proposed code was developed for non-nuclear fired, pressure vessels using the prestressed cast iron vessel concept. This concept essentially parallels the Concrete Vessel in the basic configuration, where cast iron replaces the concrete and reinforcing steel. Because the vessel concept has been adapted to non-nuclear applications, the proposed code section was based primarily on Section VIII, Division 2. Since neither code specifically met the needs for this kind of pressure vessel, a new code was developed.

The Prestressed Cast Iron Vessel (PCIV) utilizes three different components for the following functions:

- Axial and circumferential tendons consisting of high tensile strength wires are prestressed to such a degree that the basic structure is essentially in compression;
- A gray cast iron structure to carry the compressive stress, to define the shape and to contain all required penetrations;
- A liner as a means to ensure leak tightness of the vessel.

The control of design, materials, fabrication, inspection, and testing aspects of the prestressing tendons and liner was based on the Section III, Division 2 experience. The control of the gray cast iron structure was based on present technology experience and projection of future materials, fabrication and inspection techniques. Additional materials testing of gray cast iron segments is required to substantiate the described criteria and inspection/testing techniques.

The general aspects of the code such as the introduction, pressure relief devices, construction inspection, pressure testing and marking, stamping and records were based on Section VIII, Division 2 experience.

This document does not represent a final PCIV code. Additional development testing and review and approval by the ASME organization are required before the code can be issued for public "trial use and comment". Discussions on this subject may be directed to Westinghouse Advanced Energy Systems Division marked to the attention of Project Management.

PROPOSED
SECTION VIII DIV. 3

MANDATORY APPENDICES

NON-MANDATORY APPENDICES

ARTICLE CI-1000

GENERAL REQUIREMENTS

CI-1100 SCOPE AND GENERAL REQUIREMENTS[1]

Subsection CI establishes rules for material, design, fabrication, construction, examination testing, pressure relief, marking, stamping and preparation of reports and maintenance of records for prestressed cast iron pressure vessels (PCIV).

For the scope of this Division, pressure vessels are containers for the containment of internal pressure. This pressure may be obtained from an external source or by the application of heat from a direct or indirect source, or any combination thereof.

These rules cover only vessels to be installed at a fixed (stationary)[2] location for a specific service where operation and maintenance control is retained during the useful life of the vessel by the user who prepares or causes to be prepared the Design Specifications required by CI-1301.1.

The rules for Division 2 shall apply as required in this Subsection for parts and appurtenances not backed by structural cast iron for load carrying purposes. Those parts or appurtenances stamped on accordance with this Division shall meet the requirements of Subsection CI-1000, CI-6000, CI-7000, CI-8000 and Appendix 8. Those parts or appurtenances stamped in accordance with Division 2 shall meet all of the requirements of Division 2.

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[1] In those applications where there are laws or regulations issued by Municipal, State, Provincial or Federal Authorities covering pressure vessels; these laws or regulations should be reviewed to determine size or service limitations of the coverage which may be different or more restrictive than those given in this paragraph.

[2] These rules shall not be used for fabrication of cargo tanks mounted on transport vehicles.

A pressure vessel as described above may be constructed and stamped within the scope of this Division provided it meets all other requirements as specified with the following additional provisions:

(a) Loading conditions imposed by movement of the pressure vessel during operation and by relocation of the pressure vessel between work sites, or due to loading and discharge, as applicable, shall be considered as part of AD-100 of Division 2.

(b) The user's Design Specification shall include the agreements which resolve the problems of operation and maintenance control unique to the particular pressure vessel.

(c) In relation to the rules of Division 1 and 2 of Section VIII, these rules of Division 3 are more restrictive in the choice of materials which may be used and the magnitude of thermal gradients and absolute temperature values; more specialized design procedures are required permissable fabrication procedures are specifically delineated and alternate examination testing and inspection are required.

CI-1110 RULES FOR PRESTRESSED CAST IRON PRESSURE VESSELS

The thermal gradients and absolute temperatures in the cast iron must be controlled within the limits specified in CI-3000. The methods for the control of cast iron temperatures are to be determined by the Designer.

CI-1120 BOUNDARIES OF JURISDICTION

The criteria contained in Subsection CI apply to the design of the pressure retaining cast iron, liner and prestressing steel components of the PCIV. These criteria shall be applied within the boundaries of jurisdiction defined below:

In order to define the boundaries of components with respect to adjacent components and other structures, the Design Specification shall include:

(a) the locations of each such boundary

(b) the forces, moments, strains, or displacements which are imposed at each such boundary

(c) the structural characteristics of the attached components or structures, whether or not they are within this Section's jurisdiction when such components or structures provide constraints to the PCIV deflection and rotations.

(d) where external piping is to be connected to the vessel:

(1) the welding end connection for the first circumferential joint for welded connections

(2) the first threaded joint for screwed connections

(3) the face of the first flange for bolted, flanged connections

(4) the first sealing surface of proprietary connections or fittings

(e) where nonpressure parts are welded directly to either the internal or external surface of a pressure vessel, the weld attaching the part of the vessel. For parts beyond this weld and for stud bolted attachments, see Article D-9 of Division 2.

(f) pressure-retaining covers for vessel openings, such as manhole and handhole covers;

(g) the first sealing surface for proprietary fittings for which rules are not provided by this Division, such as gauges and instruments.

(h) the scope of this Division includes provisions for pressure relief devices necessary to satisfy the requirements of CI-5000 and Appendix 9.

The prestressed cast iron pressure vessel components covered by Subsection CI shall include the following:

(a) structural cast iron pressure retaining shells and shell components.

(b) metallic liners

(c) penetration liners extending the PCIV liner through the surrounding shell cast iron.

(d) prestressing steel tendons

CI-1130 FIELD ASSEMBLY OF VESSELS

Field assembly of vessels constructed to this Division may be performed as follows:

(a) The manufacturer of the vessel completes the vessel in the field.

(b) The manufacturer of parts of a vessel to be completed in the field by some other party stamps these parts in accordance with Code rules and supplies the A-2 Manufacturer's Partial Data Report Forms to the other party. The other party, who must hold a valid "U2" Certificate of Authorization, makes the final assembly, required NDE, final pressure test; completes the A-1 Manufacturer's Data Report Form; and stamps the vessel.

(c) The field portion of the work is completed by a holder of a valid "U2" Certificate of Authorization other than the vessel Manufacturer. The stamp holder performing the field work is required to supply an A-2 Manufacturer's Partial Data Report Form covering the portion of the work completed by his organization (including data on the pressure test if conducted by the stamp holder performing the field work) to the Manufacturer responsible for the Code vessel. The vessel Manufacturer applied his "U2" stamp in the presence of a representative from his Inspection Agency and complete the A-1 Manufacturer's Data Report Form with his Inspector.

In all three alternatives the party completing and signing the A-1 Manufacturer's Data Report Form assumes full Code responsibility for the vessel. In all three cases, each Manufacturer's Quality Control System shall describe the controls to assure compliance for each Code stamp holder.

ARTICLE CI-1200

ORGANIZATION OF THIS DIVISION

CI-1200 ORGANIZATION

Division 3 of Section VIII is divided into one subsection and eight articles.

(a) Article CI-1000 gives the Scope of the Division, establishes jurisdiction in terms of the extend of its coverage, and sets forth the responsibilities of the User and Manufacturer and the duties of the Inspector of vessels constructed under these rules.

(b) Article CI-2000:

(1) the individual materials which may be utilized

(2) the applicable specifications and special requirements

(c) Article CI-3000 contains requirements for the design of vessels and vessel parts.

(d) Article CI-4000 contains requirements governing the fabrication and construction of vessels and vessel parts.

(e) Article CI-5000 contains rules for pressure relieving devices.

(f) Article CI-6000 contains requirements controlling construction inspection and radiographic examination of vessels and vessel parts.

(g) Article CI-7000 contains testing requirements and procedures to demonstrate structural integrity.

(h) Article CI-8000 contains requirements for marking, stamping, reporting and maintaining records.

CI-1200.1 APPENDICES

Appendices to the subsequent subsection of this Division set forth supplementary requirements, explanations, and additional information useful in selecting materials, applying the design rules, fabricating vessels and examining them.

CI-1201 PARAGRAPHS

The Articles are divided into paragraphs which are given a three-digit number, the first of which corresponds to the article number. Each such paragraph number is prefixed with one or two letters, indicating the Article or Part of the Division in which it is found, and a title such as CI-3140 Design Criteria.

(a) Major subdivisions of paragraphs are indicated by the basic paragraph number followed by a decimal point and one or two digits.

(b) Minor subdivisions of paragraphs are designed by lower case letters in parentheses. Where further subdivisions are needed, they are designated by numerals in parentheses.

CI-1201.2 REFERENCES

When a Article or Paragraph is referred to hereinafter, the reference includes all subdivisions under at Part, Article, or Paragraph.

ARTICLE CI-1300

RESPONSIBILITIES AND DUTIES

CI-1300 GENERAL

The various parties, i.e., User, Manufacturer and Inspector, involved in the work of producing vessels under this Division, have definite responsibilities or duties in meeting Code requirements. The responsibilities set forth hereinafter relate only to Code compliance and are not to be construed as involving contractual relations or legal liabilities.

CI-1301 USER'S RESPONSIBILITY

CI-1301.1 USER'S DESIGN SPECIFICATION

It is the responsibility of the user or an agent[1] acting on his behalf, who intends that a pressure vessel be designed, constructed, tested, and certified to be in compliance with these rules, to provide or cause to be provided for such vessel or vessels a User's Design Specification. This shall set forth requirements as to constitute an adequate basis for selecting materials and designing, fabricating, testing and inspecting the vessel or vessels as required to comply with these rules. The User's Design Specification shall include the method of supporting the vessel (see CI-3110).

(a) It is the user's responsibility to specify, or cause to be specified, whether or not a fatigue analysis of the vessel shall be made for cyclic service,[2] and, when a fatigue analysis is specified, to provide, or cause to be provided, information in sufficient detail so that an analysis for cyclic operation

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[1]Wherever the work "user" appears in this document, it may be considered to apply also to an agent acting in his behalf.

[2]CI-3470 covers the evaluation of service conditions to establish the need of a vessel fatigue analysis as provide by Appendix 5.

can be carried out in accordance with Appendix 5. If the User's Design Specification lists expected operating conditions for which the service evaluation rules in CI-3470 indicate need for a fatigue analysis, then such fatigue analysis shall be mandatory and shall be incorporated in the Manufacturer's Design Report. If the User's Design Specification states that no fatigue analysis is required, the Design Specification shall include a statement that the intended vessel operation satisfied the requirements of CI-3470.

(b) It is the user's responsibility to specify, or cause to be specified, whether or not a corrosion and/or erosion allowance shall be provided, and, if so, the amount.

(c) When a vessel is to contain fluids of such a nature that a very small amount mixed or unmixed with air is dangerous to life when inhaled, it shall be the responsibility of the user and/or his designated agent to determine if it is lethal.[4] If determined as lethal, the user and/or his designated agent shall so state in the User's Design Specification. It shall be the responsibility of the Manufacturer to comply with the applicable Code provisions.

(d) The User's Design Specifications need not provide information other than that required in CI-1301.1, CI-1301, (a), (b) and (c).

CI-1301.2 CERTIFICATION OF USER'S DESIGN SPECIFICATION

A registered professional engineer, experienced in pressure vessel design, shall certify to the compliance of the User's Design Specifications with the above requirements.

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[4] By "lethal substances" are meant poisonous gases or liquids of such a nature that a very small amount of the gas or of the vapor of the liquid mixed or unmixed with air is dangerous to life when inhaled. For purposes of this Division, this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel.

CI-1302 MANUFACTURER'S RESPONSIBILITY

CI-1302.1 COMPLIANCE WITH REQUIREMENTS OF THIS DIVISION

(a) The structural integrity of a vessel or part thereof as established by conformance with all such rules of this division as are required to meet the conditions in the User's Design Specification and shown in the Manufacturer's Design Report is the responsibility of the vessel manufacturer.

(b) The manufacturer completing any vessel or part to be marked with the Code symbol has the responsibility of complying with all of the requirements of this Division and, through proper certification, of assuring that any work done by others also complies with all requirements of this Division.

(c) Some types of work, such as forming, nondestructive examination, and heat treating, may be performed by others (for welding see CI-4532.2). It is the vessel or part manufacturer's responsibility to ensure that all work so performed complies with all the applicable requirements of this Division. After ensuring Code compliance, the vessel or part may be Code stamped by the appropriate Code stamp holder after acceptance by the Inspector.

(d) The Manufacturer shall certify the compliance with these requirements by the execution of the appropriate Manufacturer's Data Report, as described in CI-8000.

CI-1302.2 MANUFACTURER'S DESIGN REPORT

As part of his responsibility, the manufacturer or design agent responsible to him shall make design calculations establishing that the design as shown on the drawings complies with the requirements of this Division for the design conditions that have been specified in the User's Design Specification. A Manufacturer's Design Report shall be prepared which shall include calculations and the drawings necessary to show compliance with this Division. When required by the rules of CI-3470, the Design Report shall include an analysis for the cyclic operation in accordance with Appendix 5.

CI-1302.3 CERTIFICATION AND FILING OF MANUFACTURER'S DESIGN REPORT

A registered professional engineer, experienced in pressure vessel design, shall certify to compliance of the Manufacturer's Design Report with the requirements of this Division. The Manufacturer's Design Report and the User's Design Specification shall be kept on file at the Manufacturer's plant for at least five years. A copy of this Design Report shall be furnished to the user or his agent.

CI-1303 INSPECTOR'S DUTIES

It is the duty of the Inspector to make all of the inspections specified by the rules of this Division; in addition, he shall make such other inspections as in his judgment are necessary to verify that the materials are in accordance with the requirements of the materials specifications, that the fabrication is in accordance with the Manufacturer's Design Report and that the requirements of this Division, including all specific design details necessary for compliance with the requirements of this Division, have been met, and he shall so certify on the Manufacturer's Data Report. The Inspector of the completed vessel does not have the duty of determining the completeness or correctness of the design calculation; however, he does have the duty of establishing that the Manufacturer of the completed vessel has the User's Design Specification and the Manufacturer's Design Report on file and that these documents are certified.

CI-1304 ESTABLISHMENT OF A QUALITY CONTROL SYSTEM

Any Manufacturer holding or applying for any official stamp of The American Society of Mechanical Engineers and the Certificate of Authorization shall have and demonstrate a quality control system to establish that all Code requirements[3] including material, design, fabrication, examination (by the Manufacturer), and inspection (by the Inspector) will be met. The quality control system shall be in accordance with the requirements of Mandatory Appendix 8.

Before issuance or renewal of a Certificate of Authorization, the Manufacturer's facilities and organization are subject to a joint review by his inspection

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[3]See CI-6001 and CI-6002.

agency and the legal jurisdiction concerned. A written description of check list of the quality control system which explains what documents and what procedures the Manufacturer will use to produce a Code item shall be available for review. A written report to the Society shall be made jointly by the jurisdiction and the inspection agency employed by the Manufacturer to do his Code inspection. See Article S-2 of Division 2.

The Manufacturer may at any time make changes to the quality control system concerning the methods of achieving results, subject to acceptance by the Inspector.

The Manufacturer must have in force, at all times, a valid inspection contract or agreement with an agency employing Authorized Inspectors as defined in CI-6130. A valid inspection contract or agreement is a written agreement between the Manufacturer and the inspection agency in which the terms and conditions of furnishing the service are specified and in which the mutual responsibilities of the Manufacturer and the Inspector are stated.

For those areas where there is no jurisdiction or where a jurisdiction does not review a Manufacturer's facility, that function shall be performed by a representative of the National Board of Boiler and Pressure Vessel Inspectors. Where the jurisdiction is the Manufacturer's inspection agency, the joint review and joint report shall be made by the jurisdiction and another representative designated by the ASME.

ARTICLE CI-2000

MATERIAL

CI-2100 GENERAL REQUIREMENTS FOR MATERIAL

CI-2110 SCOPE

CI-2111 TERMS

(a) The term material as used in this Subsection applies to those items produced to the requirements of:

(1) an SA[1] of SFA[2] specification of Section II; or

(2) any other material specification permitted by this Subsection.

(b) The term Material Manufacturer is defined as a Manufacturer who produces the materials to the requirements of the material specification and any additional or special tests designated by this Article except as provided in CI-2122. This includes, for example, Cast Iron and welding material. The Material Manufacturer shall be responsible for packaging and shipping the material in the manner prescribed in the Construction Specification.

(c) The terms pressure retaining and load bearing material apply to items such as Cast Iron, prestressing material, liners, and attachments to liners.

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[1]Material produced under an ASTM designation may be accepted as complying with the corresponding ASME specification provided that the latter specification is designated as being identical with the ASTM specification for the grade, class, or type, and provided that the material is confirmed as complying with the ASTM specification by a Certified Material Test Report (MTR) or Certificate or Compliance in accordance with the requirements of CI-2130.

[2]Welding or brazing material produced to an AWS designation may be accepted in lieu of the corresponding ASME specification provided that the latter specification is indicated to be identical with the AWS specification, and provided that the material is confirmed as complying with the AWS specification by a Material Test Report (MTR) in accordance with the requirements of CI-2130.

CI-2112 SPECIAL RULES

Material for parts and appurtenances designated to meet the requirements of Section VIII which are not backed by Cast Iron for load carrying purposes shall meet the requirements of Part AM of Division 2, CI-1000 and CI-8000.

CI-2120 PRESSURE RETAINING AND LOAD BEARING MATERIALS

CI-2121 PERMITTED MATERIAL SPECIFICATIONS

(a) Cast Iron material shall conform to the requirements of CI-2200. Steel material for pressure retaining and load bearing purposes shall conform to the requirements of one of the specifications included in this Article or in Table 1-1.1 and Table 1-2.1 of Appendix 1, and to all the special requirements of this Article which apply to the product form in which the material is used.

(b) Materials other than those described in CI-2121 (a) shall not be used until the requirements of Appendix 12 have been met.

(c) The requirements of this Article do not apply to items not associated with the pressure retaining or load bearing function of a component, such as chairs, supports, grease fittings, and retaining caps, or to seals, packing, and gaskets.

(d) Welding and brazing materials used in manufacture of items shall comply with an SFA specification except as otherwise permitted in Section IX and shall also comply with the applicable requirements of this Article.

CI-2122 SPECIAL REQUIREMENTS

The special requirements stipulated in this Article shall apply in lieu of the requirements of the material specification wherever these special requirements conflict with the material specification requirements. Where the special requirements include an examination, test, or treatment which is also required by the material specification, the examination, test, or treatment need be performed only once. All required examinations, tests, and treatments shall be performed as specified for each product in this Article and may be performed by either the Material Manufacturer, Fabricator, or Constructor, as provided in CI-4121.

CI-2123 SIZE RANGES OF METALLIC MATERIAL

Metallic material outside the limits of size or thickness given in any specification allowed by this Division may be used if the material is in compliance with the other requirements of the specification and no size limitation is given in the rules for construction. In those specifications in which chemical composition and mechanical properties are indicated to vary with size or thickness, any material outside the specification range shall be required to conform to the composition and mechanical properties shown for the nearest specified range.

CI-2130 CERTIFICATION OF MATERIAL

CI-2131 INTRODUCTION

The Material Manufacturer shall provide all material in accordance with the following subparagraphs.

CI-2131.1 CERTIFICATION BY MATERIALS MANUFACTURER

The materials manufacturer shall certify that all requirements of the Materials Specification and all special requirements of this article which are to be fulfilled by the materials manufacturer have been complied with. The certification shall include certified reports of numerical results of all required tests or certificates of compliance, and shall certify that all required inspections and repairs have been performed on the materials. All conflicts between the materials specification and the special requirements herein shall be noted and compliance with the special requirements stated.

CI-2133 PREFABRICATED OR PREFORMED PRESSURE PARTS

Prefabricated or preformed parts which are subject to the working pressure in the vessel and which are furnished by other than the shop of the manufacturer responsible for the completed vessel shall conform to all applicable requirements of the Code as related to a completed vessel, including inspection in the shop of the parts manufacturer and the furnishing of Partial Data Reports as provided for in CI-8000 except for miscellaneous parts as permitted in CI-2134.1 and CI-2134.2.

CI-2134.1 CAST, FORGED, ROLLED, OR DYE-FORMED STANDARD PRESSURE PARTS

(a) Standard pressure parts such as pipe fittings, valves flanges, nozzles, welding necks, welding caps, manhole frames, and covers that are wholly formed by casting, forging, rolling or die forming shall not require inspection, material certification, or Partial Data Reports. However, they shall be made of materials permitted under this Division. Such parts shall be marked with the name or trademark of the Manufacturer and such other markings as are required by the materials specifications and by the applicable standards. Such markings shall be considered as the Manufacturer's certification that the product complies with the material specifications and standards indicated, and is suitable for the pressure-temperature rating indicated except as limited by the rules in CI-3200 and CI-3470. The intent of the paragraph will have been met if, in lieu of the detailed marking on the part itself, the parts described herein have been marked in any permanent or temporary manner that will serve to identify the part with the Manufacturer's written listing of the particular items and such listings are available for examination by the Inspector.

(b) Steel flanges, flanged valves, or flanged fittings covered by ANSI B16.5 may be manufactured to either the 1973 or 1977 Edition. The pressure-temperature ratings used shall not exceed the ratings of the 1977 Edition except where B16.5 flanges, including specified gaskets and bolting, satisfy the rules of Article D-7 or Appendix 3 of Division 2 for the vessel design conditions.

CI-2134.2 CAST, FORGED, ROLLED, OR DYE FORMED NONSTANDARD PRESSURE PARTS

Nonstandard pressure parts such as shells, heads, removable doors, and pipe coils that are wholly formed by casting, forging, rolling, or dye forming

may be supplied basically as materials. All such parts shall be made of materials permitted under this Division and the manufacturer of that part shall furnish material certification. Such parts shall be marked with the name or trademark of the manufacturer and with such other markings as will serve to identify the particular parts with accompanying material certification. The manufacturer of the completed vessel shall satisfy himself that the part complies with the requirements of this Division for the design conditions specified for the completed vessel.

CI-2140 DETERIORATION OF MATERIAL AND COATINGS DURING SERVICE

Material provided to meet the service conditions specified in the Design Specification shall be evaluated for their adequacy to withstand the service conditions including deteriorating factors which may destroy the minimum capabilities needed to satisfy the requirements of this Subsection.

CI-2150 HEAT TREATMENT TO ENHANCE MECHANICAL PROPERTIES OF METALLIC MATERIAL

CI-2151 NOTCH TOUGHNESS AND HARDNESS PROPERTIES

Carbon and low alloy steels may be heat treated by quenching and tempering to enhance notch toughness or hardness properties. For carbon steels, postweld heat treatment of the material at a temperature of not less than 1100°F (593°C) may be considered to be the tempering phase of the heat treatment when postweld heat treatment is a requirement of CI-4500.

CI-2152 STRESS RELAXATION PROPERTIES

Wire, strand, or bar for prestressing systems may be heat treated, as in stress relieving, under load to enhance stress relaxation properties. Quenching and tempering treatments to produce specific mechanical properties are not permitted.

CI-2160 DIMENSIONAL STANDARDS

Dimensions of standard items for pipe, tube, fittings, valves, flanges, and gaskets shall comply with the standards and specifications listed in Table CI-2160-1, unless otherwise specified in the Construction Specification or designated on the Design Drawings.

TABLE CI-2160-1

DIMENSIONAL STANDARDS[1]

STANDARD	DESIGNATION
Pipe and Tubes	
Wrought Steel and Wrought Iron Pipe	ANSI B36.10-1959
Fittings, Valves, Flanges, and Gaskets	
Steel Pipe Flanges and Flanged Fittings	ANSI B16.5-1968
Wrought Steel Buttwelding Fittings	ANSI B16.9-1964
Forged Steel Fittings, Socket-Welding and Threaded	ANSI B16.11-1966
Wrought Steel Buttwelding Short Radius Elbows and Returns	ANSI B16.28-1964
Standard Finishes for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings	MSS SP-6-1963
Spot Facing for Bronze Iron and Steel Flanges	MSS SP-9-1964
Standard Marking System for Valves, Fittings, Flanges, and Unions	MSS SP-25-1964
Steel Buttwelding Fittings (26 in. and Larger)	MSS SP-48-1969

NOTE:

(1) Standards incprporated in this Division by reference. The names of the sponsoring organizations are shown in the Reference Materials portion of this Division.

CI-2200 PCIV SEGMENT MATERIAL

PCIV segments shall be produced from a class of gray cast iron defined in Specification SA 278 and identified in the Design Specification.

CI-2220 PCIV SEGMENT PROPERTIES

CI-2221 SPECIFIED PROPERTIES

CI-2221.1

The following properties shall be defined in the Design Specification and measured in accordance with the respective specifications:

TABLE CI-2221.1-1

PROPERTY	SPECIFICATION
Minimum Ultimate Tensile Strength	SA 278
Tensile Stress-Strain Curve[1] to Failure	SA 278, ASTM E8, ASTM E83[1]
Compresive Stress-Strain Curve[1] to Failure	ASTM A 256, ASTM E9, ASTM E83[1]
Maximum Allowable Compressive Stress[2]	TBD
Casting Quality[2]	TBD

CI-2221.2

The Design Specification shall specify the temperature at which mechanical properties in CI-2221.1 above shall be obtained and any environmental or design conditions which apply. If properties other than those listed in CI-222.1 above are required, they shall be defined in the Design Specification.

CI-2230 PROPERTIES DEFINITIONS

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[1] Incorporating class A or B1 extensometer measurements up to 1/3 of estimated ultimate stress levels.

[2] Section CI-2230

CI-2230.1 MAXIMUM ALLOWABLE COMPRESSIVE STRESS

The maximum allowable compressive stress is defined as that stress level which cannot be exceeded without degrading the tensile strength (and therefore shear strength) of the PCIV cast iron material. In application, the PCIV cast iron segments will be prestressed in compression, with resultant development of shear stresses in the circumferential and radial web sections incorporated in typical designs.

A paragraph will be developed in which the method of determining maximum allowable compressive stress is described. At this time, the intent is to perform tensile tests on a set of specimens which have been previously stressed in compression. The specimens would represent a wide range of compressive prestress, and a plot of ultimate tensile strength versus compressive prestress would then be made to identify the compressive prestress level at which the onset of tensile strength degradation occurs. This level would be identified as the maximum allowable compressive stress. If the design intent is that prestressing will be periodically repeated over the vessel's operating life, then the effect of several cycles of compressive prestress on ultimate tensile strength may also have to be determined. A specification for this testing will be developed and referenced in the Table CI-2221.1-1.

CI-2230.2 CASTING QUALITY

Specifications covering nondestructive inspection for internal casting defects, and defining types and conditions of defects which would be cause for rejection or recommendation for repair, will be developed for the PCIV castings and referenced in Table CI-2221.1-1. The large size and weight, and complexity of these castings makes X-ray inspection difficult, while the high damping capacity of gray cast iron will impair ultrasonic testing. Magnetic particle testing would be suitable for detection of surface defects, e.g., ASTM E 109, but simple unaided visual inspection if usually adequate to detect this condition in cast material. Based on European experience to date, it can be stated that ultrasonic testing will emerge as the favored inspection technique, although magnetic particle testing may have applicability at certain highly stressed portions of the segments.

CI-2240 TEST MATERIAL

CI-2240.1

The method of obtaining destructive test sample material shall be identified in the Design Specification for each PCIV segment configuration.

CI-2240.2

Test sample material may be obtained from a portion of the casting, an attachment to the casting, or from separately cast bars.

CI-2240.3

If sample material is obtained from the casting, it shall be taken from a region of maximum wall thickness.

CI-2240.4

If sample material is obtained from an attachment to the casting, its location and size shall be such that solidification and subsequent cooling occurs at a rate equivalent to or less than that of the maximum casting section or the controlling section of the casting as specified in the Design Specification.

CI-2240.5

If sample material is obtained from separately cast bars, the bars shall be poured from the same ladles, solidified and cooled under the same sand conditions and at a rate equivalent to or less than of the maximum casting section, and given the same thermal treatments as the PCIV casting represented. Separately cast bars shall have a minimum diameter twice that of the largest casting wall thickness; or, if smaller, correlations between mechanical properties obtained from the test bars and those of the represented PCIV casting shall have been previously established.

CI-2250 TEST LOT SIZE

CI-2250.1

Castings of the same configuration poured from the same ladles, solidified under the same sand conditions and given the same thermal treatments shall represent a test lot.

CI-2250.2

The types and numbers of property tests to be run on a test lot shall be defined in the Design Specification. As a minimum, those properties defined in CI-2221.1 shall be determined for each casting lot. If a casting lot consists of only one casting, waiver of the requirement to determine the maximum allowable compressive stress is permited provided a sufficient data base has been developed for PCIV castings of similar size and configuration poured at one foundry from one class of gray iron using a constant melt and sand practice.

CI-2400 MATERIAL FOR PRESTRESSING SYSTEMS

CI-2410 INTRODUCTION

This Subarticle establishes the requirements for the material to be used for PCIV prestressing systems.

CI-2420 PRESTRESSING STEEL

CI-2421 PERMITTED MATERIAL

Prestressing elements[6] are limited to those listed in Appendix 1, Table 1-1.1. The materials shall conform to their respective material specifications and to the additional requirements described in the following subparagraphs.

CI-2422 TEST SPECIMEN SIZES

All mechanical tests on prestressing elements shall be performed on full-diameter test pieces.

