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Guide to Life Cycle Management of Pressure Equipment Integrity

ASME
SETTING THE STANDARD

PTB-2–2022

GUIDE TO LIFE CYCLE MANAGEMENT OF PRESSURE EQUIPMENT INTEGRITY

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ASME
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FOREWORD

In 1993, ASME initiated activity to address the development of post construction standards in response to an identified need for recognized and generally accepted engineering standards for the inspection and maintenance of pressure equipment after it has been placed in service. In 1995, the Post Construction Committee (PCC) was appointed to develop and maintain standards addressing common issues and technologies related to post-construction activities, and to work with other consensus committees in the development of separate, product-specific codes and standards addressing issues encountered after initial construction of non-nuclear pressure equipment such as boilers, pressure vessels (including heat exchangers), piping and piping components, pipelines, and storage tanks. Subcommittees were formed on bolted flange joint assembly, repair and testing, and inspection planning. The subcommittees were charged with preparing standards dealing with several aspects of the in-service inspection and maintenance of pressure equipment. As a result, *ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly* was published in 2000; A*SME PCC-2 Repair of Pressure Equipment and Piping* was published in 2006 and *ASME PCC-3 Inspection Planning Using Risk-Based Methods* was published in 2007.

In the course of preparing the documents described above, the Post Construction Committee recognized the need to provide a guideline or "roadmap" to help users of pressure equipment and their designated agents, as well as manufacturers, owners, regulators and other stakeholders, identify the codes, standards, recommended practices, specifications and guidelines that apply to the life cycle management of pressure equipment integrity. Accordingly, ASME held a workshop in March 2009 to review a proposal for guidance that provides an integrated approach to the understanding and application of technologies in these standards in engineering programs for management of the life cycle of pressure equipment, including inspection, fitness for continued service and repair. The transition from new construction to post construction was an essential part of this study, as new construction standards address inspectability and provide a baseline critical to any post-construction assessment. The post construction standards presented and reviewed included:

PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
PCC-2	Repair of Pressure Equipment and Piping Standard
PCC-3	Inspection Planning Using Risk-Based Methods API 579-1/ASME FFS-1 Fitness-For-Service

This Guide is intended to fill that need. It is not intended to be an industry standard, but rather to provide general guidance. Also note that this document is not intended to be a complete listing of all of the publications related to pressure equipment integrity, which would fill many bookshelves, but rather lists the most pertinent references in the opinion of the author and the reviewers.

The first edition of ASME PTB-2, prepared by J. R. Sims, Jr., was published in 2009. This edition reflects updates to documents previously included in the first edition, as well as new documents that have been published since then. Also included is Appendix C, which includes international documents that are relevant to the life cycle management of pressure equipment integrity.

Established in 1880, ASME is a professional not-for-profit organization with more than 100,000 members promoting the art, science, and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety, and ASME provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org for more information.

STLLC is a not-for-profit limited liability company, with ASME as the sole member, formed in 2004 to carry out work related to new and developing technologies. STLLC's mission includes meeting the needs of industry and government by providing new standards-related products and services, which advance the application of emerging and newly commercialized science and technology and provides the research and technology development needed to establish and maintain the technical relevance of codes and standards. Visit http://asmestllc.org/ for more information.

ABBREVIATIONS AND ACRONYMS

API	American Petroleum Institute
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASME BPVC	ASME Boiler and Pressure Vessel Code
ASNT	American Society for Non-Destructive Testing
BPVC	Boiler and Pressure Vessel Code (ASME)
CFR	Code of Federal Regulations
MTI	Materials Technology Institute of the Chemical Process Industries
NB	National Board of Boiler and Pressure Vessel Inspectors
NBBPVI	National Board of Boiler and Pressure Vessel Inspectors
RP	Recommended Practice
SDO	Standards Developing Organization that, for the purpose of this Guide, is accredited by ANSI
SEI	Structural Engineering Institute
TEMA	Tubular Exchanger Manufacturers Association

1 SCOPE

This Guide provides a summary of some of the more commonly used codes, standards, recommended practices (RPs), publications, specifications and guidelines produced by organizations based in the United States that assist manufacturers, owners, users and their designated agents, regulators and other stakeholders in maintaining the integrity of fixed pressure equipment in process plants and in general industrial use. For the convenience of the user of this Guide, the term "documents" will be used throughout to refer collectively to "codes, standards, recommended practices, specifications and guidelines." This Guide is not all-inclusive.

There are many documents that are useful for specific applications of pressure equipment that have not been described or included as references in this Guide. This does not imply that these documents should not be used or that they have any deficiencies. Note also that engineering knowledge and experience is necessary for the proper application of most of the documents listed.

The following applications for pressure equipment are not specifically included in the scope. However, the owner of these categories of equipment may use those portions of this Guide that are applicable:

(a) Upstream "non-process" equipment in the oil and gas industry (e.g., pressure equipment used in oil and gas exploration and production such as Christmas trees, wellhead equipment, flow lines, subsea equipment).

(b) Equipment in commercial nuclear power plants.

(c) Domestic plumbing and other domestic pressure equipment, such as hot water heaters. Portable air receivers (air tanks) used by homeowners and contractors are excluded from the scope, but air receivers in industrial facilities are included.

(d) Liquefied natural gas (LNG) and liquefied petroleum gas (LPG) transport and storage (API and ship classification societies).

(e) Pipelines.

(f) Pressure equipment used in transport service.

(g) Fired tubular process heaters. However, some documents relevant to that application are included to the extent they might be used by equipment types that are covered in this Guide. Some of these documents include API Std 530, API Std 560 and API RP 573. They are mentioned here for users seeking additional information.

This Guide includes only documents that are pertinent to maintaining equipment integrity (e.g., pressure containment) through appropriate design, construction, inspection, maintenance, alteration and repair. Standards related to areas such as identification schemes, plant or pipeline operator qualification are outside of its scope.

When this Guide was originally published, it included only those documents that were developed and published within the United States. This edition includes an appendix to list documents from selected countries outside the United States that are relevant to the management of pressure equipment integrity.

The inclusion of a document in this Guide does not imply that the document is endorsed by ASME. This listing is provided only for the convenience of manufacturers, users and their designated agents, regulators and other stakeholders to help identify documents that are potentially applicable.

2 DEFINITIONS

Code – A document published by a standards developing organization (SDO) that has requirements that should be considered to be mandatory for use within its stated scope. Some codes also contain recommended practices and guidelines. In the past, some defined a code to be a document that has been adopted as a requirement by one or more legal entities, but this definition is not universally applicable.

Construction – An all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification and pressure relief.

Jurisdiction – A legal entity, such as a state or provincial government that has established laws and/or regulations governing the construction and in-service inspection, repair and alteration of pressure equipment.

NB – National Board of Boiler and Pressure Vessel Inspectors.

Petroleum and Chemical Process Industries – This term is self-explanatory and is used consistently in the main body of this document to refer to that segment of the process industry that is addressed by API Codes, Standards and Recommended Practices. However, other terms such as "hydrocarbon and chemical process industries," "refineries and related industries" and "petrochemical facilities" are used in some of the documents that are referenced in this Guide. These alternative terms are used in the document summaries in Appendix A but are considered to be equivalent to petroleum and chemical process industries for the purpose of the main body of this Guide.

Publication (also known as Technical Publication) – A document that contains useful information but is not considered to contain mandatory requirements.

Recommended Practice (RP) – A document published by an SDO that communicates recognized industry practices. Recommended Practices may include requirements, recommendations and options. In general, a Recommended Practice document will focus more on communicating information, and while they can contain requirements, such requirements will typically be fewer in number than a standard that covers a similar subject matter.

Specification – A document that contains requirements for construction of specific types of equipment items.

Standard – A document published by an SDO that contains standardized methods, requirements and recommendations. Requirements in standards should be considered to be mandatory unless written documentation has been developed to justify alternatives.

3 ORGANIZATION OF THIS GUIDE

This Guide is organized by type of equipment as described below. Each equipment type section is intended to stand alone, such that it includes all of the documents for that equipment type. This results in a lot of duplication but should provide a more user-friendly reference.

The following equipment types are included:

(a) Guide to documents that apply to boilers, including:

- *(1)* Power (steam) boilers
- *(2)* Heat recovery steam generators (HRSGs)
- *(3)* Heating boilers
- *(4)* Unfired steam boilers.

(b) Guide to documents that apply to pressure vessels, including:

- *(1)* Typical pressure vessels, including towers, drums, reactors, heat exchangers, condensers, air receivers, accumulators, etc.
- *(2)* Large, heavy wall vessels [e.g., >50 mm (2 in) wall thickness] and vessels with high design temperature [e.g., > 370°C (700°F)]
- *(3)* High pressure vessels [e.g., > 70 MPa (10 ksi)] design pressure
- *(4)* Heat exchangers (as a class of pressure vessels).

(c) Guide to documents that apply to storage tanks.

(d) Guide to documents that apply to piping systems.

(e) Guide to documents that apply to piping components including fittings.

- *(1)* Some pressure equipment contains components such as flanges, valves, expansion joints and other fittings. Specifications and standards for these components are generally referenced in the new construction codes. A listing of these documents is provided in paragraph 14 of this Guide.

(f) Guide to documents that apply to overpressure protection.

(g) Guide to documents that are focused on specific tasks, such as welding and non-destructive examination, that are routinely performed as a part of both new and post construction.

Appendix A contains a summary of each document that is referenced in this Guide describing:

(a) Title of the document.

(b) Edition that was current when this Guide was prepared. The user should check for updates. In particular, note that the general practice is to update or to reaffirm documents that have been ANSI approved every 5 years. Therefore, if an ANSI-approved document has an edition date more than 5 years old, it would be prudent to check for updates.

(c) An alternative number for the document (e.g., an ISO number) if applicable.

(d) Whether the document has been approved by ANSI.

(e) Summary of the scope of the document with comments.

(f) A description of the way in which the document is typically applied. For example:

- *(1)* Referenced in a purchase specification.
- *(2)* Manufacturer uses in construction.
- *(3)* Regulator has available to be able to audit compliance.
- *(4)* Allow users to manage the complete life cycle of pressure equipment in an effective manner.

(g) Comments containing a summary of the contents of the document. This is intended to allow a potential purchaser of the document to determine what to expect. For example, a document's scope may state

that pressure-temperature ratings for the components covered by the standard are included, when in reality there is only a reference to another standard that contains the ratings.

(h) A listing of the categories of users of the document.

Appendix B contains a summary of documents that are not necessarily codes, standards or recommended practices, which may be useful for additional reading on the topics covered.

Appendix C contains a listing of documents from various countries outside the United States that are relevant to the subject of pressure equipment integrity.

4 POWER (STEAM) BOILERS

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 1 is hyperlinked to the description in Appendix A.

Table 1: Power (Steam) Boilers

Specification/Purchase	Design/Construction	Operation
NB-370 NB-23 ASME PCC-3 API RP 580 API RP 581 API RP 538 API RP 578 API RP 588 ASCE/SEI 7	BPVC Section I BPVC Section II–Materials–Part A BPVC Section II–Materials–Part B BPVC Section II–Materials–Part C BPVC Section II–Materials–Part D BPVC Section V BPVC Section IX BPVC Section XIII API RP 578 ASCE/SEI 7 ASME PCC-1	BPVC Section VII API RP 584
In-Service Inspection	Fitness-For-Service	Repair
NB-23 NB-370 ASME PCC-3 API RP 580 API RP 581 API RP 573 BPVC Section VII EPRI CS-5235 EPRI CS-5208 BPVC Section V ASNT CP-189 ASNT RP SNT-TC-1A	API 579-1/ASME FFS-1 API 579-2/ASME FFS-2 EPRI CS-5208	NB-23 NB-370 ASME PCC-2 ASME PCC-1 API RP 577 API RP 578 API RP 582 BPVC Section IX API RP 573

4.1 Specification (Purchase) of Power (Steam) Boilers

Before acquiring a new boiler, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 4.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph (b), above).

(2) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(3) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3 above.

(4) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 538 *Industrial Fired Boilers for General Refinery and Petrochemical Service.* This recommended practice (RP) gives recommendations for design, operation, maintenance, and troubleshooting considerations for industrial fired boilers used in refineries and chemical plants.

(2) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets.* The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can

be determined by a risk assessment using the methods of risk-based inspection (Also, see 4.4(b)).

(3) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

4.2 Design and Construction of Power (Steam) Boilers

The ASME Boiler and Pressure Vessel Code, Section I (BPVC Section I) provides rules for construction of power boilers. These rules are mandatory in most jurisdictions in the US and Canada, and are frequently used worldwide. Section I references many other codes and standards, a few of which are listed below. If a user requires Section I construction in a purchase document, the internal references in Section I become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals*

(d) BPVC Section II–Materials–Part D *Properties (Customary)*

(e) BPVC Section II–Materials–Part D *Properties (Metric)*

(f) BPVC Section V *Nondestructive Examination*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the Section I, the rules for pressure relief device capacity certification have been transferred to the new BPVC Section XIII. The remaining rules for pressure relieving devices remain in BPVC Section I.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets.* The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 4.4(b)).

(j) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(k) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

4.3 Operation of Power (Steam) Boilers

BPVC Section VII *Recommended Guidelines for the Care of Power Boilers.*

API RP 584 *Integrity Operating Windows.* This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

4.4 In-service Inspection of Power (Steam) Boilers

The following documents apply to the in-service inspection of power boilers. They should be considered to be good engineering practices, with applicability that depends on the situation. However, in many cases, the manufacturers of power boilers have compiled the guidance of the applicable documents in an installation and operating manual (IOM).

(a) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 4.1(b)).

(b) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(c) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3 above.

(d) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(e) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers for use in refining and petrochemical service.

(f) BPVC Section VII *Recommended Guidelines for the Care of Power Boilers.*

(g) EPRI CS-5235 *Recommended Practices for Operating and Maintaining Steam Surface Condensers.*

(h) EPRI CS-5208 *Life Extension and Assessment of Fossil Power Plants (Conference Proceedings).*

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

4.5 Fitness-for-service Analysis of Power (Steam) Boilers

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 4.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions:

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual.* This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) EPRI CS-5208 *Life Extension and Assessment of Fossil Power Plants (Conference Proceedings).*

4.6 Repair of Power (Steam) Boilers

If the FFS assessment (see paragraph 4.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods:

(a) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(b) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(c) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(d) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers for use in refining and petrochemical service.

(e) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(f) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets.* The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 4.4(b)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(g) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein, (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(h) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

5 HEAT RECOVERY STEAM GENERATORS (HRSGS)

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 2 is hyperlinked to the description in Appendix A.

Table 2: Heat Recovery Steam Generators (HRSGs)

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section I	BPVC Section VII
API RP 534	BPVC Section VIII–Division 1	API RP 584
API RP 573	BPVC Section II–Materials–Part A	
NB-23	BPVC Section II–Materials–Part B	
API 510	BPVC Section II–Materials–Part C	
ASME PCC-3	BPVC Section II–Materials–Part D	
API RP 580	BPVC Section V	
API RP 581	BPVC Section IX	
API RP 578	BPVC Section XIII	
API RP 588	API RP 578	
ASCE/SEI 7	ASCE/SEI 7	
	ASME PCC-1	
In-Service Inspection	Fitness-For-Service	Repair
NB-23	API 579-1/ASME FFS-1	NB-23
NB-370	API 579-2/ASME FFS-2	NB-370
API 510	EPRI CS-5208	API 510
ASME PCC-3		ASME PCC-2
API RP 580		ASME PCC-1
API RP 581		API RP 577
API RP 970		API RP 578
API RP 573		API RP 582
BPVC Section VII		BPVC Section IX
BPVC Section V		
ASNT CP-189		
ASNT RP SNT-TC-1A		

5.1 Specification (Purchase) of HRSGs

Before acquiring a new HRSG, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 5.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) API RP 534 *Heat Recovery Steam Generators* is a useful reference for specification and design of HRSG systems.

(f) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers and HRSGs for use in refining and petrochemical service.

(2) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph (b), above).

(3) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(4) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(5) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(6) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(g) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets.* The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 5.4(b)).

(2) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

5.2 Design and Construction of HRSGs

The ASME Boiler and Pressure Vessel Code, Section I (BPVC Section I) provides rules for construction of power boilers, including HRSGs. These rules are mandatory in most jurisdictions in the US and Canada, and are frequently used worldwide. Section I references many other codes and standards, a few of which are listed below. If a user requires Section I construction in a purchase document, the internal references in Section I become mandatory as well.

Unless ASME Section I is required by the local jurisdiction, BPVC Section VIII–Division 1*Rules for Construction of Pressure Vessels Division 1* may be used for construction of HRSGs. Section VIII references many other codes and standards, a few of which are listed below. If a user requires Section I construction in a purchase document, the internal references in Section I become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals*

(d) BPVC Section II–Materials–Part D *Properties (Customary)*

(e) BPVC Section II–Materials–Part D *Properties (Metric)*

(f) BPVC Section V *Nondestructive Examination*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in the construction code, in this case either BPVC Section I or BPVC Section VIII Division 1, as selected.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets.* The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 5.4(b)).

(j) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(k) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

5.3 Operation of HRSGs

BPVC Section VII *Recommended Guidelines for the Care of Power Boilers.*

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

5.4 In-service Inspection of HRSGs

The following documents apply to the in-service inspection of HRSGs. They should be considered to be good engineering practices, with applicability that depends on the situation. However, in many cases, the manufacturers of HRSGs have compiled the guidance of the applicable documents in an installation and operating manual (IOM).

(a) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 5.1(b)).

(b) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3 above.

(e) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers and HRSGs for use in refining and petrochemical service.

(g) BPVC Section VII *Recommended Guidelines for the Care of Power Boilers.*

(h) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

5.5 Fitness-for-service Analysis of HRSGs

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 5.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions.

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) EPRI CS-5208 *Life Extension and Assessment of Fossil Power Plants (Conference Proceedings).*

5.6 Repair of HRSGs

If the FFS assessment (see paragraph 5.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods.

(a) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(b) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(c) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(d) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(e) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(f) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. “Positive Materials Identification” (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 5.4(b)). Also, within the context of repairs, the document cites examples of in service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(g) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the

welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(h) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

6 HEATING BOILERS

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 3 is hyperlinked to the description in Appendix A.

Table 3: Heating Boilers

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section IV	BPVC Section VI
API RP 538	BPVC Section II–Materials–Part A	API RP 584
API Std 560	BPVC Section II–Materials–Part B	
API RP 573	BPVC Section II–Materials–Part C	
NB-23	BPVC Section II–Materials–Part D	
API 510	BPVC Section V	
ASME PCC-3	BPVC Section IX	
API RP 580	BPVC Section XIII	
NACE SP0170	API RP 578	
API RP 578	ASCE/SEI 7	
API RP 588	ASME PCC-1	
ASCE/SEI 7		
In-Service Inspection	Fitness-For-Service	Repair
NB-23	API 579-1/ASME FFS-1	NB-23
NB-370	API 579-2/ASME FFS-2	NB-370
API 510	EPRI CS-5208	API 510
ASME PCC-3		ASME PCC-2
API RP 580		ASME PCC-1
API RP 573		API RP 577
API RP 970		API RP 578
NACE SP0170		API RP 582
BPVC Section VI		BPVC Section IX
BPVC Section V		
ASNT CP-189		
ASNT RP SNT-TC-1A		

6.1 Specification (Purchase) of Heating Boilers

Before acquiring a new heating boiler, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in- service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 6.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) API RP 538 *Industrial Fired Boilers for General Refinery and Petrochemical Service*. This recommended practice (RP) specifies requirements and gives recommendations for design, operation, maintenance, and troubleshooting considerations for industrial fired boilers used in refineries and chemical plants.

(f) API Std 560 *Fired Heaters for General Refinery Services*. This document applies primarily to process heaters in refineries, but contains information that may be of use in other industries. It is intended to be used as a supplement to a design code, such as ASME Section I or Section IV.

(g) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers and heating boilers for use in refining and petrochemical service.

(2) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 6.1(b)).

(3) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(4) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(5) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(6) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

(h) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 6.1(g)(3)).

(2) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

6.2 Design and Construction of Heating Boilers

The ASME Boiler and Pressure Vessel Code (BPVC) Section IV (BPVC Section IV) provides rules for construction of heating boilers. These rules are mandatory in most jurisdictions in the US and Canada, and are frequently used worldwide. Section IV references many other codes and standards, a few of which are listed below. If a user requires Section IV construction in a purchase document, the internal references in Section IV become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals*

(d) BPVC Section II–Materials–Part D *Properties (Customary)*

(e) BPVC Section II–Materials–Part D *Properties (Metric)*

(f) BPVC Section V *Nondestructive Examination*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in BPVC Section IV.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 6.1(g)(3)).

(j) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(k) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

6.3 Operation of Heating Boilers

BPVC Section VI *Recommended Rules for the Care and Operation of Heating Boilers*.

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

6.4 In-service Inspection of Heating Boilers

The following documents apply to the in-service inspection of heating boilers. They should be considered to be good engineering practices, with applicability that depends on the situation. However, in many cases, the manufacturers of heating boilers have compiled the guidance of the applicable documents in an installation and operating manual (IOM).

(a) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 6.1(b)).

(b) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3 above.

(e) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers and heating boilers for use in refining and petrochemical service. However, for typical applications of heating boilers constructed to Section IV, the rules and guidelines in the post-construction documents previously referenced are adequate, without the need to refer to API RP 573.

(f) BPVC Section VI *Recommended Rules for the Care and Operation of Heating Boilers*.

(g) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

(h) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

6.5 Fitness-for-service Analysis of Heating Boilers

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 6.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions.

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) EPRI CS-5208 *Life Extension and Assessment of Fossil Power Plants (Conference Proceedings).*

6.6 Repair of Heating Boilers

If the FFS assessment (see paragraph 6.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods.

(a) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(b) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(c) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(d) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(e) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(f) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive materials Identification", (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 6.4(b)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(g) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(h) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

7 UNFIRED STEAM BOILERS

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 4 is hyperlinked to the description in Appendix A.

Table 4: Unfired Steam Boilers

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section I	BPVC Section VII
API RP 573	BPVC Section VIII–Division 1	API RP 584
NB-23	BPVC Section II–Materials–Part A	
API 510	BPVC Section II–Materials–Part B	
ASME PCC-3	BPVC Section II–Materials–Part C	
API RP 580	BPVC Section II–Materials–Part D	
API RP 578	BPVC Section V	
API RP 588	BPVC Section IX	
ASCE/SEI 7	BPVC Section XIII	
	API RP 578	
	ASCE/SEI 7	
	ASME PCC-1	
In-Service Inspection	**Fitness-For-Service**	**Repair**
NB-23	API 579-1/ASME FFS-1	NB-23
NB-370	API 579-2/ASME FFS-2	NB-370
API 510	EPRI CS-5208	API 510
ASME PCC-3		ASME PCC-2
API RP 580		ASME PCC-1
API RP 970		API RP 577
BPVC Section VII		API RP 578
BPVC Section V		API RP 582
ASNT CP-189		BPVC Section IX
ASNT RP SNT-TC-1A		

7.1 Specification (Purchase) of Unfired Steam Boilers

Before acquiring a new unfired steam boiler, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provisions for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 7.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API RP 573 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers and Unfired Steam Boilers for use in refining and petrochemical service.

(2) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 7.1(b)).

(3) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(4) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(5) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3 above.

(6) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(f) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. “Positive Materials Identification” (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 7.4(b)).