CI-2423 TENSILE TESTS

Material produced to an ASTM specification shall be sampled and tested as required by that specification. The tensile strength, yield strength, elongation, and other pertinent data shall be reported on Material Test Report.

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[6]The term prestressing element is defined as an individual wire, strand, or bar, whether in a multiple or single wire, strand, or bar system.

CI-2424 STRESS RELAXATION PROPERTIES

The stress relaxation properties of the prestressing elements tested in accordance with ASTM E 328, Standard Recommended Practice for Stress-Relaxation Tests for Materials and Structures, shall be provided by the Material Manufacturer. Reports relating thereto shall be based upon tests performed on material previously manufactured to the same ASTM or other applicable specification and produced in the same plant utilizing the same procedures that will be employed to produce the prestressing elements for the production tendons.

CI-2424.1 DATA TO BE FURNISHED

The following data shall be furnished:

(a) Deviations from ASTM E 328 recommended testing

(b) Specimen identification

(c) Initial and final stress

(d) Loss of stress at intervals specified in ASTM E328 during the test

(e) Temperature control limits

(f) Predicted stress-relaxation design life and basis for extrapolation

CI-2424.2 NUMBER OF TESTS

A minimum of three relaxation tests of 1000 hr duration shall be performed and reported to document adequately that the relaxation losses are in compliance with the Construction Specification.

CI-2430 ANCHORAGE COMPONENTS

CI-2431 PERMITTED MATERIAL

Specific materials for anchorage components are not given in this Division. The tendon Manufacturer is allowed to use any material he feels is compatible with his tendon system, taking into account the loading conditions that the tendons will undergo during testing and in service. It is a requirement, however, that the tendon Manufacturer performed the tests prescribed in CI-2460

and accordingly documents his anchorage component materials. The following subparagraphs describe the basic material tests the tendon Manufacturer must perform on the material he selects and uses for production tendon anchorage components.

CI-2432 BEARING PLATES

Material for bearing plates shall conform to their respective material specifications. The dimensions, finish, alignment, and tolerances of the bearing plates shall be within the limits set forth in the Construction Specification.

CI-2433 ANCHORHEAD ASSEMBLIES AND WEDGE BLOCKS

CI-2433.1 GENERAL

Materials for anchorhead assemblies and wedge blocks shall conform to their respective material specifications. The dimensions, finish, alignment, and tolerances of the anchorhead assemblies and wedge blocks shall be within the limits set forth in the Construction Specification.

CI-2433.2 HARDNESS TESTS

CI-2433.2.1 SCOPE AND EXTENT OF TESTING

Rockwell or Brinell hardness tests shall be conducted on 10% of the parts from each lot. If the material is heat treated, the measurements need only be made after heat treatment. The 10% sample shall be taken at random.

CI-2433.2.2 TEST PROCEDURES

Each test shall consist of taking three measurements on each part. The test procedures shall conform to ASTM E 18 for Rockwell hardness testing and to ASTM E 10 for Brinell hardness testing.

CI-2433.2.3 ACCEPTANCE STANDARDS

The results of all measurements shall be within the limits set in the construction procedures.

CI-2433.2.4 REWORK AND RETESTS

If the hardness requirement is not met by any single part, then all parts from the lot shall be tested. Those parts failing to meet the hardness requirement may be rejected or reheat treated once. Parts which are reheat treated shall be retested for compliance with CI-2433.2.

CI-2434 WEDGES AND ANCHOR NUTS

CI-2434.1 GENERAL

Materials for wedges and anchor nuts shall conform to their respective material specifications and the hardness test requirements of CI-2434.2. The dimensions, finish, alignment, and tolerances of the wedges and anchor nuts shall be within the limits set forth in the Construction Specification.

CI-2434.2 HARDNESS TESTS

CI-2434.2.1 SCOPE AND EXTENT OF TESTING

Surface hardness tests shall be conducted on not less than 5% of the wedges and anchor nuts from each heat treatment lot. In addition, core hardness, and for wedges, case depth tests, shall be conducted on three samples of each heat treatment lot. The samples shall be taken at random after heat treatment. Each heat treatment lot shall consist of material from only one heat of steel.

CI-2434.2.2 TEST PROCEDURES

The test procedures shall be the same as stated in CI-2433.1.2.

CI-2434.2.3 ACCEPTANCE STANDARDS

All measurements shall be within the limits set down in the construction procedures. Lots not meeting the requirements shall be rejected.

CI-2440 NONLOAD-CARRYING AND ACCESSORY MATERIAL

CI-2441 TENDON DUCTS, CHANNELS, TRUMPETS, AND TRANSITION CONES

Tendon duct, channels, trumpet, and transition cone material shall have the following properties:

(a) The material shall be ferrous and shall not cause harmful electrolytic reactions with the prestressing element.

(b) Ducts and channels shall be strong enough to retain their shape and resist irreparable damage during vessel construction.

(c) When used for single element tendons, the inside diameter of ducts shall be at least ¼ in. (6 mm) larger than the nominal diameter of the tendon.

(d) When used for multiple element tendons, the inside cross-sectional area of ducts shall be at least twice the nominal net area of the tendon steel when spiral duct is used and 1.5 times the net area of the tendon steel when the duct is smooth-walled.

(e) Ducts and channels shall have adequate openings for filler injection when such injection is required.

CI-2442 CORROSION PREVENTION MATERIAL

CI-2442.1 INTRODUCTION

This subparagraph describes the requirements for material to be used for the temporary and permanent corrosion prevention of prestressing systems.

CI-2442.2 TEMPORARY COATINGS

A temporary corrosion prevention coating shall be applied to all tendons during or after fabrication. The coating materials shall be compatible with the permanent corrosion preventing coating described in CI-2442.3. The temporary coating shall be specified in the Construction Specification. It shall be made to be easily removable in the field with the use of nonchlorinated petroleum solvents for the installation of field attached anchorages.

CI-2442.3 PERMANENT COATINGS

CI-2442.3.1 PERMISSIBLE TYPES OF COATINGS

The permanent corrosion prevention coating applied to prestressing elements may be an organic base material containing additives to inhibit corrosion of the steel.

CI-2442.3.2 PROPERTIES OF THE COATING

The coating manufacturer shall provide test data verifying that the following properties are met for the service life and temperature for evaluation and acceptance by the Designer:

(a) freedom from cracking and brittleness

(b) continuous self-healing film over the coated surfaces

(c) chemical and physical stability

(d) nonreactivity with the surrounding and adjacent materials such as cast iron, tendons, and ducts

(e) moisture displacing characteristics

CI-2442.3.3 CHEMICAL ANALYSIS OF THE COATING

Each batch of coating material shall be analyzed for the presence of water soluble chlorides, nitrates, sulphides and carbonates. The analysis shall conform to the limits shown in Table CI-2440-1. The method for obtaining the water extraction shall be approved by the Designer.

CI-2450 PERFORMANCE REQUIREMENTS

CI-2451 ANCHORAGES AND COUPLINGS

Anchorages and couplings shall be designed to assure that the mode of failure of the tendon system will be a rupture of the prestressing element. Each individual item of an anchorage or coupling shall be capable of developing at least 110% of the minimum specified ultimate tensile strength of the corresponding prestressing steel element or elements being anchored or coupled. This requirement shall apply to items manufactured to the most adverse combination of tolerances set forth in the Construction Specification.

CI-2452 TENDON ASSEMBLIES

CI-2452.1 ANCHORAGES

A full-capacity straight tendon, complete with anchorages, shall develop an ultimate strength equal to at least 100% of the minimum specified ultimate

TABLE CI-2440-1

ANALYSIS LIMITS OF PERMANENT COATING MATERIAL

COMPOUND	MAX. QUANTITY ppm	ANALYSIS METHOD
Water soluble chlorides, Cl^-	10	ASTM D 512 (limit of accuracy, 0.5 ppm)
Water soluble nitrates, NO_3^-	10	ASTM D 992 (limit of accuracy, 0.5 ppm)
Water soluble sulphides, S^-	10	APHA-test methods for sulphides in water (limit of accuracy, 1.0 ppm)
Water soluble carbonates, CO_3^{--}	10	TBD

tensile strength of the prestressing element without exceeding the anticipated set of the anchorage elements. The total elongation under ultimate load of the tendon shall not be less than 2% measured in a minimum gage length of 100 in. (2540 mm).

CI-2452.2 COUPLINGS

Tendons with couplings shall conform with the requirements of CI-2452.1. Couplings shall be enclosed in housings long enough to permit the necessary movements during tensioning.

CI-2452.3 DYNAMIC REQUIREMENTS

The tendon assembly shall have a demonstrated capacity to withstand, without failure, all dynamic and fatigue loads contemplated in the design of the PCIV.

CI-2452.4 LOW TEMPERATURE REQUIREMENTS

The tendon assembly shall function as designed when exposed to the lowest temperature expected during the life of the PCIV.

CI-2460 PERFORMANCE TESTS

CI-2461 GENERAL REQUIREMENTS

A series of performance tests shall be conducted to qualify the tendon system for use in the Cast Iron vessel. The required tests are designed to demonstrate that the combination of materials for the tendon system is adequate and to assess the overall strength and integrity of the tendon system.

CI-2462 MATERIAL TO BE USEL FOR PERFORMING TESTS

The materials to be used for the performance test tendons shall be those that the tendon Manufacturer proposes using for production tendons. All of the actual material used and the necessary dimensions shall be documented on a form the same as or similar to that shown in Figure CI-2460-1.

CI-2463 TYPE AND NUMBER OF PERFORMANCE TESTS

CI-2463.1 STATIC TENSILE TEST

One static tensile test shall be conducted to destruction so that the following information may be obtained:

(a) Yield strength (or proof stress) as defined by Spec. on Table 1-1.1.

(b) Ultimate tensile strength

(c) Elongation (over 100 in. (2540 mm) minimum gage length)

(d) Number of failed wires or strands

The results shall comply with the requirements of CI-2452.

CI-2463.2 HIGH CYCLE DYNAMIC TENSILE TEST

One high cycle dynamic tensile test shall be conducted so that the tendon shall withstand, without failure, 500,000 cycles of stress variation from 60% to 66% of the minimum specified ultimate tensile strength of the tendon. One loading cycle is defined as an increase from the lower to the higher load and return.

CI-2463.3 LOW CYCLE DYNAMIC TENSILE TEST

One low cycle dynamic tensile test shall be conducted so that the tendon shall withstand, without failure, 50 cycles of stress variation from 40% to 80% of the minimum specified ultimate tensile strength of the tendon. One loading cycle is defined as an increase from the lower to the higher load and return.

NOTE: It is considered satisfactory to use the same test specimen for performing the tests prescribed in both CI-2463.2 and CI-2463.3.

CI-2464 SIZE OF PERFORMANCE TEST SPECIMENS

CI-2464.1 LENGTH

The test specimens for static tensile tests shall have a gage length not less than 100 in. (2540 mm).

CI-2464.2 NUMBER OF PRESTRESSING ELEMENTS[1]

CI-2454.2.1 SINGLE ELEMENT TENDONS

A single element specimen shall be used for both static and dynamic tensile tests.

CI-2464.2.2 MULTIPLE ELEMENT TENDONS

(a) Static tensile test - All static tensile tests shall be performed on specimen having the full anchorage capacity of the proposed tendons.

(b) Dynamic tensile test - All dynamic tensile tests shall be performed on specimen having at least 10% of the full-size prestressing steel area of the proposed production tendons.

CI-2465 TEST RESULTS

The measurements and results obtained from the tests shall be documented on a form the same as or similar to that shown in Figure CI-2460-2.

CI-2466 ESSENTIAL VARIABLES

CI-2466.1 GENERAL REQUIREMENTS

The performance tests must be complete reconducted when any of the applicable changes listed below are made to the tendon system material. Changes other than those listed below may be made in the tendon system material without the necessity for repeating the performance tests.

CI-2466.2 ESSENTIAL VARIABLES IN PRESTRESSING ELEMENT MATERIAL

Essential variables in prestressing element material shall be as stipulated in (a) through (e) below:

(a) a change in the prestressing element material from one ASTM or ASME Specification to another

(b) a change in the tensile grade of the prestressing element material within the same ASTM or ASME Specification

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[1]The term prestressing element is defined as an individual wire, strand, or bar, whether in a multiple or single wire, strand, or bar system.

Specification No. _____ Date _____

Prestressing System Type _____ Single or Multiple Element _____
(wire, strand, or bar)

If Multiple, No. of Elements _____

Prestressing Element Material _____ Nominal Size _____

Bearing Plate Material _____ Thickness _____ Diameter _____

Wedge Material _____ Hardness _____
(Attach diagram showing shape and size)

Buttonhead Shape and Size (Attach diagram)

Swaged Fitting Material _____ Hardness _____
(Attach diagram showing shape and size)

Screwed Fitting Material _____ Hardness _____
(Attach diagram showing shape and size)

Figure CI-2460-1. Manufacturer's Record of Tendon Performance Qualification Tests.

1. STATIC TENSILE TEST

Specimen No.	Effective Area, sq in.	Yield Load, lb	Tensile Load, lb	Yield Strength, psi	Tensile Strength, psi	Elongation in 100, %	Number of failed wires/strands

2. HIGH-CYCLE DYNAMIC TENSILE TEST

Specimen No.	Effective Area, sq in.	Low Load, lb	High Load, lb	Low Stress, psi	High Stress, psi	Cycle Period

3. LOW-CYCLE DYNAMIC TENSILE TEST

Specimen No.	Effective Area, sq in.	Low Load, lb	High Load, lb	Low Stress, psi	High Stress, psi	Cycle Period

Figure CI-2460-2. Record of Mechanical Test Results Obtained From Tendon Performance Qualification Tests.

(c) a change in the heat treatment condition of the prestressing element material

(d) a change in the prestressing element diameter

(e) in multiple element systems, a change of more than 10% in the number of elements in the tendon

CI-2466.3 ESSENTIAL VARIABLES IN ANCHORAGE ITEMS

Essential variables in anchorage items shall be as stipulated in (a) through (f) below:

(a) for buttonhead anchorage systems, a change in the shape or dimensions of the buttonhead

(b) for wedge anchorage systems, a change in the shape, size, or dimensions of the wedge

(c) for threaded nut anchorage systems, a change in the nut or thread size

(d) for swaged systems, a change in the shape or size of the swaged fitting

(e) a change in the anchor block material from one type to another

(f) a change in the bearing plate material from one P-Number to another P-Number from Section IX, or any other material

CI-2470 MARKING AND IDENTIFICATION OF PRESTRESSING MATERIAL

Prestressing system material shall be marked or tagged in such a manner as to ensure traceability to the Material Test Report during production and while in transit and storage.

CI-2500 MATERIAL FOR LINERS

CI-2510 INTRODUCTION

Table 1-2.1 in Appendix 1 lists the material to be used for the construction of PCIV liners. In addition to these materials, clad plate and high alloy steels may be used based on conditions specified in Part UCL-11 and Part U. HA-11 of Division 1.

NOTE: Attention is called to the difficulties that have been experienced in welding materials differing greatly in chemical composition. Mixtures of uncertain chemical composition and physical properties are produced at the line of fusion. Some of these mixtures are brittle and may give rise to cracks during solidification or afterwards. To avoid weld embrittlement, special care is required in the selection of lining material and welding electrodes, and in the application of controls over the welding process and other fabrication procedures.

CI-2520 FRACTURE TOUGHNESS REQUIREMENTS FOR MATERIALS

CI-2521 MATERIALS TO BE IMPACT TESTED

Materials for PCIV liners shall be impact tested in accordance with the requirements of this paragraph, except that the following materials are not to be tested as a requirement of this paragraph:

(a) materials with a nominal section thickness of 3/4 in. m. (16 mm) and less

(b) bars with a nominal cross-sectional area of 1 sq in. (645 mm^2) and less

(c) studs, attached to the liner with a nominal size of 1 in. (25 mm) diameter and less

(d) all thicknesses of materials for pipe, tube, and fittings with a nominal pipe size 6 in. diameter and smaller

CI-2522 IMPACT TEST PROCEDURES

CI-2522.1.1 CHARPY V-NOTCH TEST

The Charpy V-notch test (C_V), when required, shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Figure 11, Type A. A test shall consist of a set of three full-size 10 X 10 mm specimens. The test temperature, lateral expansion, absorbed energy, and percent shear fracture shall be reported in the Material Test Report. The results, orientation, and location of all tests performed to meet the requirements of CI-2523 shall be reported in the Material Test Report.

CI-2522.2 TEST SPECIMENS

CI-2522.2.1 LOCATION OF TEST SPECIMENS

Impact test speciments, regardless of heat treatment, shall be removed from the locations specified for tensile test speciments in the material specification.

CI-2522.2.2 ORIENTATION OF TEST SPECIMENS

(a) Specimens for Charpy V-notch tests shall be oriented as follows:

(1) Specimens from forgings, other than bars, shall be oriented in a direction normal to the principal direction in which the material was worked. Specimens are neither required nor prohibited from the thickness direction.

(2) Specimens from pipe, tube, and fittings, except those made from plate and castings, shall be oriented in the axial direction.

(3) Specimens from bars shall be oriented in the axial direction.

(4) Specimens from all plate materials, including those used for pipe, tube, and fittings, shall be oriented in a direction normal to the principal rolling direction, other than the thickness direction.

(5) Specimens from cast materials shall have their axes oriented the same as the axes of the tensile specimens.

(6) In all cases (1) through (5), the length of the notch of the Charpy V-notch specimen shall be normal to the surface of the material.

CI-2523 TEST REQUIREMENTS AND ACCEPTANCE STANDARDS[7]

CI-2523.1 LINER MATERIAL WITH 2½ in. (64 mm) MAXIMUM THICKNESS

Liner material with nominal thickness 2½ in. (64 mm) and less, including fittings with pipe connections of nominal wall thickness 2½ in. (64 mm) and less, shall be tested as required by (a) and (b) below:

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[7] In addition to providing a basis for acceptance standards for materials, the test data are designated to be used as a basis for establishing inservice operation.

(a) Test three Charpy V-notch specimens at a temperature lower than or equal to the lowest service temperature.[8] All three specimens shall meet the requirements of Table CI-2523-1.

(b) Apply the procedures of (a) above to each of the following:

(1) the base material

(2) the base material, heat affected zone, and weld metal from the weld procedure qualification tests of CI-4533

(3) the weld metal of CI-2612.1

CI-2525 CHARPY V-NOTCH TESTS

CI-2525.1 CHARPY V-NOTCH SPECIMENS AND TEST PROCEDURE

Charpy V-notch specimens shall be in accordance with SA-370, Figure 11, Type A. The specimens shall be tested in accordance with SA-370 and shall meet the requirements of CI-2525.3.

CI-2525.2 NUMBER OF TEST SPECIMENS

An acceptance test shall consist of a set of three full-size 10 X 10 mm specimens.

CI-2525.3 ACCEPTANCE STANDARDS

The specimens shall break at energy values no less than those required by Table 1.2.1 of Appendix 1.

CI-2525.4 DATA TO BE REPORTED

The test temperature and the absorbed energy values shall be reported in the Partial Material Test Report. In addition, the lateral expansion in inches and the percent ductile-fracture area for each specimen shall be reported for information.

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[8] Lowest service temperature is the minimum temperature of the fluid retained by the component or, alternatively, the calculated volumetric average metal temperature expected during normal operation whenever the pressure within the component exceeds 20% of the preoperational system pneumatic test pressure.

CI-2526 NUMBER OF NOTCH TOUGHNESS TESTS REQUIRED

CI-2526.1 PLATES

One test shall be made from each plate as heat treated. Where plates are furnished in the nonheat-treated condition and qualified by heat treated test specimens, one test shall be made for each plate as-rolled. The term as-rolled refers to the ingot plate rolled from a slab or directly from an ingot, not to its heat treated condition.

CI-2526.2 FORGINGS

Where the weight of an individual forging is less than 1000 lb (450 kg) one test shall be made to represent each heat in each heat treatment charge. When heat treatment is performed in a continuous-type furnace with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a heat treatment charge shall be considered as any continuous run not exceeding 8 hr duration or a total weight, so treated, not exceeding 2000 lb (910 kg). One test shall be made for each forging of 1000 to 10,000 lb (450 kg to 4540 kg) in weight. Larger ring or disk forgings shall have two tests per forging and the location of drop weight or Charpy V-notch test specimens shall be selected so that an equal number of specimens is obtained from positions in the forging 180 degree apart. When a separate test forging is used to represent forgings in any size, one test shall be required.

CI-2526.3 TUBULAR PRODUCTS AND FITTINGS

One test shall represent each lot as defined by the tensile test requirements for the individual material specifications.

CI-2527 TEST COUPON HEAT TREATMENT FOR FERRITIC MATERIAL[9]

Where ferritic steel material of a liner is subjected to heat treatment during fabrication or installation, the material used for the tensile and impact test

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[9]Any postweld heat treatment time which is anticipated to be applied to the material during fabrication or construction after completion of manufacture shall be specified in the Construction Specification. The Material Manufacturer shall include this time in the total time at temperature specified to be applied to the test specimens.

specimens shall be heat treated in the same manner as the liner, except that test coupons and specimens for P-No. 1 materials with a nominal thickness of 2 in. (51 mm) or less are not required to be so heat treated. The Fabricator shall provide the Material Manufacturer with the temperature and heating and cooling rate to be used. In the case of postweld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80% of the total time at temperature or temperatures during actual postweld heat treatment of the material, and the total time at temperature or temperatures for the test material may be performed in a single cycle.

CI-2528 RETESTS

For Charpy V-notch tests required by CI-2525, if one specimen fails to meet minimum requirements, a retest may be conducted consisting of two additional specimens taken as near as possible to the failed specimen. For acceptance of retest, both specimens shall meet the minimum requirements.

CI-2529 CALIBRATION OF INSTRUMENTS AND EQUIPMENT

Calibration of temperature instruments and Charpy V-notch impact test machines used in impact testing shall be performed at the following frequency:

(a) Temperature instruments used to control test temperature of specimens shall be calibrated and the results recorded to meet the requirements of CI-8000 at least once in each three month interval.

(b) Charpy V-notch impact test machines shall be calibrated and the results recorded to meet the requirements of CI-8000. The calibrations shall be performed at least once in each twelve month interval using methods outlined in ASTM E 23 and employing standard specimens obtained from the U.S. Army Materials Research Center.

CI-2530 EXAMINATION AND REPAIR OF LINER MATERIAL

CI-2531 EXAMINATION OF LINER MATERIAL

Liner material shall be examined by nondestructive methods applicable to the material and product form as required by the rules of this Article, except for wrought seamless pipe, tube, and fittings 2 in. nominal pipe size and smaller.

CI-2532 EXAMINATION AFTER QUENCHING AND TEMPERING

Ferritic steel products which are used in the quenched and tempered condition shall be examined by the methods specified in this Article for each product form after the quenching and tempering phase of the heat treatment.

CI-2533 EXAMINATION AND REPAIR OF PLATE

CI-2533.1 REQUIRED EXAMINATION

All plates for liners shall be examined by the straight beam ultrasonic method in accordance with SA-578 except that the examination shall be performed over 100% of one major plate surface.

CI-2533.2 EXAMINATION PROCEDURES

CI-2533.2.1 EXTENT OF EXAMINATION

One hundred percent of one major surface shall be covered by moving the search unit in parallel paths with not less than 10% overlap.

CI-2533.2.2 ACCEPTANCE STANDARDS

(a) Any area where one or more discontinuities produce a continuous total loss of back reflection, accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. (76 mm), is unacceptable.

(b) In addition, two or more defects smaller than described in (a) above shall be unacceptable unless separated by a minimum distance equal to the greatest diameter of the larger defect or unless they may be collectively encompassed by the circle described in (a) above.

CI-2533.3 TIME OF EXAMINATION

Acceptance examinations shall be performed at the following times:

(a) Ultrasonic examination shall be performed after heat treatment.

(b) Radiographic examination of repair welds, when required, may be performed prior to any required postweld heat treatment.

(c) Magnetic particle or liquid penetrant examination of repair welds may be performed prior to any postweld heat treatment.

CI-2533.4 ELIMINATION OF SURFACE DEFECTS

(a) Unacceptable surface defects shall be removed by grinding or machining provided:

(1) the remaining thickness of the section is not reduced more than 1/16 in. (1.6 mm);

(2) the depression, after defect elimination, is blended uniformly into the surrounding surface;

(3) after defect elimination, the area is reexamined by the magnetic particle method in accordance with CI-2534.3, or the liquid penetrant method in accordance with CI-2534.4, to ensure that the defect has been removed or the indication reduced to an acceptable size.

(b) If the elimination of the defect reduces the thickness of the section more than 1/16 in. (1.6 mm), the product may be repaired by welding in accordance with CI-2533.5.

CI-2533.5 REPAIR BY WELDING

The Material Manufacturer may repair by welding products from which defects have been removed, provided the depth of the repair cavity does not exceed one-third of the nominal thickness and the requirements of the following subparagraphs are met. Prior approval of the liner Fabricator shall be obtained for the repair of plates to be used in the fabrication of the liner.

CI-2533.5.1 DEFECT REMOVAL

The defect shall be removed or reduced to an acceptable size by suitable mechanical or thermal cutting or gouging methods, and the cavity prepared for welding. When thermal cutting and gouging methods are used, preheating in accordance with CI-4521.1.1 shall be used.

CI-2533.5.2 QUALIFICATION OF WELDING PROCEDURES AND WELDERS

The welding procedures and welders or welding operators shall be qualified in accordance with CI-4500 and Section IX.

CI-2533.5.3 BLENDING OF REPAIRED AREAS

After repair, the surface shall be blended uniformly into the surrounding surface.

CI-2533.5.4 EXAMINATION OF REPAIR WELDS

Each repair weld shall be examined by the magnetic particle method in accordance with the requirements of CI-2534.3 or by the liquid penetrant method in accordance with requirements of CI-2534.4. In addition, when the depth of the repair cavity exceeds the lesser of 3/8 in. (10 mm) or 10% or the section thickness, the weld repair shall be radiographed after repair in accordance with CI-5531 and to the acceptance standards of CI-5542. The penetrameter and the acceptance standards for radiographic examination of repair welds shall be based on the section thickness of the repair area.

CI-2533.5.5 HEAT TREATMENT AFTER REPAIRS

The product shall be heat treated after repair in accordance with the heat treatment requirements of CI-4554.

CI-2533.5.6 MATERIAL REPORT DESCRIBING DEFECTS AND REPAIRS

Each defect repair exceeding 3/8 in. (10 mm) in depth shall be described in the Partial Material Test Report (PMTR). The PMTR for each piece shall include a chart which shows the location and size of the prepared cavity, the welding material identification, the welding procedure, the heat treatment, and the examination results.

CI-2534 EXAMINATION AND REPAIR OF FORGINGS

CI-2534.1 REQUIRED EXAMINATIONS

Forgings and bars shall be examined in accordance with the requirements of the material specification.

CI-2534.2 ELIMINATION OF SURFACE DEFECTS

Elimination of surface defects shall be made in accordance with CI-2533.4.

CI-2534.3 REPAIR BY WELDING

Repair by welding shall be made in accordance with CI-2533.5.

CI-2535 EXAMINATION AND REPAIR OF SEAMLESS AND WELDED (WITHOUT FILLER METAL) TUBULAR PRODUCTS AND FITTINGS

For the purposes of this Subarticle, seamless and welded (without filler metal) tubular products and fittings are clasified as follows:

(a) Group A tubular products are those which contain primary coolant and which are part of the PCIV liner.

(b) Group B tubular products are those which do not contain primary coolant, such as liner and cast iron cooling tubes.

CI-2535.1 REQUIRED EXAMINATION OF GROUP B PRODUCTS

(a) Wrought seamless tubular products and fittings shall be examined in accordance with the requirements of the material specification.

(b) Welded (without filler metal) tubular products such as pipe made in accordance with SA-249, SA-312, SA-333 and SA-334 and fittings made in accordance with SA-403 shall be examined in accordance with the requirements of the material specification and, in addition, the welds shall be examined by one of the following methods:

(1) ultrasonic examination;

(2) eddy-current examination;

(3) magnetic particle or liquid penetrant examination on all external surfaces and accessible internal surfaces;

(4) radiographic examination.

CI-2535.2 ULTRASONIC EXAMINATION

CI-2535.2.1 EXAMINATION PROCEDURE

The procedure for ultrasonic examination shall provide a sensitivity which will consistently detect defects that produce indications equal to or greater than the indication produced by standard defects included in the reference specimen

specified in CI-2535.2.2. Products with defects that produce indications in excess of the reference standards are unacceptable unless the defects are eliminated or repaired in accordance with CI-2535.7 or CI-2535.8.

CI-2535.2.2 REFERENCE SPECIMENS

(a) The reference specimen shall be of the same nominal diameter and thickness and of the same nominal composition and heat treated condition as the product which is being examined. The standard defects shall be axial notches or grooves on the outside and the inside surfaces of the reference specimen and shall have a length of approximately 1 in. (25 mm) or less, a width not to exceed 1/16 in. (1.6 mm), and a depth not greater than the larger of 0.004 in. (0.102 mm) or 5% of the nominal wall thickness. The reference specimen may be the product being examined.

(b) The reference specimen shall be long enough to simulate the handling of the product being examined through the examination equipment. When more than one standard defect is placed in a reference specimen, the defects shall be located so that indications from each defect are separate and distinct without mutual interference or amplification.

CI-2535.2.3 CHECKING AND CALIBRATION OR EQUIPMENT

The proper functioning of the examination equipment shall be checked and the equipment shall be calibrated by the use of the reference specimens, as a minimum;

(a) at the beginning of each production run of a given size and thickness of a given material

(b) after each ½ hr or less during the production run

(c) at any time that malfunctioning is suspected

If during any check it is determined that the testing equipment is not functioning properly, all of the product that has been tested since the last valid equipment calibration shall be reexamined.

CI-2535.3 RADIOGRAPHIC EXAMINATION

The radiographic examination shall be performed in accordance with Article 2 of Section V as modified by CI-5531 and the acceptance standards of CI-5542.

CI-2535.4 EDDY CURRENT OR OTHER ELECTRICAL EXAMINATION

The requirements for eddy current or other electrical examination stipulated in CI-2535 are given in the following subparagraphs.

CI-2535.4.1 EXAMINATION PROCEDURE

The procedure for eddy current or other electrical examination methods shall provide a sensitivity that will consistently detect defects by comparison with the standard defects included in the reference specimen specified in CI-2535.4.2. Products with defects that produce indications in excess of the reference standards are unacceptable unless the defects are eliminated or repaired in accordance with CI-2535.6 or CI-2535.8 .

CI-2535.4.2 REFERENCE SPECIMENS

The reference specimen shall be a piece of, and shall be processed in the same manner as, the product being examined. The standard defects shall be circumferential or tangential notches or grooves on the outside and the inside surfaces of the product and shall have a length approximately 1 in. (25 mm) or less, a width not to exceed 1/16 in. (1.6 mm), and a depth not greater than the larger of 0.004 in. (0.102 mm) Or 5% or the wall thickness, and a radial hole having a nominal diameter of 1/16 in. (1.6 mm) or less. The size of a reference specimen shall be as specified in CI-2535.2.2.

CI-2535.4.3 CHECKING AND CALIBRATION OF EQUIPMENT

The checking and calibration of examination equipment shall be the same as in CI-2535.2.3.

CI-2535.5 MAGNETIC PARTICLE OR LIQUID PENETRANT EXAMINATION

Magnetic particle or liquid penetrant examination shall be performed in accordance with the requirements of CI-2534.3 or CI-2534.4.

CI-2535.6 TIME OF EXAMINATION

The requirements for time of examination of seamless tubular products and fittings shall be the same as stated in CI-2533.3. The requirements for time of examination of welded tubular products and fittings shall be at the time of manufacture as required in (a), (b), and (c) below.

(a) Ultrasonic examination shall be performed after heat treatment, except postweld heat treatment.

(b) Radiographic examination of repair welds, when required, may be performed prior to any required postweld heat treatment.

(c) Magnetic particle or liquid penetrant examination of repair welds shall be performed after final heat treatment, except that the examination may be performed prior to postweld heat treatment for P-No. 1 materials with a nominal thickness or 2 in. or less.

CI-2535.7 ELIMINATION OF SURFACE DEFECTS

(a) Unacceptable surface defects shall be removed by grinding or machining provided:

(1) The remaining thickness of the section is not reduced below that required by CI-3000.

(2) The depression, after defect elimination, is blended uniformly into the surrounding surface.

(3) After defect elimination, the area is examined by the method which originally disclosed the defect to assure that the defect has been removed or the indication reduced to an acceptable size.

(b) If the elimination of the defect reduces the thickness of the section below the minimum required to satisfy the rules of CI-3000, the product may be repaired in accordance with CI-2535.8.

CI-2535.8 REPAIR BY WELDING

Repair of defects shall be in accordance with CI-2534.7.

CI-2535.9 REQUIRED EXAMINATION OF GROUP B PRODUCTS

There are no mandatory requirements for supplementary examination of Group B tubular products other than specified in the material specification.

CI-2536 EXAMINATION OF REPAIR OF WELDED TUBULAR PRODUCTS AND FITTINGS (WITH FILLER METAL)

CI-2536.1 REQUIRED EXAMINATIONS

TBD

CI-2536.2 TIME OF EXAMINATION

Acceptance examinations, including those for repair welds, shall be performed at the time of manufacture as follows:

(a) Ultrasonic examination of plate shall be performed at the time as specified in CI-2533.3 or, if the finished product is examined, the time of examination shall be after final rolling and forming.

(b) Radiographic examination of welds, including repair welds, shall be performed prior to any required postweld heat treatment.

(c) Magnetic particle or liquid penetrant examination of welds, including repair welds, shall be performed after heat treatment, except the examination may be performed prior to postweld heat treatment of P-No. 1 material.

CI-2536.3 ELIMINATION OF SURFACE DEFECTS

(a) Unacceptable surface defects shall be removed by grinding or machining provided:

(1) the thickness of the section is not reduced more than 1/16 in. (1.6 mm);

(2) the depression, after defect elimination, is blended uniformly into the surrounding surface,

(3) after defect elimination, the area shall be reexamined by the magnetic particle method in accordance with CI-2534.3 or the liquid penetrant method in accordance with CI-2534.4 to ensure that the defect has been removed or reduced to an acceptable size.

(b) If the elimination of the defect reduces the thickness of the section more than 1/16 in. (1.6 mm), the product may be repaired in accordance with CI-2536.4.

CI-2536.4 REPAIR BY WELDING

Repair welding of base material defects shall be in accordance with CI-2533.5. Repair welding of weld seam defects shall be in accordance with CI-4545.

CI-2540 MARKING OF LINER MATERIAL

TBD

CI-2600 WELDING MATERIAL

CI-2610 WELD METAL COMPOSITION

Welds that are exposed to the corrosive action of the contents of the vessel should have a resistance to corrosion that is not substantially less than that of the base metal. The use of filler metal that will deposit weld metal with practically the same composition as the material joined is recommended. When the manufacturer is of the opinion that a physically better joint can be made by departure from these limits, filler metal of a different composition may be used provided the strength of the weld metal at the operating temperature is not appreciably less than that of the high-alloy material to be welded, and the user is satisfied that its resistance to corrosion is satisfactory for the intended service. The columbium content of weld metal shall not exceed 1.00%. The weld material is to be specified in Section II, Part C and used in conjunction with the welder qualification specified in Section IX.

CI-2700 MATERIALS MANUFACTURER'S QUALITY ASSURANCE PROGRAMS

TBD

ARTICLE CI-3000

DESIGN

CI-3100 GENERAL DESIGN CONDITIONS

CI-3110 GENERAL STRUCTURAL REQUIREMENTS

(a) The PCIV shall be designed for service conditions stipulated in the Design Specification by maintaining the levels of stress, strain, and deformation to limits that ensure an essentially elastic response under normal service life of the vessel. The PCIV shall also be designed to meet the requirements of CI-3300 and CI-3400 for the load level associated with specified design loading conditions.

(b) As an additional requirement, the vessel shall be proportioned, and prestressed in a manner such that, as its ultimate structural capacity is approached, vessel response will be gradual, observable, and predictable and in a manner such that the minimum ultimate load capacity is clearly developed. The minimum ultimate structural capacity shall be twice that required to resist the load level associated with the maximum cavity pressure. The criteria of ultimate structural capacity shall be stated in the Design Specification. The Designer shall assure that all nonconforming modes will occur at a pressure greater than the failure pressure for the lowest conforming mode.

(c) The PCIV and its individual structural components shall be designed to resist the pressure cycles specified in the Design Specification.

(d) The PCIV design shall include specific consideration of the following effects:

(1) the influence of PCIV deflections on plant functional performance

(2) foundation settlement and support tilting

(3) creep

(4) steel relaxation

(5) thermal effects on material properties of liner, cast iron and prestressing steels

(6) environmental effects on liner, cast iron and prestressing materials

(e) The PCIV may be designed in such a manner that its principal load carrying elements are prestressing tendons or a combination or prestressing tendons and constraining steel elements. The limits established in this Article apply in each case.

CI-3110.1 SCOPE

(a) The requirements of this Article CI-3000 provide some simplified design rules. Some simplified rules for the appropriate evaluation of design cycle service life have been included. This Article does not contain rules to cover all details of the design. Design of parts and appurtenances in which stress limits or design rules have not been specified in this article shall meet the requirements of Part AD of Division 2, CI-1000 and CI-8000. Attachments to parts design to the requiring of Division 2 shall meet the requirement of that Division.

(b) When complete rules are not provided for a vessel or vessel part, or when the vessel designer or user chooses, a complete stress analysis of the vessel or vessel part shall be performed considering all the loadings specified in the User's Design Specification. This analysis shall be done in accordance with Appendix 4 for all applicable stress categories and in accordance with Appendix 5 when fatigue evaluation is required.

Alternatively, design analysis by model tests can be performed in accordance with CI-3340. When either of these procedures is followed, the general principles, design requirements of Article CI-3000, and weld detail, fabrication, inspection, and testing requirements of this division shall also be met.

CI-3120 GENERAL METALLIC LINER, PENETRATION, BRACKET, AND ATTACHMENT REQUIREMENTS

CI-3121 LINER

The general requirements to be used in the design of metallic liner are as follows:

(a) The liner shall be designed to resist all direct loads and other effects such as temperature and creep, so that its leak-tight integrity will be maintained during normal operating conditions.

(b) The liner shall be entirely of welded construction. Thickened plates may be used for such items as penetrations, brackets, and insert plates.

(c) The liner shall be anchored to the cast iron structure so that the overall deformation of the liner shall be the same as that of the cast iron. This does not preclude local flexural deformation between anchor points or shear deformations at anchors. Also, it does not preclude designs where cylindrical or spherical cavities are unanchored except at the ends.

CI-3122 LINER ANCHORS

(a) The liner anchorage system shall be design so that it can accommodate tangential (shear) and normal loads or deformations exerted by the liner.

(b) The anchorage system shall be so designed that progressive failure of the entire anchorage system is precluded in the event of a defective or missing anchor.

(c) The liner and its anchorage system shall be designed to resist the effects of cooling water pressure from cooling water tube leaks, if applicable.

CI-3123 PENETRATION LINERS

The penetration liners and the nozzle, insert plate, and penetration anchors shall be designed to accommodate all imposed loads, environmental effects such as temperature, and deformations so that their structural and leak-tight integrity will be maintained. Effects such as temperature, cast iron creep shall be considered. These penetration liners and nozzles shall be designed according to the Design Specification and Section VIII, Division 2.

CI-3124 BRACKETS AND ATTACHMENTS

Brackets and attachments shall be designed to resist all imposed loads without subsequent loss of the liner integrity due to excessive deformation caused by bracket or attachment loads. It is preferred that the design of bracket and attachment assemblies be such that the liner plate is not loaded in the through-thickness direction. When the lines are loaded in the through-thickness direction, the special requirements of CI-3740 shall be met.

CI-3200 LOADS AND LOAD COMBINATIONS

CI-3210 GENERAL

(a) The specific loads and their combinations for which the PCIV shall be designed and the manner in which they shall be considered to conform with specified design limits shall involve consideration of specific plant operational parameters and site conditions.

(b) The specific loads and load combinations for the PCIV shall be established in the Design Specification for each of the load categories established by this Article. The load combinations so established shall be applied by the Designer in such a manner that the design features of the PCIV are based upon the most conservative application of these combinations.

CI-3220 LOADINGS

The loadings which shall be considered shall include but not to be limited to following if applicable:

(a) internal and external pressure, including static head

(b) weight of vessel and normal contents under operating or test conditions

(c) superimposed loads such as other vessels, operating equipment, insulation, corrosion resistant or erosion resistant linings and piping

(d) wind loads, snow loads, and earthquake loads

(e) reactions of supporting lugs, rings, saddles, or other types of vessel supports

(f) impact loads, including rapidly fluctuating pressure

(g) temperature conditions, introducing differential strain loadings, and strain induced reactions resulting from expansion or contraction of attached piping or other parts

(h) prestressing force including assembly and relaxation considerations

(i) assembly of cast iron block and prestressing conditions

(j) stress relaxation of PCIV prestressing system

(k) tendon failure or material degradation equal to total design prestress loss.

CI-3230 CORROSION

Vessels or parts thereof subject to loss of metal by corrosion, erosion, mechanical abrasion, or other environmental effects shall have provisions made for such loss during the design or specified life of the vessel by a suitable increase in or addition to the thickness of the base metal over than determined by the design formulas or stress analysis. Material added or included for these losses need not be of the same thickness for all parts of the vessel, if different rates of attack are expected for the various parts. No additional thickness need be provided when previous experience in like service has shown that corrosion does not occur or is of only a superficial nature.

CI-3240 CLADDING

When integrally clad plate or overlay weld clad plate is used for a liner material or any other section of the PCIV vessel the design rules of paragraph AD-116 of Division 2, apply.

CI-3250 LININGS

Corrosion resistant or abrasion resistant linings are those not integrally attached to the vessel wall, i.e., they are intermittently attached or not attached at all. In either case, such linings shall not be given any credit when calculating the thickness of the vessel wall.

CI-3260 DESIGN BASIS

(a) Table CI-3260-1 sets forth the pressure, temperature, and static head relationships which must be considered by the designer.

(b) The design for a vessel part is usually controlled by coincident pressure and temperature at a point. The design shall take into account the maximum difference in fluid pressure, which exists under the specified conditions of operation (which may include pressure due to static head), between the inside and outside of the vessel at any point or between two chambers of a combination unit. The design thickness for pressure should not include any metal added as corrosion or erosion allowance or any metal required for any combination of loadings listed in paragraph CI-3200 which are likely to occur coincident with the operating pressure and temperature.

CI-3261 DEFINITIONS

CI-3261.1 DESIGN PRESSURE

Design pressure is the pressure at the top of the vessel and which, together with the applicable coincident (metal) temperature, is stamped on the nameplate. The pressure at the top of the vessel is also the basis for the pressure setting of the pressure relief devices protecting the vessel.

CI-3261.2 DESIGN TEMPERATURE

The temperature used in design shall be based on the actual metal temperature expected under operating conditions for the part considered at the designated

TABLE CI-3260-1

PRESSURE AND TEMPERATURE RELATIONSHIPS

1	2 PRESSURE AT TOP OF VESSEL	3 PRESSURE DUE TO STATIC HEAD[1]	4 TEMPERATURE	5 REMARKS
CONDITION (1)				
for any Cast Iron segment	Prestress Pressure	NONE	Ambient	Maximum Cast Iron Compressive Stress Condition (Construction)
CONDITION (2)				
for any vessel as a whole	Design Pressure	NONE	Coincident Metal	Pressure and temperature to be stamped on nameplate.
at any point	Coincident Pressure	Pressure to point under consideration due to static head of vessel contents	Design Coincident Temperature	Temperature at various points may vary, in which case the maximum for these conditions should be used for the vessel as a whole or coincident conditions for specific locations shall be listed on the Manufacturer's Data Report and Stamping.
CONDITION (3)				
at any point	Coincident Pressure	Coincident pressure to point under consideration due to static head	Design Temperature	Higher temperature and lower pressure combinations (than Condition 2) must be checked or a part may be designed for the maximum design pressure and the design temperature (See Section CI-8000).
CONDITION (4)				
for vessel as whole	Test Pressure	NONE	Test Temperature	
at any point	Test Pressure	Pressure at point under consideration due to static head	Test Temperature	
CONDITION (5)				
for vessel as a whole or any part	Coincident Pressure		Minimum Permissible Temperature	Minimum permissible temperature is used together with notch toughness tests or with low maximum stresses to determine suitability of material at service temperature.
	Safety Valve Setting			Usually set above the operating pressure but not over the limits set in CI-5110.

NOTE: (1) Similar application shall be made for other sources of pressure variation such as that resulting from flow.

coincident pressure. When the occurrence of different metal temperatures during operation can be definitely predicted for different zones of a vessel, the design of the different zones may be based on their predicted temperatures.

(a) The temperature used in design shall be not less than the mean temperature through the thickness expected under operating conditions for the part considered. In necessary, the metal temperature shall be determined by computations using accepted heat transfer procedures or by measurement from equipment in service under equivalent operating conditions. In no case shall the temperature at the surface of the metal exceed the maximum temperature listed in the stress intensity tables for materials or exceed the temperature limitations specified elsewhere in Division 2.

(b) Design temperatures in excess of the maximum temperatures listed for each material specification and grade for design stress intensity values in tension given in the tables in Part AM of Division 2 are not permitted.

(c) When sudden cyclic changes in temperature are apt to occur in normal operation with only minor pressure fluctuations, the design shall be governed by the highest probable operating metal temperature (or the lowest minimum permissible temperature) and the corresponding pressure.

(d) Suggested methods for determining the operating temperatures of the wall of vessels already in service are given in Appendix 13 of Division 2.

(e) For ferrous materials the minimum permissible temperature for which the vessel is suited is established by the requirements of AD-155 of Division 2 and the toughness requirements for ferrous materials of AM-204 of Division 2.

CI-3261.3 OPERATING PRESSURE

The operating pressure is the pressure at the top of the vessel at which it normally operates. The operating pressure shall not exceed the design pressure and is usually kept at a suitable level below it to prevent the frequent opening of pressure relieving devices.

CI-3261.4 PRESTRESS PRESSURE

Prestress pressure is the maximum circumferential pressure applied to a set of cast iron body or head segments used to form a single unit. This represents the

largest compressive stress condition for the cast iron segments. This prestress pressure is applied during construction sequence and is generic to the basic PCIV design.

CI-3261.5 TEST PRESSURE

The test pressure is the pressure to be applied at the top of the vessel during the test. This pressure plus any pressure due to static head at any point under consideration is used in the applicable formula to check the vessel under test conditions (see CI-7271).

CI-3261.6 SAFETY VALVE SETTING

The pressure for which the safety or safety relief valves are set to open is established by CI-5110.

CI-3261.7 TERMS RELATING TO DESIGN AND STRESS ANALYSIS

Definitions of design and analysis terminology are included in Appendix 4.

CI-3300 SPECIAL ANALYTICAL DESIGN PROCEDURE CONSIDERATIONS

CI-3310 GENERAL

(a) The analytical methods used for various load combinations shall account for the geometric characteristics of the PCIV, and the stress, strain and deformation characteristics of the PCIV liner, cast iron and prestressing steel.

(b) When axisymmetric or planar analytical techniques are applied to situations that are three-dimensional in character, the analytical procedures to be used shall have been demonstrated as developing reasonable accurate stresses and strains with respect to those results obtainable from an analytical procedure that considers three-dimensional effects.

(c) The assumption of linear elastic stress-strain properties for cast iron and steel for loading combinations of the Construction and Operating Load Categories is permissible. When analytical methods that do not consider cracking are used in lieu of cracked section analysis, the apparent cast iron tensile stresses shall not exceed the f_{cit} values of Table CI-3421-1 or CI-3421-2. If a cracked section theory is not employed for the thermal stress analysis, the modulus of elasticity shall be assumed consistent with the temperature

variations, but in no case shall it be assumed less than 0.5 E_c unless a lower value can be justified by tests or analysis.

(d) The assumption of linear-elastic properties for cast iron material in tension with an effective cast iron modulus of elasticity established as the zero to 0.50 f_{ci} secant is permissible. The assumption of linear-elastic properties, for cast iron material in compression with an effective cast iron modulus of elasticity established as the zero to 0.40 f_{cuc} secant is permissible.

CI-3320 CAST IRON CONSIDERATION

The cast iron stress limits are specified for the constrained and unconstrained conditions. The designer must evaluate and analyze the design based on the design criteria which must accurately describes the cast iron segment design. The constrained design criteria may be used in general by the designer provided he can justify the constrained design assumption. Constrained cast iron components represent designs such that cracking may be tolerated so long as adequate consideration of large cracking is precluded. These cast iron design criteria (Table CI-3421-1 and CI-3421-2) are based on gray cast iron data and are only applicable to gray cast iron grades. The analytical techniques used to evaluate the cast iron design must be based on maximum normal stress theory rather than on maximum shear stress theory. The shear stress limit is based on the criterion that maximum shear is equal to 1.4 times the tensile stress allowable.

CI-3330 LINER CONSIDERATIONS

The use of a metallic liner for a PCIV concept is not mandatory. However, adequate modifications must be incorporated in the design to provide vessel leak-tightness and cast iron/prestressing steel corrosion protection.

The design criteria specified on Table CI-3700-1 are based on the assumption that the liner remains in intimate contact with the cast iron segments. These criteria also assume that the liner does not buckle during various cyclic pressure loadings.

Liner analysis requires consideration of the method of maintaining contact with the cast iron. Liner anchor limits have been specified to maintain structural

integrity of only the liner anchors. Special consideration must be made by the designer to define liner anchor positions and design approaches which preclude buckling and insures leak tightness of the vessel.

CI-3340 PRESTRESSING STEEL CONSIDERATIONS

The prestressing system shall be designed and analyzed to insure structural integrity of the vessel up to twice the design pressure. The PCIV shall be designed to maintain the design tension in the prestressing steel throughout the life of the vessel. The stress relaxation properties of the prestressing steel must be defined by the Design Specification. Adequate consideration must be given to the effects of loss of prestress during loading conditions specified on Table CI-3260-1. The prestressing system must be evaluated to determine effects on system when re-tensioning of system is required. This evaluation must consider the re-tensioning methods and frequency of the operation.

The prestressing system temperature must be maintained within the limits specified on Table CI-3430-1. The designer may exceed these limits for a short duration if sufficient test data indicate no degradation of the system due to a short temperature increase.

CI-3350 DESIGN ANALYSIS OF MODEL TESTING

(a) Where analytical procedures to predict PCIV ultimate strength and behavior in the range approaching failure are not established, and where a model of a prototype with characteristics similar to those of the current design has not been constructed and tested in accordance with the provisions of this Article, structural modeling to establish the PCIV's characteristics and to verify conformance with the provisions of this Article is required.

(b) The required model shall maintain similitude, including that of material, to the prototype design and be geometrically similar with respect to the principal dimensions of the prototype in a scale ratio consistent with the following test purposes:

Model Purpose	Dimensional Scale[1] or Size
Elastic Response	¼ or larger
Ultimate Failure Mode	¼ or larger
Long-term Loading	1/7 or larger
Temperature Response (long term)	¼ or larger
Temperature Response (short term)	2 ft or greater thickness

(c) The actual average cast iron strength of the model at time of test should not exceed the specified PCIV design strength capacity. If, however, the model cast iron strength is found to exceed that of the prototype, the ultimate capacity of the prototype shall be derated proportionally to the cast iron strength.

(d) Models to verify prototype head behavior and ultimate capacity shall be subjected to the most severe boundary conditions which pressures between zero and design pressure acting in the cavity can produce.

(e) The use of a sealing membrane in lieu of a liner is permitted. Prevention of liner leakage during structural testing is desirable but is not required.

(f) Failure of the model shall be considered as having occurred upon rupture of a tendon or exceeding maximum deflection limits, or inability to further increase model pressure due to model structural damage.

CI-3360 LOAD COMBINATION CATEGORIES

The integrity of the PCIV shall be designed for conditions that are postulated in the Design Specification to occur during the service life of the PCIV. These shall include the following:

(a) Construction and/or Testing

(b) Operating

(c) Operating with Environmental

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[1]Other dimensional scales may be used provided the Designer establishes their adequacy for the intended purpose, especially with regard to material scaling if smaller scales are used.

CI-3370 CONSTRUCTION AND/OR TESTING CATEGORY LOAD COMBINATIONS

Load combinations that include loads resulting from PCIV handling fabrication, construction, or preoperational testing are designated as the Construction Category. The PCIV stress values shall be within the limits of Table CI-3421-1, Table CI-3421-2, CI-3421.3 and Table CI-3422-1 for all load combinations in this category. Examples of loads that should be considered for inclusion in this category are as follows:

(a) vessel weight

(b) construction equipment loads

(c) prestressing force (including assembly and relaxation considerations)

(d) assembly of cast iron block and prestressing conditions

(e) vessel temperature and gradients

(f) vessel test pressure

(g) cast iron loading due to unpressurized vessel pressure

CI-3380 OPERATING CATEGORY LOAD COMBINATIONS[2]

Load combinations that include loads resulting from system startup, normal operating pressurization, shutdown (in the absence of abnormal failure conditions), and servicing (such as repair and refueling) are designated as the Operating Category. PCIV stress values shall be within the limits of Table CI-3421-1, Table CI-3421-2, Table CI-3421-3 and Table CI-3422-1 for all load combinations in this category. Examples of loads that should be considered for inclusion in this category are as follows if specified in Design Specification:

(a) cavity and penetration pressure ranging between shutdown subambient and peak operating pressure

(b) vessel wall temperatures and gradients

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[2]The stress and deformation limits that are applied for specified load combinations that are included in this load category are such that the capability of the PCIV for subsequent continued operation will not be impaired.

(c) vessel and internal equipment weight

(d) servicing equipment weight

(e) stress relaxation of PCIV prestressing system

(f) static reactions and loads of piping and support restraints

(g) dynamic loads from equipment operation and piping

(h) loads due to thermal movements of piping

(i) snow loads

CI-3390 OPERATING WITH ENVIRONMENTAL CATEGORY LOAD COMBINATIONS[3]

Load combinations that include loads resulting from infrequently occurring environmental effects are designated as the Operating with Environmental Category. The PCIV stress values shall be within the limits shown on Tables CI-3421-1, CI-3421-2, CI-3421-3 and CI-3422-1 for load combinations on this category. Examples of loads that should be considered for inclusion in this category are as follows:

(a) Operating Loads plus Operating Basis Earthquake selected for site if required by Design Specification.

(b) Operating Loads plus Operating Basis Wind of characteristics appropriate for the region if it can result in applied loading to the PCIV.

(c) Operating Loads plus a flood loading if it can result in an applied loading to PCIV.

These criteria do not represent normal operating conditions for the user. The environmental effects are superimposed on the normal operating conditions.

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[3]The stress and deformation limits that are applied for specified load combinations that are included in this load category are such that safe shutdown can be achieved and maintained and any localized cracking be repairable.

CI-3400 SERVICEABILITY AND STRENGTH LIMITS

CI-3410 GENERAL

The stresses in the PCIV under Operating Load Category loadings shall not exceed the Operating Load Category values prescribed by this Article. The stresses in the PCIV under Construction and/or Testing Load Category loadings shall not exceed Construction Stress Category values prescribed in this Article. The stress of the PCIV under loads of Operating with Environmental Load Categories shall not exceed the Operating with Environmental Stress Category values prescribed by this Article. This Operating with Environmental Loading Category represents a short term duration loading of either wind and normal operating loads or earthquake and normal operating loads.

CI-3420 STRUCTURAL STRENGTH AND SERVICEABILITY LIMITS

CI-3421 COMPUTED STRESS

Computed stresses shall be within the limits established by Table CI-3421-1, Table CI-3421-2, Table CI-3421-3 and Table CI-3422-1. The factor C shown in Tables CI-3421-2 may be used for the purpose of accounting for the effect of a multiaxial compressive stress field. If the factor C is used, the requirements of Appendix 2 shall apply. If the factor C is not used, a factor of 1.0 should be substituted.

CI-3422 CAST IRON SHEAR AND BEARING SERVICEABILITY LIMITS

The cast iron shear and bearing serviceability limits for the PCIV are established in Table CI-3422-1. These limits apply to Construction, and/or Testing, Operating and Operating with Environmental Category load combinations at localized shear anchor or attachment points.

CI-3430 TEMPERATURE SERVICEABILITY LIMITS

(a) The strength and serviceability criteria established in this Article include consideration of a specific range of material properties. In order that the PCIV materials maintain their intended values, the temperature limits of Table CI-3430-1 shall not be exceeded.

TABLE CI-3421-1

ADVANCED STRESS STRENGTH LIMITS FOR GRAY CAST IRON (UNCONSTRAINED)

LOAD CATEGORY	AVERAGE STRESS		POINT STRESS	
	PRIMARY	PRIMARY & SECONDARY	PRIMARY	PRIMARY & SECONDARY
CONSTRUCTION AND/OR TESTING	$f_{cic} = .80\ f_{ci}$ $f_{cit} = .26\ f_{ci}$ $f_{cis} = .36\ f_{ci}$	→	$f_{cic} = 1.10\ f_{ci}$ $f_{cit} = .37\ f_{ci}$ $f_{cis} = .50\ f_{ci}$	→
OPERATING	$f_{cic} = .60\ f_{ci}$ $f_{cit} = .20\ f_{ci}$ $f_{cis} = .28\ f_{ci}$	→	$f_{cic} = .9\ f_{ci}$ $f_{cit} = .3\ f_{ci}$ $f_{cis} = .42\ f_{ci}$	→
OPERATING WITH ENVIRONMENTAL	$f_{cic} = 1.1\ f_{ci}$ $f_{cit} = .5\ f_{ci}$ $f_{cis} = .7\ f_{ci}$	$f_{cic} = 1.4\ f_{ci}$ $f_{cit} = .75\ f_{ci}$ $f_{cis} = 1.0\ f_{ci}$	.75 (ULTIMATE CAPACITY OF CRITICAL SECTION OF MECHANISM)	

NOTE:

1) f_{ci} = Specified minimum tensile strength of grey cast iron

   f_{cic} = Cast iron compressive stress limit

   f_{cit} = Cast iron tensile stress limit

   f_{cis} = Cast iron shear stress limit

TABLE CI-3421-2

ADVANCED STRESS STRENGTH LIMITS FOR GRAY CAST IRON (CONSTRAINED)

LOAD CATEGORY	AVERAGE STRESS		POINT STRESS	
	PRIMARY	PRIMARY & SECONDARY	PRIMARY	PRIMARY & SECONDARY
CONSTRUCTION AND/OR TESTING	$f_{cic} = .33\ Cf_{cuc}$ $f_{cit} = .26\ f_{ci}$	$f_{cic} = .44\ Cf_{cuc}$ $f_{cit} = .33\ f_{ci}$	$f_{cic} = .41\ Cf_{cuc}$ $f_{cit} = .37\ f_{ci}$	$f_{cic} = .55\ Cf_{cuc}$ $f_{cis} = .45\ f_{ci}$
OPERATING	$f_{cic} = .25\ Cf_{cuc}$ $f_{cit} = .20\ f_{ci}$	$f_{cic} = .33\ Cf_{cuc}$ $f_{cit} = .25\ f_{ci}$	$f_{cic} = .37\ Cf_{cuc}$ $f_{cit} = .3\ f_{ci}$	$f_{cic} = .50\ Cf_{cuc}$ $f_{cit} = .4\ f_{ci}$
OPERATING WITH ENVIRONMENTAL		0.75 (ULTIMATE CAPACITY OF CRITICAL SECTION)		

NOTE:

1) f_{ci} = Specified minimum tensile strength of grey cast iron

f_{cuc} = Specified minimum compressive strength of grey cast iron

f_{cic} = Cast iron compressive stress limit

f_{cit} = Cast iron tensile stress limit

f_{cis} = Cast iron shear stress limit

TABLE CI-3421-3

LOAD CATEGORIES AND STRESS LIMITS FOR PRESTRESSING STEEL

LOAD CATEGORY	STRESS LIMITS[1]
Construction and/or Testing	$f_s = 0.80\ f_{su}$ and $f_s = 0.90\ f_{sy}$
Operating	$f_s = 0.70\ f_{su}$ and $f_s = 0.80\ f_{sy}$
Operating with Environmental	$f_s = 0.80\ f_{su}$ and $f_s = 1.0\ f_{sy}$

NOTE: (1) The more restrictive of the given limits applies in each case.