(2) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

7.2 Design and Construction of Unfired Steam Boilers

The ASME Boiler and Pressure Vessel Code, Section I (BPVC Section I) provides rules for construction of power boilers, including Unfired Steam Boilers. These rules are mandatory in most jurisdictions in the US and Canada, and are frequently used worldwide. Section I references many other codes and standards, a few of which are listed below. If a user requires Section I construction in a purchase document, the internal references in Section I become mandatory as well.

Unless ASME Section I is required by the local jurisdiction, BPVC Section VIII–Division 1*Rules for Construction of Pressure Vessels Division 1* may be used for construction of unfired steam boilers. Section VIII references many other codes and standards, a few of which are listed below. If a user requires Section I construction in a purchase document, the internal references in Section I become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals*

(d) BPVC Section II–Materials–Part D *Properties (Customary)*

(e) BPVC Section II–Materials–Part D *Properties (Metric)*

(f) BPVC Section V *Nondestructive Examination*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*

(h) BPVC Section XIII *Rules for Overpressure Protection*. With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in the construction code, in this case either BPVC Section I or BPVC Section VIII Division 1, as selected.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 7.4(b)).

(j) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(k) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

7.3 Operation of Unfired Steam Boilers

BPVC Section VII *Recommended Guidelines for the Care of Power Boilers*.

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

7.4 In-service Inspection of Unfired Steam Boilers

The following documents apply to the in-service inspection of Unfired Steam Boilers. They should be considered to be good engineering practices, with applicability that depends on the situation. However, in many cases, the manufacturers of unfired steam boilers have compiled the guidance of the applicable documents in an installation and operating manual (IOM).

(a) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 7.1(b).)

(b) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(e) ASME PCC-3 *Inspection of Fired Boilers and Heaters*. Although this document was written based primarily on refinery experience, it can be considered to be generally applicable. It covers process heaters as well as power (steam) boilers and unfired steam boilers.

(f) BPVC Section VII *Recommended Guidelines for the Care of Power Boilers.*

(g) API RP 970 *Corrosion Control Documents.* This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents.

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

7.5 Fitness-for-service Analysis of Unfired Steam Boilers

If damage is discovered in a pressure-retaining item, the damage should be either repaired (see paragraph 7.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions:

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) EPRI CS-5208 *Life Extension and Assessment of Fossil Power Plants (Conference Proceedings).*

7.6 Repair of Unfired Steam Boilers

If the FFS assessment (see paragraph 7.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods.

(a) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(b) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*. For the petroleum and chemical process industries, API 510 may be an alternative for equipment in this category if NB-23 is not required by the jurisdiction.

(c) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(d) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(e) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(f) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 7.4(b)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(g) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(h) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

8 TYPICAL PRESSURE VESSELS

For this Guide, typical pressure vessels include towers, drums, reactors, heat exchangers, condensers, air receivers, accumulators, etc. Heavy wall vessels [e.g., >50 mm (2 in) wall thickness] and vessels with high design pressures [e.g. > 70 MPa (10,000 psi)] and/or temperatures [e.g., > 370°C (700°F)] are covered in subsequent sections.

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 5 is hyperlinked to the description in Appendix A.

Table 5: Typical Pressure Vessels

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section VIII–Division 1	API RP 584
API 510	BPVC Section VIII–Division 2	API RP 751
NB-23	BPVC Section VIII–Division 3	
API RP 571	BPVC Section X	
API RP 572	BPVC Section II–Materials–Part A	
ASME PCC-3	BPVC Section II–Materials–Part B	
API RP 580	BPVC Section II–Materials–Part C	
API RP 581	BPVC Section II–Materials–Part D	
API RP 583	BPVC Section V	
API RP 578	BPVC Section IX	
API RP 588	BPVC Section XIII	
ASCE/SEI 7	API RP 578	
API RP 945	API RP 751	
API RP 751	ASCE/SEI 7	
API RP 939C	ASME PCC-1	
NACE MR0103/ISO 17945	ASME BPE	
NACE SP0170		
NACE SP0296		
NACE SP0472		
NACE SP0590		
In-Service Inspection	**Fitness-For-Service**	**Repair**
API 510	API 579-1/ASME FFS-1	API 510
NB-23	API 579-2/ASME FFS-2	NB-23
NB-370	API 510	NB-370
ASME PCC-3		ASME PCC-2
API RP 580		ASME PCC-1
API RP 581		API RP 572
API RP 571		API RP 577
API RP 572		API RP 578
API RP 583		API RP 582
API RP 751		API RP 583
API RP 939C		API RP 751
API RP 970		BPVC Section IX
NACE MR0103/ISO 17945		
NACE SP0170		
BPVC Section V		
ASNT CP-189		
ASNT RP SNT-TC-1A		

8.1 Specification (Purchase) of Typical Pressure Vessels

Before acquiring a new pressure vessel, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provisions for minimizing the impact of possible repairs.

Some of the steps in this consideration, and the documents that should be considered for each step are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 8.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(2) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 8.1(b)).

(3) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(4) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere.

(5) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(6) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(7) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(2) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 8.4(c)).

(3) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(4) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(5) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(6) API RP 945 *Avoiding Environmental Cracking in Amine Units*. This RP should be considered only if the equipment will be in amine service.

(7) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries-Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).

(8) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

(9) NACE SP0296 *Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H_2S Environments*. This document is applicable to carbon steel refinery equipment in wet H_2S environments and provides guidelines on the detection, repair, and mitigation of cracking.

(10) NACE SP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. This standard

should be considered only if the equipment will be in an environmental cracking service as determined by reviewing API RP 571.

(11) NACE SP0590 *Prevention, Detection, and Correction of Deaerator Cracking*. This standard should be considered only for deaerators.

8.2 Design and Construction of Typical Pressure Vessels

The ASME Boiler and Pressure Vessel Code (BPVC Section VIII–Division 1) provides rules for construction of typical pressure vessels. In many jurisdictions, this code, or an equivalent internationally recognized code of construction, is required. The requirements of the local jurisdiction should be determined. Section VIII, Division 1 references many other codes and standards, a few of which are listed in paragraph 8.5. If a user requires Section VIII construction in a purchase document, the internal references in Section VIII become mandatory as well.

The ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 2 (BPVC Section VIII–Division 2) provides alternative rules for pressure vessels. Division 2 now offers the choice to select among two vessel classes for design; Class 1 with its design-by-rules provisions in Part 4 and a Design Margin of 3.0 on the material's Ultimate Tensile Strength, or Class 2 which employs the design-by-analysis provisions of Part 5 and a Design Margin of 2.4 (which is the historical Division 2 approach). The rules for design analysis in Division 2 Class 2 are typically more complex and detailed than in Division 2 Class 1 or Division 1 and may be more costly to implement. In addition, examination and testing requirements are more stringent. For design by analysis, the maximum design temperature is limited to values that result in allowable stresses that are not based on time dependent (creep) values. However, many components can be designed using the rules without the need for design by analysis. In that case, the maximum temperature limits are the same as in Division 1. Both classes of Division 2 offer lower design margins, which can result in weight and cost savings in fabrication. Division 2 Class 2 can be selected for construction of most typical pressure vessels at the option of the owner/user, but it is used primarily for large vessels or those made from expensive alloys where the savings in fabrication cost are greater than the increase in design/analysis costs.

The ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 3 (BPVC Section VIII–Division 3) provides alternative rules for high pressure vessels. The rules for design analysis in Division 3 are more complex and detailed than in Divisions 1 and 2, particularly for fatigue (cyclic service) analysis. In addition, examination and impact testing requirements are more stringent. The maximum design temperature is limited to values that result in allowable stresses that are not based on time dependent (creep) values. However, Division 3 offers lower design margins than Division 2 in some cases, which can result in weight and cost savings in fabrication. Division 3 also has rules for low temperature hydrogen service and for steel wire and composite fiber reinforced plastic (FRP), hoop wrapped pressure vessels. Division 3 can be selected for construction of most typical pressure vessels at the option of the owner/user, but it is used primarily for large, relatively high pressure vessels, or those made from expensive alloys where the savings in fabrication cost are greater than the increase in design/analysis costs.

The ASME Boiler and Pressure Vessel Code (BPVC) Section X (BPVC Section X) provides rules for fiber reinforced plastic pressure vessels, except that rules for hoop wrapped FRP vessels are covered in Section VIII, Division 3.

The Section VIII Codes reference many other codes and standards, a few of which are listed below. If a user requires Section VIII construction in a purchase document, the internal references in the Section VIII Codes become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications.*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications.*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals.*

(d) BPVC Section II–Materials–Part D *Properties (Customary).*

(e) BPVC Section II–Materials–Part D *Properties (Metric).*

(f) BPVC Section V *Nondestructive Examination.*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in BPVC Section VIII Division 1.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 8.4(c)).

(j) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry. For vessels in this service, the document should be reviewed for details to incorporate into the vessel design/construction.

(k) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(l) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(m) ASME BPE provides rules for bioprocessing equipment, primarily related to cleanability requirements.

8.3 Operation of Typical Pressure Vessels

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

8.4 In-service Inspection of Typical Pressure Vessels

The following documents apply to the in-service inspection of typical pressure vessels. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(b) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 8.1(b)).

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(e) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of

implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(g) API RP 572 *Inspection Practices for Pressure Vessels*.

(h) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(i) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(j) API RP 939C *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*. This RP should be considered only if the equipment is subject to sulfidation corrosion.

(k) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

(l) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries-Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).

(m) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination.*

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.*

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

8.5 Fitness-for-service Analysis of Typical Pressure Vessels

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 8.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions:

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

8.6 Repair of Typical Pressure Vessels

If the FFS assessment (see paragraph 8.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods:

(a) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(b) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(c) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(d) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(e) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere. This document includes a section on methods of repair.

(f) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(g) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 8.4(c)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(h) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(i) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(j) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry. When repairing vessels in HF alkylation units, the document should be reviewed for relevant repair details.

(k) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

9 LARGE, HEAVY WALL AND HIGH TEMPERATURE PRESSURE VESSELS

For this Guide, large, heavy wall vessels include those exceeding 50 mm (2 in.) wall thickness, and high temperature vessels include those exceeding 370°C (700°F) design temperature.

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 6 is hyperlinked to the description in Appendix A.

Table 6: Large, Heavy Wall and High Temperature Pressure Vessels

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section VIII–Division 1	API RP 584
API 510	BPVC Section VIII–Division 2	API TR 934G
NB-23	BPVC Section VIII–Division 3	API RP 941
API RP 572	BPVC Section X	
ASME PCC-3	BPVC Section II–Materials–Part A	
API RP 581	BPVC Section II–Materials–Part B	
API RP 578	BPVC Section II–Materials–Part C	
API RP 588	BPVC Section II–Materials–Part D	
API RP 932-B	BPVC Section V	
API RP 934A	BPVC Section IX	
API TR 934G	BPVC Section XIII	
API RP 941	API RP 578	
ASCE/SEI 7	ASCE/SEI 7	
API RP 945	ASME PCC-1	
NACE MR0103/ISO 17945	API RP 932-B	
NACE SP0170	API RP 934A	
NACE SP0296	API RP 934C	
NACE SP0472	API RP 934E	
NACE SP0590	API TR 934G	
	API RP 941	

In-Service Inspection	Fitness-For-Service	Repair
API 510	API 579-1/ASME FFS-1	API 510
NB-23	API 579-2/ASME FFS-2	NB-23
NB-370	API 510	NB-370
ASME PCC-3	API TR 934G	ASME PCC-2
API RP 580		ASME PCC-1
API RP 581		API RP 572
API RP 571		API RP 577
API RP 572		API RP 578

In-Service Inspection	Fitness-For-Service	Repair
API RP 932-B		API RP 582
API TR 934G		API TR 934G
API RP 941		BPVC Section IX
API RP 970		NACE SP0472
NACE MR0103/ISO 17945		
NACE SP0170		
BPVC Section V		
ASNT CP-189		
ASNT RP SNT-TC-1A		

9.1 Specification (Purchase) of Large, Heavy Wall and High Temperature Pressure Vessels

Before acquiring a new pressure vessel, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 9.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(2) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 9.1(b)).

(3) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere.

(4) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(5) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(6) API RP 581 Risk-Based Inspection Methodology. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 9.4(c)).

(2) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(3) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

(4) API RP 934A *Materials and Fabrication of 2 ¼ Cr - 1 Mo, 2 ¼ Cr - 1 Mo - ¼ V, 3 Cr - 1 Mo, And 3 Cr - 1 Mo - ¼ V Steel Heavy Wall Pressure Vessels for High-temperature, High-pressure Hydrogen Service*.

(5) API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*. This document is specific to coke drums and peripheral components in delayed coking units. This class of equipment is exposed to significant temperature cycling and the document covers practices that can assist in managing the effects.

(6) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(7) API RP 941 *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*.

(8) API RP 945 *Avoiding Environmental Cracking in Amine Units*. This RP should be considered only if the equipment will be in amine service.

(9) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries-Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).

(10) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

(11) NACE SP0296 *Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H_2S Environments*. This document is applicable to carbon steel refinery equipment in wet H_2S environments and provides guidelines on the detection, repair, and mitigation of cracking.

(12) NACE SP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. This standard

should be considered only if the equipment will be in an environmental cracking service as determined by reviewing API RP 571.

(13) NACE SP0590 *Prevention, Detection, and Correction of Deaerator Cracking*. This standard should be considered only for deaerators.

9.2 Design and Construction of Large, Heavy Wall and High Temperature Pressure Vessels

Large, heavy wall or high temperature pressure vessels should be purchased to the same general requirements as the typical pressure vessels described in paragraph 9.6(f), but with some additional considerations and documents as applicable. This section includes the applicable documents from paragraph 9.6(f), as well as the additional documents that should be considered. The ASME Boiler and Pressure Vessel Code (BPVC Section VIII–Division 1) provides rules for construction of heavy wall pressure vessels, but Section VIII, Division 2 (BPVC Section VIII–Division 2) is generally preferred for this application (see the following paragraph for discussion regarding Division 2 Class 1 and Class 2 vessels). Section VIII, Division 2 Class 1 or Class 2 can also be used for some high temperature vessels, but most high temperature vessels are constructed to Section VIII, Division 1. In many jurisdictions, one of these codes, or an equivalent internationally recognized code of construction, is required. The requirements of the local jurisdiction should be determined. The Section VIII Codes reference many other codes and standards, a few of which are listed in paragraph 9.5. If a user requires Section VIII construction in a purchase document, the internal references in Section VIII become mandatory as well.

The ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 2 (BPVC Section VIII–Division 2) provides alternative rules for pressure vessels. Division 2 now offers the choice to select among two vessel classes for design; Class 1 with its design-by-rules provisions in Part 4 and a Design Margin of 3.0 on the material's Ultimate Tensile Strength, or Class 2 which employs the design-by-analysis provisions of Part 5 and a Design Margin of 2.4 (which is the historical Division 2 approach). The rules for design analysis in Division 2 Class 2 are typically more complex and detailed than in Division 2 Class 1 or Division 1 and may be more costly to implement. In addition, examination and testing requirements are more stringent. For design by analysis, the maximum design temperature is limited to values that result in allowable stresses that are not based on time dependent (creep) values. However, many components can be designed using the rules without the need for design by analysis. In that case, the maximum temperature limits are the same as in Division 1. Both classes of Division 2 offer lower design margins, which can result in weight and cost savings in fabrication. Division 2 Class 2 can be selected for construction of most typical pressure vessels at the option of the owner/user, but it is used primarily for large vessels or those made from expensive alloys where the savings in fabrication cost are greater than the increase in design/analysis costs.

The ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 3 (BPVC Section VIII–Division 3) provides alternative rules for high pressure vessels. The rules for design analysis in Division 3 are more complex and detailed than in Divisions 1 and 2, particularly for fatigue (cyclic service) analysis. In addition, examination and impact testing requirements are more stringent. The maximum design temperature is limited to values that result in allowable stresses that are not based on time dependent (creep) values. However, Division 3 offers lower design margins than Division 2 in some cases, which can result in weight and cost savings in fabrication. Division 3 also has rules for low temperature hydrogen service and for steel wire and composite fiber reinforced plastic (FRP), hoop wrapped pressure vessels. Division 3 can be selected for construction of most pressure vessels at the option of the owner/user, but it is used primarily for large, relatively high pressure vessels, or those made from expensive alloys where the savings in fabrication cost are greater than the increase in design/analysis costs.

The Section VIII Codes reference many other codes and standards, a few of which are listed below. If a user requires Section VIII construction in a purchase document, the internal references in the Section VIII Codes become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications.*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications.*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals.*

(d) BPVC Section II–Materials–Part D *Properties (Customary).*

(e) BPVC Section II–Materials–Part D *Properties (Metric).*

(f) BPVC Section V *Nondestructive Examination.*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in BPVC Section VIII Division 2.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 9.1(e)(4)).

(j) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(k) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(l) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

(m) API RP 934A *Materials and Fabrication of 2 ¼ Cr - 1 Mo, 2 ¼ Cr - 1 Mo - ¼ V, 3 Cr - 1 Mo, And 3 Cr - 1 Mo - ¼ V Steel Heavy Wall Pressure Vessels for High-temperature, High-pressure Hydrogen Service*.

(n) API RP 934C *Materials and Fabrication of 1 ¼ Cr - ½ Mo Steel Heavy Wall Pressure Vessels for High-pressure Hydrogen Service Operating at or Below 825 Degrees F (440 Degrees C).*

(o) API RP 934E *RP for Materials and Fabrication of 1¼Cr-½Mo and 1Cr-½Mo Steel Pressure Vessels for Service above 825°F (440°C).* This document has not been published as of this writing.

(p) API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*. This document is specific to coke drums and peripheral components in delayed coking units. This class of equipment is exposed to significant temperature cycling and the document covers practices that can assist in managing the effects.

(q) API RP 941 *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants.*

9.3 Operation of Large, Heavy Wall and High Temperature Pressure Vessels

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*. This document is specific to coke drums and peripheral components in delayed coking units. This class of equipment is exposed to significant temperature cycling and the document covers practices that can assist in managing the effects.

API RP 941 *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*.

9.4 In-service Inspection of Large, Heavy Wall and High Temperature Pressure Vessels

The following documents apply to the in-service inspection of large, heavy wall and high temperature pressure vessels. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(b) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 9.1(b)).

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(e) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(g) API RP 572 *Inspection Practices for Pressure Vessels*.

(h) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

(i) API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*. This document is specific to coke drums and peripheral components in delayed coking units. This class of equipment is exposed to significant temperature cycling and the document covers practices that can assist in managing the effects.

(j) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

(k) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries-Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).

(l) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination.*

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.*

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

9.5 Fitness-for-service Analysis of Large, Heavy Wall and High Temperature Pressure Vessels

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 9.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions.

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(d) API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*. This document is specific to coke drums

and peripheral components in delayed coking units. This class of equipment is exposed to significant temperature cycling and the document covers practices that can assist in managing the effects.

9.6 Repair of Large, Heavy Wall and High Temperature Pressure Vessels

If the FFS assessment (see paragraph 9.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods.

(a) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(b) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(c) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(d) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(e) API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*. This document is specific to coke drums and peripheral components in delayed coking units. This class of equipment is exposed to significant temperature cycling and the document covers practices that can assist in managing the effects.

(f) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere. This document includes a section on methods of repair.

(g) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(h) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. “Positive Materials Identification” (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 9.4(c)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(i) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(j) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

(k) NACE SP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. This standard should be considered only if the equipment will be in an environmental cracking service as determined by reviewing API RP 571.

10 HIGH PRESSURE VESSELS

For this Guide, high pressure vessels include those exceeding 70 MPa (10 ksi) design pressure.

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 7 is hyperlinked to the description in Appendix A.

Table 7: High Pressure Vessels

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section VIII–Division 3	API RP 584
API 510	BPVC Section II–Materials–Part A	
NB-23	BPVC Section II–Materials–Part B	
API RP 572	BPVC Section II–Materials–Part C	
ASME PCC-3	BPVC Section II–Materials–Part D	
API RP 580	BPVC Section V	
API RP 581	BPVC Section IX	
API RP 588	BPVC Section XIII	
API RP 578	API RP 578	
ASCE/SEI 7	ASCE/SEI 7	
	ASME PCC-1	
	API RP 934A	
	API RP 941	
In-Service Inspection	**Fitness-For-Service**	**Repair**
NB-23	API 579-1/ASME FFS-1	NB-23
NB-370	API 579-2/ASME FFS-2	NB-370
ASME PCC-3		ASME PCC-2
API RP 580		ASME PCC-1
API RP 581		API RP 572
API RP 572		API RP 577
API RP 970		API RP 578
BPVC Section V		API RP 582
ASNT CP-189		BPVC Section IX
ASNT RP SNT-TC-1A		

10.1 Specification (Purchase) of High Pressure Vessels

Before acquiring a new high pressure vessel, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 10.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 10.1(b)).

(2) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere.

(3) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(4) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(5) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(6) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(f) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that

PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 10.4(b)).

(2) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

10.2 Design and Construction of High Pressure Vessels

High pressure vessels should be purchased to the requirements of BPVC Section VIII–Division 1 because it was written specifically to cover high pressure applications. The requirements of the local jurisdiction should be determined. The Section VIII Codes reference many other codes and standards, a few of which are listed below. If a user requires Section VIII construction in a purchase document, the internal references in Section VIII become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications.*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications.*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals.*

(d) BPVC Section II–Materials–Part D *Properties (Customary).*

(e) BPVC Section II–Materials–Part D *Properties (Metric).*

(f) BPVC Section V *Nondestructive Examination.*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in BPVC Section VIII Division 3.

(i) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 10.1(e)(3)).

(j) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(k) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(l) API RP 941 *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants.*

10.3 Operation of High Pressure Vessels

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

10.4 In-service Inspection of High Pressure Vessels

The following documents apply to the in-service inspection of high pressure vessels. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 10.1(b)).

(b) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document.

(c) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3, above.

(d) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(e) API RP 572 *Inspection Practices for Pressure Vessels*.

(f) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents.

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

10.5 Fitness-for-service Analysis of High Pressure Vessels

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 10.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. However, some of the fitness-for-service analysis rules in API 579-1/ASME FFS-1 do not extend to very heavy wall construction. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions:

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

10.6 Repair of High Pressure Vessels

If the FFS assessment (see paragraph 10.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods. However, note that welding is prohibited on some of the materials used in high pressure vessels, so many of the rules in ASME PCC-2 and other repair documents do not apply.

(a) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(b) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(c) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(d) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(e) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. “Positive Materials Identification” (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 10.4(b)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(f) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

11 HEAT EXCHANGERS

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 8 is hyperlinked to the description in Appendix A.