TABLE CI-3422-1

CAST IRON SHEAR AND BEARING STRESS LIMITS

CONDITION	STRESS
Shear Stress	TBD
Constrained	TBD
Constrained between adjacent shear anchors and supports	TBD
Bearing Below Shear Anchors:	
Constrained Cast Iron[1]	TBD
Unconstrained Cast Iron	TBD
Bearing Stress Below Tendon Bearing Plates	TBD

NOTE:

(1) Provided that the confining structural members have a load factor of safety of at least 2 against failure.

TABLE CI-3430-1

CONDITION CATEGORIES AND TEMPERATURE LIMITS
FOR CAST IRON AND PRESTRESSING SYSTEM

LOAD CATEGORY	AREA	TEMPERATURE LIMITS,°F
Construction	Cast Iron	650
Operating	Liner	
	Effective at liner/cast iron Interface	TBD
	Local Hot Spots	TBD
	Prestressing Tendons	150[1]
	Liner Interface Transients Range	TBD - TBD
Operating with Environmental	Liner	
	Effective at liner/cast iron interface	TBD
	Cast Iron	650
	Local Hot Spots	TBD
	Prestressing Tendons	160[1]
	Liner Interface Transients Range	TBD - TBD

NOTE: (1) Higher temperatures may be permitted as long as effects on material behavior, for example, relaxation, are accounted for in design.

(b) The effect on PCIV structural performance of temperature induced volume changes shall be evaluated for each particular design and may require the lowering of the maximum temperatures specified herein. The development of special heat resisting materials may result in an increase in these limits being permissible.

(c) Temperature effects shall be considered for stress analysis purposes. Local liner cracking and prestressed steel stress relaxation should be considered. Material properties shall be consistent with temperature variations and loading history.

CI-3440 CAST IRON COMPRESSIVE STRESSES

Where the elastic analysis indicates local concentrations of stress as occurring due to the presence of discontinuities in PCIV geometry or thermal hot spots, it shall be the responsibility of the Designer to assess the effect on PCIV serviceability and safety and to design the PCIV considering such zones. In general, when such stresses are local and can be shown to relax or redistribute, they may be ignored. Specifically, peak stresses are not limited provided the cast iron subjected to stresses above those allowed by point stresses is neglected and all compression forces can be resisted by the remaining compression sectional area without exceeding the allowable values in Table CI-3421-1 or CI-3421-2. When they are more extensive, the Designer shall take into consideration the manner in which possible cracks in the zone of local compressive stress concentration will affect the PCIV cast iron section stress distribution during operating and shutdown conditions and, also, the effect it will have on vessel liner strains under these same conditions.

CI-3450 CAST IRON TENSILE STRESSES

Under Construction and/or Testing and Operating Categories, the limits specified in Table CI-3421-1 or CI-3421-2 may be exceeded for local tensile stresses provided the Designer ensures that:

(a) consideration is given in the analysis to any significant redistribution of the stresses which may arise in consequence of cast iron tensile cracking;

(b) liner structural and leak-tightness integrity remain within limits specified in the Design Specification.

CI-3460 SPECIAL STRESS LIMITS

The deviations from the basic stress limits provided in Tables CI-3421-1, CI-3421-2, CI-3421-3 and CI-3422-1 are identified to cover special conditions, configurations, materials and/or components which have not been identified previously. The stress limits are specified in Part AD-132 of Section VIII Division 2. All components included in the PCIV configuration not previously covered in the above mentioned Tables are to be designed, analyzed and fabricated per Section VIII, Division 2, requirements.

CI-3470 FATIGUE EVALUATION

When determining whether or not a vessel fatigue analysis shall be specified, the user may consider experience with comparable equipment operating under similar conditions in accordance with the provisions of Part AD-160-1 of Section VIII Division 2. When not based upon significant applicable service experience, the need for fatigue analysis shall be determined in accordance with the provisions of rules similar to AD-160.2 and AD-160.3 of Section VIII, Division 2.

CI-3500 PRESTRESSED CAST IRON

CI-3510 GENERAL

In a PCIV, numerous cast iron blocks are preloaded against each other (prestressed) at mating interfaces by a prestressing system. The basic requirement is to provide sufficient compressive preload between blocks during construction to maintain contact of the blocks (net compression) when tensile loads produced by internal pressure are superimposed on the construction compressive preloads. Shear keys will usually be provided to ensure alignment during construction and to transmit shear loads between blocks.

CI-3520 PRESTRESSING

The distribution and magnitude of required prestressing forces shall be determined taking into account the losses during tensioning and time dependent losses including cast iron creep and prestressing steel stress relaxation. If documented experimental data on tendon friction, anchorage seating losses and the relaxation characteristics of the prestressing system are not available, experimental evidence shall be obtained to justify the losses provided for in the design.

CI-3530 SAFETY FACTORS

The cast iron blocks and prestressing system shall be designed to maintain nominal compression across the cast iron/cast iron interface under normal operating conditions. Localized overstraining of the PCIV liner is prevented by providing an inherent factor of safety, F_g, against gapping or opening of the prestressed interfaces. The minimum factor of safety against gapping, F_g, shall be equal to or greater than 1.2. F_g is defined as the ratio or internal pressure required to begin opening of preloaded interfaces to operating pressure.

The complete loss of structural integrity of the PCIV during overpressure conditions is prevented by providing an ultimate factor of safety, F_f, against tendon failure or cast iron/cast iron interface instability (i.e., in the head and transition area). This required factor, F_f, has been established as 2.0.

CI-3540 CYLINDRICAL SECTION OF VESSEL

Individual cast iron body segments are assembled together into rings and preloaded in hoop compression by the circumferential prestressing system. The rings are then stacked into a cylindrical shape and preloaded axially by the axial prestressing system. The sequence of prestressing (with possible Poisson effects), the component temperature, dead weight and all other construction variables shall be considered in establishing initial prestress. When the vessel is pressurized, both circumferential and axial cast iron/cast iron interface preloads decrease and both circumferential and axial prestressing system loads increase.

The PCIV wall loads and load combinations shall be determined by CI-3200. The special analytical design procedures of CI-3300 shall be used. All components shall meet the serviceability and strength limits of CI-3400 with stress levels within the allowables of Tables CI-3421-1, CI-3421-2 CI-3421-3, CI-3422-1 and CI-3430-1. Paragraphs CI-3440 through CI-3470 also apply. The prestressing considerations of CI-3520 apply. Both gap initiation and ultimate factors of safety, F_g and F_f as defined in CI-3530 shall be provided in the design.

CI-3550 CAST IRON HEAD

A PCIV cast iron head has many similarities to the cylindrical side wall. Individual cast iron blocks are preloaded together into a circular plate by a circumferential prestressing system. Several layers of blocks or plates may be used in the head. The fundamental difference in the head (from the side wall) is that shear and bending loads are developed at block interfaces as well as at the head to cylinder transition. Features such as shear keys must be incorporated into the design to provide cast iron/cast iron shear attachment where required to react shear loads. In addition sufficiently wide preloaded interfaces are needed to provide reaction to bending loads by developing compressive stress profiles across the interfaces.

The head loads and load combinations shall be determined by CI-3200. The special analytical design procedures of CI-3300 shall be used. All components shall meet the serviceability and strength limits of CI-3400 with stresses within the allowables of Tables CI-3421-1, CI-3421-2, CI-3421-3, CI-3422-1 and CI-3430-1. Paragraphs CI-3440 through CI-3470 apply. The prestressing considerations of CI-3520 apply. Both gap initiation and ultimate factors of safety, F_g and F_f, as defined in CI-3530 shall be provided in the design.

CI-3560 PRESTRESSING COMPONENTS

The PCIV circumferential and axial prestressing systems shall be designed to satisfy the loads and load combinations as determined by CI-3200. The serviceability and strength limits of CI-3400 apply with stress levels limited by Table CI-3421-3. The prestressing considerations of CI-3520 apply. Gap initiation and ultimate factors of safety, F_g and F_f, as defined in CI-3530 apply.

CI-3570 ANCHORAGE ZONE DESIGN

Prestressing anchorages and the supporting cast iron shall be designed to support the maximum jacking load at the specified compressive strength, and the end anchorage zone shall be designed to develop 110% of the guaranteed ultimate tensile strength of the tendons. The high capacity anchorage zone design acceptability shall be established by data from actual or comparable loading tests.

CI-3580 SHEAR KEYS

The function of the cast iron/cast iron shear keys is described in CI-3550. The key loadings are determined from the loads and load combinations of CI-3200 using special analytical design procedures of CI-3300. The keys shall be designed to withstand the entire shear force developed at the cast iron/cast iron interfaces without assuming any load sharing capability from friction between cast iron blocks. The special stress limits of CI-3460 shall apply to the shear keys.

CI-3600 LINER DESIGN ANALYSIS PROCEDURES

CI-3610 GENERAL

(a) A stress analysis shall be prepared in sufficient detail to show that none of the design requirements of CI-3700 is exceeded when the vessel is subjected to the loadings of CI-3200.

(b) Experimental methods may be used to evaluate the capability of a component to withstand static or cyclic loading conditions which cannot be predicted adequately by stress analysis.

CI-3620 LINER

Analysis or experimental methods shall consider the most adverse combination of fabrication and construction tolerances and material variations permitted in CI-2000 and CI-4000.

CI-3630 ANALYTICAL METHODS

The analytical methods used for investigation of liner stress, strain and stability shall have been demonstrated to predict the behavior of the selected liner anchorage system under the loadings specified in the Design Specification. When such an analysis procedure is not available, the ability of the liner to perform as required shall be established through prototype testing.

CI-3640 PENETRATION LINERS AND ANCHORS

Penetrations and their anchors shall be analyzed in accordance with Part AD and CI-3000, as applicable, with due regard for loadings of pressure, temperature, cracks, and strains caused by the deformation of cast iron in which the penetration is embedded.

CI-3650 BRACKETS AND ATTACHMENTS

Brackets and attachments connected to the liner shall be analyzed using the theories applicable to the type of element being considered.

CI-3700 LINER DESIGN

CI-3710 LINER

The maximum stress and effective strain for all liner material shall not exceed those shown in Table CI-3700-1. Effective strain is defined as the actual cast iron imposed strain induced in the liner due to the deformation of the backing cast iron plus the strain caused by restrained (stress inducing) thermal effects.

CI-3720 LINER ANCHORS

(a) The anchorage system shall be designed so that it can accommodate any tangential (shear) loads or deformations exerted by the liners and loads applied normally to the liner surface.

(b) The allowable force and displacement values are given in Table CI-3700-2.

CI-3730 PENETRATION LINERS

Each penetration liner shall be provided with an anchorage system capable of transferring pressure and other mechanical loads such as piping reactions, including thermal effects, to the cast iron. Design allowables for penetration liner anchors shall meet the requirements of Part AM, Tables ACS, AHA, ANF and AQT, of Division 2. Cast iron stresses shall meet the requirements specified in Table CI-3422-1. Allowables for penetrations not backed by cast iron and prestressing steel shall meet the requirements of Division 2. Embedded portions shall meet the requirements of Table CI-3700-1.

TABLE CI-3700-1

LINER ALLOWABLES

Maximum Allowable Stress or Effective Strain

LOAD CATEGORY	COMPRESSION		TENSION	
	MEMBRANE	MEMBRANE PLUS BENDING	MEMBRANE	MEMBRANE PLUS BENDING
Construction and/or Testing Operating	$\varepsilon_{su}/30$	$\varepsilon_{su}/20$	$1.0S_m$	$1.5S_m$
Operating with Environmental	$\varepsilon_{su}/20$	$\varepsilon_{su}/10$	$\varepsilon_{su}/10$	$\varepsilon_{su}/10$

NOTES:

ε_{su} = Steel ultimate strain in uniaxial tension for tensile tests conducted with SA-20. The strain value to be compared to the strain allowables of this table shall be the maximum biaxial or triaxial at the location of the consideration.

S_m = Design stress intensity values as shown in Tables ACS, AHA, ANF and AQT of Division 2.

TABLE CI-3700-2

LINER ANCHOR ALLOWABLES

LOAD CATEGORY	Force and Displacement Allowables	
	MECHANICAL LOADS	DISPLACEMENT LIMITED LOADS
Construction and/or Testing	lesser of:	
	$F_a = 0.67\ F_y$ (1)	$\delta_a = 0.25\ \delta_u$
	$F_a = 0.33\ F_u$	
Operating	lesser of:	
	$F_a = 0.67\ F_y$ (1)	$\delta_a = 0.25\ \delta_u$
	$F_a = 0.33\ F_u$ (1)	
Operating with Environmental	lesser of:	
	$F_a = 0.9\ F_y$ (1)	$\delta_a = 0.5\ \delta_u$
	$F_a = 0.5\ F_u$	

NOTE: (1) In cases where the allowable load on the anchor is based on test results, the allowable load shall be one-third of the ultimate load capacity.

CI-3740 BRACKETS AND ATTACHMENTS

(a) Internal brackets and attachments shall be designed in accordance with the requirements of Division 2. Attachments to the liner shall be anchored directly to the cast iron unless the liner is capable of supporting the imposed loading without exceeding the allowable stress intensities of Tables ACS, AHA, ANF, and AQT of Division 2.

(b) It is preferable to design attachments so that the liner is not loaded in the through-thickness direction. If this is not possible, material loaded in the through-thickness direction shall have the allowable stress intensities reduced by a factor of two.

CI-3750 FATIGUE

The Designer shall ensure the suitability of the liner and liner attachments for the specific operating conditions involving cyclic application of loads and thermal conditions that have been established in the Design Specification. The fatigue analysis methods and limits in accordance with CI-3470 and Part AD-160 of Division 2 shall be used in performing the analysis.

CI-3800 LINER DESIGN DETAILS

CI-3810 LINER ANCHORS

The anchor design and analysis shall consider the effects of the following:

(a) The unbalanced loads between adjacent liner panels resulting from the variation of liner curvature -- Some areas of the liner may have inward curvature between the anchors whereas other areas may have outward curvature. Experimental or analytical evidence shall be provided to substantiate the values of the unbalanced loads used in this analysis. The variation will result in shear load and displacement at the anchor.

(b) Liner plate thicker than the nominal due to the rolling tolerances given in SA-20--If panels of different thicknesses are adjacent to each other, the thicker plate will impose

larger forces and displacements on the anchorage system than a panel of nominal thickness. The design shall consider the case of adjacent minimum and maximum thickness plates.

(c) Yield strength higher than the minimum specified due to the rolling processes and biaxial loading--Adequate consideration of yield strength in excess of the minimums may be provided by the following:

- converting liner strains to stress and membrane forces assuming the material remains elastic;
- conducting biaxial yield strength tests to establish the biaxial yield strength of materials used in the liner. Biaxial yield strength tests are required only when anchor designs rely on liner plate yielding to limit the forces applied to the anchors.

(d) Weld offset, structural discontinuities behind the liner;

(e) The maximum effects of variation in yield stress between adjacent liner materials.

CI-3820 PENETRATION LINERS

For penetration liners designed for pipe rupture loads, the design shall provide for the following:

(a) the maximum moment, torque, and shear loadings which the piping is capable of producing

(b) penetration loads based on an analysis considering pipe rupture thrust as a function of time

CI-3830 TRANSITIONS FROM CAST IRON TO STEEL

CI-3831 TRANSITION DETAILS

The vessel may be constructed using a combination of cast iron and metal as the pressure boundary. Where this type of construction is used, the following rules shall govern the design of transition sections, which shall be divided into two categories:

(a) Category One - full vessel diameter transitions, penetrations, with nozzles embedded in the cast iron for attachment of piping, hatches, and locks, etc.

(b) Category Two - local zones backed up by compressible materials.

CI-3831.1 CATEGORY ONE TRANSITION SECTIONS

Metal sections not backed up by cast iron and prestressing steel shall meet the requirements of Division 2. Metal sections may be attached to cast iron sections by one of the following methods:

(a) The metal elements of the vessel may be attached to either the cast iron meridional prestressing systems or to a special meridional prestressing system attached to the foundation.

(b) A shear anchoraged system may be attached to the metal shell and extended into the cast iron vessel. Where the shear anchorage system is used, the metal shell attached to the cast iron anchor may be reduced below the minimum thickness required for that portion of the shell not backed up by the cast iron provided that the liner stress and strain allowables of Table CI-3700-1 have been met.

CI-3831.2 CATEGORY TWO TRANSITION SECTIONS

Sections backed up by compressible material to allow local flexibility shall meet the requirements for material, design, fabrication, and examination in accordance with the requirements of Division 2 in the region where compressible material is present. Where the sections attach to cast iron and prestressing steel backed or embedded members, only the requirements for liners apply.

CI-3840 WELDED CONSTRUCTION

The welded joints of the liner shall be performed in accordance with Article D-4 of Part AD of Division 2. This article describes the weld joint categories, type of joints permitted and special aspects of the welded liner construction.

ARTICLE CI-4000

FABRICATION AND CONSTRUCTION

CI-4100 GENERAL REQUIREMENTS

CI-4110 INTRODUCTION

Prestressed cast iron vessels shall be fabricated and constructed in accordance with the requirements of this Article. The requirements apply to fabrication and construction operations, whether performed in a shop or at the field site. Unless otherwise indicated, throughout this Article the term component shall be understood to include parts and appurtenances. The fabrication of parts and appurtenances which are not backed up by cast iron for load carrying purposes shall meet the requirements of Part AF of Division 2, CI-1000 and CI-8000. Attachments to parts fabricated to the requirements of Division 2 shall meet the requirements of that Division.

CI-4120 CERTIFICATION OF MATERIAL AND FABRICATION OR CONSTRUCTION BY COMPONENT FABRICATOR OR CONSTRUCTOR

CI-4121 MEANS OF CERTIFICATION

The Fabricator or Constructor of a prestressed cast iron pressure vessel component shall certify, by application of the appropriate Code symbol and completion of the appropriate Data Report in accordance with CI-8000, that the material used complies with the requirements of CI-2000 and that fabrication and construction comply with the requirements of CI-4000.

CI-4121.1 CERTIFICATION OF TREATMENTS, TEST, AND EXAMINATIONS

If the Fabricator or Constructor performs treatments, test, repairs, or examinations required by other Articles of this Division, he shall certify that he has fulfilled that requirement. Reports of all required treatments and of the results of all required tests, repairs, and examinations shall be available to the Authorized Inspector.

CI-4121.2 REPEAT OF TESTS

If during the fabrication or construction of the component the material is subjected to conditions which cause a change in principal characteristics that has not been accounted for in the Design Report and that may change properties from the required values, the tests shall be repeated or additional tests made by the Fabricator or Constructor for verification of acceptability.

CI-4122 MATERIAL IDENTIFICATION

CI-4122.1 CAST IRON

Each cast iron body section shall be identified on the as-built sketch and records made of the date, together with manufacturing tickets with traceability to the information required in CI-4220 and records made of the testing performed in accordance with CI-6220.

CI-4122.2 PRESTRESSING SYSTEM MATERIAL

Material for prestressing systems shall carry identification markings or tags which shall remain distinguishable until the tendon assembly is completed. If the original identification markings are cut out or the material is divided into two or more pieces, the markings shall be accurately transferred to the pieces prior to cutting, or a coded marking or other means of control shall be used to ensure identification of each piece of material during the subsequent assembly. A tabulation shall be made of the Material Test Report for the materials used in an assembly or group of assemblies.

CI-4122.3 LINER MATERIAL

Material for liners (excluding attachment material) shall carry identification markings which will remain distinguishable until the liner is assembled. If the original identification markings are cut out or the material is divided into two or more pieces, the marks shall either be accurately transferred to all pieces prior to cutting, or a coded marking shall be used to ensure identification of each piece of material during subsequent fabrication or installation. In either case, an as-built sketch or a tabulation or materials shall be made identifying each piece of material with the Material Test Report and the coded marking.

Welding and brazing materials shall be identified and controlled so that they can be traced to each liner, or else a control procedure shall be employed which ensures that the specified material is used.

CI-4200 CAST IRON

CI-4210 GENERAL

TBD

CI-4220 SCORING AND HANDLING OF MATERIAL

TBD

CI-4230 CAST IRON FABRICATION AND MACHINING

TBD

CI-4400 FABRICATION AND INSTALLATION OF PRESTRESSING SYSTEMS

CI-4410 GENERAL

This Subarticle covers the requirements for the fabrication, installation, tensioning, and protection of prestressing systems.

CI-4420 RECEIVING, STORING, AND HANDLING OF MATERIAL

The construction procedures shall specify the manner in which material is to be received, stored, and handled in the Fabricator's plant and/or at the construction site. The Constructor's, Fabricator's, or material supplier's Quality Assurance Program shall provide for material identification and segregation in accordance with CI-2470. The handling shall not cause detrimental mechanical damage to the material. The Construction Specification shall establish requirements for storage of all material to ensure that it is protected from detrimental corrosion. Limits of detrimental corrosion shall be specified in the Construction Specification.

CI-4430 TENDON FABRICATION

CI-4431 ANCHORAGE COMPONENTS

CI-4431.1 BEARING PLATE — TRUMPET ASSEMBLY

All welding shall be performed using welding procedures and welders qualified in accordance with Section IX. The suggested preheat schedules of Appendix 14 of Division 2 shall be taken into account.

CI-4431.2 ANCHOR ASSEMBLIES, COUPLINGS, WEDGE BLOCKS, SHIMS, WEDGES, AND ANCHOR NUTS

The construction procedures shall set forth the manufacturing limits and tolerances applicable to these items.

CI-4432 TENDON ASSEMBLY

CI-4432.1 INTRODUCTION

The following subparagraphs apply to both shop and field assembly operations.

CI-4432.2 CUTTING

The construction procedures shall specify the methods and procedures for cutting and cutting tolerances of prestressing elements.

CI-4432.3 ASSEMBLY PROCEDURES

A detailed fabrication procedure, including a checklist of work and information as required by the Construction Procedures, shall be prepared before tendon fabrication. The checklist information for each tendon shall include traceability data such as heat number or element coil number, anchorage component serial numbers, etc. It shall also include length, location, numerical designations of the tendons, and the temporary corrosion protection of the tendon.

CI-4432.4 DETAILS

Attention shall be given to specific aspects such as dimensions, geometry, concentricity, alignment, angularity, and surface conditions. Limits and tolerances of these aspects shall be specified in the construction procedures.

CI-4432.5 TWISTING AND COILING

Twisting, when required to minimize the differential trajectory length of the individual prestressing steel elements, shall be prescribed in the construction procedures. Coiling, when required for transportation, shall be performed in a manner not to cause damage to the tendon. Coil diameter shall be specified in the construction procedures.

CI-4432.6 CORROSION PROTECTION APPLIED DURING FABRICATION

The type of corrosion protection, the detailed procedure for its application, and the pertinent time limitations shall be specified in the construction procedures. The material which is used for both the temporary and permanent protection systems shall be in accordance with CI-2442.

CI-4440 TENDON IDENTIFICATION

Upon completion of fabrication into a whole or partial tendon, the tendon shall be identified with a tendon number. The materials in the tendon shall be recorded so that they can be traced to the tests which have determined their quality.

CI-4450 TENDON INSTALLATION

CI-4451 INSTALLATION PROCEDURE

A detailed installation procedure, including a checklist of work and information as required by the construction procedures, shall be prepared before the tendon installation. The checklist shall include lengths, locations, and numerical designations of the tendons; inspection and preparation of the tendon ducts; method and materials for the corrosion protection of the tendons; requirements for welding or burning where tendons are handled and installed; and sequencing of installation. Prestressing system components shall not be installed, or shall be removed and replaced, if handling or storage causes their characteristics to change beyond the tolerances established in the Construction Specification.

CI-4452 TENDON DUCTS AND CHANNELS

The Construction Specification shall specify the tolerances for position and alignment. Tendon ducts and channels shall be adquately supported against displacement during assembly. Open ducts shall be protected by capping or plugging to prevent entry of deleterious material. All joints shall be made tight against the inleakage of appreciable water from environmental conditions. The Construction Specification shall specify the temporary corrosion protection system, if any, and the construction procedures shall define the method for its application. All water and debris shall be removed from ducts prior to installation of tendons.

CI-4460 PRESTRESSING

CI-4461 SUPERVISION

Prestressing operations shall be under the direction of an experienced supervisor and shall be carried out only by trained operators.

CI-4462 STRESSING SEQUENCE

The required sequence of prestressing shall be specified in the Construction Specification.

CI-4463 ALIGNMENT

Components of the tensioning equipment shall be accurately set and supported in line with the axis of the tendon to which they are fitted and they shall be squarely seated on each other and on the anchorages before stressing is commenced. All anchorages, temporary connections, and jacks shall be checked for alignment before transmitting any significant load to the tendon.

CI-4464 LOAD AND EXTENSION MEASUREMENT

CI-4464.1 PROCEDURE FOR TENDONS TENSIONED AT ONE OR BOTH ENDS

Tendon extension shall be measured during the application of the jacking force. The measurement of extension shall commence at a specified load equivalent of

approximately 10% of the ultimate load of the tendon. The calculated elongation due to the initial force applied prior to commencing measurement shall be added to the measured elongation. In addition, proper allowance shall be made for any significant elongations within the stressing equipment if they are included in the measured elongation. The load applied to any tendon immediately prior to anchoring shall not exceed the limits prescribed in the Construction Specification. The tensioning load shall be measured by load cells or equivalent means having an accuracy not less than ±2% of the required tensioning force. Hydraulic pressure gages or dynamometers shall be calibrated against standards traceable to the National Standards before their use in the prestressing operation. Pressure gages and jacks shall be calibrated as a unit and shall always be used together. During stressing, records shall be made of elongations as well as forces obtained. Dynamometer or gage readings shall be checked against elongation of the tendons. The cause of any discrepancy exceeding ±5% of that predicted by calculations, using average load elongation curves, shall be resolved in consultation with the Designer. Final elongation and stress shall be recorded.

CI-4464.2 PROCEDURE FOR TENDONS CONTINUOUSLY TENSIONED ALONG THEIR LENGTH

The nominal load and permissible load variations applied to every portion of the tendon shall not exceed the limit prescribed in the Construction Specification. The tensioning load shall be measured by load cells on the tensioning machine. The tensioning machine load cells shall have an accuracy not less than ±2% of the required nominal tensioning force. Force variations imposed by the tensioning machine shall include consideration of load cell accuracy. Records shall be made of the force applied to the tendon during the entire stressing operation. At the onset of all prestressing operations, and at least weekly thereafter, the force indicated by the tensioning machine load cells shall be compared with the force indicated by independent load cells that have a calibration traceable to National Standards. Discrepancies greater than the permissible load variation shall be resolved in consultation with the Designer.

CI-4464.3 LUBRICANTS

If lubricants are used to reduce friction, they shall comply with the requirements of CI-2442.

CI-4465 LOSS OF PRESTRESSING FORCE

The loss of prestressing force due to unreplaced broken or damaged prestressing elements shall not exceed the percentage of the total prestressing force specified in the Construction Specification.

CI-4470 PERMANENT CORROSION PROTECTION

The Construction Specification shall specify the permanent corrosion protection system, if any, and the construction procedures shall define the method for its application. Material shall conform to the requirements of CI-2242.3.

CI-4500 FABRICATION OF LINERS

CI-4510 GENERAL REQUIREMENTS

CI-4511 INTRODUCTION

(a) The rules in the following paragraphs apply specifically to the fabrication of metal liners and penetrations backed by cast iron for prestressed cast iron pressure vessels.