Table 8: Heat Exchangers

Specification/Purchase	Design/Construction	Operation
NB-370	BPVC Section VIII–Division 1	API RP 584
API 510	BPVC Section VIII–Division 2	TEMA Standards
NB-23	BPVC Section VIII–Division 3	
API RP 572	BPVC Section II–Materials–Part A	
ASME PCC-3	BPVC Section II–Materials–Part B	
API RP 580	BPVC Section II–Materials–Part C	
API RP 581	BPVC Section II–Materials–Part D	
API RP 578	BPVC Section V	
API RP 583	BPVC Section IX	
API RP 588	API Std 660	
ASCE/SEI 7	API Std 661	
API RP 571	API Std 662, Part 1	
API Std 660	API Std 663	
API Std 661	API Std 664	
API Std 662, Part I	API Std 668	
API Std 663	TEMA Standards	
API Std 664	API RP 578	
API Std 668	API RP 751	
TEMA Standards	ASCE/SEI 7	
API RP 945	ASME PCC-1	
API RP 751		
API RP 932-B		
API RP 939C		
NACE MR0103/ISO 17945		
NACE SP0170		
NACE SP0296		
NACE SP0472		

In-Service Inspection	Fitness-For-Service	Repair
API 510	API 579-1/ASME FFS-1	API 510
NB-23	API 579-2/ASME FFS-2	NB-23
NB-370	API 510	NB-370
ASME PCC-3		ASME PCC-2
API RP 580		API RP 583
API RP 581		ASME PCC-1
API RP 583		API RP 572
API RP 571		API RP 577
API RP 572		API RP 578
API RP 751		API RP 582
API RP 932-B		API RP 751
API RP 939C		TEMA Standards
API RP 970		BPVC Section IX
TEMA Standards		
NACE MR0103/ISO 17945		
NACE SP0170		
BPVC Section V		
ASNT CP-189		
ASNT RP SNT-TC-1A		

11.1 Specification (Purchase) of Heat Exchangers

Before acquiring a new heat exchanger, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the equipment, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 11.2.

(b) Determine legally mandated new construction and in-service inspection requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(c) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(d) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(e) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(2) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in many jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 11.1(b)).

(3) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere.

(4) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document.

(5) API RP 580 Risk-based Inspection is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(6) API RP 581 Risk-Based Inspection Methodology. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 11.4(c)).

(2) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(3) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(4) API Std 660 *Shell-and-Tube Heat Exchangers*.

(5) API Std 661 *Petroleum, Petrochemical, and Natural Gas Industries – Air-cooled Heat Exchangers.*

(6) API Std 662, Part 1 *Plate Heat Exchangers for General Refinery Services – Part 1 – Plate-and-Frame Heat Exchangers.*

(7) API Std 663 *Hairpin-type Heat Exchangers.*

(8) API Std 664 *Spiral Plate Heat Exchangers.*

(9) API Std 668 *Brazed Aluminum Plate-fin Heat Exchangers.*

(10) *Standards of the Tubular Exchanger Manufacturers Association (TEMA)*.
(11) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.
(12) API RP 945 *Avoiding Environmental Cracking in Amine Units*. This RP should be considered only if the equipment will be in amine service.
(13) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.
(14) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.
(15) API RP 939C *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*. This RP should be considered only if the equipment is subject to sulfidation corrosion.
(16) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries–Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).
(17) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.
(18) NACE SP0296 *Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H_2S Environments*. This document is applicable to carbon steel refinery equipment in wet H_2S environments and provides guidelines on the detection, repair, and mitigation of cracking.
(19) NACE SP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. This standard should be considered only if the equipment will be in an environmental cracking service as determined by reviewing API RP 571.

11.2 Design and Construction of Heat Exchangers

There are many types of heat exchangers, condensers, etc. The ASME Boiler and Pressure Vessel Code (BPVC Section VIII–Division 1) provides rules for construction of typical heat exchangers. In many jurisdictions, this code, or an equivalent internationally recognized code of construction, is required. In addition, there are API documents that cover many specific types of heat exchangers, as described below. The requirements of the local jurisdiction should be determined. Section VIII, Division 1 references many other codes and standards. If a user requires Section VIII construction in a purchase document, the internal references in Section VIII become mandatory as well.

The ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 2 (BPVC Section VIII–Division 2) provides alternative rules for pressure vessels. Division 2 now offers the choice to select among two vessel classes for design; Class 1 with its design-by-rules provisions in Part 4 and a Design Margin of 3.0 on the material's Ultimate Tensile Strength, or Class 2 which employs the design-by-analysis provisions of Part 5 and a Design Margin of 2.4 (which is the historical Division 2 approach). The rules for design analysis in Division 2 Class 2 are typically more complex and detailed than in Division 2 Class 1 or Division

1 and may be more costly to implement. In addition, examination and testing requirements are more stringent. For design by analysis, the maximum design temperature is limited to values that result in allowable stresses that are not based on time dependent (creep) values. However, many components can be designed using the rules without the need for design by analysis. In that case, the maximum temperature limits are the same as in Division 1. Both classes of Division 2 offer lower design margins, which can result in weight and cost savings in fabrication. Division 2 Class 2 can be selected for construction of most typical pressure vessels at the option of the owner/user, but it is used primarily for large vessels or those made from expensive alloys where the savings in fabrication cost are greater than the increase in design/analysis costs.

The ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 3 (BPVC Section VIII–Division 3) provides alternative rules for high pressure vessels and heat exchangers, but the majority of heat exchangers are constructed to Division 1. The rules for design analysis in Division 3 are more complex and detailed than in Divisions 1 and 2, particularly for fatigue (cyclic service) analysis. In addition, examination and impact testing requirements are more stringent. The maximum design temperature is limited to values that result in allowable stresses that are not based on time dependent (creep) values. However, Division 3 offers lower design margins than Division 2 in some cases, which can result in weight and cost savings in fabrication. Division 3 also has rules for low temperature hydrogen service and for steel wire and composite fiber reinforced plastic (FRP), hoop wrapped pressure vessels. Division 3 can be selected for construction of most typical pressure vessels at the option of the owner/user, but it is used primarily for large, relatively high pressure vessels, or those made from expensive alloys where the savings in fabrication cost are greater than the increase in design/analysis costs.

The Section VIII Codes reference many other codes and standards, a few of which are listed below. If a user requires Section VIII construction in a purchase document, the internal references in the Section VIII Codes become mandatory as well.

(a) BPVC Section II–Materials–Part A *Ferrous Material Specifications.*

(b) BPVC Section II–Materials–Part B *Nonferrous Material Specifications.*

(c) BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals.*

(d) BPVC Section II–Materials–Part D *Properties (Customary).*

(e) BPVC Section II–Materials–Part D *Properties (Metric).*

(f) BPVC Section V *Nondestructive Examination.*

(g) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

(h) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in BPVC Section VIII Divisions 1, 2, or 3 as applicable.

(i) API Std 660 *Shell-and-Tube Heat Exchangers*.

(j) API Std 661 *Petroleum, Petrochemical, and Natural Gas Industries–Air-cooled Heat Exchangers.*

(k) API Std 662, Part I *Plate Heat Exchangers for General Refinery Services–Part 1–Plate-and-Frame Heat Exchangers.*

(l) API Std 663 *Hairpin-type Heat Exchangers.*

(m) API Std 664 *Spiral Plate Heat Exchangers.*

(n) API Std 668 *Brazed Aluminum Plate-fin Heat Exchangers.*

(o) Standards of the Tubular Exchanger Manufacturers Association (TEMA).

(p) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of

another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 11.4(c)).

(q) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(r) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(s) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

11.3 Operation of Heat Exchangers

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

Standards of the Tubular Exchanger Manufacturers Association (TEMA)

11.4 In-service Inspection of Heat Exchangers

The following documents apply to the in-service inspection of heat exchangers. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(b) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 11.1(b)).

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(e) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(g) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions

in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(h) API RP 572 *Inspection Practices for Pressure Vessels*.

(i) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(j) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

(k) API RP 939C *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*. This RP should be considered only if the equipment is subject to sulfidation corrosion.

(l) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

(m) Standards of the Tubular Exchanger Manufacturers Association (TEMA).

(n) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries – Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).

(o) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*. This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents.

(a) BPVC Section V *Nondestructive Examination.*

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.*

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

11.5 Fitness-for-service Analysis of Heat Exchangers

If damage is discovered in a pressure retaining item, the damage should be either repaired (see paragraph 11.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions:

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

11.6 Repair of Heat Exchangers

If the FFS assessment (see paragraph 11.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods:

(d) API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration* for pressure vessels in the petroleum and chemical process industries.

(e) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(f) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(g) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(h) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(i) API RP 572 *Inspection Practices for Pressure Vessels*. Written for the petroleum and chemical process industries, but can be applied elsewhere. This document includes a section on methods of repair.

(j) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(k) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 11.4(c)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(l) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(m) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(n) Standards of the Tubular Exchanger Manufacturers Association (TEMA).

(o) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

12 STORAGE TANKS

For this Guide, the types of storage tanks that are included are listed in paragraph 12.2.

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 9 is hyperlinked to the description in Appendix A.

Table 9: Storage Tanks

Specification/Purchase	Design/Construction	Operation
API Publication 327	API Std 650	API RP 584
API Std 653	API RP 651	API RP 651
API RP 575	API Std 2000	
ASME PCC-3	API RP 652	
API RP 580	API Std 653	
API RP 581	API Std 620	
API RP 583	ASME RTP-1	
API RP 578	BPVC Section V	
API Std 2350	BPVC Section IX	
ASCE/SEI 7	API RP 578	
API RP 945	ASCE/SEI 7	
NACE SP0472	ASME PCC-1	
API RP 571		
In-Service Inspection	**Fitness-For-Service**	**Repair**
API Std 653	API 579-1/ASME FFS-1	API Std 653
API RP 575	API 579-2/ASME FFS-2	API RP 575
ASME PCC-3	API Std 653	API RP 583
API RP 580		ASME PCC-2
API RP 581		ASME PCC-1
API RP 571		API RP 577
API RP 583		API RP 578
API RP 970		API RP 582
BPVC Section V		BPVC Section IX
ASNT CP-189		
ASNT RP SNT-TC-1A		

12.1 Specification (Purchase) of Storage Tanks

Before acquiring a new storage tank, it is important for the equipment owner/user to consider the life cycle cost and integrity requirements for the tank, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 12.2.

(b) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of storage tanks.

(c) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in pressure equipment using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API Publication 327 *Aboveground Storage Tank Standards: A Tutorial.*

(2) API Std 653 *Tank Inspection, Repair, Alteration, and Reconstruction*. Although this standard was developed primarily for the petroleum and chemical process industries, it is widely used in other industries.

(3) API RP 575 *Inspection Practices for Atmospheric and Low pressure Storage Tanks.*

(4) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(5) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(6) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(7) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(d) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 12.4(c)).

(2) API Std 2350 *Overfill Protection for Storage Tanks in Petroleum Facilities*. This document applies to atmospheric storage tanks associated with refining, marketing, pipeline, and terminals that contain NFPA Class I or Class II liquids and assists owner/operators and operating personnel in the prevention of tank overfilling by implementation of a comprehensive overfill prevention system.

(3) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(4) API RP 945 *Avoiding Environmental Cracking in Amine Units*. This recommended practice should be considered only if the equipment will be in amine service.

(5) NACE SP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. This standard should be considered only if the equipment will be in an environmental cracking service as determined by reviewing API RP 571.

12.2 Design and Construction of Storage Tanks

Storage tanks in many industries are purchased in accordance with the requirements of API standards:

(a) API Std 650 *Welded Tanks for Oil Storage*. This standard covers tanks that are essentially at atmospheric pressure.

(b) API RP 651 *Cathodic Protection of Aboveground Petroleum Storage Tanks.*

(c) API Std 2000 *Venting Atmospheric and Low-pressure Storage Tanks.*

(d) API RP 652 *Linings of Aboveground Petroleum Storage Tank Bottoms*.

(e) API Std 653 *Tank Inspection, Repair, Alteration, and Reconstruction*. Although this standard was developed primarily for the petroleum and chemical process industries, it is widely used in other industries.

(f) API Std 620 *Design and Construction of Large, Welded, Low-pressure Storage Tanks*. This standard covers tanks that have design pressures up to 1 bar (15 psig), with design temperatures up to 120°C (250°F).

(g) ASME RTP-1 *Reinforced Thermoset Plastic Corrosion-Resistant Equipment*. This standard covers pressure vessels with internal pressures up to 15 psig. However, it is listed in the storage tank section of this document because equipment constructed to this standard is used primarily for atmospheric or low pressure storage.

In addition, the following documents are referenced or should be considered for storage tank construction:

(a) BPVC Section V *Nondestructive Examination*.

(b) BPVC Section IX *Welding, Brazing, and Fusing Qualifications.*

(c) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. “Positive Materials Identification” (PMI) is one way to minimize these failures. Although API RP 578 is targeted toward piping systems, the principles can be used for other alloy equipment. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 12.1(c)(4)).

(d) ASCE/SEI 7 *Minimum Design Loads for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(e) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

12.3 Operation of Storage Tanks

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

API RP 651 *Cathodic Protection of Aboveground Petroleum Storage Tanks.*

12.4 In-service Inspection of Storage Tanks

The following documents apply to the in-service inspection of storage tanks. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) API Std 653 *Tank Inspection, Repair, Alteration, and Reconstruction*. Although this standard was developed primarily for the petroleum and chemical process industries, it is widely used in other industries.

(b) API RP 575 *Inspection Practices for Atmospheric and Low pressure Storage Tanks.*

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(e) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(g) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(h) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(i) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

In implementing an in-service inspection plan, various non-destructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

12.5 Fitness-for-service Analysis of Storage Tanks

If damage is discovered in a storage tank, the damage should be either repaired (see paragraph 12.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions.

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following documents can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

(c) API Std 653 *Tank Inspection, Repair, Alteration, and Reconstruction* for storage tanks. Although this standard was developed primarily for the petroleum and chemical process industries, it is widely used in other industries.

12.6 Repair of Storage Tanks

If the FFS assessment (see paragraph 12.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods:

(a) API Std 653 *Tank Inspection, Repair, Alteration, and Reconstruction*. Although this standard was developed primarily for the petroleum and chemical process industries, it is widely used in other industries.

(b) API RP 575 *Inspection Practices for Atmospheric and Low pressure Storage Tanks.*

(c) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(d) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(e) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(f) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(g) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection

(see 12.4(c)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(h) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(i) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

13 PIPING SYSTEMS

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 10 is hyperlinked to the description in Appendix A.

Table 10: Piping Systems

Specification/Purchase	Design/Construction	Operation
API 570	ASME B31.1	API RP 584
API RP 574	ASME B31.3	
ASME PCC-3	ASME B31.5	
API RP 580	ASME B31.9	
API RP 581	ASME B31.12	
API RP 2611	ASME B31E	
API RP 578	ASME B31J	
API RP 583	ASME B31P	
API RP 588	ASME B31T	
API Std 598	API RP 686	
API RP 571	API RP 751	
API RP 751	API RP 932-B	
API RP 932-B	BPVC Section V	
API RP 939C	BPVC Section IX	
ASCE/SEI 7	ASME B16.5	
NACE MR0103/ISO 17945	ASME B16.47	
NACE SP0170	API RP 578	
NACE SP0296	ASCE/SEI 7	
NACE SP0472	ASME PCC-1	
ASME B16.5	API Std 1104	
ASME B16.47	ASME NM.1	
ASME B36.10M	ASME NM.2	
ASME B36.19M	ASME NM.3.1	
	ASME NM.3.2	
	ASME NM.3.3	

In-Service Inspection	Fitness-For-Service	Repair
API 570	API 579-1/ASME FFS-1	API 570
API RP 574	API 579-2/ASME FFS-2	ASME PCC-2
ASME PCC-3		API RP 583
API RP 580		API RP 751
API RP 581		ASME PCC-1
In-Service Inspection	Fitness-For-Service	Repair
API RP 2611		API RP 577
API RP 571		API RP 621
API RP 583		API RP 2201
API RP 751		API RP 2611
API RP 932-B		API RP 578
API RP 939C		API RP 582
API RP 970		BPVC Section IX
API Std 598		
BPVC Section V		
ASNT CP-189		
ASNT RP SNT-TC-1A		

13.1 Specification (Purchase) of Piping Systems

Before acquiring a new piping system, it is important for the equipment owner/user to consider the life cycle cost and pressure integrity requirements for the system, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step are:

(a) Determine which design and construction codes will be specified. These are described in paragraph 13.2.

(b) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of piping systems. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(c) Determine the methods and frequency of in-service inspection that will be needed to ensure equipment integrity. Post-construction (in-service) documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs. Note that some post-construction codes provide for the evaluation of damage in piping systems using methods and acceptance criteria that are not permitted by the new construction codes. This is consistent with the intent of many new construction codes to provide a margin for deterioration in service. Therefore, it is not necessary to satisfy all of the new construction rules after the equipment has been placed in service.

(1) API 570 *Piping Inspection Code: In-service Inspection, Rating,-Repair, and Alteration of Piping Systems* for piping in the petroleum and chemical process industries. However, the scope states that it may be used in other industries where practical.

(2) API RP 574 *Inspection Practices for Piping System Components*.

(3) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(4) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(5) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(6) API RP 2611 *Terminal Piping Inspection—Inspection of In-Service Terminal Piping Systems*. This document covers the inspection and repair of typical terminal piping systems within terminal boundaries, which includes off-plot piping. It aligns current terminal piping inspection practices with the appropriate and applicable elements of API 570.

(d) Determine if there are additional documents that should be referenced in the purchase specification. For example:

(1) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 13.4(c)).

(2) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(3) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(4) API Std 598 *Valve Inspection and Testing.*

(5) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(6) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(7) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems.* Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

(8) API RP 939C *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*. This RP should be considered only if the equipment is subject to sulfidation corrosion.

(9) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(10) NACE MR0103/ISO 17945 *Petroleum, petrochemical and natural gas industries – Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*. This document is applicable for equipment in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. Such environments are susceptible to sulfide stress cracking (SSC).

(11) NACE SP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment.* This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment.

(12) NACE SP0296 *Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H_2S Environments*. This document is applicable to carbon steel refinery equipment in wet H_2S environments and provides guidelines on the detection, repair, and mitigation of cracking.

(13) NACE SP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. This standard should be considered only if the equipment will be in an environmental cracking service as determined by reviewing API RP 571.

(14) ASME B16.5 *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*. This standard provides standard dimensions for flanges and flanged fittings up to NPS 24 and pressure-temperature ratings from Class 150 through Class 2500.

(15) ASME B16.47 *Large Diameter Steel Flanges (NPS 26 through NPS 60 Metric/Inch Standard)*. This standard provides standard dimensions for flanges in sizes from NPS 26 through NPS 60 and pressure-temperature ratings from Class 75 through Class 900.

(16) ASME B36.10M *Welded and Seamless Wrought Steel Pipe*. This standard provides standard dimensions for pipe NPS 12 and smaller.

(17) ASME B36.19M *Stainless Steel Pipe*. This standard provides standard dimensions for stainless steel pipe.

13.2 Design and Construction of Piping Systems

The codes and standards for new construction of piping systems are organized by the industry or application in which they will be used, as described below. Note that piping components and fittings are covered in paragraph 14.

(a) ASME B31.1 *Power Piping*. This standard covers piping in electric power generating stations, industrial and institutional plants (except as covered by B31.3), geothermal heating systems and central and district heating and cooling systems.

(b) ASME B31.3 *Process Piping*. This standard covers piping in petroleum refineries and chemical, pharmaceutical, textile, paper, semiconductor, cryogenic and related processing plants and terminals.

(c) ASME B31.5 *Refrigeration Piping*. This standard covers piping for refrigerants and secondary coolants.

(d) ASME B31.9 *Building Services Piping*. This standard covers piping in industrial, institutional, commercial, and public buildings and in multi-unit residences, which do not require the range of sizes, pressures and temperatures covered in B31.1.

(e) ASME B31.12 *Hydrogen Piping and Pipelines*. This document is applicable to piping in gaseous and liquid hydrogen service and to pipelines in gaseous hydrogen service.

(f) ASME B31E *Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems.*

(g) ASME B31J *Stress Intensification Factors (i-Factors), Flexibility Factors (k-Factors), and Their Determination for Metallic Piping Components*. This document provides a standardized method to develop the stress intensification factors (i-factors), flexibility factors (k-factors), and sustained stress factors used in ASME B31 piping analysis. It is primarily a tool for piping designers.

(h) ASME B31P *Standard Heat Treatments for Fabrication Processes*. This document is intended to provide requirements for preheating and PWHT when mandated by the applicable piping code section or by the engineering design being used.

(i) ASME B31T *Standard Toughness Requirements for Piping*. This document provides guidance for evaluating the suitability of materials used in piping systems for piping that may be subject to brittle failure due to low-temperature service conditions.

The piping codes reference many other codes and standards, a few of which are listed below.

(a) BPVC Section V *Nondestructive Examination*.

(b) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

(c) ASME B16.5 *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*. This standard provides standard dimensions for flanges and flanged fittings up to NPS 24 and pressure-temperature ratings from Class 150 through Class 2500.

(d) ASME B16.47 *Large Diameter Steel Flanges (NPS 26 through NPS 60 Metric/Inch Standard)*. This standard provides standard dimensions for flanges in sizes from NPS 26 through NPS 60 and pressure-temperature ratings from Class 75 through Class 900.

Other standards that should be considered for construction include:

(a) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. "Positive Materials Identification" (PMI) is one way to minimize these failures. API RP 578 should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 13.4(c)).

(b) ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. This document is used primarily by manufacturers and designers of pressure equipment to determine the magnitude of earthquake and wind loads.

(c) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(d) API Std 1104 *Welding of Pipelines and Related Facilities*. Although 1104 was developed for pipelines, it can be used for large diameter or critical piping in process units.

(e) API RP 686 *Recommended Practice for Machinery Installation and Installation Design–Chapter 6–Piping*. Chapter 6 of this document provides guidelines (including a checklist) for the installation and pre-installation design of piping that is connected to machinery. While written for petroleum and chemical processing facilities, it may be consulted as a resource for machinery in other industries.

(f) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(g) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

Standards that should be considered for construction of nonmetallic piping include:

(a) ASME NM.1 *Thermoplastic Piping Systems*. This standard prescribes requirements for the design, materials, fabrication, erection, examination, testing, and inspection of thermoplastic piping systems.

(b) ASME NM.2 *Glass-Fiber-Reinforced Thermosetting-Resin Piping Systems*. This standard provides requirements for the design, materials, manufacture, fabrication, installation, examination, and testing of glass-fiber-reinforced thermosetting-resin (FRP) piping systems.

(c) ASME NM.3.1 *Nonmetallic Materials Part 1—Thermoplastic Material Specifications*. This Part is one of three contained in the Standard that includes specifications for nonmetallic materials and is in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. It is analogous to ASME Section II, Parts A and B for metallic materials.

(d) ASME NM.3.2 *Nonmetallic Materials Part 2—Reinforced Thermoset Plastic Material Specifications*. This Part is one of three contained in the Standard that includes specifications for nonmetallic materials and is in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. It is analogous to ASME Section II, Parts A and B for metallic materials.

(e) ASME NM.3.3 *Nonmetallic Materials Part 3—Properties*. This Part provides tables and data sheets for allowable stresses, mechanical properties (e.g., tensile and yield strength), and physical properties (e.g., coefficient of thermal expansion and modulus of elasticity) for nonmetallic materials. It is analogous to ASME Section II, Part D for metallic materials.

13.3 Operation of Piping Systems

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

13.4 In-service Inspection of Piping Systems

The following documents apply to the in-service inspection of typical pressure vessels. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) API 570 *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems* for piping in the petroleum and chemical process industries. However, the scope states that it may be used in other industries where practical.

(b) API RP 574 *Inspection Practices for Piping System Components.*

(c) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(d) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(e) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some

chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(f) API RP 2611 *Terminal Piping Inspection—Inspection of In-Service Terminal Piping Systems*. This document covers the inspection and repair of typical terminal piping systems within terminal boundaries, which includes off-plot piping. It aligns current terminal piping inspection practices with the appropriate and applicable elements of API 570.

(g) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(h) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(i) API RP 686 *Recommended Practice for Machinery Installation and Installation Design–Chapter 6–Piping*. Chapter 6 of this document provides guidelines (including a checklist) for the installation and pre-installation design of piping that is connected to machinery. While written for petroleum and chemical processing facilities, it may be consulted as a resource for machinery in other industries.

(j) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(k) API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*. Equipment and piping associated with hydroprocessing reactor effluent systems in refineries are subject to corrosion and fouling. This document is applicable to equipment and piping in that service.

(l) API RP 939C *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*. This RP should be considered only if the equipment is subject to sulfidation corrosion.

(m) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

(n) API Std 598*Valve Inspection and Testing.*

In implementing an in-service inspection plan, various nondestructive examination (NDE) techniques are often used. Additionally, the execution of these techniques requires qualified NDE personnel. Guidance in these areas can be found in the following documents:

(a) BPVC Section V *Nondestructive Examination*.

(b) ASNT CP-189 *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*.

(c) ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*. The major difference between ASNT RP SNT-TC-1A and ASNT CP-189 is that the latter is a standard while the former is a recommended practice. It is probably not necessary to use both.

13.5 Fitness-for-service Analysis of Piping Systems

If damage is discovered in a piping component, the damage should be either repaired (see paragraph 13.6) or subjected to a fitness-for-service (FFS) assessment to determine whether the item is acceptable for continued service without repair. These methods can also be used in combination (e.g., some portions of the damaged area can be repaired while others could be assessed). The fitness-for-service assessment could result in one or more of the following actions:

(a) Continue operation at current operating conditions with periodic inspection or monitoring for further damage.

(b) De-rate the equipment by reducing pressures, temperatures and/or other loads to reduce stresses.

(c) Repair the equipment.

The following document can be used for the fitness-for-service (FFS) assessment:

(a) API 579-1/ASME FFS-1 *Fitness-For-Service*. This document provides detailed guidance on the evaluation of many types of flaws to help the user determine whether re-rating or repairs are needed.

(b) API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*. This document provides example problems illustrating the use and calculations required for the Fitness-For-Service Assessments described in API 579-1/ASME FFS-1.

13.6 Repair of Piping Systems

If the FFS assessment (see paragraph 13.5) indicates that a repair is necessary for continued operation, the following documents provide guidance on many repair methods:

(a) API 570 *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems* for piping in the petroleum and chemical process industries. However, the scope states that it may be used in other industries where practical.

(b) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(c) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(d) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(e) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(f) API RP 577 *Welding Processes, Inspection, and Metallurgy*. This document can also be used for inspection of new construction.

(g) API RP 621 *Reconditioning of Metallic Gate, Globe and Check Valves.*

(h) API Std 1104 *Welding of Pipelines and Related Facilities*. Although 1104 was developed for pipelines, it can be used for large diameter or critical piping in process units.

(i) API RP 2201 *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*. Although 2201 was developed for pipelines, it can be used for large diameter or critical piping in process units.

(j) API RP 2611 *Terminal Piping Inspection—Inspection of In-Service Terminal Piping Systems*. This document covers the inspection and repair of typical terminal piping systems within terminal boundaries, which includes off-plot piping. It aligns current terminal piping inspection practices with the appropriate and applicable elements of API 570.

(k) API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*. The use of material other than the material specified can result in failures in service. “Positive Materials Identification” (PMI) is one way to minimize these failures. Note that PMI is not normally performed on equipment constructed of carbon steel. However, it should be applied in cases where substitution of another alloy for a specified alloy can result in failure with significant safety, health, environmental or financial losses. This can be determined by a risk assessment using the methods of risk-based inspection (see 13.4(c)). Also, within the context of repairs, the document cites examples of in-service maintenance activities where material verification should be established (paragraph 5.7.4 of the third edition).

(l) API RP 582 *Welding Guidelines for the Chemical, Oil, and Gas Industries*. This recommended practice (RP) provides supplementary guidelines and practices for welding and welding-related topics for shop

and field fabrication, repair and modification. This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered herein (e.g., pipeline welding and offshore structural welding are intentionally not covered).

(m) BPVC Section IX *Welding, Brazing, and Fusing Qualifications*.

14 ACQUISITION (PURCHASE) OF COMPONENTS, INCLUDING FITTINGS

The codes and standards for construction of components are organized by component or fitting type, as described below. Although these standards are frequently used in construction of pressure equipment, they are used primarily by the component or fitting manufacturer. However, a user may wish to refer to these standards for new construction dimensions and design requirements that could be used for reference in a fitness-for-service analysis.

(a) Valves.

(b) Flanges and flanged fittings.

(c) Gaskets.

(d) Fittings.

New construction codes, standards and recommended practices for valves are listed below:

(a) ASME B16.10 *Face-to-Face and End-to-End Dimensions of Valves*.

(b) ASME B16.34 *Valves – Flanged, Threaded, and Welding End*.

(c) API RP 591 *Process Valve Qualification Procedure*.

(d) API Std 594 *Check Valves: Flanged, Lug, Wafer and Butt-Welding*.

(e) API Std 598 *Valve Inspection and Testing*.

(f) API Std 599 *Metal Plug Valves—Flanged, Threaded, and Welding Ends*.

(g) API Std 600 *Steel Gate Valves—Flanged and Butt-welding Ends, Bolted Bonnets*.

(h) API Std 602 *Gate, Globe and Check Valves for Sizes DN 100 (NPS 4) and Smaller for the Petroleum and Natural Gas Industries.*

(i) API Std 603 *Corrosion-resistant, Bolted Bonnet Gate Valves—Flanged and Butt-welding Ends.*

(j) API Std 607 *Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats*.

(k) API Std 608 *Metal Ball Valves–Flanged, Threaded and Welding Ends.*

(l) API Std 609 *Butterfly Valves: Double-flanged, Lug and Wafer-Type, and Butt Welding Ends*.

(m) API RP 615 *Valve Selection Guide*.

(n) API Std 622 *Type Testing of Process Valve Packing for Fugitive Emissions*.

(o) API Std 623 *Steel Globe Valves—Flanged and Butt-welding Ends, Bolted Bonnets*.

(p) API Std 624 *Type Testing of Rising Stem Valves Equipped with Graphite Packing for Fugitive Emissions*.

(q) API Std 641 *Type Testing of Quarter-turn Valves for Fugitive Emissions*.

New construction codes, standards and recommended practices for flanges and flanged fittings are listed below:

(a) ASME B16.1 *Gray Iron Pipe Flanges and Flanged Fittings.*

(b) ASME B16.5 *Pipe Flanges and Flanged Fittings NPS ½ Through NPS 24 Metric/Inch Standard*. This is the most common standard that is used for flanges and flanged fittings.

(c) ASME B16.24 *Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500, and 2500*

(d) ASME B16.36 *Orifice Flanges*.

(e) ASME B16.42 *Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300.*

(f) ASME B16.47 *Large Diameter Steel Flanges (NPS 26 Through 60 Metric/Inch Standard).*

New construction codes, standards and recommended practices for gaskets are listed below:

(a) ASME B16.20 *Metallic Gaskets for Pipe Flanges*.

(b) ASME B16.21 *Nonmetallic Flat Gaskets for Pipe Flanges*.

New construction codes, standards and recommended practices for fittings are listed below:

(a) ASME B16.3 *Malleable Iron Threaded Fittings (Classes 150 and 300)*.

(b) ASME B16.4 *Gray Iron Threaded Fittings (Classes 125 and 250)*.

(c) ASME B16.9 *Factory-Made Wrought Butt-welding Fittings*.

(d) ASME B16.11 *Forged Fittings, Socket-Welding and Threaded*.

(e) ASME B16.14 *Ferrous Pipe Plugs, Bushings and Locknuts with Pipe Threads*.

(f) ASME B16.15 *Cast Copper Alloy Threaded Fittings; Classes 125 and 250*.

(g) ASME B16.18 *Cast Copper Alloy Solder Joint Pressure Fittings*.

(h) ASME B16.22 *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*.

(i) ASME B16.24 *Cast Copper Alloy Pipe Flanges, Flanged Fittings, and Valves: Classes 150, 300, 600, 900, 1500, and 2500*.

(j) ASME B16.25 *Butt-welding Ends*.

(k) ASME B16.26 *Cast Copper Alloy Fittings for Flared Copper Tubes*.

(l) ASME B16.39 *Malleable Iron Threaded Pipe Unions–Classes 150, 250, and 300*.

(m) ASME B16.48 *Line Blanks*.

(n) ASME B16.50 *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*.

(o) ASME B16.52 *Forged Nonferrous Fittings, Socket-Welding and Threaded (Titanium, Titanium Alloys, Aluminum, and Aluminum Alloys)*.

(p) ASME B40.100 *Pressure Gauges and Gauge Attachments*.

15 POST-CONSTRUCTION DOCUMENTS FOR COMPONENTS, INCLUDING FITTINGS

Post-construction codes, standards and recommended practices for valves are listed below:

(a) API Std 598 *Valve Inspection and Testing.*

(b) API RP 621 *Reconditioning of Metallic Gate, Globe and Check Valves*.

16 OVERPRESSURE PROTECTION SYSTEMS

These documents are briefly summarized in the paragraphs that follow. A more detailed summary of each document can be found in Appendix A. In electronic versions of this Guide, the document number in Table 11 is hyperlinked to the description in Appendix A.

Table 11: Overpressure Protection

Note: Almost all of the new construction codes have overpressure protection requirements, so these will not be repeated here.		
Specification/Purchase	Design/Construction	Operation
NB-370	NB-23	API RP 584
API Std 526	NB-370	
API Std 520	BPVC Section XIII	
API Std 520 Part II	API Std 527	
API Std 521	ASME PTC 25	
NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS (NBBPVI) STANDARDS	ASME PCC-1	
NB-18		
ASME PCC-3		
API RP 580		
API RP 581		
API RP 588		
API RP 751		
In-Service Inspection	Fitness-For-Service	Repair
NB-23	None listed	ASME PCC-2
NB-370		ASME PCC-1
ASME PCC-3		API RP 751
API RP 580		
API RP 581		
API RP 571		
API RP 576		
API RP 751		
API RP 970		

16.1 Specification (Purchase) of Overpressure Protection Systems

Before specifying an overpressure protection system, it is important for the equipment owner/user to consider life cycle cost and in-service testing requirements, including requirements for in-service inspection, testing, maintenance, and repair. This will allow the design and construction to be optimized to provide appropriate access for these activities, as well as provide ways for minimizing the impact of possible repairs. Some of the steps in this consideration, and the documents that should be considered for each step, are:

(a) Determine legally mandated new construction and in-service testing requirements. Requirements of legal jurisdictions in the US and Canada can be obtained from NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*. Most individual jurisdictions have made the full version of applicable laws and regulations available on their respective websites, and hard copies are generally made available on request.

(b) Determine potential manufacturers. One useful reference is the National Board *Manufacturer and Repair Directory*, an online searchable directory containing a listing of manufacturers of pressure equipment and pressure relief devices and repair organizations.

(c) Determine third-party or other contractual requirements, such as insurance requirements, that may exist. Some insurance companies have specific requirements for design, construction, inspection and operation of pressure equipment. Some building owners or owner entities impose conditions for use of their facilities that may apply to pressure equipment.

(d) Determine the methods and frequency of in-service testing that will be needed to ensure equipment integrity and to comply with jurisdictional regulations. Documents that should be considered in the design/specification/new construction phase are listed in the following paragraphs.

(1) API Std 526 *Flanged Steel Pressure Relief Valves*.

(2) API Std 520 *Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries, Part I – Sizing and Selection.*

(3) API Std 520 Part II *Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries, Part II – Installation*.

(4) API Std 521 *Guide for Pressure-relieving and Depressuring Systems*.

(5) NB-18 *Pressure Relief Device Certifications*. This document contains a listing of the device designs certified by the National Board. Also listed are the certifications issued to pressure relief device manufacturers and assemblers to apply the National Board "NB" and construction code symbols as well as companies holding "VR" Certificates of Authorization for the repair of pressure relief valves. Also included is a listing of combination capacity factors determined for various rupture disk devices installed in series with pressure relief valves.

(6) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(7) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(8) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(9) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(10) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

16.2 Design and Construction of Overpressure Protection Systems

The following documents apply to the construction of overpressure protection devices:

(a) NB-23 *National Board Inspection Code Part 3 (Repairs/Alterations)* provides rules for repairs and alterations that are mandatory in many jurisdictions. NB-370 provides some guidance on this.

(b) ASME PTC 25 *Pressure Relief Devices*. This document contains procedures for determining the relieving pressure and flow capacity of pressure relief devices.

(c) BPVC Section XIII *Rules for Overpressure Protection.* With the publication of the 2021 Edition of the BPVC, the rules for pressure relief devices have been transferred to the new BPVC Section XIII. The remaining rules for overpressure protection remain in referencing construction code.

(d) API Std 527 *Seat Tightness of Pressure Relief Valves*. This standard describes methods of determining the seat tightness of metal- and soft-seated pressure relief valves, including those of conventional, bellows, and pilot-operated designs.

(e) API RP 576 *Inspection of Pressure Relieving Devices.* This document describes the inspection and repair practices for self-actuated pressure-relieving devices commonly used in the oil/gas and petrochemical industries. The document also contains coverage on handling and installation that could be applied in the construction of overpressure protection systems.

(f) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

16.3 Operation of Overpressure Protection Systems

API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

16.4 In-service Inspection of Overpressure Protection Systems

The following documents apply to the in-service inspection of typical pressure vessels. They should be considered to be good engineering practices, with applicability that depends on the situation.

(a) NB-23 *National Board Inspection Code Part 2 (Inspection)* provides rules for in-service inspection that are mandatory in some jurisdictions. NB-370 provides some guidance on this. (Also, see paragraph 16.1(a)).

(b) ASME PCC-3 *Inspection Planning Using Risk-Based Methods* can be used to develop an optimum, cost-effective inspection program for all pressure equipment. This standard uses an analytical risk-based approach to provide more detailed guidance on developing an optimum inspection plan than does NB-23. However, ASME PCC-3 should be used as a supplement to the basic requirements in NB-23, as permitted by that document. For a small, simple boiler, the basic guidance in NB-23 may be sufficient.

(c) API RP 580 *Risk-based Inspection* is similar to ASME PCC-3, but is focused on equipment in the petroleum and chemical process industries. See comments under ASME PCC-3.

(d) API RP 581 *Risk-Based Inspection Methodology*. This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable.

(e) API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* provides detailed descriptions of damage mechanisms and can be used to supplement the general summary descriptions

in ASME PCC-3 and API RP 580. It is important to determine the damage mechanisms that can affect the equipment in the design stage because that can steer the selection of materials of construction, the corrosion allowance and possibly the design (e.g., if crevice corrosion is an applicable damage mechanism, it may be possible to eliminate crevices during design).

(f) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

(g) API RP 576 *Inspection of Pressure Relieving Devices*. This document describes the inspection and repair practices for self-actuated pressure-relieving devices commonly used in the oil/gas and petrochemical industries.

(h) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

16.5 Fitness-for-service Analysis of Overpressure Protection Systems

No documents listed.

16.6 Repair of Overpressure Protection Systems

The following document provides some guidance on repair of overpressure protection devices:

(a) API RP 576 *Inspection of Pressure Relieving Devices*. This document describes the inspection and repair practices for self-actuated pressure-relieving devices commonly used in the oil/gas and petrochemical industries.

The following documents provide some guidance on repair methods, but most do not apply to overpressure protection devices:

(a) ASME PCC-2 *Repair of Pressure Equipment and Piping*. ASME PCC-2 provides guidance on a broad range of repair techniques that can be employed.

(b) ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly* provides guidance on techniques for flange joint assembly to minimize leakage in service.

(c) API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*. The document is written specifically for hydrofluoric acid (HF) alkylation units that are used in the refining industry.

17 SPECIFIC TASKS

The following documents are focused on tasks that are performed as a part of both new and post construction activities. They should be referenced when the subject activity is to be performed.

(a) API RP 577 *Welding Processes, Inspection, and Metallurgy*.

(b) API RP 582 *Welding Guidelines for the Chemical, Oil and Gas Industries*.

(c) API RP 583 *Corrosion Under Insulation and Fireproofing*. This document covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF).

(d) API RP 584 *Integrity Operating Windows*. This recommended practice (RP) explains the importance of integrity operating windows (IOWs) for process safety management and guides users in establishing and implementing an IOW program for refining and petrochemical process facilities to avoid unexpected equipment degradation that could lead to loss of containment. While the document emphasis is on monitoring exceedances of IOWs, the process of establishing relevant IOWs could reveal details that merit incorporation into the equipment specifications.

(e) API RP 585 *Pressure Equipment Integrity Incident Investigation*. This document offers owner/users a framework for developing, implementing, sustaining, and enhancing an investigation program for pressure equipment integrity (PEI) incidents. It is applicable to all of the equipment categories covered by this PTB document. While specifically targeted for application to pressure equipment in the oil, gas, refining and petrochemical industries, it could be applied to other equipment and industries at the discretion of the owner/user.

(f) API Bulletin 587 *Guidance for the Development of Ultrasonic Examiner Qualification Programs*. This publication outlines the general guidelines for the development of owner/user ultrasonic examiner qualification programs that are consistent with API performance demonstration programs for detection, characterization, and crack height sizing of weld discontinuities in weldments.

(g) API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*. This document outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner.

(h) API RP 970 *Corrosion Control Documents*. This document assists owner/users in the process of developing and maintaining corrosion control documents as a tool to understand and manage the materials damage mechanisms in their process facilities. While written for the refining industry, its principles may be used elsewhere.

(i) API Std 936 *Refractory Installation Quality Control—Inspection and Testing Monolithic Refractory Linings and Materials*. This standard provides installation quality control procedures for monolithic refractory linings.

(j) API Std 976 *Refractory Installation Quality Control—Inspection and Testing of AES/RCF Fiber Linings and Materials*. This standard provides installation quality control procedures and lining system design requirements for Alkaline Earth Silicate/Refractory Ceramic Fiber (AES/RCF) fiber linings.

(k) API Std 1104 *Welding of Pipelines and Related Facilities*. Although 1104 was developed for pipelines, it can be used for large diameter or critical piping in process units.

(l) API RP 2201 *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*. Although 2201 was developed for pipelines, it can be used for large diameter or critical piping in process units.

APPENDIX A SUMMARY OF STANDARDS REFERENCED

AMERICAN PETROLEUM INSTITUTE (API) STANDARDS

A-1 API 510 *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*

<table>
<tr><td>Current Edition:</td><td>10th Edition, May 2014 through Addendum 2, March 2018 (84 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>No</td></tr>
<tr><td>Scope:</td><td>Provides rules for in-service inspection, repair, overpressure protection, alteration and rerating of pressure vessels in the petroleum and chemical process industries. Applies to vessels whether or not constructed to a recognized code. Application of API 510 is restricted to owner/users that have access to the following technically qualified individuals and organizations:
• An authorized inspection agency.
• A repair organization.
• An engineer.
• An inspector.
• Examiners.</td></tr>
<tr><td>Application:</td><td>Owners and users of pressure vessels can use API 510 to develop an in-service (post-construction) inspection program for their equipment. Other inspection planning documents as listed below can be used for inspection planning if permitted by local jurisdictional authorities:
• API RP 580 “Risk-based Inspection”
• API RP 581 “Base Resource Document–Risk Based Inspection.” This document provides specific, detailed guidance for risk-based inspection.
• ASME PCC-3 “Inspection Planning Using Risk-Based Methods.” This document is very similar to API RP 580, but applies to equipment in areas in addition to the hydrocarbon and chemical process industries.
Owners and users of pressure equipment can use API 510, in combination with other documents as listed below, to evaluate flaws and to plan for repairs and alterations to pressure equipment. Other documents include:
• API 579-1/ASME FFS-1–“Fitness-For-Service”
• ASME PCC-2 “Repair of Pressure Equipment and Piping”</td></tr>
<tr><td>Comments:</td><td>API 510 provides administrative requirements for certification of authorized pressure vessel inspectors as well as requirements for owner-user inspection organizations. API 510 also provides:
• General guidance on examination techniques and pressure testing.
• Descriptions of a limited number of damage (deterioration) mechanisms.
• General requirements for inspection of pressure vessels.
• Requirements for inspection and repair of overpressure protection devices.
• Methods for determining inspection intervals.
• General requirements for repairs and alterations and re-rating.</td></tr>
<tr><td>User:</td><td><table><tr><td>Purchaser</td><td>Consultant</td><td>Owner</td><td>Inspector</td><td>Regulator</td></tr><tr><td></td><td>S</td><td>P</td><td>P</td><td>S</td></tr></table>P – Primary User
S – Secondary User</td></tr>
</table>

A-2 API Std 520 Part I *Sizing, Selection, and Installation of Pressure-relieving Devices—Part I: Sizing and Selection*

Current Edition:	Tenth Edition, October 2020 (172 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This recommended practice applies to the sizing and selection of pressure relief devices used in refineries and related industries for equipment that has a maximum allowable working pressure (MAWP) of 15 psig [103 kPag] or greater. The pressure relief devices covered in this RP are intended to protect unfired pressure vessels and related equipment against overpressure from operating and fire contingencies. Atmospheric and low-pressure storage tanks covered in API Standard 2000 and pressure vessels used for transportation of products in bulk or shipping containers are not within the scope of this RP. The rules for overpressure protection of fired vessels are provided for in Section 1 of the ASME Boiler and Pressure Vessel Code and ASME B31.1, and are not within the scope of this RP.
Application:	This RP can be used by pressure vessel and/or instrument designers to aid in selecting the type of pressure relief device and then to determine the appropriate size. Manufacturers of pressure vessels can use this RP to assess the adequacy of the pressure-relieving device specified by the purchaser.
Comments:	This RP includes basic definitions and information about the operational characteristics and applications of various pressure relief devices. It also includes sizing procedures and methods based on steady flow of Newtonian fluids. Pressure relief devices protect a vessel against overpressure only; they do not protect against structural failure when the vessel is exposed to extremely high temperatures such as during a fire. See API RP 521 for information about appropriate ways of reducing pressure and restricting heat input. The information in this RP is intended to supplement the information contained in Section VIII, "Pressure Vessels," of the ASME Boiler and Pressure Vessel Code. The recommendations presented in this publication are not intended to supersede applicable laws and regulations.
User:	Designer: **P**; Manufacturer: **P**; Owner: **S**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-3 API Std 520 Part II *Sizing, Selection, and Installation of Pressure-relieving Devices—Part II: Installation*

Current Edition:	Seventh Edition, October 2020 (69 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP covers methods of installation for pressure-relief devices for equipment that has a maximum allowable working pressure (MAWP) of 15 psig [103kPag] or greater. Pressure-relief valves or rupture disks may be used independently or in combination with each other to provide the required protection against excessive pressure accumulation. As used in this RP, the term pressure-relief valve includes safety-relief valves used in either compressible or incompressible fluid service, and relief valves used in compressible fluid service. This RP covers gas, vapor, steam, two-phase and incompressible fluid service; it does not cover special applications that require unusual installation consideration.
Application:	This RP can be used by the pressure vessel designer, fabricator, and erector to aid in determining how pressure relief devices, along with the associated piping and supports, should be installed.
Comments:	This RP covers the following topics: inlet piping to pressure-relief devices, discharge piping from pressure-relief devices, isolation (stop) valves in pressure-relief piping, bonnet or pilot vent piping, drain piping, pressure-relief device location and position, bolting and gasketing, multiple pressure-relief valves with staggered settings, pre-installation handling and inspection, rupture disk installation guidelines, and installation and maintenance of pin- actuated non-reclosing pressure-relief devices.
User:	Designer: **P**; Manufacturer: **P**; Owner: **S**; Inspector: **S**; Regulator: **P** P – Primary User S – Secondary User