(b) Each Fabricator or Constructor shall be responsible for the quality of the welding done by his organization, and he shall conduct tests not only of the welding procedure to determine its suitability to ensure welds which will meet the required tests, but also the welds which will meet the required tests, but also of the welders and welding operators to determine their ability to apply the procedure properly.

(c) No production work shall be undertaken until both the welding procedure and the welders or welding operators have been qualified in accordance with Section IX.

CI-4512 ELIMINATION AND REPAIR OF DEFECTS

Defects in materials may be eliminated or repaired by the Constructor or Fabricator by welding provided that the defects are removed, repaired, and examined in accordance with the requirements of CI-2530 for the applicable product form, except that the limitation of the depth of repair does not apply.

CI-4520 FORMING, FITTING, AND ALIGNING

CI-4521 CUTTING, FORMING, AND BENDING

CI-4521.1 CUTTING

Liner materials, edges of heads, and other parts may be cut to shape and size by mechanical means, such as machining, shearing, chipping, or grinding, or by thermal cutting. After oxygen cutting, all slag, dross, or other deleterious material which has been molten shall be removed by mechanical means prior to further fabrication or use.

CI-4521.1.1 PREHEATING PRIOR TO THERMAL CUTTING

When thermal cutting is performed to prepare weld joints or edges, to remove attachments or defective material, or for any other purpose, consideration shall be given to preheating the material using preheat schedules such as suggested in Appendix 14.

CI-4521.2 FORMING AND BENDING PROCESSES

Any process may be used to hot or cold form or bend liner plate materials, including weld metal, provided the notch toughness properties of the materials, where required, are not reduced below the minimum specified values or they are effectively restored by heat treatment following the forming operation. Hot forming is defined as forming with the material temperature higher than 100°F (55°C) below the lower critical temperature of the material.

CI-4521.3 QUALIFICATIONS OF FORMING AND BENDING PROCESSES

A procedure qualification test shall be conducted on specimens taken from coupons of the same material specifications, grade or class, heat treatment, and similar impact requirements as employed for the material of the component involved. These specimens shall be subjected to the equivalent forming or bending process or heat treatment as the material in the component. Applicable tests shall be conducted to determine that the required impact properties are met after straining.

CI-4521.3.1 EXEMPTIONS

Procedure qualification tests are not required for the following:

(a) Hot-formed material, such as forgings, in which the hot forming is completed by the Material Manufacturer prior to removal of the impact test specimens.

(b) Hot-formed material represented by test coupons which have been subjected to heat treatment representing the hot forming procedure and the heat treatments to be applied to the parts.

(c) Material which does not required impact testing in accordance with CI-2500.

(d) Material which has a final strain after forming of less than 0.5%.

(e) Material where the final strain is less than that of a previously qualified procedure for the material.

(f) Material from which the impact testing is required by CI-2522 to be performed on each heat and lot, as applicable, after forming.

CI-4521.3.2 PROCEDURE QUALIFICATION TEST

The procedure qualification test shall be performed in the following manner:

(a) The tests shall be performed on three different heats of material both before and after straining to establish the effects of the forming and subsequent heat treatment operations.

(b) Specimens shall be taken in accordance with the requirements of this Division and shall be taken from the tension side of the strain material.

(c) The percent strain shall be established by the following equations:

for cylinders

$$\% \text{ strain} = \frac{50t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

for spherical or dished surfaces

$$\% \text{ strain} = \frac{65t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

and for pipe

$$\% \text{ strain} = \frac{100r}{R}$$

where

t = nominal thickness

R_f = final radius to center line of shell

R_o = original radius (equal to infinity for a flat part)

R = nominal bending radius to the center line of the pipe

r = nominal radius of the pipe

(d) The procedure qualification shall simulate the maximum percent surface strain, employing a bending process similar to that used in the fabrication of the material or by direct tension on the specimen.

(e) Sufficient Charpy V-notch impact test specimens shall be taken from each of the three heats of material to establish a transition curve showing both the upper and lower shelves. Tests consisting of three impact specimens taken from each of three heats shall be conducted at a maximum of five different temperature distributions throughout the transition region. The upper and lower shelves may be established by the use of individual test specimens. As an alternative to the transition curve, drop weight tests may be used, or one set of Charpy V-notch impact test specimens tested after forming at the specified temperature may be used if performed on each heat or lot, as applicable, of formed material.

(f) From the impact test transition curves or drop weight tests from each of the three heats, both before and after straining, determine either:

(1) the maximum changes in temperature considering various energy levels when transition curves are used, or the change in NDT temperature as determined by the drop weight tests; or

(2) the maximum loss of impact energy for the material considering each temperature increment of 10°F (increment of 6°C).

CI-4521.3.3 ACCEPTANCE STANDARDS

To be acceptable, the material used in the liner must have impact properties sufficient to compensate for the maximum change in temperature or energy levels established by the qualification procedures for all material subjected to the equivalent strain used in the liner.

CI-4521.3.4 REQUALIFICATION

A new procedure qualification test is required when any of the following changes are made:

(a) where the postweld heat treatment time at temperature is greater than previously qualified (if the material is not postweld heat treated, the procedure must qualify without postweld heat treatment);

(b) where the maximum calculated strain of the material exceeds the previously qualified strain by more than 0.5%;

(c) where preheat over 250°F (121°C) is used in the forming or bending operation but not followed by a subsequent postweld heat treatment.

CI-4521.4 MINIMUM THICKNESS OF FABRICATED MATERIAL

If any fabrication operation reduces the thickness below the minimum required to satisfy the requirements of CI-3000, the material may be repaired in accordance with CI-2530.

CI-4522 FORMING TOLERANCE

CI-4522.1 TOLERANCES FOR LINER SHELLS

At all cross sections, shells of completed liners shall meet the requirements of the following subparagraphs.

CI-4522.1.1 MAXIMUM DEVIATION FROM TRUE THEORETICAL FORM

The maximum plus-or-minus deviation from the true circular from of cylinders or the theoretical from of other shapes, measured radially on the inside or outside of the component, shall not exceed the maximum permissible deviation specified in the Construction Specification and considered in the analysis.

CI-4522.1.2 DEVIATIONS FROM TOLERANCES

Deviations from the tolerance requirements stipulated in CI-4522.1.1 are permitted provided the drawings are modified and reconciled with the Design Report and provided the modifications are approved by the Designer.

CI-4522.1.3 TOLERANCE DEVIATIONS FOR LINER PARTS FABRICATED FROM PIPE

Liner parts fabricated from pipe meeting all other requirements of this Subarticle may have variations of diameter and deviations from circularity permitted by the material specification for such pipe.

CI-4523 FITTING AND ALIGNING

CI-4523.1 FITTING AND ALIGNING METHODS

Parts that are to be joined by welding may be fitted, aligned, and retained in position during the welding operation by the use of bars, clamps, tack welds, or temporary attachments.

CI-4523.1.1 TACK WELDS

Tack welds used to secure alignment shall either be removed completely when they have served their purpose, or their stopping and starting ends shall be properly prepared by grinding or other suitable means so that they may be satsifactorily incorporated into the final weld. Tack welds shall be made by qualified welders using qualified welding procedures. When tack welds are to become part of the finished weld, they shall be visually examined and defective tack welds removed.

CI-4523.1.2 TEMPORARY ATTACHMENTS AND THEIR REMOVAL

Attachments which are welded to the liner or parts of the liner during fabrication but which are not incorporated into the final component, such as alignment lugs or straps, tie straps, lifting lugs, braces, or preheat equipment, are permitted provided the following requirements are met:

(a) The material is identified and is suitable for welding but need not be certified material.

(b) The material is compatible for welding to the component material to which it is attached.

(c) The welding material is compatible with the base material and is certified in accordance with CI-2130.

(d) The welder and welding procedure are qualified in accordance with Section IX.

(e) The temporary attachment is completely removed in accordance with the procedures of CI-4521.1.

(f) After the temporary attachment has been removed, the marked area is examined by a magnetic particle or liquid penetrant method in accordance with the requirements of Articles 6 or 7 of Section V and meets the acceptable standards of Appendix 9 Articles 9-1 and 9-2, whichever is applicable.

(g) The attachment weld or the area after removal of the attachment is postweld heat treated when required by CI-4550.

CI-4523.2 MAXIMUM OFFSET OF ALIGNED SECTIONS

Alignment of sections shall be such that the maximum offset of the finished weld will not be greater than the applicable amount listed in Table CI-4523-1, where t is the nominal thickness of the thinner section of the joint.

CI-4523.2.1 FAIRING OR OFFSETS

Any offset within the allowable tolerance provided above shall be faired to at least a three to one taper over the width of the finished weld, or, if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

CI-4523.3 SUPPORT DURING INSTALLATION OF CAST IRON

The liner shall be adequately supported, braced, and tied to prevent displacement beyond the tolerances set forth in CI-4522.

TABLE CI-4523-1

MAXIMUM ALLOWABLE OFFSET
IN FINAL WELDING JOINTS

SECTION THICKNESS, in.	OFFSET
Up to 3/4 incl.	1/4 t
Over 3/4 to 1-1/2 incl.	3/16 in.
Over 1-1/2	1/8t to 3/4 in. max.

CI-4530 WELDING FABRICATION REQUIREMENTS

CI-4531 WELDING PROCESSES

The welding processes that may be used in the construction of PCIV under this article are restricted as follows:

(a) Arc or gas welding processes are restricted to shielded metal arc, submerged arc, gas metal arc, gas tungsten arc, plasma arc, atomic hydrogen metal arc, oxyhydrogen, oxyacetylene, electroslag, and electron beam.

(b) The electroslag process is permissible for butt welds only in ferritic steels and the following austenitic steels which are welded to produce a ferrite containing weld metal: SA-240 TP304, TP304L, TP316 and TP316L; SA-182 F304, F304L, F316 and TP316L; SA-351 CF3, CF 3A, CF3M, CF8, CF8A, and CF8M.

(c) Definitions are given in Section IX which include variations of these processes.

(d) Pressure welding processes are restricted to flash, induction, resistance, pressure thermit, and oxyacetylene.

(e) Arc stud welding and resistance stud welding may be used only for non-pressure-bearing attachments, having a load- or non-load carrying function, except for materials listed in Table AQT-1 Division 1 provided that, in the case of ferrous materials, heat treatment requirements of CI-4551 and CI-4552 for the materials used in the vessel are met. Studs shall be limited to 1 in. (25 mm) diameter maximum for round studs and an equivalent cross-sectional area for studs with other shapes.

CI-4532 WELDING QUALIFICATIONS AND RECORDS

CI-4532.1 MANUFACTURER'S RESPONSIBILITY

Each manufacturer is responsible for the welding done by his organization and shall establish the procedure and conduct the tests required in Section IX or, if not included in Section IX, the additional tests required herein to qualify the welding procedures and the performance of welders and welding operators who apply these procedures.

CI-4532.2 PERFORMANCE QUALIFICATION TESTS LIMITATIONS

The performance qualification tests for welders and welding operators conducted by one manufacturer or contractor shall not qualify the welders or welding operators to weld for any other manufacturer or contractor.

CI-4532.3 PRODUCTION WELDING PRIOR TO QUALIFICATION

No production welding shall be undertaken until after the welding procedures which are to be used have been qualified.

CI-4532.4 QUALIFICATIONS TO BE IN ACCORDANCE WITH SECTION IX

(a) The procedure used in welding pressure parts and in joining load-carrying nonpressure parts (attachments) to pressure parts shall be qualified in accordance with Section IX.

(b) When making procedure test plates for butt welds in accordance with Section IX, consideration should be given to the effect of angular, lateral, and end restraint on the weldment. This applies particularly to material and weld metal of 80,000 psi (552 mPa) strength or higher and thick sections of both low- and high-tensile strength material. The addition of restraint during the welding may result in cracking difficulties that otherwise might not occur.

(c) Nonpressure part attachments which have essentially no load-carrying function (such as extended heat transfer surfaces insulation attachment pins, etc.) may be joined to pressure parts by any machine welding process performed in accordance with a Welding Procedure Specification (in compliance with Section IX as far as applicable) except that Procedure Qualification Testing is not required.

(d) The welders and the welding operators used in welding pressure parts and in joining load-carrying nonpressure parts (attachments) to pressure parts shall be qualified in accordance with Section IX. The qualification test for welding operators of machine welding equipment shall be performed on a separate test plate prior to start of welding on the first work piece,

Such tests shall be conducted by the Manufacturer or Contractor. Performance qualification testing is not required for joining nonpressure part attachments which have essentially no load-carrying function (such as extended heat transfer surfaces, insulation attachment pins, etc.) to pressure parts by any machine

welding processes performed in accordance with a Welding Procedure Specification (in compliance with Section IX as far as applicable).

In the case where stud welding is used to attach load-carrying studs, a production stud weld test of the procedure and welding operator shall be performed on a separate test plate or tube prior to start of welding on each work shift. This weld test shall consist of two studs, welded and tested in accordance with either the bend or torque stud weld testing described in Section IX.

In the case where stud welding is used to attach non-load-carrying studs, a production stud weld test appropriate to the end use application requirements shall be specified by the Manufacturer or assembler and carried out as a separate test plate or tube at the start of each shift.

CI-4532.5 MAINTENANCE OF QUALIFICATION AND PRODUCTION RECORDS

The manufacturer shall maintain a record of the welding procedures and the welders and welding operators employed by him, showing the date and results of tests and the identification mark assigned to each welder. These records shall be certified by the manufacturer or contractor and shall be accessible to the Inspector. The welder or welding operator shall stamp the identification mark assigned to him by the manufacturer adjacent to all welded joints made by him, at 3 ft (0.9 m) or smaller intervals with stamping procedures that meet the requirements of CI-4120 or as an alternative, the manufacturer shall keep a record of the welded joints in a vessel and of the welders and welding operators used in making each of the joints.

CI-4533 PRECAUTIONS TO BE TAKEN BEFORE WELDING

CI-4533.1 IDENTIFICATION, HANDLING, AND STORING OR ELECTRODES AND OTHER WELDING MATERIALS

The manufacturer is responsible for control of the welding electrodes and other materials which are to be used in the fabrication of the vessel. Suitable identification, storage, and handling of electrodes, flux, and other welding materials shall be maintained. Precautions shall be taken to minimize absorption of moisture by low-hydrogen electrodes and flux.

CI-4533.2 LOWEST PERMISSIBLE TEMPERATURE FOR WELDING

It is recommended that no welding of any kind be done when the temperature of the metal is lower than 0°F (-18°C). At temperatures between 32°F (0°C) and 0°F (-18°C), the surface of all areas within 3 in. (76 mm) of the point where a weld is to be started should be heated to a temperature at least warm to the hand (estimated to be above 60°F (16°C)) before welding is started. It is recommended also that no welding be done when surfaces are wet or covered with ice, when snow is falling on the surfaces to be welded, or during periods of high wind unless the welders or welding operators and the work are properly protected.

CI-4534 SPECIFIC REQUIREMENTS FOR WELDED JOINTS

CI-4535 TYPE NO. 1 BUTT JOINTS

Type No. 1 butt joints are those produced by double-welding or by other means which product the same quality of deposited weld metal on both inside and outside weld surfaces. Welds using backing strips which remain in place do not qualify as Type No. 1 butt joints.

CI-4535.1 WELD PENETRATION AND REINFORCEMENT

Type No. 1 butt joints shall have complete joint penetration and full fusion and shall be free from undercuts, overlaps, or abrupt ridges or valleys.[1] To assure that the weld grooves are completely filled so that the surface of the weld metal at any point does not fall below the surface of the adjoining plate, weld metal may be built up as reinforced on both sides of the plate. The thickness of the reinforcement on each side of the plate shall not exceed the limits specified in CI-6611(a).

CI-4535.2 EXAMINATION REQUIREMENTS

Note 1 to Column 1 of Table AF-241.1 of Division 2 permits reduced examination requirements under certain conditions. Otherwise, Type No. 1 butt joints, whether longitudinal or circumferential, shall be fully radiographed for their

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[1] If the reinforcement is built up so as to form a ridge with a valley or depression in the weld at the edge next to the plate, the result is a notch that causes concentration of stress and reduces the strength of the joint.

entire length of periphery in accordance with the requirements of CI-6600. In addition, all welds made by the electroslag welding process in ferrite materials shall be ultrasonically examined in accordance with the requirements of Appendix 7. This ultrasonic examination shall be done following the grain refining (austenitizing) heat treatment or postweld heat treatment. All welds made by the electron beam welding process shall also be ultrasonically examined for their entire length in accordance with the requirements of Appendix 7.

CI-4536 TYPE NO. 2 BUTT JOINTS

Type No. 2 butt joints are single-welded butt joints having backing strips which remain in place. See CI-3840 for stress concentration factors to be applied to Type No. 2 joints when a fatigue analysis is required.

CI-4536.1 PENETRATION AND REINFORCEMENT

When Type No. 2 butt joints are used, particular care shall be taken in aligning and separating the components to be joined so that there will be complete penetration and fusion at the bottom of the joints for their full length. However, for assuring complete filling of the weld grooves, weld reinforcement need be supplied only on the side opposite the backing strip.

CI-4536.2 BACKING STRIPS

Backing strips shall be continuous and any splices shall be butt-welded. Circumferential single-welded butt joints with one plate offset to form a backing strip are prohibited.

CI-4536.3 EXAMINATION REQUIREMENTS

Note 1 to Column 1 of Table AF-241.1 of Division 2 permits reduced examination requirements under certain conditions. Otherwise, Type No. 2 butt joints shall be radiographically examined throughout their entire periphery in accordance with the requirements of CI-6600. In addition, all welds made by the electroslag welding process in ferritic materials shall be ultrasonically examined in accordance with the requirements of Appendix 7. This ultrasonic examination shall be done following the grain refining (austenitizing) heat treatment or

postweld heat treatment. All welds made by the electron beam welding process shall also be ultrasonically examined for their entire length in accordance with the requirements of Appendix 7.

CI-4537 FULL PENETRATION CORNER JOINTS

Corner joints are those connecting two members at right angles to each in the form of an L or T, and shall be made with full penetration welds.

CI-4537.1 PENETRATION AND FUSION

Welds in full penetration corner joints shall be groove welds extending completely through at least one of the parts being joined and shall be fully fused to each part (see Fig. AD-610.1, Fig. AD-612.1, sketches (b), (c), (e), (f), and (g), Fig. AD-701.3, and Fig. 3-310.1, sketches (g) and (h) of Division 2.

CI-4537.2 EXAMINATION REQUIREMENTS

(a) For nozzle connections with necks abutting vessel wall (see Fig. AD-610.1 sketches (a) and (b) of Division 2), the radially disposed surface of the opening cut in the vessel wall thickness to the approximate inside diameter of the nozzle shall be magnetic particle or liquid penetrant examined in accordance with the requirements of Appendix 7, whichever is applicable.

(b) For corner joint constructions as illustrated in Fig. AD-701.3 of Division 2, sketches (b) and (c), except when dimension b is equal to or greater than t_s the unstayed flat head, prior to welding, shall be 100% examined by the ultrasonic method in accordance with the requirements of Specificaion SA-435, except that no lamination in the head is acceptable.

(c) The welds shall be examined on both interior and exterior surfaces by either the magnetic particle or liquid penetrant method, in accordance with the requirements of Appendix 7 except;

(1) For Category C joints when the shell material is greater in thickness than 2½ in. (64 mm), the examination shall be performed by the ultrasonic method in accordance with the requirements of Appendix 7 or by radiography in accordance with the requirements of CI-6600.

(2) For Category D joints when an opening is greater than 6 in. in diameter in shell material greater than 2½ in. (64 mm) in thickness, the examination shall be by the ultrasonic or radiographic procedures in accordance with the methods stated in (1) above.

(d) The required magnetic particle or liquid penetrant examination shall be performed after postweld heat treatment, if done, for materials covered by Column 2 of Table AF-241.1 of Division 2.

CI-4538 PARTIAL PENETRATION JOINTS FOR NOZZLE ATTACHMENTS

Partial penetration welds of the groove type may be used for connections not subject to external loadings, as permitted by AD-414.1 of Division 2.

CI-4538.1 PENETRATION REQUIREMENTS

Partial penetration welds shall have a minimum depth of penetration equal to 1¼ times the nominal thickness of the nozzle neck (see AD-621 and Fig. AD-621.1) of Division 2.

CI-4538.2 EXAMINATION REQUIREMENTS

Partial penetration welds shall be examined by a magnetic particle method in accordance with the requirements of Appendix 7 or a liquid penetrant method in accordance with the requirements of Appendix 7. The required magnetic particle or liquid penetrant examination shall be performed after postweld heat treatment, if done, for materials covered by Column 2 of Table AF-241.1 of Division 2.

CI-4539 FILLET WELDED JOINTS

Fillet welded joints, permitted by the rules of this Division, are those of approximately triangular cross section, joining two surfaces at approximately right angles to each other and having a throat dimension at least 70% of the smaller thickness of the parts being joined but not less than ¼ in. (6 mm).

For connection attachments, fillet welds shall meet the requirements of AD-620 and AD-635 of Division 2. For attachment of nonpressure parts, fillet welds shall meet the requirements of AD-911 or AD-912, whichever is applicable, and of AF-227 of Division 2.

CI-4539.1 QUALITY REQUIREMENTS

The surface of fillet welds shall be free from coarse ripples or grooves, undercuts, overlaps, and abrupt ridges or valleys and shall merge smoothly with the surfaces joined.

CI-4539.2 EXAMINATION REQUIREMENTS

(a) The radially disposed surfaces of the openings cut in the vessel walls to the approximate inside diameters of nozzles to be attached by means of fillet welds shall be examined by either a magnetic particle method in accordance with the requirements of Appendix 7 or a liquid penetrant method in accordance with the requirements of Appendix 7. Unacceptable defects thus discovered shall be removed and repaired as required by the applicable Article.

(b) Note 1 to Column 1 of Table AF-241.1 of Division 2 permits reduced examination requirements under certain conditions. Otherwise, after completion, the surface of fillet welds shall also be magnetic particle or liquid penetrant examined in accordance with the requirements of Appendix 7, whichever is applicable.

(c) Fillet welds used to connect nonpressure parts shall be examined in accordance with the requirements of AF-227.1 of Division 2.

CI-4540 WELDS ATTACHING NOZZLES AND OTHER CONNECTIONS

The design requirements for welds attaching nozzle necks and other connections are set forth in Article D-6 of Division 2. The applicable paragraphs and figures governing the various types of construction are shown in Table CI-4540-1.

CI-4542 LIQUID PENETRANT EXAMINATION

All austenitic chromium-nickel alloy steel welds, both butt and fillet, in vessels whose shell thickness exceeds 3/4 in. (19 mm) shall be examined by

TABLE CI-4540-1

TYPE CONSTRUCTION	APPLICABLE PARAGRAPH OF DIVISION 2	APPLICABLE FIG. NO. OF DIVISION 2
Nozzle necks abutting vessel wall	AD-610	AD-610.1, sketches (a) and (b)
Inserted nozzles without added reinforcing element	AD-611	AD-610.1, sketches (c), (d), (d-1), (e), (e-1), (f), and (g)
Inserted nozzles with added reinforcement	AD-612	AD-612.1, sketches (a), (b), and (c)
Nozzles with integral reinforcement	AD-613	AD-613.1, sketches (a), (b), (c), (c-1), (d), (e), and (f)
Fittings with internal threads attached by welds	AD-620	AD-612.2, sketches (e), (f), (g), and (h)
Welded connections not subject to external loadings	AD-621	AD-621.1
Studded connections subject to external loadings	AD-630	
Studded pad connections not subject to external loading	AD-635	AD-612.1, sketch (1)

the liquid penetrant method (see Appendix 7). This examination shall be made following heat treatment, if heat treatment is performed. All cracks shall be eliminated.

CI-4543 MISCELLANEOUS WELDING REQUIREMENTS

CI-4543.1 PREPARATION OF REVERSE SIDE OF DOUBLE-WELDED JOINTS

Where single-welded joints are used, particular care shall be taken in aligning and separating the components to be joined so that there will be complete penetration and fusion at the bottom of the joint for its full length.

CI-4543.2 ALIGNING AND SEPARATING COMPONENTS OF SINGLE-WELDED JOINTS

Where single-welded joints are used, particular care shall be taken in aligning and separating the components to be joined so that there will be complete penetration and fusion at the bottom of the joint for its full length.

CI-4543.3 PRECAUTIONS TO BE TAKEN WHEN WELDING IS RESTARTED

If the welding is stopped for any reason, extra care shall be taken in restarting to get the required penetration and fusion.

CI-4543.4 PEENING

Controlled peening may be performed to reduce distortion. Peening shall not be used on the initial (root) layer of weld metal nor on the final (face) layer unless the weld is postweld heat treated.

CI-4543.5 IDENTIFICATION MARKINGS OR RECORDS FOR WELDERS AND WELDING OPERATORS

Each welder and welding operator shall stamp the identifying number, letter, or symbol, assigned by the manufacturer, adjacent to and at intervals of not more than 3 ft (0.9 m) along the welds which he makes in plates ¼ in. (6 mm) and over in thickness, or a record shall be kept by the Manufacturer of those employed on welding each joint, which shall be available to the Inspector.

CI-4543.6 JOINTS IN CLADDING AND APPLIED LININGS

The types of joints and welding procedure used shall be such as to minimize the formation of brittle weld composition by the mixture of metals of corrosion resistant alloy and the base material. Clad plate joints are to be made in UCL-30 through UCL-46 of Division 1.

NOTE: Because of the different thermal coefficients of expansion of dissimilar metals, caution should be exercised in design and construction under the provisions of these paragraphs in order to avoid difficulties in service under extreme temperature conditions, or with unusual restraint of parts such as may occur at points of stress concentration.

CI-4543.7 JOINTS IN HIGH ALLOY STEEL LINER

The type of joints, requirements of Postweld Heat Treatment and specific fabrication requirements for fabricating a high alloy steel liner will be made in accordance with applicable paragraphs of Part UHA of Division 1.

CI-4544 SUMMARY OF JOINTS PERMITTED AND THEIR EXAMINATION

CI-4544.1 TYPES OF JOINTS PERMITTED

CI-3840 establishes the types of joints permitted, according to location, in vessels and their components. Article D-6 of Division 2 estalishes rules for attaching nozzles and other pressure connections by welding. Likewise, Article D-9 of Division 2 gives rules for attaching nonpressure parts and stiffeners. The requirements of these articles are summarized in Table AF-241.1 of Division 2.

CI-4544.2 EXAMINATION REQUIREMENTS

In addition to summarizing the types of joints permitted, Table AF-241.1 of Division 2 gives the concomitant examination requirements as set forth in CI-4542. AF-652, and AF-653 of Division 2. Unless specifically exempted, all welds shall be examined as required by these paragraphs and by Table AF-241.1 of Division 2.

CI-4545 REPAIR OF WELD DEFECTS

CI-4545.1 REMOVAL OF UNACCEPTABLE DEFECTS

Unacceptable defects detected visually or by the examinations described in CI-6000, Appendix 7, and defects detected by leakage tests shall be removed by mechanical means or by thermal gouging processes.

CI-4545.2 REWELDING OF AREAS TO BE REPAIRED

The areas to be repaired shall be rewelded by qualified welders using qualified welding procedures.

CI-4545.3 EXAMINATION OF REPAIRED WELDS

Repaired welds shall be reexamined by the methods the original examination of the weld. The repaired weld shall not be accepted unless the examination shows the repair to be satisfactory.

CI-4545.4 POSTWELD HEAT TREATMENT OF REPAIRED WELDS

The postweld heat treating rules in CI-4550 shall apply to all weld repairs.

CI-4550 HEAT TREATMENT OF WELDMENTS

CI-4551 REQUIREMENTS FOR PREHEATING

The welding procedure specification for the material being welded shall specify the minimum preheating requirements in accordance with the weld procedure qualification requirements of Section IX. Where preheating is not required by the welding procedure, preheating may be employed during welding to assist in completion of the welded joint. The need for and temperature of preheat are dependent on a number of factors, such as the chemical analysis, degree of restraint of the parts being joined, elevated temperature physical properties, and material thicknesses. Specific rules for preheating are not given in this Division. Some practices used for preheating are given in nonmandatory Appendix 10, as a general guide for the materials listed by P-Numbers of Section IX. It is cautioned that the preheating listed therein does not necessarily ensure

satisfactory completion of the welded joint, and requirements for individual materials within the P-Number listing may have preheating more or less restrictive than this general guide.

CI-4552 REQUIREMENTS FOR POSTWELD HEAT TREATMENT[1]

Before applying the detailed requirements and exemptions in these paragraphs, satisfactory qualification of the welding procedures to be used shall be performed in accordance with all the variables of Section IX, including conditions of postweld heat treatment or its omission, and the restrictions listed below. Except for nonferrous materials and except as otherwise provided in Table AF-402.1 and Table AF-402.2 of Division 2 for ferrous materials, all welded pressure vessels or pressure vessel parts shall be given a postweld heat treatment at a temperature not less than that specified in those tables when the nominal thickness, including corrosion allowance, of any welded joint in the vessel or vessel parts exceeds the limits in those tables. The exemptions for postweld heat treatment, as provided for in Table AF-402.1 and Table AF-402.2 of Division 2 are not permitted when the vessel is designed for use in lethal service.

CI-4552.1 WHEN HOLDING TEMPERATURES AND TIMES MAY BE EXCEEDED

Except where prohibited in Table AF-402.1 of Division 2 holding temperatures and/or holding times in excess of the minimum values given in Table AF-402.1 of Division 2 may be used. A time-temperature recording of all postweld heat treatments shall be provided for review by the Inspector. The holding time at temperature specified in Table AF-402.1 need not be continuous. It may be an accumulation of time of multiple postweld heat treat cycles.