A-4 API Std 521 *Pressure-relieving and Depressuring Systems*

Current Edition:	Seventh Edition, June 2020 (247 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies requirements and gives guidelines for examining the principal causes of overpressure; and determining individual relieving rates; and selecting and designing disposal systems, including such component parts as piping, vessels, flares and vent stacks. This standard does not apply to direct-fired steam boilers. This standard is applicable to pressure-relieving and vapor-depressuring systems. Although intended for use primarily in oil refineries, it is also applicable to petrochemical facilities, gas plants, liquefied natural gas (LNG) facilities and oil and gas production facilities. The information provided is designed to aid in the selection of the system that is most appropriate for the risks and circumstances involved in various installations. This standard is intended to supplement the practices set forth in ISO 4126 or API RP 520-I for establishing a basis of design.
Application:	For new construction, this standard can be used by process designers to aid in 1) assessing the cause of overpressure associated with various process operations, 2) determining relieving rates and 3) selecting and designing disposal systems. It can also be used for evaluating existing systems.
Comments:	This standard covers the following topics: causes of overpressure determination of individual relieving rates, selection and design of disposal systems, determination of fire relief rates, sample calculations for sizing a subsonic flare stack, typical details and sketches and high integrity protection systems (HIPS). The portions of this standard dealing with flares and flare systems are an adjunct to API Std 537, which addresses mechanical design, operation and maintenance of flare equipment. It is important for all parties involved in the design and use of a flare system to have an effective means of communicating and preserving design information about the flare system. To this end, API has developed a set of flare data sheets, which can be found in API Std 537, Appendix A. The use of these data sheets is both recommended and encouraged as a concise, uniform means of recording and communicating design information.
User:	Designer: **P**; Manufacturer: ; Owner: **P**; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-5 API Std 526 *Flanged Steel Pressure-relief Valves*

Current Edition:	Seventh Edition, September 2017 through Errata 1 September 2018 (54 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard is a purchase specification for flanged steel pressure-relief valves. Basic requirements are given for direct spring-loaded pressure-relief valves and pilot-operated pressure-relief valves as follows: • Orifice designation and area. • Valve size and pressure rating, inlet and outlet. • Materials. • Pressure-temperature limits. • Center-to-face dimensions, inlet and outlet.
Application:	Purchasers can use this standard to determine the information required for the purchase specification. Purchasers can also reference this standard in a purchase specification. Valve manufacturers can use this standard to assess the adequacy of a purchase specification.
Comments:	The topics covered in this standard are purchaser and manufacturer responsibilities, orifice area designations, determination of effective orifice area, valve selection, valve material, inspection and shop tests, identification, preparation for shipment, pressure-relief valve specification sheets and nameplate nomenclature.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: ; Regulator: P – Primary User S – Secondary User

A-6 API Std 527 *Seat Tightness of Pressure Relief Valves*

Current Edition:	Fifth Edition, July 2020 (13 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard describes methods of determining the seat tightness of metal- and soft-seated pressure relief valves, including those of conventional, bellows, and pilot-operated designs. The maximum acceptable leakage rates are defined for pressure relief valves with set pressures from 103 kPa gauge (15 psig) to 41,379 kPa gauge (6000 psig). If greater seat tightness is required, the purchaser shall specify it in the purchase order. The test medium for determining the seat tightness-air, steam, or water-shall be the same as that used for determining the set pressure of the valve. For dual-service valves, the test medium-air, steam, or water-shall be the same as the primary relieving medium.
Application:	Purchasers can use this standard to determine the information required for the purchase specification. Purchasers can also reference this standard in a purchase specification. Valve manufacturers can use this standard to assess the adequacy of a purchase specification. To ensure safety, the procedures outlined in this standard shall be performed by persons experienced in the use and functions of pressure relief valves.
Comments:	The test methods of determining seat tightness are air, steam, or water. An alternative method is provided for testing with air valves with open bonnets that cannot be readily tested by the primary air testing procedure. Each test method details the relevant procedure (test medium, configuration, test pressure, how to check for leakage), along with the acceptance criteria.
User:	Purchaser: **P** Manufacturer: **P** Owner: Inspector: Regulator: P – Primary User S – Secondary User

A-7 API Std 530 *Calculation of Heater-tube Thickness in Petroleum Refineries*

Current Edition:	Seventh Edition, April 2015 through Addendum 1, July 2019 (347 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies the requirements and gives recommendations for the procedures and design criteria for calculating the required wall thickness of new tubes and associated component fittings for petroleum-refinery heaters. These procedures are appropriate for designing tubes for service in both corrosive and non-corrosive applications. These procedures have been developed specifically for the design of refinery and related process-fired heater tubes (direct-fired, heat-absorbing tubes within enclosures). These procedures are not intended to be used for the design of external piping, nor do they apply to boiler tubes. This standard does not give recommendations for tube retirement thickness; Annex A describes a technique for estimating the life remaining for a heater tube.
Application:	For new equipment, this standard can be used by heater designers to determine the required thickness of the heater/boiler tubes. It can also be used for estimating the remaining life of existing heater tubes. However, the preferred method for remaining life assessment is provided in API 579-1/ASME FFS-1 Fitness-For-Service. This standard can be referenced in a purchase specification.
Comments:	This is a comprehensive design document intended for use by persons knowledgeable in stress calculations and materials properties. The main sections in this standard cover the following: general design information; design; allowable stresses; and sample calculations. Annexes are provided on the following: a) Estimation of allowable skin temperature, tube retirement thickness, and remaining life; b) Calculation of maximum radiant section tube skin temperature (including those operating below the creep rupture range); c) Thermal stress limitations in the elastic range; d) Calculation sheets; e) Stress curves and data tables in SI units; f) Stress curves and data tables in US customary units; g) Derivation of corrosion fraction and temperature fraction; and h) Data sources.
User:	Purchaser: — ; Manufacturer: **P**; Owner: **S**; Inspector: **S**; Regulator: **P** P – Primary User S – Secondary User

A-8 API RP 534 *Heat Recovery Steam Generators*

Current Edition:	Second Edition, February 2007, Reaffirmed October 2013 (72 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP provides guidelines for the selection or evaluation of heat recovery steam generator (HRSG) systems. Details of related equipment designs are considered only where they interact with HRSG system design. This publication does not provide rules for design, but indicates areas that need attention and offers information and description of HRSG types available to the designer or user to aid in the selection of the appropriate HRSG system. The HRSG systems discussed are those currently in industry use. A general description of fire tube and water tube HRSG systems is given. The description of an HRSG system in this document does not imply other systems are not available or recommended. Many individual features described in this document will be applicable to any type of HRSG system.
Application:	This RP can be used by designers and owners to aid in the selection of an appropriate HRSG system.
Comments:	The main topics covered in this RP are firetube heat recovery steam generators, watertube heat recovery steam generators, steam drums, heat flux and circulation ratio and sootblowers. An HRSG may be subject to boiler licensing rules, which require all inspection, maintenance, and repair tasks be conducted in accordance with specific codes, as adopted by local jurisdictions. In almost all US jurisdictions, the governing codes are the ASME Boiler and Pressure Vessel Code (BPVC) and the National Board of Boiler and Pressure Vessel Inspectors Code. The appropriate portions of the Boiler and Pressure Vessel Code include: • Section I: "Power Boilers" • Section II: "Materials" • Section III: "Nondestructive Testing" • Section VII: "Guidelines for the Care of Power Boilers" • Section IX: "Welding and Brazing Qualifications." Of these, Section VII most directly affects the maintenance of HRSGs because it contains specific inspection and repair guidelines. Section VIII can be used as the design code when allowed by the local jurisdiction.
User:	Purchaser: – ; Manufacturer: – ; Owner: **P** ; Inspector: **P** ; Regulator: – P – Primary User S – Secondary User

A-9 API Std 537 *Flare Details for Petroleum, Petrochemical, and Natural Gas Industries*

Current Edition:	Third Edition, March 2017 through Addendum 1, June 2020 (195 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard specifies requirements and provides guidance for the selection, design, specification, operation, and maintenance of flares and related combustion and mechanical components used in pressure-relieving and vapor-depressurizing systems for petroleum, petrochemical, and natural gas industries. While this standard is primarily intended for onshore facilities, guidance related to offshore applications is included.
Application:	This RP can be used by designers and owners to aid in the selection and design of a flare system for their facilities.
Comments:	The main topics covered in this RP are design, mechanical details of elevated flares and enclosed flame flares. Annex A, Annex B, Annex C, and Annex D provide further guidance and best practices for the selection, specification, and mechanical details for flares and on the design, operation, and maintenance of flare combustion and related equipment. Annex E explains how to use the datasheets provided in Annex F; it is intended that these datasheets be used to communicate and record design information.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-10 API RP 538 *Industrial Fired Boilers for General Refinery and Petrochemical Service*

Current Edition:	First Edition, October 2015, Reaffirmed April 2021 (360 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This recommended practice (RP) specifies requirements and gives recommendations for design, operation, maintenance, and troubleshooting considerations for industrial fired boilers used in refineries and chemical plants. It covers waterside control, combustion control, burner management systems (BMSs), feedwater preparation, steam purity, emissions, etc. This RP does not apply to fire tube boilers, gas turbine exhaust boilers, or fluidized bed boilers. This RP does not cover boiler mechanical construction. Purchaser or owner shall specify codes such as ASME, ISO, etc. This RP does not cover forced circulation boilers.
Application:	This RP can be used by designers and owners to aid in the selection and design of industrial fired boiler system.
Comments:	Regarding the specifics of pressure component design, this RP refers to other codes and standards, such as the ASME Boiler and Pressure Vessel Codes and the appropriate B31 standard.
User:	Purchaser: — ; Manufacturer: — ; Owner: **P** ; Inspector: **P** ; Regulator: — P – Primary User S – Secondary User

A-11 API Std 560 *Fired Heaters for General Refinery Service*

Current Edition:	Fifth Edition, February 2016 through Addendum 1, May 2021 (337 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing, preparation for shipment and erection of fired heaters, air preheaters, fans and burners for general refinery service. This standard is not intended to apply to the design of steam reformers or pyrolysis furnaces.
Application:	Purchasers can reference this standard in a purchase specification, and manufacturers can use it in the design and fabrication of fired heaters. This standard includes equipment data sheets for fired-heater, burner, air-preheater, fan and sootblower. The data sheets are started by the purchaser and completed by the purchaser. The information in the standard on field erection is very limited.
Comments:	The topics covered in this standard are pressure design code; regulations, purchaser's and manufacturer's responsibilities; documentation and final records; process, combustion and mechanical design; tubes; headers and return bends; piping, terminals and manifolds; tube supports; refractory linings; structures and appurtenances; stacks, ducts and breaching; burners and auxiliary equipment (sootblowers, fans, dampers); instrument and auxiliary connections; shop fabrication and field erection; and inspection, examination and testing. The annex titles are Equipment data sheets, Purchaser's check list, Proposed shop-assembly conditions, Stress curves for use in the design of tube-support elements, Centrifugal fans for fired-heater systems, Air preheat systems for fired-process heaters, Measurement of efficiency of fired-process heaters, Stack design, Measurement of Noise from Fired-process Heaters, Refractory Compliance Data Sheet, Burner-to-Burner and Burner-to-Coil Spacing Example Calculations, Damper Classifications and Damper Controls for Fired Heaters, and Ceramic Coating for Outer Surfaces of Fired Heater Tubes, Fiber, and Monolithic Refractories. There are numerous (72) documents referenced in this standard that are stated to be indispensable for the application of the standard.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: **S** P – Primary User S – Secondary User

A-12 API 570 *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*

Current Edition:	Fourth Edition, February 2016 through Errata 1, April 2018 (90 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	Provides rules for in-service inspection, repair, alteration and rerating of piping. It was developed for the petroleum and chemical process industries, but may be used, where practical, for any piping system. Applies to piping whether or not constructed to a recognized code. It is intended for use by organizations that have access to the following: • An authorized inspection agency. • A repair organization. • Technically qualified piping engineers. • Inspectors. • Examiners.
Application:	Owners and users of piping systems can use API 570 to develop an in-service (post-construction) inspection program for their equipment. Other inspection planning documents as listed below can be used for inspection planning if permitted by local jurisdictional authorities: • API RP 580 "Risk-based Inspection." • API RP 581 "Base Resource Document-Risk Based Inspection." This document provides specific, detailed guidance for risk-based inspection. • ASME PCC-3 "Inspection Planning Using Risk-Based Methods." This document is very similar to API RP 580, but applies to equipment in areas in addition to the hydrocarbon and chemical process industries. Owners and users of pressure equipment can use API 570, in combination with other documents as listed below, to evaluate flaws and to plan for repairs and alterations to pressure equipment. Other documents include: • API 579-1/ASME FFS-1 Fitness-For-Service. • ASME PCC-2 "Repair of Pressure Equipment and Piping."

Comments:	API 570 provides administrative requirements for certification of authorized piping inspectors as well as requirements for owner-user inspection organizations. API 570 also provides:
	• Guidance on examination techniques, including specific guidance for:
	  o Injection points.
	  o Deadlegs.
	  o Corrosion under insulation.
	  o Environmental and fatigue cracking.
	  o Corrosion under linings and deposits.
	  o Creep cracking.
	  o Buried piping.
	• Methods for selecting thickness measurement locations (TMLs) and for determining inspection intervals based on piping classification.
	• General requirements for repairs, alterations and re-rating.

User:	Purchaser: (blank); Consultant: **S**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-13 API RP 571 *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry*

Current Edition:	Third Edition, March 2020 (376 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Provides detailed descriptions of the damage mechanisms that can affect pressure equipment in the refining and petrochemical industries.
Application:	Owners and users of piping systems, particularly plant inspection personnel, can use API RP 571 to assist in identifying the likely causes of damage in equipment. When the most likely types of damage have been identified, an inspection program can be designed to locate the damage before a failure occurs.
Comments:	API RP 571 provides detailed descriptions of approximately 70 damage mechanisms. Of these, 44 apply generally to a broad range of industries. The description of each damage mechanism includes: A description of the damage and the materials affected. A list of the "critical factors" or variables that lead to the damage. The appearance or morphology of the damage, often with photographs. Prevention/mitigation, inspection and monitoring techniques The descriptions of the damage mechanisms are much more detailed than the descriptions in ASME PCC-3 and API RP 580. Note that WRC Bulletin 489 is a "sister document" to API RP 571.
User:	Purchaser: — ; Consultant: **S** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-14 API RP 572 *Inspection Practices for Pressure Vessels*

Current Edition:	Fourth Edition, December 2016 (154 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP covers the inspection of pressure vessels. It includes a description of the various types of pressure vessels and the standards for their construction and maintenance. The reasons for inspection, causes of deterioration, frequency and methods of inspection, methods of repair and preparation of records and reports are covered. Safe operation is emphasized.
Application:	This RP can be used by inspectors and plant owners as an aid in the proper inspection of refinery and petrochemical plant pressure vessels. It can also be used by consultants and regulators as an aid in assessing the adequacy of a plant's inspection program.
Comments:	The main topics covered in this RP are introduction to pressure vessels, reasons for inspection, inspection plans, frequency and extent of inspection, safety precautions and preparatory work, inspection methods and limitations, condition assessment and repair, and records and reports. It also has an appendix describing heat exchanger types, an appendix on towers and their internals, and an appendix with sample inspection sheets and report forms. The information contained in this RP was previously presented as Chapter VI and Chapter VII of the Guide for Inspection of Refinery Equipment. The information in this RP does not constitute, and should not be construed as, a code of rules, regulations or minimum safe practices. The practices described in this publication are not intended to supplant other practices that have proven satisfactory, nor is this publication intended to discourage innovation and originality in the inspection of pressure vessels. Users of this RP are reminded that no book or manual is a substitute for the judgment of a responsible, qualified person.
User:	Purchaser: — ; Consultant: **S** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-15 API RP 573 *Inspection of Fired Boilers and Heaters*

Current Edition:	Fourth Edition, January 2021 (129 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP covers the inspection practices for fired boilers, process heaters, and furnaces used in petroleum refineries and petrochemical plants. It includes a description of the common heater and boiler designs, and a synopsis of reliability programs/philosophy for these items. The practices described in this document are focused to improve equipment reliability and plant safety by describing the operating variables which impact reliability, and to ensure that inspection practices obtain the appropriate data, both on-stream and off-stream, to assess current and future performance of the equipment.
Application:	This RP can be used by inspectors and plant owners as an aid in the proper inspection of refinery and petrochemical plant fired boilers and heaters. It can also be used by consultants and regulators as an aid in assessing the adequacy of a plant's inspection program.
Comments:	The main topics covered in this RP are common heater and boiler designs; heater, furnace and boiler mechanical reliability; damage mechanisms; frequency and timing of inspections; safety precautions, preparatory work and cleaning; outage inspection programs; boiler outage inspection; on-stream inspection programs; tube reliability assessment; method of inspection for foundations, settings and other appurtenances; repairs; and records and reports. It also includes five appendices: 1) Sample inspection checklists for heaters and boilers, 2) Sample heater inspection records, 3) Sample semiannual stack inspection record, 4) Parameters for Integrity Operating Windows in Fired Heaters, and 5) Cleaning methods.
User:	Purchaser: – ; Consultant: **S** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-16 API RP 574 *Inspection Practices for Piping System Components*

Current Edition:	Fourth Edition, November 2016 (122 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP covers the inspection practices for piping, tubing, valves (other than control valves) and fittings used in petroleum refineries and petrochemical plants. Although this publication is not specifically intended to cover specialty items, many of the inspection methods described in this RP are applicable to specialty items such as control valves, level gauges, instrument controls columns, etc.
Application:	This RP can be used by inspectors and plant owners as an aid in the proper inspection of piping systems in refineries and petrochemical plants. It can also be used by consultants and regulators in assessing the adequacy of a plant's inspection program.
Comments:	The main topics covered in this RP are piping components; pipe joining methods, reasons for inspection; inspection plans; frequency and extent of inspection; safety precautions and preparatory work; inspection procedures and practices; pressure tests; determination of minimum required thickness; and records. It also contains a one page appendix, External Inspection Checklist for Process Piping, with the headings: leaks, misalignment, vibration, and supports. Some of the information contained in this RP was previously presented as a Chapter XI of the Guide for Inspection of Refinery Equipment, which is currently being reorganized as individual RPs. The information in this RP does not constitute and should not be construed as a code of rules, regulations or minimum safe practices. The practices described in this RP are not intended to supplant other practices that have proven satisfactory, nor is this RP intended to discourage innovation and originality in the inspection of refineries and chemical plants. Users of this RP are reminded that no book or manual is a substitute for the judgment of a responsible, qualified inspector or piping engineer.
User:	Purchaser: (blank); Consultant: **S**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-17 API RP 575 *Inspection Practices for Atmospheric and Low-pressure Storage Tanks*

Current Edition:	Fourth Edition, July 2020 (116 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This document provides useful information and recommended practices for the maintenance and inspection of atmospheric and low-pressure storage tanks. While some of these guidelines may apply to other types of tanks, these practices are intended primarily for existing tanks that were constructed to API Spec 12A and API Spec 12C, and API Std 620 and API Std 650.
Application:	This RP can be used by inspectors and plant owners as an aid in the proper inspection of atmospheric and low-pressure storage tanks used in refineries and petrochemical plants. It can also be used by consultants and regulators in assessing the adequacy of a plant's inspection program.
Comments:	The main topics covered in this RP are types of storage tanks; reasons for inspection and causes of deterioration; inspection plans; interval/frequency and extent of inspection; inspections; leak testing and hydraulic integrity of the bottom; integrity of repairs and alterations; and records. It also includes appendices for selected nondestructive examination (NDE) methods, and similar service evaluation tables. Some of the information contained in this RP was previously presented as Chapter XIII of the API Guide for Inspection of Refinery Equipment, which is being reorganized as an individual RP. The information in this RP does not constitute, and should not be construed as, a code of rules, regulations or minimum safe practices. The practices described on this RP are not intended to supplant other practices that have proven satisfactory, nor is this recommended practice intended to discourage innovation and originality in the inspection of refineries and chemical plants. Users of this RP are reminded that no book or manual is a substitute for the judgment of a responsible, qualified inspector or piping engineer.
User:	Purchaser: (blank); Consultant: **S**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-18 API RP 576 *Inspection of Pressure-Relieving Devices*

Current Edition:	Fourth Edition, April 2017 (82 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP describes the inspection and repair practices for automatic pressure-relieving devices commonly used in the oil and petrochemical industries. As a guide to the inspection and repair of these devices in the user's plant, it is intended to ensure their proper performance. This RP covers such automatic devices as pressure-relief valves, pilot-operated pressure-relief valves, rupture disks, and weight-loaded pressure vacuum vents. The recommendations in this RP are not intended to supersede requirements established by regulatory bodies. This RP does not cover weak seams or sections in tanks, explosion doors, fusible plugs, control valves or other devices that either depend on an external source of power for operation or are manually operated. Inspections and tests made at manufacturers' plants, which are usually covered by codes or purchase specifications, are not covered by this publication. This RP does not cover training requirements for mechanics involved in the inspection and repair of pressure-relieving devices. Those seeking these requirements should see API 510, which gives the requirements for a quality control system and specifies that the repair organization maintain and document a training program ensuring that personnel are qualified.
Application:	This RP can be used by inspectors and plant owners as an aid in the proper inspection of pressure-relieving devices used in the oil and petrochemical industries. It can also be used by consultants and regulators in assessing the adequacy of a facility's inspection program.
Comments:	The main topics covered in this RP are dimensional and operational characteristics; pressure-relieving valves (descriptions, applications and limitations); pressure-relieving rupture disks (descriptions, applications and some limitations); causes of improper performance; inspection and testing; inspection and replacement of rupture disk devices; pressure relief valve visual on-stream inspection; inspection frequency; and records and reports. It also includes two appendices: 1) Sample record and report forms and 2) Pressure relief valve testing. The repair practices given in this RP are limited.
User:	Maintenance: **S**; Consultant: **S**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-19 API RP 577 *Welding Processes, Inspection, and Metallurgy*

Current Edition:	Third Edition, October 2020 (194 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP provides guidance to the API authorized inspector on welding inspection as encountered with fabrication and repair of refinery and chemical plant equipment and piping, pipelines, and other related industries. Common welding processes, welding procedures, welder qualifications, metallurgical effects from welding and inspection techniques are described to aid the inspector in fulfilling their role implementing API 510, API 570, API Std 653 and API RP 582. The level of learning and training obtained from this document is not a replacement for the training and experience required to be an American Welding Society (AWS) Certified Welding Inspector (CWI), or equivalent schemes in Canada and Europe. This RP does not require all welds to be inspected, nor does it require welds to be inspected to specific techniques and extent. Welds selected for inspection, and the appropriate inspection techniques, should be determined by the welding inspectors, engineers or other responsible personnel using the applicable code or standard. The importance, difficulty, and problems that could be encountered during welding should be considered by all involved. A welding engineer should be consulted on any critical, specialized or complex welding issues.
Application:	This RP can be used by inspectors as an aid in proper welding inspection. It can also be used as a general welding resource by manufacturers, erectors and consultants.
Comments:	The main topics covered in this RP are welding processes (for eight types–descriptions, advantages and limitations); welding procedure (specification and qualification record); welding materials; welder qualification; non-destructive examination; welding inspection; metallurgy; refinery and petrochemical plant welding issues; and safety precautions. It also includes seven appendices: 1) Terminology and symbols, 2) Actions to address improperly made production welds, 3) WPS/PQR review, 4) Guide to common filler metal selection, 5) Example report of RT results, 6) Inspection considerations, and 7) Welding safety.
User:	Erector: **S**; Manufacturer: **S**; Consultant: **S**; Inspector: **P**; Regulator: (blank) P – Primary User S – Secondary User

A-20 API RP 578 *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*

Current Edition:	Third Edition, February 2018 (28 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	The purpose of this RP is to provide the guidelines for an owner/user to develop and implement a material verification program (MVP) as part of an asset integrity program. The MVP uses positive material identification and other methods to verify that the nominal composition of an asset, an asset component, or weldment within the pressure envelope is consistent with the selected or specified construction materials. A well-designed and well-implemented MVP is an important management system used to minimize the potential for release of hazardous substances due to nonconforming materials of construction. This RP provides the guidelines for material verification programs involving ferrous and nonferrous alloys during the construction, installation, maintenance and inspection of new and existing process equipment. This practice applies to metallic materials purchased for use either directly by the owner/user or indirectly through distributors, fabricators, or contractors and includes the supply, fabrication and installation of these materials.
Application:	A material verification program may involve participation of several groups within the operating plant or the shop of a contractor, distributor, or fabricator. When establishing a material verification program, consideration should be given to the roles and responsibilities that each group has within the specific organization. These roles and responsibilities should be clearly defined and documented. Within the operating plant, this can include those groups responsible for purchasing, engineering, warehousing/receiving, operating, reliability, maintenance, and inspection.
Comments:	The main topics covered in this RP are considerations and general concerns; material verification programs; PMI methodology and technology test methods; evaluation of PMI test results; materials identification; and documentation and record-keeping. When determining the need to perform material verification on carbon steel, the effect that the process steam could have on substituted alloy materials should be evaluated. In some cases, the substitution of hardenable alloy materials for carbon steel resulted in failure and loss of containment. Examples of such systems include wet hydrogen sulfide (H_2S), hydrofluoric acid (HF) and sulfuric acid (H_2SO_4) services.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: **P** P – Primary User S – Secondary User

A-21 API 579-1/ASME FFS-1 *Fitness-For-Service*

Current Edition:	June 2016 (1320 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Provides methods for evaluating flaws that are found in pressure equipment, usually as a result on an in-service inspection, to determine acceptability for continued service.
Application:	Owners and users of pressure equipment can use the methods in this standard to evaluate flaws that are discovered during an inspection of boilers, pressure vessels, piping, and storage tanks.