CI-4552.2 HEAT TREATMENT OF PRESSURE PARTS CONSISTING OF DIFFERENT P-NUMBER GROUPS

When pressure parts of two different P-no. Groups are joined by welding, the postweld heat treatment shall be that specified in Table AF-402.1 with applicable notes for the material requiring the higher postweld heat treatment temperature.

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[1]Additional postweld heat treatment requirements may result from the requirements of CI-6500.

When nonpressure parts are welded to pressure parts, the postweld heat treatment temperature of the pressure part shall control.

CI-4552.3 HEAT TREATMENT OF PARTS OF DIFFERENT THICKNESS

Nominal thickness in Table AF-402.1 is the thickness of the weld, pressure-retaining material, or the thinner of the sections being joined, whichever is least. For fillet welds, the nominal thickness is the throat thickness. When the welded joint connects parts that are of different thickness, the thickness to be used in applying the requirements for postweld heat treatment in CI-4552 shall be the following:

(a) the thinner of two adjacent butt-welded plates, including head-to-shell connections

(b) the thickness of the shell in connections to tubesheets, flat heads, covers or similar constructions

(c) except for Fig. AD-610.1 of Division 2, Sketches (a) and (b), the thickness of the shell or head; for Fig. AD-610.1 Sketches (a) and (b), the thickness of the nozzle neck or shell or head, whichever is least.

(d) the thickness of the nozzle neck at the joint in nozzle neck to flange connections

(e) the thickness of the weld at the point of attachment where a nonpressure part is welded to a pressure part

(f) the depth of the repair weld

CI-4552.4 HEAT TREATMENT OF WELDS

Electroslag welds in ferritic materials over 1½ in. (38 mm) in thickness at the joint shall be given a grain refining (austenizing) heat treatment.

CI-4553 HEATING PORTIONS BEFORE JOINING AND LOCAL HEATING OR CIRCUMFERENTIAL JOINTS AFTER JOINING

The postweld heat treatment shall be performed in accordance with one of the procedures of this paragraph.

CI-4553.1 HEATING VESSEL IN A FURNACE IN ONE HEAT

Heating the vessel as a whole in a closed furnace. This procedure is preferable and should be used whenever practicable.

CI-4553.2 HEATING VESSEL PORTIONS IN A FURNACE IN MORE THAN ONE HEAT

Heating the vessel in more than one heat in a furnace, provided the overlap of the heated sections of the vessel is at least 5 ft (1.5 m). When this procedure is used, the portion outside of the furnace shall be shielded so that the temperature gradient is not harmful. The cross section where the vessel projects from the furnace shall not intersect a nozzle or other structural discontinuity.

CI-4553.3 HEATING SHELL SECTIONS, HEADS, AND OTHER PORTIONS BEFORE JOINING

Heating shell sections, heads and/or portions of vessels for postweld heat treatment of longitudinal joints or complicated welded details before joining to make the completed vessel. When it is not practicable to postweld heat treat the complete vessel as a whole or in two or more heats as provided in CI-4553.2, any circumferential joints not previously postweld heat treated may thereafter be locally postweld heat treated by heating a circumferential band which includes such joints by any appropriate means that will ensure the required uniformity. The width of the heated band on each side of the greatest width of the finished weld shall be not less than two times the shell thickness. The portion outside the heating device shall be protected so that the temperature gradient is not harmful.

CI-4553.4 HEATING VESSEL INTERNALLY

The vessel may be heated internally by any appropriate means when adequate indicating and recording temperature devices are utilized to aid in the control and maintenance of a uniform distribution of temperature in the vessel wall. Previous to this operation, the vessel should be fully enclosed with insulating material.

CI-4553.5 LOCAL HEATING OF NOZZLES TO VESSELS AND EXTERNAL ATTACHMENTS

(a) Heating a circumferential band containing nozzles or other welded attachments that require postweld heat treatment in such a manner that the entire band shall be brought up uniformly to the required temperature and held for the specified time.

The circumferential band shall extend around the entire vessel, shall include the nozzle or welded attachment, and shall extend at least six times the plate thickness beyond the welding which connects the nozzle or other attachment to the vessel. The portion of the vessel outside of the circumferential band shall be protected so that the temperature gradient is not harmful; this procedure may also be used for local heat treatment of circumferential joints in pipe, tubing, or nozzle necks. In the latter case, proximity to the shell increases thermal restraint, and the designer should provide adequate length to permit heat treatment without harmful gradients at the nozzle attachment.

(b) The procedure in (a) may also be used for postweld heat treatment of portions of vessels after repairs.

CI-4554 OPERATION OF POSTWELD HEAT TREATMENT

The operation of postweld heat treatment shall be carried out by one of the procedures given in CI-4553 in accordance with the following requirements:

(a) The temperature of the furnace shall not exceed 800°F (427°C) at the time the vessel or part is place in it.

(b) Above 800°F (427°C), the rate of heating shall be not more than 400°F/hr (222°C/hr) divided by the maximum metal thickness of the shell or head plate in inches but in no case more than 400°F/hr (222°C/hr) and in no case need it be less than 100°F/hr (56°C/hr). During the heating period there shall not be a greater variation in temperature throughout the portion of the vessel being heated than 250°F (139°C) within any 15 ft (4.6 m) interval of length.

(c) The vessel or vessel part shall be held at or above the temperature specified in Table AF-402.1 of Division 2 or Table AF-402.2 of Division 2 for the period of time specified in the Tables. During the holding period, there shall not be a difference greater than 100°F (56°C) between the highest and lowest temperatures throughout the portion of the vessel being heated, except where the range is further limited in Table AF-402.1

(d) During the heating and holding periods, the furnace atmosphere shall be so controlled as to avoid excessive oxidation of the surface of the vessel. The furnace shall be of such design as to prevent direct impingement of the flame on the vessel.

(e) Above 800°F (427°C), cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500°F/hr (278°C/hr) divided by the maximum metal thickness of the shell or head plate in inches but in no case need it be less than 100°F/hr (56°C/hr). From 800°F (427°C) the vessel may be cooled in still air.

CI-4555 POSTWELD HEAT TREATMENT AFTER REPAIRS OR ALTERATIONS

Vessels or parts of vessels that have been postweld heat treated in accordance with the requirements of this Article shall again be postweld heat treated after repairs or alterations have been made if the welds made in such repairs or alterations require postweld treatment under the requirements of this subsection CI-4550.

ARTICLE CI-5000

GENERAL REQUIREMENTS FOR PRESSURE RELIEF DEVICES

CI-5100 PROTECTION AGAINST OVERPRESSURE[1]

(a) All pressure vessels within the scope of this Division shall be provided with protection against overpressure in accordance with the requirements of CI-5130.

(b) Heat exchangers and similar vessels shall be protected against overpressure in case of an internal failure.

CI-5110 TYPE OF OVERPRESSURE PROTECTION

Pressure relief valves[2], non-reclosing pressure relief devices[3] or flow paths or vents, open directly or indirectly to the atmosphere, may be used as protection devices. Non-reclosing pressure relief devices may be used either alone or, if applicable, in combination with safety or safety relief valves on vessels.

NOTE: Use of non-reclosing revices of some types may be advisable on Vessels containing substances that may render a safety or safety relief valve inoperative, where a loss of valuable material by leakage should be avoided, or where contamination of the atmosphere by leakage or noxious fluids must be avoided. The use of rupture disk devices may also be advisable when very rapid rates of pressure rise may be encountered.

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[1] Safety devices need not be provided by the vessel Manufacturer, but overpressure protection shall be provided prior to placing the vessel is service.

[2] A pressure relief valve is a pressure relief device which is designed to reclose and prevent the further flow of fluid after normal conditions have been restored.

[3] A non-reclosing pressure relief device is a pressure relief device designed to remain open after operation.

CI-5110 PRESSURE RELIEF VALVES[4]

(a) Safety, safety relief, and relief valves shall be of the direct spring loaded type.

(b) Pilot operated pressure relief valves may be used, provided that the pilot is self-actuated and the main valve will open automatically at not over the set pressure and will discharge its full rated capacity if some essential part of the pilot should fail.

(c) The spring in a pressure relief valve in service for pressures up to and including 250 psi (1720 kPA) shall not be reset for any pressure more than 10% above or 10% below that for which the valve is marked. For higher pressures, the spring shall not be reset for any pressure more than 5% above or 5% below that for which the pressure relief valve is marked.

(d) The set pressure tolerances, plus or minus, of pressure relief valves shall not exceed 2 psi (14 kPa) for pressures up to and including 70 psi (483 kPa) and 3% for pressures above 70 psi (483 kPa).

(e) Safety and safety relief valves for steam service shall meet the requirements of CI-5511.

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[4]A safety valve is a pressure relief valve actuated by inlet static pressure and characterized by rapid opening or pop action. A relief valve is a pressure relief valve actuated by inlet static pressure which opens in proportion to the increase in pressure over the opening pressure. A safety relief valve is a pressure relief valve characterized by rapid opening or pop action, or by opening in proportion to the increase in pressure over the opening pressure, depending on application. A pilot operated pressure relief valve is a pressure relief valve in which the major relieving device is combined with and is controlled by a self-actuated auxiliary pressure relief valve.

CI-5130 PERMISSIBLE OVERPRESSURES

CI-5131 RUPTURE DISK DEVICES[5]

CI-5131.1 BURSTING PRESSURE

Every rupture disk shall have a stamped bursting pressure within a manufacturing design range[6] at a specified disk temperature[7], shall be marked with a lot number, and shall be guaranteed by its manufacturer to burst within 5% (plus or minus) of its stamped bursting pressure at the coincident disk temperature.

The stamped bursting pressure within the manufacturing design range at the coincident disk temperature shall be derived by one of the following methods: All the tests of disks for a given lot shall be made in a holder of the same form and dimensions as that with which the disk is to be used.

(a) At least two sample rupture disks from each lot of rupture disks, made from the same materials and of the same size as those to be used, shall be burst to verify that the stamped bursting pressure falls within the manufacturing design range at the coincident

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[5]A rupture disk device is a non-reclosing pressure relief device actuated by inlet static pressure and designed to function by the bursting of a pressure containing disk. A rupture disk is the pressure containing and pressure sensitive element of a rupture disk device. A rupture disk holder is the structure which encloses and clamps the rupture disk in position. Rupture disks may be designed in several configurations, such as plain flat, pre-bulged, or reverse buckling, and may be made of either ductile or brittle material; rupture disk material is not required to conform to an ASME specification. The material of the rupture disk holder shall be listed in Section II and this Division.

[6]The manufacturing design range is a range of pressure within which the average burst pressure of test disks must fall to be acceptable for a particular requirement as agreed upon between the rupture disk manufacturer and the user or his agent. The disk will be marked with the average burst pressure of all test disks.

[7]The specified disk temperature supplied to the rupture disk manufacturer should be the expected temperature of the disk when an emergency condition exists and the disk is expected to rupture.

disk temperature. At least one disk shall be burst at room temperature. The stamped rating at the specified disk temperature shall be the averge of the bursts at coincident disk temperature.

(b) At least four sample rupture disks, but not less than 5%, from each lot of rupture disks, made from the same material and of the same size as those to be used, shall be burst at four different temperatures, distributed over the applicable temperature range for which the disks will be used. This data shall be used to establish a curve of bursting pressure versus temperature for the lot of disks. The stamped rating at the coincident disk temperature shall be interpolated from this curve.

(c) For pre-bulged, solid metal disks or graphite disks only, a curve of percentage ratio at temperatures other than ambient may be established as in (b) above, using one size of disk for each lot of material. At least four bursts at four different temperatures shall be used to establish the above curve over the applicable temperature range. At least two disks from each lot of disks made from this lot of material and of the same size as those to be used shall be burst at ambient temperature to establish the room temperature rating of the lot of disks.

The percent change of bursting pressure taken from the above curve shall be used to establish the stamped rating at the coincident disk temperature for the lot of disks.

CI-5131.2 CAPACITY RATING

(a) The calculated capacity rating of a rupture disk device shall not exceed a value based on the applicable theoretical formula (see CI-5500) for the various media multiplied by:

K = Coefficient = 0.62

The area "A" (square inches) in the theoretical formula shall be the minimum net area existing after disk burst.[8]

(b) In lieu of the method of capacity rating given in (a) above, a manufacturer may have the capacity of a given rupture disk device design certified for the K_D coefficient in general accordance with the procedures of CI-5500, as applicable.

CI-5131.3 SOLE RELIEF DEVICE

Application of rupture disk devices to liquid service should be carefully evaluated to assure that the design of the rupture disk device and the dynamic energy of the system on which it is installed with result in sufficient opening of the rupture disk.

A rupture disk device may be used as the sole pressure relieving device on a vessel.

NOTE: When rupture disk devices are used, it is recommended that the design pressure of the vessel be sufficiently above the intended operating pressure to provide sufficient margin between operating pressure and rupture disk bursting pressure to prevent premature failure of the rupture disk due to fatigue or creep.

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[8]The minimum net flow area is defined as the calculated net area after complete burst of the disk with appropriate allowance for any structural members which may reduce the net flow area through the rupture disk device. The net flow area for sizing purposes shall not exceed the nominal pipe size area of the rupture disk device.

CI-5131.4 INSTALLED UPSTREAM OF PRESSURE RELIEF VALVE

A rupture disk device may be installed between a pressure relief valve[9] and the vessel provided:

(a) The combination of the spring loaded safety of safety relief valve and the rupture disk device is ample in capacity to meet the requirements of CI-5150.

(b) The stamped capacity of a spring loaded safety or safety relief valve (nozzle type) when installed with a rupture disk device between the inlet of the valve and the vessel shall be multiplied by a factor of 0.80 of the rated relieving capacity of the valve alone, or alternatively, the capacity of such a combination shall be established in accordance with (c).

(c) The capacity of the combination of the rupture disk device and the spring loaded safety or safety relief valve may be established in accordance with the appropriate paragraphs of CI-5560. Certification of Capacity of Safety and Safety Relief Valves in Combination with Non-reclosing Pressure Relief Devices.

(d) The space between a rupture disk device and a safety or safety relief valve shall be provided with a pressure gage, a try cock, free vent, or suitable telltale indicator. This arrangement permits detection of disk rupture or leakage.[10]

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[9]Use of a rupture disk device in combination with a pressure relief valve should be carefully evaluated to insure that the media being handled and the valve operational characteristics will result in opening action of the valve coincident with the bursting of the rupture disk.

[10]Users are warned that a rupture disk will not burst at its design pressure if back pressure builds up in the space between the disk and the safety or safety relief valve which will occur should leakage develop in the rupture disk due to corrosion or other cause.

(e) The opening (see Footnote 8) provided through the rupture disk, after burst, is sufficient to permit a flow equal to the capacity of the valve (see (b) and (c) above), and there is no chance of interference with proper functioning of the valve; but in no case shall this area be less than 80% of the area of the inlet of the valve unless the capacity and functioning of the specific combination of rupture disk and valve have been established by test in accordance with CI-5560.

CI-5131.5 INSTALLED DOWNSTREAM OF A SPRING LOADED SAFETY RELIEF VALVE

A rupture disk device may be installed on the outlet side[11] of as spring loaded safety relief valve which is opened by direct action of the pressure in vessel provided:

(a) The valve is so designed that it will not fail to open as its proper pressure setting regardless of any back pressure that can accumulate between the valve disk and the rupture disk and the rupture disk. The space between the valve disk and the rupture disk shall be vented or drained to prevent accumulation of pressure due to small amount of leakage from the valve.

(b) The valve is ample in capacity to meet the requirements of CI-5150 (a), (b), and (c).

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[11]This use of a rupture disk device in series with the safety or safety relief valve is permitted to minimize the loss by leakage through the valve or valuable or of noxious or otherwise hazardous materials, and where a rupture disk alone or disk located on the inlet side of the valve is impracticable, or to prevent corrosive gases from a common discharge line reaching the valve internals.

[12]Users are warned that an ordinary spring loaded safety relief valve will not open at its set pressure if back pressure builds up in the space between the valve and rupture disk. A specially designed valve is required, such as a diaphragm valve or a valve equipped with a bellows above the disk.

(c) The stamped bursting pressure of the rupture disk at the coincident temperature plus any pressure in the outlet piping shall not exceed the design pressure of the outlet portion of the safety or safety relief valve and any pipe or fitting between the valve and the rupture disk device. However, in no case shall the stamped bursting pressure of the rupture disk at the coincident disk temperature plus any pressure in the oulet piping exceed the maximum allowable working pressure of the vessel or the set pressure of the safety or safety relief valve.

(d) The opening provided through the rupture disk device after breakage is sufficient to permit a flow equal to the rated capacity of the attached safety or safety relief valve without exceeding the allowable overpressure.

(e) Any piping beyond the rupture disk cannot be obstructed by the rupture disk or fragment.

(f) The contents of the vessel are clean fluids, free from gumming or clogging matter, so that accumulation in the space between the valve inlet and the rupture disk (or in any other outlet that may be provided) will not clog the outlet.

(g) The bonnet of the safey relief valve shall be vented to prevent accumulation of pressure.

CI-5132 BREAKING PIN DEVICE[13]

(a) Breaking pin devices shall not be used as single devices but only in combination between the safety or safety relief valve and the vessel.

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[13] A breaking pin device is a non-reclosing pressure relief device actuated by inlet static pressure and design to function by the breakage of a load carrying section of a pin which supports a pressure containing member. A breaking pin is the load-carrying element of a breaking pin device. A breaking pin housing is the structure which encloses the breaking pin mechanism. The material of the housing shall be listed in Section II and this Division.

(b) The space between a breaking pin device and a safety or safety relief valve shall be provided with a pressure gage, a try cock, a free vent, or suitable telltale indicator. This arrangement permits detection of breaking pin device operation or leakage.

(c) Each breaking pin device shall have a rated pressure and temperature at which the pin will break. The breaking pin shall be identified by a lot number and shall be guaranteed by the manufacturer to break when the rated pressure, within the following tolerances, is applied to the device.

Rated Pressure, psi		Tolerance Plus or Minus, psi
Minimum	Maximum	
30	150	5
151	275	10
276	375	15

(d) The rated pressure of the breaking pin plus the tolerance in pounds per square inch shall not exceed 105% of the maximum allowable working pressure of the vessel to which it is applied.

(e) The rated pressure at the coincident operating temperature[14] shall be verified by breaking two or more sample breaking pins from each lot of the same material and the same size as those to be used. The lot size shall not exceed 25. The test shall be made in a device of the same form and pressure dimensions as that in which the breaking pin is to be used.

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[14]The specified temperature supplied to the breaking pin manufactuer should be the temperature of the breaking pin when an emergency condition exists and the pin is expected to break.

CI-5133 SPRING LOADED NON-RECLOSING PRESSURE RELIEF DEVICES

(a) A spring loaded non-reclosing pressure relief device, pressure actuated by means which permit the spring loaded portion of the device to open at the specified set pressure and remain open until manually reset, may be used provided the design of the spring loaded non-reclosing device is such that if the actuating means fail the device will achieve full opening at or below its set pressure. Such a device may not be used in combination with any other pressure relief device. The tolerance on opening point shall not exceed ±5%.

(b) The calculated capacity rating of a spring loaded non-reclosing pressure relief device shall not exceed a value based on the applicable theoretical formula (see CI-5500) for the various media, multiplied by:

$$K = \text{Coefficient} = 0.62$$

The area "A" (square inches) in the theoretical formula shall be the flow area through the minimum opening of the non-reclosing pressure relief device.

(c) In lieu of the method of capacity rating given in (b) above, a manufacturer may have the capacity of a spring loaded non-reclosing pressure relief device design certified in general accordance with the procedures of CI-5500, as applicable.

CI-5140 SET PRESSURES

CI-5141 FOR A SINGLE RELIEF DEVICE

A single pressure-relieving device shall be set to operate[15] at a pressure (see CI-5145 for tolerances (not exceeding the design pressure of the vessel at the operating temperature, except as permitted in CI-5142.

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15 Set to operate means: the set pressure of a pressure relief valve or a spring loaded non-reclosing device; the bursting pressure of a rupture disk device; or the breaking pressure of a breaking pin device.

CI-5142 FOR MULTIPLE RELIEF DEVICES

(a) If the required discharging capacity is supplied by more than one device, only one need be set to operate at a pressure not exceeding the design pressure of the vessel. The additional device or devices may be set at a higher pressure but not to exceed 105% of the design pressure of the vessel, except as provided in (b).

(b) When supplemental relieving devices are provided for protection against excessive pressure due to exposure to fire or other unexpected sources of external heat, such devices shall be set to operate at a pressure not in excess of 110% of the design pressure of the vessel [see CI-5150 (c)].

CI-5143 PRESSURE EFFECTS TO BE INCLUDED IN SETTING

The pressure at which any device is set shall include the effects of static head and back pressures.

CI-5144 WHEN PRESSURE SETTING IS NOT APPLICABLE

When protection is provided by methods stated in Article CI-5300, set pressure requirements are not appliable.

CI-5145 SET PRESSURE TOLERANCES

Set pressure tolerances, as stated in CI-5120 and CI-5130, are sufficiently restrictive so that the nominal set-to-operate pressure of the overpressure protection device may equal the design pressure of the vessel.

CI-5150 PERMISSIBLE OVERPRESSURES

The aggregate capacity of the pressure relieving devices, open flow paths, or vents shall be sufficient to prevent overpressure in excess of those specified in (a), (b), and (c) when the pressure relieving devices are discharging.

(a) The permissible overpressure for all pressure vessels constructed according to this Division shall be limited to not more than 10% above the design pressure of the vessel, except as provided in (b) and (c). See CI-5140 for pressure settings.

(b) The permissible overpressure for vessels provided with multiple pressure relieving devices in accordance with CI-5142 (a) shall be limited to 16% above the design pressure.

(c) The permissible overpressure shall be limited to 21% of the design pressure when the pressure relief devices are discharging for conditions such as exposure to fire or other unexpected sources of external heat.

(d) The same pressure relieving devices may be used to satisfy the capacity requirements of (a) and (c) or (b) and (c) provided the pressure setting requirements of CI-5140 are met.

CI-5160 PRORATION OF STAMPED CAPACITY

To prorate the relieving capacity of any relieving pressure greater than 1.10p, as permitted under CI-5140 and CI-5150, a multiplier may be applied to the official relieving capacity of a pressure relieving device as follows:

$$\frac{P + 14.7}{1.10p + 14.7}$$

where

P = relieving pressure, psig (kPa)

p = set pressure, psig (kPa)

ARTICLE CI-5200

MATERIAL AND DESIGN REQUIREMENTS

CI-5200 MINIMUM REQUIREMENTS FOR PRESSURE RELIEF VALVES

(a) The design shall incorporate guiding arrangements necessary to insure consistent operation and tightness.

(b) The spring shall be designed so that the full life spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and height measured 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 0.5% of the free height.

(c) To insure the valve being free, each pressure relief valve on air, hot water, or steam service shall have a substantial lifting device by which the valve disk may be positively lifted from its seat when the valve is subjected to a pressure of at least 75% of the set pressure of the valve. The lifting device shall be such that it cannot lock or hold the valve disk in lifted position when the exterior lifting force is released. Pressure and safety relief valves for service other than steam, hot water, and air need not be provided with a lifting device, although a lifting device is desirable if the vapors are such that their release will not create a hazard.

(d) The seat of a safety valve shall be fastened to the body of the valve in such a way that there is no possibility of leakage.

(e) In the design of the body of the valve, consideration shall be given to minimizing the effects of deposits.

(f) Valves having screwed inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damaging operating parts.

(g) Means shall be provided in the design of all valves for use under this Division for sealing all external adjustments. Seals shall be installed by the Manufacturer at the time of initial shipment and after field adjustment or repair of the valves by either the Manufacturer, his authorized representative, repairer, or the user. Seals shall be installed in such a manner as to prevent changing the adjustment without breaking the seal and in addition, shall serve as a means of identifying the Manufacturer, assembler, repairer, or user making the adjustment.

CI-5210 MATERIAL SELECTIONS

(a) Cast iron seats and disks are not permitted.

(b) Adjacent sliding surfaces such as guides and disks or disk holders shall both be of corrosion resistant material. Springs or corrosion resistant material or having a corrosion resistant coating are required. The seats and disks of pressure relief valves shall be of suitable material to resist corrosion by the fluid to be contained.

NOTE: The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the manufacturer and the purchaser.

(c) Materials used in bodies and bonnets or yokes shall be listed in Section II and this Division. Materials used in nozzles, disks, and other parts contained within the external structure of the safety or safety relief valves shall be one of the following categories:

(1) listed in Section II

(2) listed in ASTM Specifications

(3) controlled by the Manufacturer of the pressure relief valve by a specification insuring control of chemical and physical properties and quality at least equivalent to ASTM Standards.

CI-5211 MINIMUM SIZE OF SAFETY RELIEF VALVES

Any safety relief valve used for liquid service shall be at least ½-in. iron pipe size.

CI-5213 DRAIN REQUIREMENTS

If the design of a safety or safety relief valve is such that liquid can collect on the discharge side of the disk, the valve shall be equipped with a drain at the lowest point where liquid can collect.

CI-5220 INSPECTION OF MANUFACTURING AND/OR ASSEMBLY OF SAFETY, SAFETY RELIEF, AND PILOT OPERATED VALVES

(a) A manufacturer or assembler shall demonstrate to the satisfaction of a designated representative of the National Board of Boiler and Pressure Vessel Inspectors that his manufacturing, production, and testing facilities and quality control procedures will insure close agreement between the performance of random production samples and the performance of those valves submitted for National Board Capacity Certification.

(b) Manufacturing, assembly, inspection, and test operations including capacity are subject to the inspection at any time by a designated representative of the National Board of Boiler and Pressure Vessel Inspectors.

(c) The following schedule of tests applied to production pressure relief valves certified under this Division, produced, assembled, tested, sealed, and shipped by the manufacturer or assembler, and having a normal scope of size and capacity within the capability of ASME accepted laboratories. Production valves for capacity and operational testing shall be selected by a representative of

the National Board of Boiler and Pressure Vessel Inspectors and the testing shall be carried out in the presence of a representative of the same organization at an ASME accepted laboratory in accordance with the following:

(1) Initial capacity certification shall be valid for one year during which time two production valves shall be tested for operation and stamped capacity verification. Initial capacity certification may be extended for one-year intervals until the valve is in production.

(2) Thereafter, two valves shall be tested within each 5 year period of time. The valve manufacturer shall be notified of the time of the test and may have a witness present during the test. Should any of these valves fail to relieve at or above its stamped capacity or should it fail to meet performance requirements of this Division after adjustments, the test shall be repeated at the rate of two valves for each valve that failed. These valves shall be furnished by the manufacturer or assembler. Failure of any of these valves to meet the stamped capacity or the performance requirements of this Division, shall be cause for revocation within 60 days of the authorization to use the Code symbol on that particular type of valve. During this period, the manufacturer shall demonstrate the cause of such deficiency and the action taken to guard against future occurrence, and the requirements of CI-5220(c)(1) shall apply.

(d) An assembler may be granted permission to use a Code symbol stamp after complying with the requirements of CI-5220(c)(1), at the time of permission being granted by the Society. The requirements

of CI-5200(c)(1) and (2), as stated, must also be met. Use of the Code symbol stamp as an assembler indicates the use of original, unmodified parts in strict accordance with the instructions of the manufacturer of the valve. In addition to the requirements of CI-5400, the nameplate marking shall include the name of the manufacturer and the assembler. The Code symbol stamp shall be that of the assembler.

NOTE: Within the requirements of CI-5220 and CI-5230: A manufacturer is defined as a person or organization who is completely responsible for design, material selection, capacity certification, and manufacture of all component parts, assembly, testing, sealing, and shipping or pressure relief valves certified under this Section of the Code.

An assembler is defined as a person or organization who purchases or receives from a manufacturer the necessary component parts and assemblies, tests, seals, and ships pressure relief valves certified under this Division, at a geographical location other than and using facilities other than those used by the manufacturer. An assembler may be organizationally independent of a manufacturer or may be wholly or partly owned by a manufacturer.

CI-5230 PRODUCTION TESTING

(a) Every valve shall be tested by the manufacturer or assembler to demonstrate popping point and tightness. Valves marked for steam service or having special internal parts for steam service shall be tested with steam, except that valves beyond the capability of the production steam test facility, either because of size or set pressure, may be tested on air. Necessary corrections for differential in popping pressure between steam and air shall be established by the manufacturer and applied to the popping point on air. Valves marked for general service may be tested with air. Valves intended for liquid service may be tested with air or water.

(b) A tightness test shall be conducted at a maximum expected operating pressure, but at a pressure not exceeding the reheating pressure of the valve. When testing with either water or steam, a valve exhibiting no visible signs of leakage shall be considered adequately tight. Leakage tests conducted with air shall be in accordance with industry accepted standards.

(c) A manufacturer or assembler shall have a documented program for the application, calibration, and maintenance of test gages.

(d) Testing time on steam valves shall be sufficient, depending on size and design, to insure that test results are repeatable and representative of field performance.

(e) Test fixtures and test drums where applicable shall be of adequate size and capacity to insure representative pop action and response to blowdown adjustment.

CI-5240 DESIGN REQUIREMENTS

At the time of the submission of valves for capacity certification, or testing in accordance with CI-5220, the National Board of Boiler and Pressure Vessel Inspectors and/or its consultants has the authority for conformity with the requirements of CI-5200(a) and CI-5200(b) and to reject or require modification of designs which do not conform, prior to capacity testing.

ARTICLE CI-5400

MARKING AND STAMPING

CI-5400 MARKING

CI-5401 SAFETY, SAFETY RELIEF, AND PILOT OPERATED VALVES

Each safety, safety relief, and pilot operated valve ½ in. pipe size and larger shall be plainly marked by the manufacturer or assembler with the required data in such a way that the marking will not be obliterated in service. The marking may be placed on the valve or on a plate or plates securely fastened to the valve. The Code symbol shall be stamped on the valve or nameplate, but the other required data may be stamped, etched, impressed, or cast on the valve or nameplate. The marking shall include the following:

(a) the name or identifying trademark of the manufacturer

(b) manufacturer's design or type number

(c) size _____ in. (the pipe size of the valve inlet)

(d) set pressure _____psi

(e) capacity _____cu ft/min of air (60°F and 14.7 psia)

NOTE: In addition, the manufacturer may indicate the capacity in other fluids (see Appendix 10).

(f) capacity _____lb/hr of saturated steam for valves certified on steam or complying with CI-5511

(g) heat built, or alternatively, a coding may be marked on the valve such that the valve manufacturer can identify the year built

(h) ASME symbol as shown in Figure AR-401.1 of Division 2. Valves smaller than ½ in. pipe size are exempt from requirements (c), (e), and (f). Requirements (a), (b), (d), (g), and (h) may be marked on tags attached by wire, adhesive, or other means suitable for the service conditions.

CI-5401.1 SAFETY AND SAFETY RELIEF VALVES CERTIFIED FOR STEAM DISCHARGING CAPACITY

Safety and safety relief valves certified for a steam discharging capacity under the provisions of Section I, and bearing the official Code symbol stamp of that Section for safety valves, may be used on pressure vessels. The rated capacity in terms of other fluids shall be determined by the method of conversion given in Appendix 9 (see CI-5550).

CI-5402 PRESSURE RELIEF VALVES IN COMBINATION WITH RUPTURE DISK DEVICES

Pressure relief valves in combination with rupture disk devices shall be marked with the capacity established in accordance with CI-5131.1(b)(2) or CI-5131.3(b)(3), in addition to the marking of CI-5401 and CI-5405. The marking may be placed on the valve or on a plate or plates securely fastened to the valve. The marking shall include the following:

(a) A combination with capacity certified per CI-5131.3(b)(2) shall be marked, prior to installation, as follows:

(1) capacity of combination _____lb/hr of saturated steam or ___cu ft/min or air (60°F and 14.7 psia)

(b) A combination with capacity certified per CI-5131.3(b)(3) shall be marked by the responsible manufacturer, as follows:

(1) name of manufacturer of valve

(2) design or type number of valve

(3) name of manufacturer of rupture disk device

(4) design or type number of rupture disk device

(5) capacity of combination__lb/hr of saturated steam or ___cu ft/min or air (60°F and 14.7 psia)

CI-5403 PRESSURE RELIEF VALVES IN COMBINATION WITH BREAKING PIN DEVICES

Pressure relief valves in combination with breaking pin devices shall be marked in accordance with CI-5401. In addition, the rated pressure shall be marked on the breaking pin and the breaking pin housing.

CI-5404 LIQUID RELIEF VALVES

Each liquid relief valve shall be marked with the following data:

(a) name or identifying trademark of the manufacturer

(b) manufacturer's design or type number

(c) size_____in. (pipe size of inlet)

(d) set pressure_____psi

(e) relieving capacity_____gal/min of water at 70°F

CI-5405 RUPTURE DISK DEVICES

Every rupture disk shall be plainly marked by the manufacturer in such a way that the marking will not be obliterated in service. The rupture disk marking may be placed on the flange of the disk or on a metal tab permanently attached thereto.[1] The marking shall include the following:

(a) the name or identifying trademark of the manufacturer

(b) manufacturer's design or type number

(c) lot number

(d) size_____in.

(e) stamped bursting pressure_____psi

(f) coincident disk temperature_____F

(g) capacity_____lb/hr of saturated steam, or_____cu ft/min of air (60°F and 14.7 psia)

NOTE: In addition, the manufacturer may indicate the capacity in other fluids (see Appendix 9).

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[1]In lieu of marking all of the listed items on the flange or tab of each rupture disk, the marking any consist of the stamped bursting pressure and a manufacturer's coding number sufficient to identify each disk with a Certificate which includes the required information, if such a Certificate is supplied for each lot of rupture disks.

Items (a) (b) and (d) shall also be marked on the rupture disk holder.

CI-5406 SPRING LOADED NON-RECLOSING PRESSURE RELIEF DEVICES

Spring loaded non-reclosing pressure relief devices shall be marked in accordance with CI-5401 except that the Code symbol stamp is to be applied only when the capacity has been estalished and certified in accordance with CI-5500 and all other requirements of CI-5410 have been met.

CI-5410 USE OF CODE SYMBOL STAMP

Each pressure relief valve[2] to which the Code symbol is to be applied shall be fabricated by a manufacturer who is in possession of a Code symbol stamp (see Fig, AR-401.1 of Division 2) and a valid Certificate of Authorization, obtainable when the conditions of CI-5411 through CI-5416 have been complied with.

CI-5411 AUTHORIZATION TO USE STAMP

Authorization to use the Code symbol stamp referred to in CI-5401 will be granted by the Society pursuant to the provisions of CI-5412 through CI-5416.

CI-5412 APPLICATION FOR STAMP

Any manufacturer may apply to the Boiler and Pressure Vessel Committee of the Society, in writing, upon forms issued by the Society for authorization to use the stamp. Each applicant must agree that, if authorization to use the stamp is granted, it will be used according to the rules and regulations of this Code, that any safety or safety relief valve to which the symbol is applied will have the capacity that has been Certified by the National Board of Boiler and Pressure Vessel Inspectors in accordance with the requirements of CI-5540 stamped upon the valve and that any stamp will be promptly returned to the Society upon demand or in case the applicant discontinues the manufacture of the safety and safety relief valves to which the Code symbol is applied or in case the Certificate of Authorization issued to such applicant has expired and no new certificate has been issued. The holder of any such stamp shall not permit any other manufacturer to use his stamp.

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[2]Liquid relief and vacuum relief valves are not covered by Code symbol stamp requirements.

CI-5413 CERTIFICATE OF AUTHORIZATION

Permission to use the stamp may be granted or withheld by the Society in its absolute discretion. If permission is given and the proper administrative fee paid, a Certificate of Authorization evidencing permission to use such symbol, expiring on the triennial anniversary data thereafter, will be forwarded to the applicant. Each such certificate will be signed by the Chairman and Secretary, or other duly authorized officer or officers, of the Boiler and Pressure Vessel Committee. Six (6) months prior to the date of expiration of any such certificate, the applicant must apply for a renewal of such permission and the issuance of a new certificate.

CI-5414 RIGHT OF SOCIETY TO CANCEL OR REFUSE RENEWAL OF AUTHORIZATION

The Society reserves the absolute right to cancel or refuse to renew such permission, returning fees paid for the prorated unexpired term.

CI-5414 REGULATIONS CONCERNING ISSUANCE AND USE OF STAMP

The Boiler and Pressure Vessel Committee may at any time and from time to time make such regulations concerning the issuance and use of such stamps as it deems appropriate and all such regulations shall become binding upon the holders of any valid certificates of authorization.

CI-5416 OBTAINING OF STAMPS

All steel stamps for applying the symbol shall be obtained from the Society.

ARTICLE CI-5500

CERTIFICATION OF CAPACITY OF SAFETY AND SAFETY RELIEF VALVES

CI-5500 CERTIFICATION OF CAPACITY BEFORE APPLYING SYMBOL

Before the symbol is applied to any pressure relief valve, the valve manufacturer shall have the capacity of his valves certified as prescribed in this article.

CI-5510 FLUID MEDIA AND TEST PRESSURES

CI-5511 FLUID MEDIA FOR CAPACITY CERTIFICATION TESTS

Capacity certification tests shall be conducted on dry saturated steam, air, or natural gas. When dry saturated steam is used, the limits for test purposes shall be 98% minimum quality and 20 F maximum superheat. Correction from within these limits may be made to the dry saturated condition. Valves for steam service may be rated as above, but at least one valve of each series shall be tested on steam to demonstrate the steam capacity and performance.

CI-5512 MAXIMUM TEST PRESSURE

Capacity certification tests shall be conducted at a pressure not to exceed 100% of the pressure for which the pressure relief valve is set to operate. The re-heating pressure shall be noted and recorded. Valves having an adjustable blow-down construction shall be adjusted prior to testing so that the blowdown does not exceed 5% of the set pressure.

CI-5513 TESTS OF PILOT OPERATED VALVES

Capacity certification of pilot operated pressure relief valves may be based on tests without the pilot valves installed provided, prior to capacity tests, it has been demonstrated by test to the satisfaction of the authorized observer that the pilot valve will cause the main valve to open fully within 110% of the set pressure of the main valve and that the pilot valve in combination with the main valve will meet all the requirements of this Division.

CI-5520 PROCEDURES FOR CAPACITY CERTIFICATION TESTS

CI-5521 THREE-VALVE METHOD

A capacity certification test is required on a set of three valves for each combination of size, design, and pressure setting. The stamped capacity rating for each combination of design, size, and test pressure shall not exceed 90% of the average capacity of the three valves tested.

NOTE: The capacity of a set of three valves shall fall within a range of plus or minus 5% of the average capacity. Failure to meet this requirement shall be cause to refuse certification of that particular safety valve design.

CI-5522 CURVE METHOD

If a manufacturer wishes to apply the Code Symbol to a design of safety relief valves, four valves of each combination of pipe size and orifice size shall be tested. These four valves shall be set at pressures which cover the approximate range of pressures for which the valve will be used or covering the range available at the certified test facility which shall conduct the tests. The capacities, as determined by these four tests, shall be plotted against the absolute flow test pressure and a curve drawn through these four points and zero-zero. If the four points do not lie within ±5% in capacity value of the plotted line, the authorized observer shall require that additional valves be tested at the rate of two for each point outside the tolerance with a limit of four additional valves. From this curve, relieving capacities shall be obtained. The stamped capacity shall not exceed 90% of the capacity from the curve.

As an alternative method the instantaneous slope of each test point (dw)/(dp) may be calculated and averaged. All values of instantaneous slope must then fall within plus or minus 5% of the average value, (dw/dp) is defined as the rate of change of the measured capacity with respect to absolute inlet pressure. The relieving capacity that may be stamped on the valve shall not exceed 90% of the value determined by the witnessed tests.

CI-5523 COEFFICIENT OF DISCHARGE METHOD

Instead of individual capacity certification, as provided in CI-5521 and CI-5522, a coefficient of discharge K may be established for a specific pressure relief valve design according to the procedure in (a) and (b).

(a) For each design the pressure relief valve manufacturer shall submit for test at least three valves for each of three different sizes (a total of nine valves) together with detailed drawings showing the valve construction. Each valve of a given size shall be set at a different pressure.

(b) Tests shall be made on each pressure relief valve to determine its capacity life, popping and blowdown pressures, and actual capacity in terms of the fluid used in the test. A coefficient,

K_D, shall be established for each test run as follows:

$$K_D = \frac{\text{actual flow}}{\text{theoretical flow}} = \text{coefficient of discharge}$$

where actual flow is determined quantitatively be test and theoretical flow is calculated by the appropriate formula which follows:

For test with dry saturated steam

$$W_T = 51.5\ AP$$

NOTE: For dry saturated steam pressures over 1500 psig (10,300 kPa) and up to 3200 psig (12,100 kPa) the value of W_T calculated by the above equation, shall be corrected by being multiplied by the following factor:

$$\frac{0.1906\ P - 1000}{0.2292\ P - 1061}$$

For test with air

$$W_T = 356AP\sqrt{M/T}$$

For test with natural gas

$$W_T = CAP\sqrt{M/ZT}$$

where

W_T = theoretical flow, lb/hr (kg/h)

A = actual discharge area through the valve at developed lift, sq in. (mm^2)

P = (set pressure X 1.10) plus atmospheric pressure, psia (kPa absolute)

M = molecular weight

T = absolute temperature at inlet [degrees Fahrenheit plus 460 (degrees Celsius plus 273)]

C = constant for gas or vapor based on the ratio of specific heats = C_p/C_v (see Fig. 10-100.1)

Z = compressibility factor corresponding to P and T

The average of the coefficients, K_D, of the nine tests required shall be multiplied by 0.90 and this product shall be taken as the coefficient, K, of that design.

NOTE: All experimentally determined coefficients K_D, shall fall within a range of ±5% of the average K_D found. Failure to meet this requirement shall be cause to refuse certification of that particular valve design.

(c) The official relieving capacity of all sizes and pressures of a given design, for which K has been established under the provisions of (b), that are manufactured subsequently

shall not exceed the value calculated by the appropriate formula in (b) multiplied by the coefficient, K (see Appendix 9).

CI-5524 RATING OF NOZZLE TYPE VALVES

Rating of nozzle type valves i.e., coefficient, K_D, greater than 0190 and nozzle construction, for saturated water shall be according to 9-101 in Appendix 9.

CI-5530 WHERE AND BY WHOM CAPACITY TESTS SHALL BE CONDUCTED

Tests shall be conducted at a place where approved equipment and personnel are available to conduct pressure relieving capacity tests. Tests shall be made in the presence of and certified by an authorized observer. The place, personnel, equipment, and the authorized observer shall be subject to approval by the Boiler and Pressure Vessel Committee. Laboratory approval is subject to review within each 5 year period.

CI-5540 TEST DATA REPORT

Capacity test data reports for each valve model, type, and size signed by the manufacturer and the authorized observer witnessing the tests shall be submitted to The National Board of Boiler and Pressure Vessel Inspectors for certification[1]. Where changes are made in the design, capacity certification tests shall be repeated.

CI-5550 WAIVER OF FURTHER TESTS OF VALVES TESTED PER SECTION 1

It shall be permissible to rate safety valves under PG-69.2 of Section 1 with capacity ratings of 103% flow, for use on pressure vessels, without further test. In such instances, the capacity rating of the valve may be increased to allow for the flow pressure permitted in CI-5512 namely 110% by the multiplier

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[1]Valves certified by the National Board of Boiler and Pressure Vessel Inspectors are published in "Relieving Capacities of Safety Valves and Relief Valves approved by the National Board." This publication may be obtained from the National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Ave., Columbus, Ohio 43229.

$$\frac{1.10p + 14.7}{1.03p + 14.7}$$

where

p = set pressure, psig (kPa)

Such valves shall be marked in accordance with CI-5401. This multiplier shall not be used as a divisor to transform test ratings from a higher to a lower flow.

CI-5560 CERTIFICATION OF CAPACITY OF SAFETY AND SAFETY RELIEF VALVES IN COMBINATION WITH NON-RECLOSING PRESSURE RELIEF DEVICES

CI-5561 CAPACITY OF SAFETY OR SAFETY RELIEF VALVES IN COMBINATION WITH A RUPTURE DISK DEVICE AT THE INLET

(a) For each combination of safety or safety relief valve design and rupture disk device design, the safety valve manufacturer or the rupture disk device manufacturer may have the capacity of the combination certified as prescribed in (c) and (d).

(b) Capacity certification test shall be conducted on saturated steam, air, or natural gas. When saturated steam is used, corrections for moisture content of the steam shall be made.

(c) The valve manufacturer or the rupture disk device manufacturer may submit for tests the smallest rupture disk device size with the equivalent size of safety or safety relief valve that is intended to be used as a combination device. The safety or safety relief valve to be tested shall have the largest orifice used in the particular inlet size.

(d) Test may be performed in accordance with the following sub-paragraphs. The rupture disk device and safety or safety relief valve combination to be tested shall be arranged to duplicate the combination assembly design.

(1) The test shall embody the minimum burst pressure of the rupture disk device design which is to be used in combination with safety or safety relief valve design. The stamped bursting pressure shall be between 90-100% of the stamped set pressure of the valve.

(2) The test procedure to be used shall be as follows: The safety or safety relieve valve (one valve) shall be tested for capacity as an individual valve, without the rupture disk device, at a pressure 10% above the valve set pressure. The rupture disk device shall then be installed ahead of the safety or safety relief valve and the disk burst to operate the valve. The capacity test shall be performed on the combination at 10% above the valve set pressure duplicating the individual safety or safety relief valve capacity test.

(3) Tests shall be repeated with two additional rupture disks of the same nominal rating for a total of three rupture disks to be tested with the single valve. The results of the test capacity shall fall within a range of 10% of the average capacity of the three tests. Failure to meet this requirement shall be cause to require retest for determination of cause of the discrepancies.

(4) From the results of the tests, a Combination Capacity Factor shall be determined. The Combination Capacity Factor is the ratio of the average capacity determined by the combination tests to the capacity determined on the individual valve.

The Combination Capacity Factor shall be used as a multiplier to make appropriate changes in the ASME rated relieving capacity of the safety or safety

relief valve in all sizes of the design. The value of the Combination Capacity Factor shall not be greater than one. The Combination Capacity Factor shall apply only to combinations of the same design of safety or safety relief valve and the same design of rupture disk device as those tested.

(5) The test laboratory shall submit to the National Board the test results for approval of the Combination Capacity Factor for certification of the capacity of the combination of the safety or safety relief valve with the rupture disk device design.

CI-5562 OPTIONAL TESTING OF RUPTURE DISK DEVICES AND SAFETY OR SAFETY RELIEF VALVES

(a) If desired, a valve manufacturer or a rupture disk manufacturer may conduct tests in the same manner as outlined in CI-5561(d)(3) and (d)(4) using the next two larger sizes of the design of rupture disk device and safety or safety relief valve to determine a Combination Capacity Factor applicable to larger sizes. If a greater Combination Capacity Factor is established and can be certified, it may be used for all larger sizes of the combination, but shall not be greater than one.

(b) If desired, additional tests may be conducted at higher pressure in accordance with CI-5561(d)(3) and CI-5561(d)(4) to establish a maximum Combination Capacity Factor to be used at all pressures higher than the highest tested, but shall not be greater than one.

CI-5570 CAPACITY OF BREAKING PIN DEVICES IN COMBINATION WITH SAFETY RELIEF VALVES

(a) Breaking pin devices in combination with safety relief valves shall be capacity tested in compliance with CI-5522 or CI-5523 as a combination.

(b) Capacity certification and Code symbol stamping shall be based on the capacity established in accordance with these paragraphs.

ARTICLE CI-5600

PROVISIONS IN VESSELS FOR INSTALLATION OF PRESSURE RELIEVING DEVICES

CI-5600 NUMBER, SIZE, AND LOCATION OF CONNECTIONS

CI-5601 CONNECTIONS FOR VAPOR RELIEF VALVES

Vessels shall have at least one connection, in the vapor space, for directly mounted pressure relieving devices or for piping to pressure relieving devices, open paths or vents; such connections are not required when the provisions of CI-5300 are used.

CI-5602 CONNECTIONS FOR LIQUID RELIEF VALVES

A connection below the normal liquid level shall be provided for a relief valve, if the latter is to be used. Any safety relief valve used for liquid service shall be at least ½-in. iron pipe size.

CI-5610 SIZE OF OPENINGS AND NOZZLES

The opening through all pipe and fittings between a pressure vessel and its pressure-relieving device shall have at least the area of the pressure-relieving device inlet, and the flow characteristics of this upstream system shall be such that the pressure drop will not reduce the relieving capacity below that required or adversely affect the proper operation of the pressure-relieving device. The opening in the vessel wall shall be designed to provide direct and unobstructed flow between the vessel and its pressure-relieving device.

CI-5615 INTERVENING STOP VALVES

There shall be no intervening stop valves between the vessel and its protective device or devices or between the protective devices and the point of discharge; except:

(a) when these stop valves are so constructed or positively controlled that the closing of the maximum number of block valves possible at one time will not reduce the pressure relieving capacity provided by the unaffected relieving devices below the required relieving capacity; or

(b) under the conditions set forth in Appendix 10.

CI-5620 LOCATION OF OPENINGS AND CONNECTIONS

Openings and connections for pressure relieving purposes shall be so located that the nature of the vessel contents will not hinder flow through such openings and connections.

ARTICLE CI-6000

CONSTRUCTION INSPECTION AND TESTING

CI-6100 GENERAL REQUIREMENTS

The inspection and examination of pressure vessels with the Code symbol shall conform to the general requirements for inspection and examination in this Article and, in addition, to the specific requirements for inspection and examination given in the applicable paragraphs.

CI-6110 MANUFACTURER'S RESPONSIBILITY

(a) The Manufacturer who completes any vessel to be marked with the Code symbol has the responsibility of complying with all the requirements of this Division and, through proper certification, of ensuring that any work done by others also complies with all requirements of this Division.

(b) This responsibility includes providing the Inspector with all specified information and of ensuring that the quality control system covering the detailed examinations and tests, required by this Division, are performed at the stages of construction to permit them to be meaninful (see Appendix 8). These shall include, but not be limited to, the following:

(1) the Certificate of Authorization from the ASME Boiler and Pressure Vessel Committee authorizing the Manufacturer to fabricate the class of vessel being constructed (CI-8000);

(2) the drawings and design calculations for the vessel or part (CI-1300);

(3) the mill test report or Material Certification for all material used in the fabrication of the vessel or part (CI-2130) and sample test coupons (CI-6420) when required;

(4) any Partial Data Reports when required by CI-2130 and CI-8000;

(5) access for the Inspector to those parts of his plant concerned with the supply or fabrication of materials for the vessel, keeping the Inspector informed of the progress of the works so the required inspections can be performed in the proper sequence (CI-6140);

(6) evidence of examination of all materials before fabrication to make certain it has the required thickness in accordance with the design specification for detection of unacceptable defects (CI-4121), to make certain the material is one of the acceptable materials permitted by this Division (CI-2120) and the identification traceable to the mill test report or material certification has been maintained (CI-4121);

(7) documentation of impact tests when such tests are required (CI-2520);

(8) concurrence of the Inspector prior to any repairs when required by CI-4512, CI-4545;

(9) examination of head and shell sections to confirm they have been properly formed to the specified shapes within permissible tolerances (AD-420, AF-111, AF-130, AF-605, AF-710 and AF-730 of Division 2);

(10) qualification of the welding procedures before they are used in fabrication (CI-4530 and CI-6510);

(11) qualification of all welders and welding operators before using welders in production work (CI-4530);

(12) examination of all parts prior to joining to make certain they have been properly fitted for welding and that the surfaces to be joined have been cleaned and the alignment tolerances are maintained (AF-140 of Division 2);

(13) examine parts as fabrication progresses for material identification (CI-4121.1), that surface defects are not evident and that dimensional geometrics are maintained;

(14) provide records of all heat treatments performed on the vessel or vessel parts (CI-4521.1, CI-4545.4, and CI-4550);

(15) provide records of NDE examinations performed on the vessel or vessel parts;

(16) subject vessel to required hydrostatic or pneumatic test and have required inspection performed during such test. Pressure test gage calibration records shall be available (CI-7236);

(17) affix the required stamping and/or nameplate to the vessel and make certain it is affixed to the proper vessel (CI-8000);

(18) prepare required Manufacturer's Data Report form and have it certified by the Inspector (CI-8000).

CI-6120 INSPECTOR'S DUTY

(a) The Inspector of vessels to be marked with the Code symbol has the duty of making all required inspections and such other inspections as he considers are necessary in order to satisfy himself that all requirements have been met (see CI-1303).

(b) The required inspections and verifications shall include, but not be limited to, the following:

(1) that the Manufacturer has a valid Certificate of Authorization and is working according to a quality control system (CI-1304);

(2) that the applicable design report, user's design specification, drawings and related documents are available (CI-1303);

(3) materials used in the construction of vessel comply with the requirements of Articles CI-2000 and CI-6200;

(4) all welding procedures have been qualified (CI-4532 and CI-6244);

(5) all welders and welding operators have been qualified (CI-4532 and CI-6244.1);

(6) that the heat treatments, including PWHT, have been performed (CI-6110)(b)(14) and CI-4552);

(7) material imperfections repaired by welding are acceptably repaired and reexamined (CI-4545);

(8) required NDE examinations and tests have been performed and that the results are acceptable (CI-6244.2);

(9) visual inspection of vessel to confirm that the material numbers have been properly transferred (CI-4122);

(10) performing internal and external inspections and witnessing the hydrostatic or pneumatic tests (CI-7000);

(11) verify that the nameplate stamping is proper, and that the nameplate has been permanently attached to the proper vessel or vessel chamber (CI-8000);

(12) sign the Certificate of Inspection on the Manufacturer's Data Report when the vessel, to the best of his knowledge and belief, is complete and in compliance with all the providions of this Division (CI-8000).

CI-6130 THE INSPECTOR

All references to Inspectors throughout this Division mean the Authorized Inspector as defined in this paragraph. All inspections required by this Division shall be by an Inspector employed by a State or Municipality of the United States, a Canadian Province, an Inspector regularly employed by an insurance company authorized to write boiler and pressure vessel insurance or an Inspector continuously employed by a company for making inspections of pressure vessels to be used exclusively by such company and not for resale.

The Inspector shall not be in the employ of the Manufacturer. All Inspectors shall have been qualified by a written examination under the rules of any State of the United States or Province of Canada which has adopted the Code.

CI-6140 ACCESS FOR INSPECTOR

The Manufacturer of the vessel or part thereof shall arrange for the Inspector to have free access to such parts of all plants as are concerned with the supply or manufacture of materials for the vessel, when so requested. The Inspector shall be permitted free access, at all times while work on the vessel is being performed, to all parts of the Manufacturer's shop that concern the construction of the vessel and to the site of field erected vessels during the period of assembly and testing of the vessel. The Manufacturer shall keep the

Inspector informed of the progress of the work and shall notify him reasonably in advance when the vessel or materials will be ready for any required tests or inspections.

CI-6200 INSPECTION OF MATERIALS

CI-6210 COMPLIANCE OF MATERIALS WITH REQUIREMENTS

The Inspector shall assure himself that all materials used comply in all respects with the requirements of this Division. The manufacturer shall submit to the Inspector certification of materials compliance (see CI-2130). He shall examine certified test reports or certificates of compliance for the materials used, except as otherwise provided for in the material specification or in this Division.

CI-6220 EXAMINATION OF CAST IRON SECTION

CI-6221 GENERAL

TBD

CI-6222 REQUIRED EXAMINATION

TBD

CI-6230 EXAMINATION OF PRESTRESSING SYSTEMS

CI-6231 GENERAL

This Subarticle describes the examination requirements for prestressing systems. Aspects of the systems which affect quality such as tendon fabrication, placement and tensioning of tendons, installation of ducts and bearing plates, and the application of the corrosion prevention materials shall be examined.

CI-6232 REQUIRED EXAMINATIONS

CI-6232.1 GENERAL

The design, fabrication, and installation of prestressing systems shall be in conformance with the Construction Specification. The Construction

Specification shall include provisions to control and examine tendon length, twist, temporary protective coating, if required, anchorage hardware, conformance to Manufacturer's standards, coiling and packaging requirements, handling, shipping, and storage procedures.

CI-6232.3 BEARING PLATES

Following installation, the position of all bearing plates shall be examined prior to tendon loading for proper location and orientation. Placement tolerances shall be in accordance with the Construction Specification.

CI-6232.3 TENDON DUCTS

CI-6232.3.1 PREPLACEMENT

Tendon ducts shall be examined to ensure compliance with requirements of the Construction Specification as to type, diameter, and wall thickness. The frequency of examination shall be specified in the Construction Specification.

CI-6232.3.2 POST-PLACEMENT

Tendon ducts shall be examined for position and alignment in accordance with CI-4452. After installation, the ducts shall be visually examined for damage, including holes and cracks, and for dents and ovalling which may affect required minimum clear aperture. The criteria for the visual examination shall be given in the Construction Specification. Following cast iron placement, all ducts shall be examined to ensure that minimum clear aperture is provided.

CI-6232.4 PRESTRESSING STEEL

(a) All tendons shall be examined to verify that proper element quantities are present. The elements shall be examined at the frequency defined in the Construction Specification to verify proper diameter.

(b) The exposed surfaces of the prestressing elements shall be visually examined upon shipping, receipt, and prior to installation to ensure that damage such as nicks, bends, or corrosion has not occured to a detrimental degree. Criteria for acceptance shall be given in the Construction Specification. Tendons shall be examined for banding and twisting of the bundle to ensure compliance with the field drawings.

CI-6232.5 ANCHORAGE COMPONENTS

(a) Anchorage components shall be examined for dimensions, thread, and surface conditions. The frequency of such examinations as well as tolerance and any other acceptance criteria shall be in accordance with the Construction Specification.

(b) Following tensioning, all anchorange assemblies shall be visually examined. The total number of rejectable wires, strands, or bars shall not exceed the limit set forth in CI-4465.

CI-6232.6 TENSIONING

The tensioning of tendons shall be examined for conformance with written procedures. The frequency of this examination shall be specified in the Construction Specification.

CI-6240 EXAMINATION OF LINERS

CI-6241 GENERAL

CI-6241.1 SCOPE

This Subarticle contains the nondestructive examination requirements for PCIV liners and attachments thereto.

CI-6241.2 TIME OF EXAMINATION

(a) Radiographic examination, when required may be performed prior to postweld heat treatment (PWHT) for applicable materials.