Comments:	Detailed rules for the evaluation of the following types of flaws and damage are provided:
	• Potential for brittle fracture and creep damage.
	• General or widespread metal loss due to corrosion, erosion, or other causes.
	• Local metal loss due to corrosion, pitting, erosion, gouging, or other causes.
	• Misalignment, distortion, dents, etc.
	• Cracking due to fatigue, the environment, creep, hydrogen damage, etc.
	• Assessment of fatigue damage.
	Three levels of evaluation are provided covering screening that can be done by plant inspection personnel (Level 1), engineering evaluations that can be done by plant engineers (Level 2), and more detailed evaluations that require the services of experts (Level 3).
	Note: An update is in final stages of approval with publication in late 2021, to include:
	• Revisions to Part 2 (*Fitness-For-Service Engineering Assessment Procedure*), including Annexes 2C, 2D, and 2E.
	• Revisions to Part 3 (*Assessment of Existing Equipment for Brittle Fracture*).
	• Revisions to Part 4 (*Assessment of General Metal Loss*).
	• Revisions to Part 9 (*Assessment of Crack-Like Flaws*), including Annexes 9B, 9C, 9F, and:
	  o New Annex 9H (Constraint Effects for Surface Flaws in Carbon and Low-Alloy Steel Components in the Ductile-Brittle Transition Region).
	  o New Annex 9I (Alternative Estimate of Mode I Stress Intensity Factors).
	  o New Annex 9J (Determination of the Minimum Allowable Temperature (MAT) using a Fracture Mechanics Approach).
	• Revisions to Part 10 (Assessment of Components Operating in the Creep Range), including Annex 10B.
	• Revisions to Part 11 (Assessment of Fire Damage).
	• Revisions to Part 12 (Assessment of Dents, Gouges, and Dent-Gouge Combinations).
	• Revisions to Part 14 (Assessment of Fatigue Damage), including Annex 14B.

User:	Purchaser: – ; Consultant: **P** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-22 API 579-2/ASME FFS-2 *Fitness-For-Service Example Problem Manual*

Current Edition:	August 11, 2009 (374 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Example problems illustrating the use and calculations required for Fitness-For-Service Assessments described in API 579-1/ASME FFS-1 are provided in this document. Example problems are provided for all calculation procedures in both SI and US Customary units.
Application:	Owners and users of pressure equipment can use the methods in this standard to evaluate flaws that are discovered during an inspection of boilers, pressure vessels, piping, and storage tanks.
Comments:	An introduction to the example problems in this document is described in Part 2 of this standard. The remaining parts of this document contain the example problems. The parts in this document coincide with the parts in API 579-1/ASME FFS-1.
User:	Purchaser: (blank); Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-23 API RP 580 *Risk-Based Inspection*

Current Edition:	Third Edition, February 2016 (94 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	Provides guidance for developing and implementing a risk-based inspection program for fixed pressure-containing equipment and components in the hydrocarbon and chemical process industry. The approach is focused on maintaining mechanical integrity.
Application:	Owners and users of pressure equipment can use the guidance in this standard to develop an in-service (post-construction) inspection program for their equipment. The guidance applies broadly to boilers, pressure vessels, piping, pipelines, and storage tanks. However, other standards that are specific to one or more of these equipment types should also be consulted in developing inspection plans. These include: • API RP 581 "Risk Based Inspection Methodology." This document provides specific, detailed guidance for risk-based inspection. • API 510 "Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration" for pressure vessels in refining and chemical process services. • API 570 "Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems" for piping systems. Although developed for the refining and chemical process industries, it may be used, where practical, for any piping system.
Comments:	API RP 580 provides an overall methodology that can be used to develop an inspection plan using risk-based methods. It provides guidance and detailed tables to assist in defining the damage (deterioration) mechanisms that can affect pressure equipment. It provides methods for establishing RBI teams to determine the probability and consequence of failure and to calculate the risk of continued operation. The result of applying the process is an optimized, cost-effective inspection plan.
User:	Purchaser: (blank); Consultant: **S**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-24 API RP 581 *Risk-Based Inspection Methodology*

Current Edition:	Third Edition, April 2016 through Addendum 2, October 2020 (664 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This document provides a detailed, prescriptive methodology for determining inspection methods and intervals. It provides one method of implementing the more general guidance in ASME PCC-3 and API RP 580 for refinery and some chemical plant equipment. Since the document relies on damage mechanism information that is specific to certain refinery processes (e.g., fluid catalytic cracking), it is not universally applicable. The methodology is based on the experience of experts in the refining industry and provides consistent results among refineries with similar process units.
Application:	The RP can be applied to most refinery units by typical refinery inspection and materials engineering personnel.
Comments:	This RP is particularly valuable for refineries that have smaller or less experienced staffs, since it provides probabilities (likelihoods) and consequences of failure based on input of parameters that are readily obtained, such as process fluids, materials of construction, temperatures, pressures, and volume of fluid in the equipment. This reduces the need to make judgments based on experience and expertise.
User:	Purchaser: — ; Consultant: **S** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-25 API RP 582 *Welding Guidelines for the Chemical, Oil and Gas Industries*

Current Edition:	Third Edition, May 2016 (38 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP, initiated and developed through the joint efforts of API and Process Industry Practices (PIP), provides supplementary guidelines and practices for welding and welding-related topics for shop and field fabrication, repair, and modification of: • Pressure-containing equipment (such as pressure vessels, heat exchangers, tankage, piping, heater tubes, pressure boundaries of rotating equipment, and attachments welded thereto). • Non-removable internals for process equipment. • Structural items attached and related to process equipment. • Any other equipment or component item when referenced by an applicable purchase document. This document is general in nature and is intended to augment the welding requirements of ASME Section IX and similar codes, standards, and practices such as those issued by API, ASME, ASTM, AWS, NACE, and the National Board. The intent of this document is to be inclusive of chemical, oil and gas industry standards, although there are many areas not covered (e.g., pipeline welding and offshore structural welding). This document is based on industry experience, and any restrictions or limitations may be waived or augmented by the purchaser.
Application:	This RP can be used by manufacturers and field contractors as an aid in establishing welding procedures. It can also be used by the equipment owners as an aid in developing a welding specification.
Comments:	The main topics covered in this RP are general welding requirements; welding processes; filler metal and flux; shielding and purging gases; preheating and interpass temperature; postweld heat treatment; cleaning and surface preparation; special procedure qualification requirements/testing (general, tube-to-tubesheet welding, additional procedure qualification requirements for duplex and super duplex stainless steels); and other items (backing materials, peening, overlay and clad restoration, temporary attachments, stud welding, hardness testing, and single pass welds). It also includes two appendices: 1) Welding consumables for shielded metal arc welding and 2) Weld overlay and clad restoration (back cladding). As indicated in Scope above, this is not a stand-alone document and is intended to augment other welding codes, standards, and practices.
User:	Field Contractor: **P** · Manufacturer: **P** · Owner: **P** · Inspector: · Regulator: P – Primary User S – Secondary User

A-26 API RP 583 *Corrosion Under Insulation and Fireproofing*

<table>
<tr><td>Current Edition:</td><td>Second Edition, March 2021 (105 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>No</td></tr>
<tr><td>Scope:</td><td>This recommended practice (RP) covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF). The document discusses the external corrosion of carbon and low alloy steels under insulation and fireproofing and the external chloride stress corrosion cracking (ECSCC) of austenitic and duplex stainless steels under insulation. The document does not cover atmospheric corrosion or corrosion at uninsulated pipe supports, but does discuss corrosion at insulated pipe supports.</td></tr>
<tr><td>Application:</td><td>This RP can be used by owner/users to help them understand the complexity of the many CUI/CUF issues; provide them understanding on the advantages and limitations of the various NDE methods used to identify CUI/CUF damage; provide an approach to risk assessment; and provide guidance on how to design, install, and maintain insulation systems to avoid CUI and CUF damage.

The practices described in this document apply to pressure vessels, piping, and storage tanks and spheres. The document discusses the factors impacting the damage mechanisms, the guidelines to prevent external corrosion/cracking under insulation, the maintenance practices to avoid damage, the inspection practices to detect/assess damage, and the guidelines for risk assessment of equipment or structural steel subject to CUI and CUF damage.</td></tr>
<tr><td>Comments:</td><td>The main topics covered in this RP are introduction to the causes of damage; areas susceptible to damage; insulation and fireproofing systems; inspection for CUI and CUF damage; risk-based inspection; design practices to minimize CUI and CUF; maintenance to mitigate CUI/CUF issues; and repair techniques/strategies. Two informative annexes are included; Annex A provides examples of a qualitative likelihood assessment system, and Annex B provides examples of insulation techniques for various applications.</td></tr>
<tr><td>User:</td><td>Purchaser: (blank) | Consultant: P | Owner: P | Inspector: P | Regulator: (blank)

P – Primary User
S – Secondary User</td></tr>
</table>

A-27 API RP 584 *Integrity Operating Windows*

Current Edition:	First Edition, May 2014 (46 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	The purpose of this recommended practice (RP) is to explain the importance of integrity operating windows (IOWs) for process safety management and to guide users in how to establish and implement an IOW program for refining and petrochemical process facilities for the express purpose of avoiding unexpected equipment degradation that could lead to loss of containment. The scope of this document includes: • Definitions of IOWs and related terminology. • Creating and establishing IOWs. • Data and information typically needed to establish IOWs. • Descriptions of the various types of IOWs needed for process units. • Risk ranking IOWs. • Documenting and implementing IOWs. • Monitoring and measuring process variables within established IOWs. • Communication of IOW exceedances. • Reviewing, changing, and updating IOWs. • Integrating IOWs with other risk management practices. • Roles and responsibilities in the IOW work process. • Knowledge transfer to affected personnel.
Application:	It is not the intent of this document to provide a complete list of specific IOWs or operating variables that might need IOWs for the numerous types of hydrocarbon process units in the industry (though some generic examples are provided in the text and in Annex A); but rather to provide the user with information and guidance on the work process for development and implementation of IOWs to help strengthen the Mechanical Integrity (MI) program for each process unit.
Comments:	The key goals of an IOW program are: 1. Defining IOW limits which will result in predictable and acceptable levels of equipment degradation to meet reliability expectations. 2. Enabling effective communication of equipment limits and exceedances between key Process, Operations, Maintenance, and other MI stakeholders to facilitate safe and reliable process operation and management. 3. Facilitating the reliable operation of equipment without loss of containment or the need for unplanned maintenance activities between scheduled outage or shutdowns.
User:	Purchaser: – ; Consultant: **P** ; Owner: **P** ; Inspector: – ; Regulator: – P – Primary User S – Secondary User

A-28 API RP 585 *Pressure Equipment Integrity Incident Investigation*

Current Edition:	Second Edition, March 2021 (52 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	The purpose of this document is to provide owners/operators with practices for developing, implementing, sustaining, and enhancing an investigation program for pressure equipment integrity (PEI) incidents. This recommended practice (RP) describes characteristics of how an effective investigation could be structured so organizations can learn from PEI incidents.
Application:	The investigation principles and concepts that are presented in this RP are specifically targeted for application to process pressure equipment in the refining and petrochemical industry but could be applied to other equipment at the discretion of the owner/user. Because of the broad diversity in organizations' size, culture, national, and/or local regulatory requirements, API RP 585 offers users the flexibility to apply the investigation methodology within the context of existing incident investigation practices and to accommodate unique local circumstances. API RP 585 is intended to promote the use of systematic investigations as a way to learn from unexpected leaks and equipment degradation or near misses associated with PEI.
Comments:	This RP is not intended to define or supplement criteria for compliance with regulatory requirements for which companies already have defined investigation processes in place. Rather, API RP 585 provides a specific focus on investigating PEI failures that are precursors to potential incidents that could have significant impact on safety, health, and environment.
User:	Purchaser: —; Consultant: **P**; Owner: **P**; Inspector: —; Regulator: — P – Primary User S – Secondary User

A-29 API Bulletin 587 *Guidance for the Development of Ultrasonic Examiner Qualification Programs*

Current Edition:	First Edition, May 2021 (31 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This publication outlines the general guidelines for the development of owner/user ultrasonic examiner qualification programs that are consistent with API performance demonstration programs for detection, characterization, and crack height sizing of weld discontinuities in weldments. The performance demonstration programs covered in this publication include qualification of ultrasonic testing examiners in the following methods: • Detection and Characterization of Flaws Using Manual Angle Beam Testing: QUTE • Detection and Characterization of Flaws Using Manual UT-Phased Array: QUPA • Manual UT-Angle Beam Crack Sizing: QUSE • Manual UT-Phased Array Crack Sizing: QUSE-PA
Application:	The purpose of this publication is to provide owner/users with guidelines for developing basic in-house qualification programs to identify industry-qualified ultrasonic testing (UT) angle beam examiners that are equivalent to those possessing an ultrasonic angle beam qualification from API (e.g., API QUTE/QUSE detection and sizing tests) for inspection of pressure equipment and piping as required by API 510 and API 570.
Comments:	The availability of high quality and accurate UT data is often the cornerstone for weld and base metal discontinuity detection and sizing for equipment integrity assessments. As a result, API has implemented several certification programs to assist in defining the minimum criteria for assessing the performance of UT technicians. Examinations for these programs are administered differently than other Individual Certification Program (ICP) certifications in that they are based on hands-on performance demonstration tests. It should be noted that UT certifications are issued by accredited NDE certification authorities, such as the American Society for Nondestructive Testing (ASNT), and these API UT ICP certifications are considered performance demonstration qualifications by such NDE certification schemes.
User:	Purchaser: — ; Consultant: — ; Owner: **P** ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-30 API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment*

Current Edition:	First Edition, July 2019 (72 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This recommended practice (RP) covers the process of specifying the necessary quality surveillance of materials, equipment, and fabrications being supplied for use in the oil, petrochemical, and gas industry, including upstream, midstream, and downstream segments. This RP outlines the fundamentals of source inspection and may be useful to all personnel conducting such activities to perform their jobs in a competent and ethical manner. The primary purpose of this RP is to summarize the basic body of knowledge that the source inspector typically needs to know to perform as a source inspector for fixed equipment. A secondary purpose is to assist candidates intending to take the API Source Inspection Examination to become certified source inspectors.
Application:	This RP focuses primarily on pressure-containing and structural equipment (fixed equipment), including but not limited to vessels, columns/towers, heat exchangers, piping, valves, pressure-relief devices, tubulars, and supporting structural fabrications. The principles of the document can be applied to other equipment disciplines. This RP may be used as the basis for providing a systematic approach to risk-based source inspection to provide confidence that materials and equipment being purchased meet the minimum requirements as specified in the project documents and contractual agreements.
Comments:	The activities outlined in this RP are not intended to replace the manufacturer's/fabricator's own quality systems, but rather are meant to guide source inspectors (SIs) acting on behalf of the purchaser to determine whether manufacturer's/fabricator's own quality systems have functioned appropriately, such that the purchased equipment and materials will meet contractual agreements.
User:	Purchaser: **P**; Consultant: ; Owner: **P**; Inspector: **P**; Regulator: P – Primary User S – Secondary User

A-31 API RP 591 *Process Valve Qualification Procedure*

Current Edition:	Sixth Edition, April 2019 (32 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP provides recommendations for evaluation of a manufacturer's valve construction and quality assurance program for the purpose of determining a manufacturer's capability to provide new valves manufactured in accordance with the following API standards: 594, 599, 600, 602, 603, 608, 609, and 623. Qualification of valves under this RP is "manufacturing facility specific" and does not cover valves manufactured by other manufacturing facilities, whether owned by the same manufacturer or a third party.
Application:	This RP can be used by the valve end user or purchaser (e.g., contractor) as an aid in assessing a valve manufacturer's capability to supply quality products.
Comments:	The main topics covered in this RP are manufacturer quality management system evaluation (general, record and documentation review, right of access, and document control); valve qualification (data to be provided by the manufacturer, valve qualification facility, selection of valves to be tested, required examination and testing and documentation of examination and test results); and post qualification. It also includes four appendices: 1) Suggested selection quantities for examination and test of valves made in accordance with API Valve Standards; 2) Strength tests for stem-shaft-to-closure-element connections; 3) Suggested minimum acceptable casting radiographic results for wall thickness; and 4) Examination and testing tables.
User:	Purchaser: — ; Consultant: **P** ; Owner: **P** ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-32 API Std 594 *Check Valves: Flanged, Lug, Wafer and Butt-Welding*

Current Edition:	Eighth Edition, July 2017 (35 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	Design, material, face-to-face dimensions, pressure-temperature ratings and examination, inspection and test requirements for two types of check valves. • Type “A” check valves which are short face-to-face and can be wafer, lug, or double flanged. o Classes 125, 150, 250 and 300 in $50 \geq \text{DN} \leq 1200$ ($2 \geq \text{NPS} \leq 48$) o Class 600 in $50 \geq \text{DN} \leq 1050$ ($2 \geq \text{NPS} \leq 42$) o Classes 900 and 1500 in $50 \geq \text{DN} \leq 600$ ($2 \geq \text{NP} \leq 24$) o Class 2500 in $50 \geq \text{DN} \leq 300$ ($2 \geq \text{NPS} \leq 12$) • Type “B” bolted cover swing check values, which are long face-to-face and can be flanged or butt-welding ends. o Classes 150 through 1500 in $50 \geq \text{DN} \leq 600$ ($2 \geq \text{NPS} \leq 24$) o Class 2500 in $50 \geq \text{DN} \leq 300$ ($2 \geq \text{NPS} \leq 12$)
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. Regulators can reference as desired.
Comments:	The main topics covered by this standard are pressure-temperature ratings; design; materials; inspection, examination testing and repair; marking; shipment; and recommended spare parts. Annexes are also provided on the API Monogram Program, information to be specified by the Purchaser, and standard nomenclature for valve parts.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-33 API Std 598 *Valve Inspection and Testing*

<table>
<tr><td>Current Edition:</td><td>Tenth Edition, October 2016 (22 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>No</td></tr>
<tr><td>Scope:</td><td>This standard covers inspection, examination, supplementary examinations and pressure test requirements for resilient-seated, nonmetallic-seated (e.g., ceramic) and metal-to-metal-seated valves of the gate, globe, plug, ball, check and butterfly types. Resilient seats are considered to be:
• Soft seats, both solid and semi-solid grease type (e.g., lubricated plug).
• Combination soft and metal seats.
• Any other type valve designed to meet resilient seat leakage rates as specified in Table 5 of this standard.
API Std 598 supplements API standards that reference it, but it may also be applied to other types of valves by agreement between the purchaser and the valve manufacturer.
The inspection requirements pertain to examinations and testing by the manufacturer and any supplementary examinations that the purchaser may require at the valve manufacturer's plant. The test requirements cover both required and optional pressure tests at the valve manufacturer's plant.</td></tr>
<tr><td>Application:</td><td>Purchasers can reference this standard in a purchase specification, and manufacturers need it to comply with the purchase specification when the standard is cited therein. It can also be used as a reference for shop inspection.</td></tr>
<tr><td>Comments:</td><td>The main topics covered in this standard are inspection at the manufacturer's plant; inspection outside the manufacturer's plant; examination; pressure tests; pressure test procedures; and certification and retesting.
The following tests and examinations are specified in this standard:
• Shell test.
• Backseat test.
• Low-pressure closure test.
• High-pressure closure test.
• Double block and bleed high-pressure closure test.
• Visual examination of castings.
• High-pressure pneumatic shell test.</td></tr>
<tr><td>User:</td><td>Purchaser: P
Manufacturer: P
Owner:
Inspector: S
Regulator:

P – Primary User
S – Secondary User</td></tr>
</table>

A-34 API Std 599 *Metal Plug Valves—Flanged, Threaded, and Welding Ends*

<table>
<tr><td>Current Edition:</td><td>Eighth Edition, March 2020 (26 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>No</td></tr>
<tr><td>Scope:</td><td>This standard specifies the requirements for quarter turn metal plug valves, including the lift plug type, for the petroleum, petrochemical, and industrial applications.
This standard is applicable to:
• Steel, nickel base, and other alloy plug valves with flanged or butt-welding ends and ductile iron plug valves with flanged ends in sizes 15 ≤ DN ≤ 900 (½ ≤ NPS ≤ 36);
• Threaded or socket-welding end plug valves for sizes 15 ≤ DN ≤ 50 (½ ≤ NPS ≤ 2);
• Plug valve bodies conforming to ASME B16.34, which may have any combination of flanged, threaded, socket welding, or butt-welding ends;
• Lubricated and nonlubricated plug valves that have two-way coaxial ports.
NOTE: Three-way and four-way plug valves do not fall under the scope of this standard.
• Tandem plug valves that have two independent operating plugs in a single body.
This standard covers plug valves of the nominal diameter sizes DN: 15, 20, 25, 32, 40, 50, 65, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 650, 700, 750, 800, 850, 900; corresponding to nominal pipe sizes NPS: 1/2, 3/4, 1, 11/4, 11/2, 2, 21/2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 26, 28, 30, 32, 34, 36; and applies to pressure class designations: 150, 300, 600, 900, 1500, 2500.
This standard includes requirements for plug valves fitted with internal body, plug, and port linings or applied hard facings on the body, body ports, plug, and plug port. The extent of linings and the facing materials of which they are made are not covered in this standard.
This standard also provides additional requirements for plug valves that are in full conformance to the requirements of ASME B16.34 for Class 150 through 2500.</td></tr>
<tr><td>Application:</td><td>Purchasers can reference this standard in a purchase specification, and manufacturers can use it in the design and fabrication of bolted bonnet steel gate valves. It can also be used as a reference for shop inspection.</td></tr>
<tr><td>Comments:</td><td>The main topics covered by this standard are pressure-temperature ratings; design; materials; sealing system; inspection, examination and testing; marking; shipment; and recommended spare parts. Annexes are also provided on information to be specified by the Purchaser, and standard nomenclature for valve parts.</td></tr>
<tr><td>User:</td><td><table><tr><td>Purchaser</td><td>Manufacturer</td><td>Owner</td><td>Inspector</td><td>Regulator</td></tr><tr><td>P</td><td>P</td><td></td><td>S</td><td></td></tr></table>P – Primary User
S – Secondary User</td></tr>
</table>

A-35 API Std 600 *Steel Gate Valves – Flanged and Butt-welding Ends, Bolted Bonnets*

Current Edition:	Fourteenth Edition, May 2021 (42 pages)
Alt. Number:	Formerly co-branded with ISO 10434:2001 (Modified)
ANSI Approved?	No
Scope:	This standard specifies the requirements for a heavy duty series of bolted bonnet steel gate valves for petroleum refinery and related applications where corrosion, erosion and other service conditions indicate a need for full port openings, heavy wall sections and large stem diameters. This specification sets forth the requirements for the following gate valve features: • Bolted bonnet. • Outside screw and yoke. • Rising stems. • Non-rising handwheels. • Single or double gate. • Wedge or parallel seating. • Metallic seating surfaces. • Flanged or butt-welded ends. It covers valves of the nominal sizes DN: 25, 32, 40, 50, 65, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 650, 700, 750, 800, 850, 900, 950, 1000, 1050; corresponding to nominal pipe sizes NPS: 1, 1 ¼, 2, 2 ½, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42; and applies for nominal Class ratings: 150, 300, 600, 900, 1500, and 2500.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication of bolted bonnet steel gate valves. It can also be used as a reference for shop inspection.
Comments:	This standard gives thickness and/or other requirements (directly or by reference to other standards) for the following valve components: body, bonnet, flanged ends, welded ends, gate, yoke, stem, stem nut, packing, bolting and auxiliary connections. It also covers (directly or by reference to other standards) materials, repair, testing, inspection, examination, marking and preparation for shipment.
User:	Purchaser: **P** Manufacturer: **P** Owner: Inspector: **S** Regulator: P – Primary User S – Secondary User

A-36 API Std 602 *Gate, Globe and Check Valves for Sizes DN 100 (NPS 4) and Smaller for the Petroleum and Natural Gas Industries*

Current Edition:	Ninth Edition, May 2015 through Errata 1, September 2016 (66 pages)
Alt. Number:	Formerly co-branded with ISO 15761:2002
ANSI Approved?	No
Scope:	This standard specifies the requirements of a series of compact steel gate, globe, and check valves for petroleum and natural gas industry applications. It is applicable to valves of: • Nominal size DN 8, 10, 15, 20, 25, 32, 40, 50, 65, 80 and 100. • Corresponding to NPS ¼, ⅜, ½, ¾, 1, 1¼, 1½, 2, 2 ½, 3 and 4. • Corresponding to pressure designations of Class 150, Class 300, Class 600, Class 800 and Class 1500. Class 800 is not a listed class designation, but is an intermediate class number widely used for socket-welding and threaded end compact valves. It includes provisions for the following valve characteristics: • Outside screw with rising stems (OS&Y), in sizes $8 \le DN \le 100$ ($¼ \le NPS \le 4$) and pressure designations $150 \le Class \le 1500$ including Class 800. • Inside screw with rising stem (ISRS), in sizes $8 \le DN \le 65$ ($¼ \le NPS \le 2½$) and pressure designations of Class < 800. • Socket-welding or threaded ends, in sizes $8 \le DN \le 65$ ($¼ \le NPS \le 2½$) and pressure designations of Class 800 and Class 1500. • Flanged or butt-welding ends, in sizes $15 \le DN \le 100$ ($½ \le NPS \le 4$) and pressure designations of $150 \le Class \le 1500$, excluding flanged end Class 800. • Bonnet joint construction–bolted, welded and threaded with seal weld for Class ≤ 1500 and union nut for Class < 800. • Extended body, in sizes $15 \le DN \le 50$ ($½ \le NPS \le 2$) and pressure designations of Class 800 and Class 1500. • Bellows stem seal, in sizes $8 \le DN \le 50$ ($¼ \le NPS \le 2$) and pressure designations of $<$ Class 1500. • Bellows stem seal testing requirements. • Standard and full-bore body seat openings. • Materials, as specified. • Testing and inspection. This standard is applicable to valve end flanges in accordance with ASME B16.5, valve body ends having tapered pipe threads to ASME B 1.20.1, valve body ends having socket weld ends to ASME B16.11 and butt-weld connections per the requirements described within this standard.
Application:	Purchasers can reference this standard in a purchase specification, and manufacturers can use it in the design and fabrication of steel gate, globe, and check valves. It can also be used as a reference for shop inspection.
Comments:	The main topics covered by this standard are design; materials; marking; testing and inspection; and preparation for shipment. There are seven annexes in support of these topics: 1) Requirements for extended body gate valve bodies, 2) Requirements for valves with bellows stem seals, 3) Type testing of bellows stem seals, 4) Identification of valve parts, 5) Information to be specified by the purchaser, 6) Valve material combinations and 7) Use of API Monogram by Licensees.

	Purchaser	Manufacturer	Owner	Inspector	Regulator
User:	**P**	**P**		**S**	
	P – Primary User S – Secondary User				

A-37 API Std 603 *Corrosion-resistant, Bolted Bonnet Gate Valves—Flanged and Butt-welding Ends*

Current Edition:	Ninth Edition, September 2018 (33 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies the requirements for corrosion-resistant bolted bonnet gate valves meeting the requirements of Standard Class, ASME B16.34 and having full port openings for use in process piping applications. This standard sets forth the requirements for the following gate valve features: • Bolted bonnet. • Outside screw and yoke. • Rising stems. • Non-rising handwheels. • Single or double gate. • Wedge or parallel sealing. • Metallic seating surfaces. • Flanged or butt-welding ends. Covering valves of the nominal pipe size DN: • 15; 20; 25; 32; 40; 50; 65; 80; 100; 150; 200; 250; 300; 350; 400; 450; 500; 600. Corresponding to the nominal pipe size NPS: • ½; ¾; 1; 1¼; 1½; 2; 2½; 3; 4; 6; 8; 10; 12; 14; 16; 18; 20; 24. Applies to pressure class designations: • 150; 300; 600.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication of steel gate, globe and check valves. It can also be used as a reference for shop inspection.
Comments:	The main topics covered by this standard are pressure-temperature ratings; design; materials; testing, inspection and examination; marking; and preparation for shipment. There are three annexes in support of these topics: 1) API Monogram Program, 2) Information to be specified by the purchaser, and 3) Identification of valve terms.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-38 API Std 607 *Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats*

Current Edition:	Seventh Edition, June 2016 (22 pages)
Alt. Number:	Formerly co-branded with ISO 10497
ANSI Approved?	No
Scope:	Specifies fire type-testing requirements and a fire type-test method for confirming the pressure-containing capability of quarter-turn valves and other valves with nonmetallic sealing under pressure during and after the fire test. It does not cover the testing requirements for valve actuators other than manually operated gear boxes or similar mechanisms when these form part of the normal valve assembly. Other types of valve actuators (e.g., electrical, pneumatic, or hydraulic) may need special protection to operate in the environment considered in this valve test, and the fire testing of such actuators is outside the scope of this standard.
Application:	This standard is intended for use by valve manufacturers and testing facilities for conducting and reporting on fire testing of valves.
Comments:	The main topics covered by this standard are test conditions; the fire test method; performance during the test; and using the results for qualification of other valves by representative size, pressure rating, and materials of construction.
User:	Purchaser: ; Manufacturer: **P**; Testing Laboratory: ; Inspector: ; Regulator: P – Primary User S – Secondary User

A-39 API Std 608 *Metal Ball Valves-Flanged, Threaded and Welding Ends*

Current Edition:	Sixth Edition, January 2020 (32 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard covers Class 150, 300, and 600 metal ball valves used in on-off service that have butt-welding of flanged ends for nominal pipe sizes NPS ½ through NPS 12 and Classes 150, 300, 600, and 800 valves in threaded or socket-welding ends for sizes NPS ¼ through NPS 2, corresponding to the nominal pipe sizes in ASME B36.10M. Also covers additional requirements for ball valves that are otherwise in full conformance to the requirements of ASME B16.34, Standard Class.
Application:	Purchasers can reference this document in an equipment purchase specification and manufacturers can use it to certify that requirements have been met. It can also reference for inspection at the manufacturer's plant.
Comments:	This standard establishes requirements for bore sizes described as: • Full bore. • Single reduced bore. • Double reduced bore. The main topics covered by this standard are pressure-temperature ratings; design; materials; inspection, examination and testing; marking; packaging and shipping requirements; and spare parts. Annexes are provided on the API Monogram Program, information to be specified by the purchaser, and typical floating and trunnion ball valve component nomenclature.
User:	Purchaser: **P** Manufacturer: **P** Owner: Inspector: **S** Regulator: P – Primary User S – Secondary User

A-40 API Std 609 *Butterfly Valves: Double-flanged, Lug- and Wafer-Type, and Butt Welding Ends*

Current Edition:	Ninth Edition, April 2021 (34 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard covers design, materials, face-to-face dimensions; pressure-temperature ratings; and examination, inspection and test requirements for gray iron, ductile iron, bronze, steel, nickel-base alloy or special alloy butterfly valves.
Application:	Purchasers can reference this document in an equipment purchase specification and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspection at the manufacturer’s plant.
Comments:	Two categories of butterfly valves are included: • Category A: Sizes covered are NPS 2 to NPS 60 for ASME Class 125 or Class 150. • Category B: Sizes covered are: o For lug and wafer, NPS 2 to NPS 60 for ASME Classes 150 and 300. o For lug and wafer, NPS 3 to NPS 60 for Class 600. o For double-flanged short and long pattern, NPS 3 to NPS 60 for ASME Classes 150, 300 and 600. o For butt-welding ends, NPS 3 to NPS 60 for ASME Classes 150, 300, and 600.
User:	Purchaser: P Manufacturer: P Owner: Inspector: S Regulator: P – Primary User S – Secondary User

A-41 API RP 615 *Valve Selection Guide*

Current Edition:	Second Edition, August 2016 (44 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This Recommended Practice (RP) provides general guidance on valve selection for the hydrocarbon processing industry (HPI), which includes refineries and petrochemical, chemical, and liquefied natural gas (LNG) plants and their various associated processes. Selection guidance is provided for valve types covered by ASME B16.34 and API Valve Standards for the Downstream Segment, which include gate, ball, plug, butterfly, check, and globe valves. Modulating control valves and pressure relief valves are outside the scope of this RP.
Application:	The objective of this RP is to disseminate suggested information on valve selection recommendations as an aid to reduce operational problems and maintenance costs. Although this RP provides guidance on the selection of valves, the valve specifier or end user is required to pay particular attention to, and is ultimately responsible for, all aspects of the application involving process, metallurgical, and mechanical considerations.
Comments:	Typical purchase descriptions are provided in the Annex to assist in the complete definition of valve details to help ensure that the correct product is specified for the intended application. Primarily, however, this RP is a general guideline for valve selection; the final responsibility is that of the user of this document.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-42 API Std 620 *Design and Construction of Large, Welded, Low-pressure Storage Tanks*

Current Edition:	Twelfth Edition, October 2013 through Addendum 2, April 2018 (288 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	**General** The API Downstream Segment has prepared this standard to cover large, field-assembled storage tanks of the type described below that contain petroleum intermediates (gases or vapors) and finished products, as well as other liquid products commonly handled and stored by the various branches of the industry. The rules presented in this standard cannot cover all details of design and construction because of the variety of tank sizes and shapes that may be constructed. Where complete rules for a specific design are not given, the intent is for the manufacturer–subject to the approval of the purchaser's authorized representative–to provide design and construction details that are as safe as those which would otherwise be provided in this standard. The manufacturer of a low-pressure storage tank that will bear the API 620 nameplate shall ensure that the tank is constructed in accordance with the requirements of this standard. The rules presented in this standard are further intended to ensure that the application of the nameplate shall be subject to the approval of a qualified inspector who has made the checks and inspections that are prescribed for the design, materials, fabrication and testing of the completed tank. **Coverage** This standard covers the design and construction of large, welded, low-pressure carbon steel aboveground storage tanks (including flat-bottom tanks) that have a single vertical axis of revolution. This standard does not cover design procedures for tanks that have walls shaped in such a way that the walls cannot be generated in their entirety by the rotation of a suitable contour around a single vertical axis of revolution. The tanks described in this standard are designed for metal temperatures not greater than 250°F (121°C) and with pressures in their gas or vapor spaces not more than 15 lbf/in.^{2} (100 kPa) gauge. The basic rules in this standard provide for installation in areas where the lowest recorded 1-day mean atmospheric temperature is –50°F (–46°C). Appendix S covers stainless steel low-pressure storage tanks for refrigerated products at temperatures from +40°F to –60°F (+4°C to –51°C). Appendix Q covers low-pressure storage tanks for liquefied hydrocarbon gases at temperatures not lower than –270°F (–168°C). The rules in this Standard are applicable to tanks that are intended to (a) hold or store liquids with gases or vapors above their surface or (b) hold or store gases or vapors alone. These rules do not apply to lift-type gas holders. Although the rules in this standard do not cover horizontal tanks, they are not intended to preclude the application of appropriate portions to the designs and construction of horizontal tanks designed in accordance with good engineering practice. The details for horizontal tanks not covered by these rules shall be equally as safe as the design and construction details provided for the tank shapes that are expressly covered by this standard.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication/erection of large, welded, low-pressure storage tanks. It can also be used as a reference for shop and field fabrication/erection inspection. Regulators can reference as desired.
Comments:	This is a comprehensive document covering the following main topics: materials; design; fabrication; inspection, examination and testing; marking; and pressure and vacuum-relieving devices. It also includes 21 appendices in support of these topics.

	Purchaser	Manufacturer	Owner	Inspector	Regulator
User:	**P**	**P**		**P**	**S**
	P – Primary User S – Secondary User				

A-43 API RP 621 *Reconditioning of Metallic Gate, Globe, and Check Valves*

Current Edition:	Fourth Edition, October 2018 (36 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP provides guidelines for reconditioning heavy wall (API 600, API 623 and API 594 type) carbon steel, ferritic alloy (up to 9% Cr), stainless steel, and nickel alloy gate, globe and check valves for ASME pressure classes 150, 300, 400, 600, 900, 1500, and 2500. Guidelines contained in this RP apply to flanged and butt-weld cast or forged valves. This RP does not cover reconditioning or re-manufacturing of used or surplus valves intended for resale. The only intent of this RP is to provide guidelines for refurbishing an end user's (owner's) valves for continued service in the owner's facility. Valves reconditioned or re-manufactured to this RP may not meet API standard requirements for new valves. The correct application of a valve reconditioned to this practice remains the responsibility of the owner. It is an expectation of this RP that a contractual agreement shall be established between the owner and the valve reconditioning facility. The reconditioning facility may be OEM owned/operated, or directly associated and approved by the OEM. At the owner's option, an independent facility may be used. The owner shall determine that the facility selected for valve reconditioning has a documented and established working quality assurance program. The quality assurance program should include the essential elements described in the ISO 9000 standard.
Application:	This RP can be used by the owner and the reconditioner as an aid in reconditioning valves.
Comments:	This RP covers what information should be provided to the reconditioner by the owner, and how the owner should prepare the valve for shipment to the reconditioner. For the reconditioner, it provides guidance on how to assess and take action on each valve component. It also covers, for the reconditioner (some with owner approval or input), welding, non-destructive examination, pressure test, preparation for shipment and tagging.
User:	Purchaser: — ; Reconditioner: **P** ; Owner: **P** ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-44 API Std 622 *Type Testing of Process Valve Packing for Fugitive Emissions*

Current Edition:	Third Edition, October 2018 (37 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies the requirements for comparative testing of valve stem packing for process applications where fugitive emissions are a consideration. Packing(s) shall be suitable for use at –20°F to 1000°F (–29°C to 538°C). Factors affecting fugitive emissions performance that are considered by this standard include temperature, pressure, thermal cycling, mechanical cycling, and corrosion. This standard is not intended to replace proof testing of valve assemblies or valve production testing. This standard establishes requirements and parameters for the following packing tests: • Fugitive emissions. • Corrosion. • Packing material composition and properties. Test methods apply to valve packing for use in on-off valves with the following stem motion(s): • Rising stem; • Rotating stem; or • Rising and rotating stem.
Application:	This standard can be used by packing manufacturers and testing laboratories to design and build test facilities, and to perform the testing. It can also be referenced by packing and valve manufacturers, and valve end users, in a purchase specification for packing testing services.
Comments:	The purpose of this API standard is to establish a uniform procedure for evaluation of process valve stem packing. The testing approaches defined within this standard provide a method for evaluating packing systems. This testing program will provide a basis for the comparison of the emissions and life cycle performance of packing. This standard includes test documentation data sheets and test fixture construction information.
User:	Manufacturer: **P** · Consultant: **P** · Owner: **S** · Inspector: · Regulator: P – Primary User S – Secondary User

A-45 API Std 623 *Steel Globe Valves—Flanged and Butt-welding Ends, Bolted Bonnets*

Current Edition:	Second Edition, January 2021 (39 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies the requirements for a heavy-duty series of bolted bonnet steel globe valves for petroleum refinery and related applications where corrosion, erosion and other service conditions would indicate a need for heavy wall sections and large stem diameters. This standard sets forth the requirements for the following globe valve features: • Bolted bonnet. • Outside screw and yoke. • Rotating rising stems, and nonrotating rising stems. • Rising handwheels and nonrising handwheels. • Straight pattern, y-pattern, right-angle. • Stop-check (nonreturn type globe valves in which the disc may be positioned against the seat by action of the stem, but is free to rise as a check valve due to flow from under the disc, when the stem is in a full or partially open position). • Plug, narrow, conical, ball, or guided disc. • Metallic seating surfaces. • Flanged or butt-welding ends. It covers valves of the nominal pipe sizes NPS: • 2, 2-1/2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, and 24. Corresponding to nominal pipe sizes DN: • 50, 65, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, and 600. Applies for pressure class designations: • 150, 300, 600, 900, 1500, and 2500.
Application:	This standard can be used by packing manufacturers and testing laboratories to design and build test facilities and to perform the testing. It can also be referenced by packing and valve manufacturers, and valve end users, in a purchase specification for packing testing services.
Comments:	The main topics covered by this standard are design; materials; testing, inspection and examination; marking; and preparation for shipment. There are three annexes in support of these topics: 1) Information to be specified by the purchaser, 2) Identification of valve terms, and 3) Valve material combinations.
User:	Manufacturer: **P**; Consultant: **P**; Owner: **S**; Inspector: ; Regulator: P – Primary User S – Secondary User

A-46 API Std 624 *Type Testing of Rising Stem Valves Equipped with Graphite Packing for Fugitive Emissions*

Current Edition:	First Edition, February 2014 (20 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies the requirements and acceptance criteria (100 ppmv) for fugitive emission type testing of rising and rising-rotating stem valves equipped with packing previously tested in accordance with API 622. Packing shall be suitable for use at service temperatures –29°C to 538°C (–20°F to 1000°F). The type testing requirements contained herein are based upon elements of EPA Method 21. Valves larger than NPS 24 or valves greater than class 1500 are outside the scope of this standard.
Application:	This standard can be used by packing manufacturers and testing laboratories to design and build test facilities and to perform the testing. It can also be referenced by packing and valve manufacturers, and valve end users, in a purchase specification for packing testing services.
Comments:	The purpose of this standard is to establish a uniform procedure for the evaluation of emission performance of process valves. The testing program will provide a basis for the comparison of the emissions and performance of process valves.
User:	Manufacturer: **P**; Consultant: **P**; Owner: **S**; Inspector: ; Regulator: P – Primary User S – Secondary User

A-47 API Std 641 *Type Testing of Quarter-turn Valves for Fugitive Emissions*

Current Edition:	First Edition, October 2016 (22 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies the requirements and acceptance criteria for fugitive emission type testing of quarter-turn valves. The type testing requirements contained herein are based on elements of EPA Method 21. Valves larger than NPS 24 and valves greater than ASME B16.34 class 1500 are outside the scope of this standard. Valves with a pressure rating at ambient temperature less than 6.89 barg (100 psig) are outside the scope of this standard. Repacking or resealing of valves is outside the scope of this standard.
Application:	This standard can be used by packing manufacturers and testing laboratories to design and build test facilities, and to perform the testing. It can also be referenced by packing and valve manufacturers, and valve end users, in a purchase specification for packing testing services.
Comments:	The purpose of this standard is to establish a uniform procedure for the evaluation of emission performance of process valves. The testing program will provide a basis for the comparison of the emissions and performance of process valves.
User:	Manufacturer: **P** / Consultant: **P** / Owner: **S** / Inspector: / Regulator: P – Primary User S – Secondary User

A-48 API Std 650 *Welded Tanks for Oil Storage*

Current Edition:	Thirteenth Edition, March 2020 through Errata 1 January 2021 (515 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard establishes minimum requirements for material, design, fabrication, erection and testing for vertical, cylindrical, aboveground, closed and open-top, welded storage tanks in various sizes and capacities for internal pressures approximating atmospheric pressure (internal pressures not exceeding the weight of the roof plates), but a higher internal pressure is permitted when additional requirements are met. This standard applies only to tanks whose entire bottom is uniformly supported and to tanks in non-refrigerated service that have a maximum design temperature of 93°C (200°F) or less. This standard is designed to provide industry with tanks of adequate safety and reasonable economy for use in the storage of petroleum, petroleum products, and other liquid products. This standard does not present or establish a fixed series of allowable tank sizes; instead, it is intended to permit the purchaser to select whatever size tank may best meet his needs. This standard is intended to help purchasers and manufacturers in ordering, fabricating, and erecting tanks; it is not intended to prohibit purchasers and manufacturers from purchasing or fabricating tanks that meet specifications other than those contained in this standard.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication/erection of welded oil storage tanks. It can also be used as a reference for shop and field fabrication/erection inspection. Regulators can reference as desired.
Comments:	This is a comprehensive document covering the following main topics: materials; design; fabrication; erection; method of examining joints; vacuum testing; welding procedure and welder qualifications; and marking. It also includes 27 appendices in support of these topics.
User:	Purchaser: **P** Manufacturer: **P** Owner: Inspector: **P** Regulator: **S** P – Primary User S – Secondary User