(b) Magnetic particle or liquid penetrant examinations may be performed either before or after any PWHT. Weld surfaces which are not accessible after a PWHT shall be examined prior to the operations which caused the inaccessibility.

CI-6242 REQUIRED EXAMINATION OF WELDS

CI-6242.1 CATEGORY WELDS

(a) Category A, B, C, and D welds shall be fully examined in accordance with CI-6243. Either ultrasonically examined in accordance with CI-6243.2 or examined by the liquid penetrant method in accordance with CI-6243.3 or the magnetic particle method in accordance with CI-6243.4. Welds may be examined radiographically according to CI-6243.1 if applicable. When the liquid penetrant or magnetic particle method is used, the examination shall be performed at the following locations:

(1) at the 1/2 t location and on the final weld surface for weld thickness less than 3/4 in. (19 mm);

(2) at 3/4 in. (6 mm) intervals and on the final weld surface for weld thicknesses 3/4 in. (19 mm) and greater;

CI-6242.2 ATTACHMENT WELDS

(a) Attachment welds which penetrate the liner shall be examined by either the magnetic particle method or liquid penetrant method.

(b) The surfaces of all welds between splice sleeves and the liner shall be visually examined.

CI-6242.3 STUD WELDS

Stud welds shall be visually examined for lack of fusion around the periphery of each weld.

CI-6243 EXAMINATION PROCEDURES

CI-6243.1 RADIOGRAPHIC EXAMINATION

Radiographic examination shall be performed in accordance with Article 2 of Section V, except that:

(a) fluorescent type screws shall not be used;

(b) geometric unsharpness shall not exceed the limits of T-251 of Section V;

(c) the penetrameters of Table CI-6243-1 shall be used in lieu of those shown in Table T-262.2 of Section V.

CI-6243.2 ULTRASONIC EXAMINATION

Ultrasonic examination shall be performed in accordance with Appendix 7.

CI-6243.3 LIQUID PENETRANT EXAMINATION

Liquid penetrant examination shall be performed in accordance with Appendix 7.

TABLE CI-6243-1

THICKNESS, PENETRAMETER DESIGNATIONS, AND ESSENTIAL HOLES

SIMPLE WALL MATERIAL THICKNESS RANGE, in.	PENETRAMETER			
	SOURCE SIDE		FILM SIDE	
	DESIGNATION	ESSENTIAL HOLE	DESIGNATION	ESSENTIAL HOLE
Up to 1/4 incl.	5	4T	5	4T
Over 1/4 thru 3/8	7	4T	7	4T
Over 3/8 thru 1/2	10	4T	10	4T
Over 1/2 thru 5/8	12	4T	12	4T
Over 5/8 thru 3/4	15	4T	12	4T
Over 3/4 thru 7/8	17	4T	15	4T
Over 7/8 thru 1	20	2T	15	2T
Over 1 thru 1-1/4	25	2T	17	2T
Over 1-1/4 thru 1-1/2	30	2T	20	2T
Over 1-1/2 thru 2	35	2T	25	2T
Over 2 thru 2-1/2	40	2T	30	2T
Over 2-1/2 thru 3	45	2T	35	2T
Over 3 thru 4	50	2T	40	2T
Over 4 thru 6	60	2T	45	2T
Over 6 thru 8	80	2T	50	2T
Over 8 thru 10	100	2T	60	2T
Over 10 thru 12	120	2T	80	2T
Over 12 thru 16	160	2T	100	2T
Over 16 thru 20	200	2T	120	2T

CI-6243.4 MAGNETIC PARTICLE EXAMINATION

Magnetic particle examination shall be performed in accordance with Appendix 7.

CI-6243.5 VISUAL EXAMINATION

Visual examination shall be performed in accordance with Article 9 of Section V.

CI-6244 CHECK OF WELDING PROCEDURE SPECIFICATIONS

It is the duty of the Inspector to assure himself that the welding procedures employed in construction have been qualified under the provisions of Section IX and as specified in this Division. The manufacturer shall submit evidence to the Inspector that those requirements have been met. When there is a specific reason to question a welding procedure, the Inspector may require requalification as a requirement for the procedure to be used on work subject to his inspection.

CI-6244.1 CHECK OF WELDER AND WELDING OPERATOR PERFORMANCE QUALIFICATION

It is the duty of the Inspector to assure himself that all welding is done by welders or welding operators qualified under the provisions of Section IX. The Manufacturer shall make available to the Inspector a certified copy of the record of performance qualification tests of each welder and welding operator as evidence that these requirements have been met. When there is a specific reason to question the ability of a welder or welding operator to make welds that meet the requirements of the welding procedure specification, the Inspector may require requalification as a requirement for the welder or welding operator to continue welding on work subject to his inspection.

CI-6244.2 CHECK OF NONDESTRUCTIVE EXAMINATION METHODS

It is the duty of the Inspector to assure himself that the nondestructive examination methods of Appendix 7 which are used follow the techniques specified therein, that the examinations are performed by operators who are certified by the Manufacturer as being qualified in the techniques of the methods employed and in the interpretation and evaluation of the results, and that the Manufacturer has met the requirements of the rules. If there is a specific reason

to question an operator's qualifications, the Inspector has the right to require proof of the operator's ability to perform and interpret the examinations specified. The Inspector may witness nondestructive examinations at his discretion.

CI-6244.3 CERTIFICATION OF COMPETENCY OF NONDESTRUCTIVE TEST OPERATOR

The Manufacturer shall certify that each operator meets the following requirements:

(a) He has vision, with correction if necessary, equivalent to 20/30 for distance and is able to read a Jaeger Type No. 2 Standard Chart at a distance of not less than 12 in. This requirement shall be checked annually.

(b) He is competent in the techniques of the particular nondestructive examination method for which he is certified, including making the examination and interpreting and evaluating the results, except that, where the examination method consists of more than one operation, he may be certified as being qualified only for one or more of these operations.

CI-6245 POST EXAMINATION CLEANING

Following any nondestructive examination in which examination materials are applied to the piece, the piece shall be thoroughly cleaned in accordance with procedure specifications.

CI-6250 MARKING ON PLATES AND OTHER MATERIAL

The Inspector shall see that the material, before use, bears the material manufacturer's markings. If the identifying marks are obliterated during fabrication or the material is divided into two or more parts, the marks or coded marking shall be properly transferred as provided in CI-4122.

CI-6251 DIMENSIONAL CHECK OF COMPONENT PARTS

The Inspector shall satisfy himself that:

(a) Heat and shell sections conform to the prescribed shape and meet the thickness requirements after forming;

(b) Nozzles, manhole frames, reinforcement around openings, and other appurtenances to be attached to the inside or outside of the vessel fit properly to the curvature of the vessel surface;

(c) The dimensional requirements have been met. This shall include making such dimensional measurements as he considers necessary.

CI-6252 CHECK OF HEAT TREATMENT PRACTICE

The Inspector shall satisfy himself that the manufacturer has conducted all heat treatment operations required by this Division. Certificates furnished by the manufacturer may be accepted as evidence that the heat treatment operations were correctly carried out.

CI-6300 FINAL INSPECTION

CI-6310 REQUIRED PRESSURE TESTS

After all required heat treatments have been performed, the completed vessel shall be subjected either to the hydrostatic test prescribed in CI-7100 or to the pneumatic test prescribed in CI-7200.

CI-6320 INSPECTOR'S DUTY

The Inspector shall witness the hydrostatic test prescribed in CI-7100 or the pneumatic test prescribed in CI-7200.

CI-6400 TESTING REQUIREMENTS

CI-6410 GENERAL REQUIREMENTS

The tests to be made relative to PCIV covered by this Division shall be performed in accordance with the rules in this Article.

CI-6420 REQUIREMENTS FOR SAMPLE TEST COUPONS

When material is subjected to heat treatment during fabrication, the test specimens required by the applicable specification shall be obtained from sample coupons which have been heat treated in the same manner as the material, including such heat treatments as were applied by the material producer before shipment. The required tests may be performed by the material producer or the fabricator.

CI-6422 HEAT TREATING OF SAMPLE TEST COUPONS

The material used in the vessel liner shall be represented by test specimens which have been subjected to the same manner of heat treatment, including postweld heat treatment. The kind and number of tests and test results shall be as required by the material specification. The vessel manufacturer shall specify the temperature, time, and cooling rates to which the material will be subject during fabrication. Material from which the specimens are prepared shall be heated at the specified temperature within the tolerances established by the Manufacturer for use in actual fabrication. The total time at temperature shall be at least 80% of the total time at temperature during actual heat treatment of the product and may be performed in a single cycle. Simulation of postweld heat treatment may be applied to the test specimen blanks.

CI-6423 OPERATIONS NOT CONSIDERED AS HEAT TREATMENT

Heat treatment of material is not intended to include such local heating as flame or arc cutting, preheating, welding, or heating below the critical range of tubing and pipe for bending or sizing.

CI-6424 EXEMPTIONS FROM REQUIRMENT OF SAMPLE TEST COUPONS

CI-6424.1 FOR STANDARD PRESSURE PARTS

An exception to the requirments of CI-6421 and CI-6422 shall apply to standard items such as described in CI-2133. These may be subjected to postweld heat treatment with the vessel or vessel part without the same treatment being required of the test specimens. This exception shall not apply to specially designed cost or wrought fittings.

CI-6424.2 FOR P-NO. 1 MATERIALS WHEN POSTWELD HEAT TREATED ONLY

Materials conforming to one of the specifications listed in Classification P-1, Gr. 1, 2, and 3 of QW-422 of Section IX are exempt from the requirements of CI-6421 and CI-6422 when the heat treatment during fabrication consists of a postweld heat treatment only.

CI-6500 IMPACT TESTING OF WELDS AND VESSEL TEST PLATES OF FERROUS MATERIALS

CI-6510 IMPACT TESTS

(a) For steel vessels of welded construction the impact toughness of welds and heat affected zones of procedure qualification test plates and vessel test plates (production test plates) shall be determined as required in this Article.

(b) Test plates shall be subjected to heat treatment, including cooling rates and aggregate time at temperature or temperatures, essentially the same as established by the manufacturer for use in actual manufacture.

CI-6520 LOCATION, ORIENTATION, TEMPERATURE, AND VALUES OF WELD IMPACT TESTS

All weld impact tests shall comply with the following requirements:

(a) Each set of weld metal impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch is normal to the surface of the material, and one face of the specimen shall be within 1/16 in. of the surface of the material. When procedure tests are made on material over 1-1/2 in. in thickness, two sets of impact specimens shall be taken from the weld with one set located near (within 1/16 in.) the surface of one side of the material and one set taken as near as practical midway between the surface and the center of thicness of the opposite side as described above.

(b) Each set of heat affected zone impact specimens shall be taken across the weld and of sufficient length to locate, after etching, the notch in the affected zone. The notch shall be cut approximately normal to the material surface in such a manner as to include as much heat affected zone material as possible in the resulting fracture.

(c) The test temperature for welds and heat affected zones shall not be higher than for the base materials.

(d) Impact values shall be at least as high as those required for the base materials (see AM-211, AM-213, AM-311.4, and AM-311.5 of Division 2).

CI-6530 IMPACT TESTS OF WELDING PROCEDURES

(a) Welding procedure impact tests shall be made:

(1) on all high-alloy steel weld metal

(2) on welds and heat affected zones when welding base materials are required to be impact tested

(b) If impact tests are required for the welding procedure, but the material is exempted from impact tests, the test plate material shall be the material of the same specification used in the vessel. One set of impact specimens shall be taken with the notch in the weld metal; the heat affected zone need not be impact tested.

CI-6531 VARIABLES FOR IMPACT WHEN LOWER CRITICAL TEMPERATURE IS EXCEEDED

(See Section IX, QW-250.)

CI-6532 THICKNESS QUALIFIED WHEN LOWER CRITICAL TEMPERATURE IS EXCEEDED

For test plates or pipe receiving a postweld heat treatment in which the lower critical temperature is exceeded, the maximum thickness qualified is the thickness of the test plate or pipe.

CI-6540 IMPACT TESTS OF VESSEL TEST PLATES

(a) When the base material is required to be impact tested, impact tests of welds and heat affected zones shall be made in accordance with CI-6520 for each qualified welding procedure used on each vessel. The test plate shall be from one of the heats of steel used for the vessel or group of vessels and shall be welded as an extension to the end of a production Category A joint where practicable, or welded immediately prior to the start of production welding utilizing equipment, welding materials, and procedures which are to be used on the production joint.

(b) For Category B joints that are welded using a different welding procedure than used on Category A joints, a test plate shall be welded under the production welding conditions used for the vessel, using the same type of equipment and at the same location and using the same procedures as used for the joint and it shall be welded concurrently with the production welds or immediately prior to the start of production welding.

(c) In addition, for Category A and B joints the following requirements shall apply:

(1) If automatic or semiautomatic welding is performed, a test plate shall be made in each position employed in the vessel welding.

(2) If manual welding is also employed, a test plate shall be made in the flat position only, except if welding is to be performed in other positions, a test plate need be made in the vertical position only (where the major portions of the layers of welds are deposited in the vertical upward direction). The vertically welded test plate will qualify the manual welding in all positions.

(3) The vessel test plate shall qualify the impact requirements for vessel materials, thickness in accordance with QW-451.1 and QW-451.2 (including notes) of Section IX, except that, if the thickness is less than 5/8 in. (16 mm), the thickness of the test material is the minimum thickness qualified.

CI-6541 REJECTION

If the vessel test plate fails to meet the impact requirements, the welds represented by the test plate shall be unacceptable. Reheat treatment and retesting are permitted.

CI-6600 RADIOGRAPHIC EXAMINATION

CI-6610 TECHNIQUE FOR RADIOGRAPHIC EXAMINATION OF WELDED JOINTS

CI-6611 WELDED JOINTS TO BE RADIOGRAPHED

All welded joints to be radiographed shall be examined in accordance with Article 2 of Section V except as specified below.

(a) The reinforcement on each side of all butt welded joints shall not exceed the following thickness:

Material Thickness	Thickness of Reinforcement
1/16 in. (1.6 mm) to, but not including 3/32 in. (2.4 mm)	1/32 in. (0.8 mm)
3/32 in. (2.4 mm) to, but not including 3.6 in. (4.8 mm)	1/16 in. (1.6 mm)
3/16 in. (4.8 mm) to, but not including 1 in. (25 mm)	3/32 in. (2.4 mm)
1 in. (25 mm) to, but not including 2 in. (51 mm)	1/8 in. (3mm)
2 in. (51 mm) to, but not including 3 in. (76 mm)	5/32 in. (4 mm)
3 in. (76 mm) to, but not including 4 in. (102 mm)	7/32 in. (5.6 mm)

Material Thickness	Thickness of Reinforcement
4 in. (102 mm) to, but not including 5 in. (12 mm)	1/4 in. (6 mm)
5 in. (127 mm) and over	5/16 in. (18 mm)

(b) A complete set of radiographs and records for each job, as described in T-292 and T-293 of Article 2 of Section V, shall be retained by the Manufacturer and kept on file for a period of at least 5 years.

(c) The Manufacturer shall certify that Personnel performing radiographic examinations under this paragraph have been qualified in accordance with SNT-TC-1A[1] (1975 Edition) as applicable for the technique and methods used.

(d) The requirements of T-251 of Article 2 of Section V are to be used only as a guide. Final acceptance of radiographs shall be based on the ability to see the prescribed penetrameter image and the specified hole.

CI-6620 ACCEPTANCE STANDARDS FOR RADIOGRAPHS OF WELDS

CI-6621 UNACCEPTABLE DEFECTS AND REPAIR REQUIREMENTS

Sections of weld that are shown by radiography to have any of the following types of defects are unacceptable unless the defects are removed, the weld is repaired in accordance with the requirements of CI-4543.2 and the repaired weld is reexamined in accordance with the requirements of CI-4543.3:

(a) any type of crack or zone of incomplete fusion or penetration;

(b) any elongated inclusion such as slag, which has a length greater than:

1/4 in. (6 mm) for t up to 3/4 in. (19 mm)
1/3 t for t from 3/4 in. (19 mm) to 2-1/4 in. (57 mm)
3/4 in. (19 mm) for t over 2-1/4 in. (57 mm)

where

t = the thickness of the weld;

[1]Recommended Practice No. SNT-TC-1A (1975 Edition) "Personnel Qualification and Certification in Nondestructive Testing" is published by The American Society for Nondestructive Testing, Inc., 3200 Riverside Drive, Columbus, Ohio 43221.

(c) any group of inclusions in line that has an aggregate length greater than t in a length of 12 t, except then the distance between the successive imperfections exceed 6L, where L is the length of the longest imperfection in the group;

(d) rounded indications in excess of that specified by the acceptance of the standards given in Appendix 6.

CI-6621.1 TREATMENT OF IMPERFECTIONS BELIEVED NONRELEVANT

Any indication of an imperfection which is believed to be nonrelevant shall be regarded as a defect unless, on reevaluation, it is shown by reexamination by the same method or by the use of other nondestructive conditioning, that no unacceptable imperfection is present.

CI-6622 EXAMINATION OF AREAS FROM WHICH DEFECTS HAVE BEEN REMOVED

After a defect is thought to have been removed and prior to making weld repairs, the area shall be examined by suitable methods to ensure that the defect has been eliminated.

CI-6623 REEXAMINATION OF REPAIRED AREAS

After repairs have been made, the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners and reexamined by radiography and all other methods of examination that were originally required for the affected area, except that, when the depth of the repair is less than the radiographic sensitivity required, reradiography may be omitted.

ARTICLE CI-7000

STRUCTURAL INTEGRITY TEST OF PRESTRESSED CAST IRON PRESSURE VESSELS

CI-7100 GENERAL REQUIREMENTS

CI-7110 SCOPE

This Article contains the requirements for initial acceptance testing of a PCIV. The PCIV shall be tested for structural acceptability as a prerequisite for Code acceptance and stamping. The requirements for the structural test are contained in CI-7200. Test results and conclusions shall be documented in the Construction Report.

CI-7200 STRUCTURAL ACCEPTANCE REQUIREMENTS

CI-7210 TEST CONDITIONS

CI-7271 TEST PRESSURE

In order to ensure structural integrity, each PCIV shall be subjected to an acceptance test in which the internal pressure is increased from atmospheric pressure to at least 1.15 times the Design Pressure, unless a lower value can be justified by the Designer, in five or more approximately equal pressure increments. Measurements and observations as stipulated or as otherwise required by the Designer shall be made at each such increment.

CI-7212 CONDITIONS PRIOR TO TEST

The vessel shall be brought to essentially operational steady state temperature to simplify evaluation of pressure test results. Cavity pressure controls and instrumentation systems shall be checked to verify that the various components are functional and ready for the test to proceed.

CI-7213 ACCEPTANCE

The PCIV shall be considered to have satisfied the structural acceptance test if the following requirements are met:

(a) no visible signs of permanent damage to the CI structure are detected;

(b) the measured deflections and loads of the tendons do not exceed predicted values by more than 10%.

(c) No leaks are found on the vessel.

CI-7214 RETEST

If the PCIV experiences major structural changes or significant damage or leaks occur requiring repairs after the test, the acceptance test shall be repeated following the completion of the corrective actions.

CI-7220 TEST AND INSTRUMENTATION PLAN

CI-7221 PURPOSE

A complete test and instrumentation plant shall be developed and included in the Construction Specification. This plan shall describe the type and location of instrumentation and relate the data to the needs of the Designer regarding verification of design.

CI-7222 SCOPE

The plan shall include a description of the method of applying the test loads, timing with respect to heatup program, if required, and the instrumentation location and type.

CI-7223 ALTERATION OF TEST PLAN

It will be possible to alter this test plan, provided all requirements of this Code are met, upon approval of the Owner and Designer and Constructor.

CI-7230 INSTRUMENTATION

CI-7231 PURPOSE

Instrumentation shall be incorporated into the PCIV for measurement of overall deformation and tendon force for measurement of overall deformation and tendon force for nonprototype structures. In addition, the PCIV shall be monitored during testing for unexpected cracking and signs of structural distress.

CI-7232 DEFLECTION MEASUREMENTS

At each specified pressure level, a planned series of deflection, measurements and observations shall be made at selected location, as outlined by the test plan.

CI-7233 DEFLECTION MEASURING DEVICES

The deformation measurement devices shall provide for a minimum accuracy of ±10% of the maximum anticipated value calculated at the point on the structure where the greatest deformation is expected.

CI-7234 TENDON FORCE MEASUREMENTS

If tendon force change measurements are specified by the Designer, the load cells used for this purpose shall have an accuracy of at least ±3% of the initial tendon force.

CI-7235 TEMPERATURE MEASUREMENTS

Thermocouples shall be installed in the PCIV wall near the inner and outer face at a minimum of three locations and at one location in the head. Measurements from these instruments shall be made at each pressurization and depressurization level during the test.

CI-7236 PRESSURE GAGES

Pressure test gages used in pressure testing shall be indicating pressure gages and shall be connected directly to the component. If the indicating gage is not readily visible to the operator controlling the pressure applied, an additional indicating gage shall be provided where it will be visible to the operator throughout the duration of the test. It is recommended that a recording gage

be used in addition to the indicating gages.

CI-7236.1 RANGE OF INDICATING PRESSURE GAGES

Indicating pressure gages used in testing shall have dials graduated over a range of about double the intended maximum test pressure, but in no case shall range be less than 1½ times the intended test pressure no more than four times that pressure.

CI-7236.2 CALIBRATION OF PRESSURE GAGES

All gages shall be calibrated against a standard deadweight tester or a calibrated master gage prior to each test or series of tests. Gages shall be calibrated before and after acceptance test.

CI-7240 PRETEST REQUIREMENTS

The PCIV shall be examined prior to acceptance test as follows:

> The accessible PCIV exterior surfaces shall be visually examined for surface cracking. Measured crack widths in excess of 0.010 in. (0.25 mm) shall be recorded on a set of drawings as to width, length, estimated depth, and date of observance.

CI-7241 PREDICTIONS REQUIRED PRIOR TO TEST

Predictions as to expected readings of all devices used to monitor vessel behavior shall have been made. Stress, strain, and deformation data shall have been developed by the Designer using the same techniques as were employed in the design of the vessel. Acceptance limits shall be provided for each pressurization increment for all devices that, in the judgment of the Designer, are necessary in order to permit a determination that the test may proceed safely to the next increment of increased pressure.

CI-7242 PRETEST OF INSTRUMENTATION

Readings from all load cells and temperature measuring devices shall be recorded daily for a period of 3 days prior to the commencement of the pressure test.

Deflection measuring devices load cells and thermocouples shall be monitored for at least 1 day prior to the test in order to establish the stability of these instruments and to eliminate those that exhibit excessive drift. These readings shall be made at approximately equal intervals.

CI-7250 TEST PROCEDURE

CI-7251 PRETEST EXAMINATION

Prior to pressure testing, a thorough examination of the structure shall be made by the Designer. The objective of such examination is to record such conditions as cracks in the CI and other data which may be needed to interpret the behavior of the structure. The Designer shall be on site during the acceptance testing.

CI-7252 TEST SEQUENCE

All measurements shall be recorded at atmospheric pressure and at each pressure level of pressurization and depressurization cycles. At each level, the pressure shall be held constant for at least ½ hr before the deflections and loads are recorded. The vessel shall be depressurized in the same number of increments as was used during pressurization.

CI-7253

Any liquid, nonhazardous at operating temperature, may be used for the hydrostatic test if below its boiling point. Combustible liquids having a flash point less than 110°F (43°C), such a petroleum distillates, may be used only for near atmospheric temperature tests. For vessels constructed of steels whose resistance to brittle fracture at low temperature has not been enhanced, test temperatures above 60 F (16 C) may be useful in minimizing risk of brittle fracture during hydrostatic testing. The test pressure shall not be applied until the vessel and the pressurizing medium are at about the same temperature. Modifications to the rules established herein may be required if other gases or liquids are used. When pneumatic pressure test is required, performance of this is to be in accordance with Article T-4 of Section VIII; Division 2.

CI-7254 EXAMINATION FOR LEAKAGE AFTER APPLICATION OF PRESSURE

Following the application of the hydrostatic test pressure, examination for leakage shall be made of all joints and connections and of all regions of high stress such as head knuckles, regions around openings, and thickness transition sections. This examination shall be made at a pressure equal to the greater of the design pressure or three-fourths of the test pressure and shall be witnessed by the Inspector. Any leaks that are present shall be corrected in accordance with the rules after which the vessel shall be retested in accordance with these requirements.

CI-7260 ANALYSIS OF DATA AND PREPARATION OF REPORT

CI-7261 RESOLUTION OF TEST DATA

The results of the test shall be furnished to, and be examined by, the Designer, Discrepancies between measured and predicted extremes of tendon force, temperature, or deformation shall be resolved by review of the design, evaluations of measurement tolerances, and exploration of the vessel. The tests shall be acceptable if the requirements of CI-7213 are met.

CI-7262 PRESENTATION OF DATA

Data shall be presented in the final report so that direct comparisons between predicted values and measured values may be made.

CI-7263 REPORT REQUIREMENTS

(a) a description of the test procedure and the instrumentation

(b) a comparison of the test measurements with the allowable limits (predicted response plus tolerance) for deflections, strains, and crack width

(c) an evaluation of the estimated accuracy of the measurements

(d) an evaluation of any deviation (such as test results that exceed the allowable limits), the disposition of the deviations, and the need for corrective measures

ARTICLE CI-8000

MARKING, STAMPING, REPORTS AND RECORDS

CI-8100 GENERAL REQUIREMENTS

The requirements for marking, stamping, reporting and maintaining records for components shall be as given in Part AS of Section VIII, Division 2.

MANDATORY APPENDICES

APPENDIX 1

TABLES OF PRESTRESSING AND LINER MATERIALS
(Obtained from Section III, Div. 2, Appendix 1)

1) Eliminate tables relative to Containment Materials

2) Expand Table 1-2.1 to include the following material specifications

SA-204	Gr A	3	1
SA-240	All	8	—
ASTM B-463	—	8	—

APPENDIX 2

CAST IRON MULTIAXIAL COMPRESSIVE STRENGTH MODIFICATION
(Obtained from Section III, Div. 2, Appendix 2)

1) Use same format as in original appendix but replace concrete data with to be determined cast iron data.

APPENDIX 3

GLOSSARY OF TERMS AND NOMENCLATURE
(Obtained from Section III, Div. 2, Appendix 3 and Section VIII, Div. 2 Definitions)

1) Remove terms and descriptions referring to concrete code.

2) Replace with cast iron and any other applicable terms needed or required by the draft code.

APPENDIX 4

DESIGN BASED ON STRESS ANALYSIS
(Obtained from Section VIII, Div. 2, Appendix 4)

1) Revise and update the references to paragraphs in Section VIII, Div. 2 to applicable paragraphs in the draft PCIV code.

APPENDIX 5

DESIGN BASED ON FATIGUE ANALYSIS
(Obtained from Section VIII, Div. 2, Appendix 5)

1) Revise and update the references to paragraphs in Section VIII, Div. 2 to applicable paragraphs in draft PCIV code.

APPENDIX 6

POROSITY OR ROUNDED INDICATOR CHARTS
(Obtained from Section VIII, Div. 2, Appendix 8)

1) Revise and update paragraph numbers.
2) Revise references from Section VIII, Div. 2 to draft PCIV code (No change in content).

APPENDIX 7

NONDESTRUCTIVE EXAMINATION METHODS
(Obtained from Section VIII, Div. 2, Appendix 9)

1) Revise and update paragraph numbers.

2) Revise references from Section VIII, Div. 2 to draft PCIV code (No change in content).

APPENDIX 8

QUALITY CONTROL SYSTEM
(Obtained from Section VIII, Div. 2, Appendix 18)

1) Revise and update paragraph numbers.

2) Revise references from Section VIII, Div. 2 to draft PCIV code (No change in content).

APPENDIX 9

CAPACITY CONVERSION FOR SAFETY VALVES
(Obtained from Section VIII, Div. 2, Appendix 10)

1) Revise and update paragraph numbers.

2) Revise references from Section VIII, Div. 2 to draft PCIV code (No change in content).

NON-MANDATORY APPENDICES

APPENDIX 10

NON-MANDATORY PREHEATING
(Obtained from Section VIII, Div. 2, Appendix 14)

1) Revise and update paragraph numbers.

2) Revise references from Section VIII, Div. 2 to draft PCIV code (No change in content).

APPENDIX 11

LINER DIMENSIONAL TOLERANCES
(Obtained from Section III, Div. 2, Appendix F)

1) Review content and remove or add paragraphs to make appendix consistent with Section VIII philosophy.

2) Revise and update paragraph numbers.

3) Revise references from Section III, Div. 2 to draft PCIV code.

APPENDIX 12

APPROVAL OF NEW MATERIAL
(Obtained from Section VII, Div. 2, Appendix 4
and Section VIII, Div. 2, Appendix 16)

1) Remove references to concrete and add new paragraphs for cast iron.

2) Review both appendices in order to meld a new appendix described herein.

3) Remove stringent paragraphs to create a consistent appendix with Section VIII philosophy.

APPENDIX 13

SI UNITS
(Obtained from Section VIII, Div. 2, Reference Material)

1) Review for consistency with national standards (No change in content).

APPENDIX 20

GUIDE FOR PREPARING MANUFACTURERS' DATA REPORT
(Obtained from Section VIII, Div. 2, Appendix 20)

1) Update references from Section VIII, Div. 2 to draft PCIV code (No change in content).

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