A-49 API RP 651 *Cathodic Protection of Aboveground Petroleum Storage Tanks*

Current Edition:	Fourth Edition, September 2014 (56 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP presents procedures and practices for achieving effective corrosion control on aboveground steel storage tank bottoms through the use of cathodic protection. It is the intent of this RP to provide information and guidance for the application of cathodic protection to existing and new storage tanks in hydrocarbon service. Specific cathodic protection designs are not provided. Certain practices recommended herein may also be applicable to tanks in other services. Corrosion control methods based on chemical control of the environment or the use of protective coatings are not covered in detail.
Application:	Tank owners and manufacturers, and consultants, can use this RP to develop specific cathodic protection designs.
Comments:	The intent of this RP to provide information and guidance specific to aboveground steel storage tanks in hydrocarbon service. Certain practices recommended herein may also be applicable to tanks in other services.
User:	Consultant: **P**; Manufacturer: **P**; Owner: **P**; Inspector: ; Regulator: P – Primary User S – Secondary User

A-50 API RP 652 *Linings of Aboveground Petroleum Storage Tank Bottoms*

Current Edition:	Fifth Edition, May 2020 (40 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP provides guidance on achieving effective corrosion control by the application of tank bottom linings in aboveground storage tanks. It contains information pertinent to the selection of lining materials, surface preparation, lining application, cure and inspection of tank bottom linings for existing and new storage tanks. In many cases, tank bottom linings have proven to be an effective method of preventing internal corrosion of steel tank bottoms.
Application:	Tank owners and manufacturers, and consultants, can use this RP to develop specific tank bottom lining designs and lining specifications.
Comments:	The intent of this RP is to provide information and guidance specific to aboveground steel storage tanks in hydrocarbon service. Certain practices recommended herein may also be applicable to tanks in other services. This RP is intended to serve only as a guide and detailed tank bottom lining specifications are not included. The main topics covered by this standard are corrosion mechanisms; determination of the need for tank bottom lining; tank bottom lining selection; surface preparation; lining application; inspection; evaluation, repair, and replacement of existing linings; maximizing lining service life by proper material selection and specification; and health, safety, and environmental.
User:	Consultant: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: **P** P – Primary User S – Secondary User

A-51 API Std 653 *Tank Inspection, Repair, Alteration, and Reconstruction*

Current Edition:	Fifth Edition, November 2014 through Addendum 2, May 2020 (189 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard covers steel storage tanks built to API Standard 650 and its predecessor API 12C. It provides minimum requirements for maintaining the integrity of such tanks after they have been placed in service and addresses inspection, repair, alteration, relocation, and reconstruction. The scope is limited to the tank foundation, bottom, shell, structure, roof, attached appurtenances and nozzles to the face of the first flange, first threaded joint, or first welding-end connection. Many of the design, welding, examination, and material requirements of API Std 650 can be applied in the maintenance inspection, rating, repair, and alteration of in-service tanks. In the case of apparent conflicts between the requirements of this standard and API Std 650 or its predecessor API 12C, this standard shall govern for tanks that have been placed in service. This standard employs the principles of API Std 650; however, storage tank owner/operators, based on consideration of specific construction and operating details, may apply this standard to any steel tank constructed in accordance with a tank specification. This standard does not contain rules or guidelines to cover all the varied conditions which may occur in an existing tank. When design and construction details are not given, and are not available in the as-built standard, details that will provide a level of integrity equal to the level provided by the current edition of API Std 650 must be used.
Application:	This standard is intended for use by organizations that maintain or have access to engineering and inspection personnel technically trained and experienced in tank design, fabrication, repair, construction and inspection. Regulators may use as desired.
Comments:	The main topics covered in this standard are suitability for service; brittle fracture considerations; inspection; materials; design considerations for reconstructed tanks; tank repair and alteration; dismantling and reconstruction; welding; examination and testing; and marking and record keeping. It also contains 13 appendices in support of these topics.
User:	Purchaser: — ; Contractor: **P** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-52 API Std 660 *Shell-and-Tube Heat Exchangers*

Current Edition:	Ninth Edition, March 2015 through Addendum 1, August 2020 (77 pages)
Alt. Number:	Formerly co-branded with ISO 16812:2007
ANSI Approved?	No
Scope:	This standard specifies requirements and gives recommendations for the mechanical design, material selection, fabrication, inspection, testing, and preparation for shipment of shell-and-tube heat exchangers for the petroleum, petrochemical, and natural gas industries. This standard is applicable to the following types of shell-and-tube heat exchangers: heaters, condensers, coolers, and reboilers. This standard is not applicable to vacuum-operated steam surface condensers and feed-water heaters.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication of shell-and-tube heat exchangers. It can also be used as a reference for shop inspection.
Comments:	The main topics covered in this standard are: proposal information required; design; materials; fabrication; inspection and testing; preparation for shipment; supplemental requirements (if specified by the purchaser); and supplemental requirements for services subject to high temperature hydrogen service (HTHS). It also includes three appendices: 1) Recommended practices, 2) Shell-and-tube heat exchanger checklist, and 3) Shell-and-tube heat exchanger data sheets. The completion of the heat exchanger data sheets is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets. This standard states that the pressure design code shall be specified by, or agreed to by, the purchaser. Some welding requirements are included in the standard, but no guidance on a welding code is given.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-53 API Std 661 *Petroleum, Petrochemical, and Natural Gas Industries – Air-cooled Heat Exchangers*

Current Edition:	Seventh Edition, July 2013, Reaffirmed June 2018 (160 pages)
Alt. Number:	Formerly co-branded with ISO 13706-1:2005
ANSI Approved?	No
Scope:	This standard gives requirements and recommendations for the mechanical design, materials, fabrication, inspection, testing, and preparation for shipment of air-cooled heat exchangers for use in the petroleum, petrochemical, and natural gas industries. This standard is applicable to air-cooled heat exchangers with horizontal bundles, but the basic concepts can also be applied to other configurations.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication of air-cooled heat exchangers. It can also be used as a reference for shop inspection. This standard includes data sheets whose completion is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets.
Comments:	The main topics covered in this standard are manufacturer's proposal requirements; documentation; design; materials; fabrication of tube bundle; inspection, examination, and testing; preparation for shipment; and supplemental requirements (if specified by the purchaser). It also includes five annexes: 1) Recommended practices, 2) Checklist and data sheets, 3) Winterization of air-cooled heat exchangers, 4) Recommended Procedure for Airflow Measurement of Air-cooled Heat Exchangers, and 5) Measurement of Noise from Air-cooled Heat Exchangers. The completion of the heat exchanger data sheets is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets. This standard states that the pressure design code shall be specified by, or agreed to by, the purchaser, and that welding shall be in accordance with the pressure design code.
User:	Purchaser: **P** Manufacturer: **P** Owner: Inspector: **S** Regulator: P – Primary User S – Secondary User

A-54 API Std 662, Part 1 *Plate Heat Exchangers for General Refinery Services–Part 1–Plate-and-Frame Heat Exchangers*

Current Edition:	First Edition, February 2006, Reaffirmed February 2011 (36 pages)
Alt. Number:	ISO 15547-1:2005 (Identical)
ANSI Approved?	Yes
Scope:	This Part 1 of the standard gives requirements and recommendations for the mechanical design, materials selection, fabrication, inspection, testing, and preparation for shipment of plate-and-frame heat exchangers for use in petroleum, petrochemical, and natural gas industries. It is applicable to gasketed, semi-welded, and welded plate-and-frame heat exchangers.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication of plate-and-frame heat exchangers. It can also be used as a reference for shop inspection.
Comments:	The main topics covered in this standard are manufacturer's proposal requirements; drawings and other data requirements; design; materials; fabrication; inspection and testing; preparation for shipment. It also includes three annexes: 1) Recommended practices, 2) Plate-and-frame heat exchanger checklist and 3) Plate-and frame heat exchanger data sheets. The completion of the heat exchanger data sheets is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets. This standard states that the pressure design code and the structural welding code shall be specified, or agreed to, by the purchaser.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-55 API Std 663 *Hairpin-type Heat Exchangers*

Current Edition:	First Edition, May 2014 (54 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies requirements and gives recommendations for the mechanical design, materials selection, fabrication, inspection, testing and preparation for shipment of hairpin heat exchangers for use in the petroleum, petrochemical and natural gas industries. Hairpin heat exchangers include double-pipe and multi-tube type heat exchangers.
Application:	Purchasers can reference this standard in a purchase specification, and manufacturers can use it in the design and fabrication of hairpin heat exchangers. It can also be used as a reference for shop inspection.
Comments:	The main topics covered in this standard are general requirements, proposal information required, drawings and other required data, design, materials, fabrication, inspection and testing, preparation for shipment, and supplemental requirements specified by the purchaser. It also includes three appendices: 1) Recommended practices, 2) Hairpin heat exchanger checklist, and 3) Hairpin heat exchanger data sheets. The completion of the heat exchanger data sheets is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-56 API Std 664 *Spiral Plate Heat Exchangers*

Current Edition:	First Edition, March 2014, Reaffirmed June 2019, Errata 1, February 2021 (50 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard specifies requirements and gives recommendations for the mechanical design, materials selection, fabrication, inspection, testing, and preparation for shipment of spiral plate heat exchangers for the petroleum, petrochemical, and natural gas industries. It is applicable to standalone spiral plate heat exchangers and those integral with a pressure vessel.
Application:	Purchasers can reference this standard in a purchase specification and manufacturers can use it in the design and fabrication of spiral plate heat exchangers. It can also be used as a reference for shop inspection.
Comments:	The main topics covered in this standard are general requirements, proposal information required, drawings and other data requirements, design, materials, fabrication, inspection and testing, and preparation for shipment. It also includes three appendices: 1) Recommended practices, 2) Spiral heat exchanger checklist, and 3) Spiral heat exchanger data sheets. The completion of the heat exchanger data sheets is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-57 API Std 668 *Brazed Aluminum Plate-fin Heat Exchangers*

Current Edition:	First Edition, November 2018 (49 pages)
Alt. Number:	Formerly API Standard 662 Part 2
ANSI Approved?	No
Scope:	This standard gives requirements and recommendations for the mechanical design, materials selection, fabrication, inspection, testing and preparation for shipment of brazed aluminum plate-fin heat exchangers for use in petroleum, petrochemical, and natural gas industries.
Application:	Purchasers can reference this standard in a purchase specification, and manufacturers can use it in the design and fabrication of brazed aluminum plate-fin heat exchangers. It can also be used as a reference for shop inspection.
Comments:	The main topics covered in this standard are general requirements, proposal information required, drawings and other required data, design, materials, fabrication, inspection and testing, and preparation for shipment. It also includes four appendices: 1) Recommended practices, 2) Plate-fin heat exchanger checklist, 3) Plate-fin heat exchanger data sheets, and 4) Block-in-shell heat exchangers. The completion of the heat exchanger data sheets is the joint responsibility of the purchaser and the manufacturer. The purchaser is responsible for the process data on the data sheets.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-58 API RP 686 *Recommended Practice for Machinery Installation and Installation Design–Chapter 6–Piping*

Current Edition:	Second Edition, December 2009 (64 pages)
Alt. Number:	Originally PIP REIE 686
ANSI Approved?	No
Scope:	This recommended practice (RP) provides guidelines for the installation and pre-installation design of piping that is connected to machinery in petroleum or chemical processing facilities. It does not address piping materials, nor piping fabrication and testing requirements, which are part of equipment user specified piping specifications. This RP covers rotating and reciprocating fluid-handling machinery and includes pumps, compressors, blowers, and turbines in both horizontal and vertical configurations.
Application:	This RP is written such that it can be used as a contractual document between an owner company and an engineering and construction (E&C) contractor. The major benefit is that it provides a detailed scope of supply for machinery installation requirements, with acceptance criteria, and documentation requirements. There is then no ambiguity amongst multiple E&C bidders as to the requirements for project machinery installation.
Comments:	The main topics covered in this RP are the machinery piping installation design, the machinery-specific piping design (pumps, compressors/blowers, and steam turbines), and the machinery piping installation. Four annexes are provided: 1) a checklist for machinery piping installation; 2) machinery installation piping diagrams; 3) steam piping for turbines; and 4) field relief of pipe strain.
User:	Engineering Contractor: **P**; Construction Contractor: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-59 API RP 751 *Safe Operation of Hydrofluoric Acid Alkylation Units*

Current Edition:	Fourth Edition, May 2013, Reaffirmed August 2020 (75 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	The Hydrofluoric Acid (HF) alkylation process presents operational risk and relies upon the proper design, maintenance, and operation practices to assure safe operation. API RP 751 is an industry document that communicates proven industry practices to support the safe operation of an HF acid alkylation unit. The philosophy of this fourth edition is to build on the previous editions' base of recommendations for HF acid leak prevention, detection and mitigation with the document section topics of hazard management, operating procedures and worker protection, material inspection and maintenance, transportation and inventory control, relief and utility systems, and risk mitigation. The recommendations presented in the document are those that have been found effective or those which are advised for safe operations.
Application:	This RP is relevant for the entire life cycle involving HF acid alkylation units. It could be used by the owner and engineering contractor in design and construction, as well as by the owner during operation and maintenance activities.
Comments:	Within the context of pressure equipment, the primary area of interest in this RP is the section on Materials, New Construction, Inspection, and Maintenance (Section 3 in the Fourth Edition). This section covers materials performance in HF service, construction and equipment guidelines (pressure vessels, piping, valves, flanged joints, heat exchangers, fired heaters, and safety relief valves), inspection of commissioned HF unit equipment, equipment and maintenance. Another section of the RP covers relief and utility systems (Section 5 in the Fourth Edition). An annex in the document highlights specific materials issues known to be potentially problematic within HF alkylation units.
User:	Engineering Contractor: **P**; Manufacturer: ; Owner: **P**; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-60 API RP 932-B *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*

<table>
<tr><td>Current Edition:</td><td>Third Edition, June 2019 (70 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>No</td></tr>
<tr><td>Scope:</td><td>This recommended practice provides guidance to engineering and plant personnel on equipment and piping design, material selection, fabrication, operation, and inspection practices to manage corrosion and fouling in the wet sections of hydroprocessing reactor effluent systems.

The reactor effluent system includes the equipment and piping subject to ammonium salting, NH_4HS corrosion, and associated fouling. This system usually begins at the last feed/effluent exchanger or first water injection point and continues through the cold high pressure separator (1, 2, and 3 separator designs) or cold high- and low-pressure separators (4 and 5 separator designs). The reactor effluent system specifically excludes the stripper, fractionator, and final separation sections. However, guidance in this RP may be applicable to ammonium salt corrosion mitigation in those areas, as well.

An understanding of all variables impacting corrosion and fouling in these systems is necessary to improve the reliability, safety, and environmental impact associated with them. Past attempts to define generic optimum equipment design and acceptable operating variables to minimize fouling and corrosion have had limited success due to the interdependence of the variables. Corrosion can occur at high rates and be extremely localized, making it difficult to inspect for deterioration and to accurately predict remaining life of equipment and piping.

Within the refining industry, continuing equipment replacements, unplanned outages, and serious past incidents illustrate the current need to better understand the corrosion characteristics and provide guidance on factors that can impact fouling and corrosion.</td></tr>
<tr><td>Application:</td><td>This recommended practice is applicable to process streams in which NH_4Cl and NH_4HS salts can form and deposit in equipment and piping or dissolve in water to form aqueous solutions of these salts. Included in this practice are:
Details of deterioration mechanisms.
Methods to assess and monitor the corrosivity of systems.
Details on materials selection, design, and fabrication of equipment for new and revamped processes.
Considerations in equipment repairs.
Details of an inspection plan.</td></tr>
<tr><td>Comments:</td><td>Materials and corrosion specialists should be consulted for additional unit-specific interpretation and application of this document. Each facility needs to establish its own safe operating envelope to ensure satisfactory service. This RP helps to identify key variables necessary for monitoring and establishing the operating envelope.</td></tr>
<tr><td>User:</td><td><table><tr><td>Purchaser</td><td>Manufacturer</td><td>Owner</td><td>Inspector</td><td>Regulator</td></tr><tr><td>P</td><td>P</td><td>S</td><td>S</td><td></td></tr></table>
P – Primary User
S – Secondary User</td></tr>
</table>

A-61 API RP 934A *Materials and Fabrication of 2¼Cr-1Mo, 2¼Cr-1Mo-¼V, 3Cr-1Mo and 3Cr-1Mo-¼V Steel Heavy Wall Pressure Vessels for High-temperature, High-pressure Hydrogen Service*

Current Edition:	Third Edition, January 2019 (57 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP presents materials and fabrication requirements for new 2-¼Cr and 3Cr steel heavy wall pressure vessels for high temperature, high pressure hydrogen service. It applies to vessels that are designed, fabricated, certified and documented in accordance with ASME Code Section VIII, Division 2, including Appendix 26, Mandatory Rules for Cr-Mo Steels and Additional Requirements for Welding and Heat Treatment and ASME Code Case 2151, if applicable. Materials covered by this RP are conventional steels including standard 2-¼Cr-1Mo and standard 3Cr-1Mo steels, advanced steels including enhanced 2-¼Cr-1Mo, 2-¼Cr-1Mo-¼V, 3Cr-1Mo-¼V-Ti-B, and 3Cr-1Mo-¼V-Cb-Ca steels. The interior surfaces of these heavy wall pressure vessels may have an austenitic stainless steel weld overlay to provide additional corrosion resistance. Licensors and owners of process units in which these heavy wall pressure vessels are to be used may modify and/or supplement this RP with additional proprietary requirements.
Application:	Purchasers can reference this document in a purchase specification and manufacturers can use it in the design and fabrication of pressure vessels. It can also be used as a reference for shop inspection, and as a resource when modifying existing pressure vessels.
Comments:	This RP is based on decades of industry operating experience and the results of experimentation and testing conducted by independent manufacturers, fabricators, and users of heavy wall pressure vessels for this service. The main topics covered in this RP are design (per ASME Code); two design issues (weld seam layout and nozzle neck transition); base metal requirements; welding requirements; heat treatment; testing requirements; nondestructive examination (NDE); hydrostatic testing; preparation for shipping; documentation; and supplementary material examination and NDE requirements. Annexes include guidance for inspection for transverse reheat cracking, and alternate probe setup with offset for detecting transverse defects.
User:	Purchase: **P**; Manufacturer: **P**; Owner: **S**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-62 API RP 934C *Materials and Fabrication of 1¼Cr-½Mo Steel Heavy Wall Pressure Vessels for High-pressure Hydrogen Service Operating at or Below 825°F (440°C)*

Current Edition:	Second Edition, February 2019 (25 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP presents materials and fabrication requirements for new 1 ¼Cr-½Mo steel heavy wall pressure vessels and heat exchangers for high-temperature, high-pressure hydrogen service. It applies to vessels that are designed, fabricated, certified, and documented in accordance with ASME *BPVC*, Section VIII, Division 1 or Division 2. This document may also be used as a resource for equipment fabricated of 1Cr-½2Mo Steel. This document may also be used as a resource when planning to modify an existing heavy wall pressure vessel. The interior surfaces of these heavy wall pressure vessels may have an austenitic stainless steel or ferritic stainless steel weld overlay or cladding to provide additional corrosion resistance. For this RP, the heavy wall is defined as shell thickness 2 in. (50 mm) or greater but less or equal to 4 in. (100 mm). Integrally reinforced nozzles, flanges, tubesheets, bolted channel covers, etc. can be greater than 4 in. (100 mm). At shell or head thicknesses greater than 4 in. (100 mm), 1¼Cr-½Mo has been shown to have difficulty meeting the toughness requirements given in this document. Although outside of the scope of this document, it can be used as a resource for vessels down to 1 in. (25 mm) shell thickness with changes defined by the purchaser. This RP is not intended for use for equipment operating above 825°F (440°C) or in the creep range.
Application:	Purchasers can reference this document in a purchase specification and manufacturers can use it in the design and fabrication of pressure vessels. It can also be used as a reference for shop inspection, and as a resource when modifying existing pressure vessels.
Comments:	This RP is based on decades of industry operating experience and the results of recent experimentation and testing conducted by independent manufacturers, fabricators and users of pressure vessels for this service. The main topics covered in this RP are design (per ASME Code); three design issues (thickness allowance, weld seam layout and nozzle neck transition); base metal requirements; welding requirements; heat treatment; testing requirements; nondestructive examination (NDE); hydrostatic testing; preparation for shipping; documentation; and summary material examination and NDE requirements.
User:	P – Primary User S – Secondary User

Purchaser	Manufacturer	Owner	Inspector	Regulator
P	**P**	**S**	**S**	

A-63 API RP 934E *Recommended Practice for Materials and Fabrication of 1¼Cr-½Mo Steel Pressure Vessels for Service above 825°F (440°C)*

Current Edition:	Second Edition, January 2018 (27 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP includes materials and fabrication requirements for new 1¼Cr-½Mo and 1Cr-½Mo steel pressure vessels and heat exchangers for high temperature service in petroleum refining, petrochemical, and chemical facilities. It applies to vessels that are designed, fabricated, certified, and documented in accordance with ASME Code Section VIII, Division 1. This document may also be used as a resource when planning to modify existing pressure vessels. This RP is not intended for use for equipment operating below 825°F (440°C). Refer to API RP 934-C for information on design for lower temperature ranges. When designing equipment that operates in the 825-850°F (440-454°C) temperature range, refer to guidelines in both of these RPs.
Application:	Purchasers can reference this document in a purchase specification and manufacturers can use it in the design and fabrication of pressure vessels. It can also be used as a reference for shop inspection, and as a resource when modifying existing pressure vessels.
Comments:	This RP is based on decades of industry operating experience and the results of recent experimentation and testing conducted by independent manufacturers, fabricators, and users of pressure vessels for this service. The main topics covered in this RP are design (per ASME Code); three design issues (thickness allowance, weld seam layout, and nozzle neck transition); base metal requirements; welding requirements; heat treatment; testing requirements; nondestructive examination (NDE); hydrostatic testing; preparation for shipping; and documentation.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **S**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-64 API TR 934G *Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units*

Current Edition:	First Edition, April 2016 (66 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This technical report includes information and guidance on the practices used by industry practitioners on the design, fabrication, operation, inspection, assessment, and repair of coke drums and peripheral components in delayed coking units. The guidance is general and does not reflect specific details associated with a design offered by licensors of delayed coking technology, or inspection tools, operating devices/components, repair techniques, and/or engineering assessments offered by contractors. For details associated with the design offered by a licensor or services provided by contractors, the licensor or contractor should be consulted for guidance and recommendations for their design details and operating guidance. This document is a technical report and as such, provides generally used practices in industry and is not an API Recommended Practice for coke drums in delayed coking units.
Application:	Purchasers can reference this document in a purchase specification and manufacturers can use it in the design and fabrication of coke drums and peripheral equipment. It can also be used as a reference for shop inspection, and as a resource when modifying existing coke drums and peripheral equipment. Finally, it can be used by owners/operators to establish strategies for operations, maintenance, and repair in a manner that will optimize the life of the coke drums given their unique circumstances.
Comments:	This technical report is based on decades of industry operating experience and the results of recent experimentation and testing conducted by independent manufacturers, fabricators, and users of coke drums and peripheral equipment. The main topics covered in this technical report are design (including design approaches, materials selection, thickness considerations, fatigue design considerations, skirt & vessel support details, insulation details, and tolerances); fabrication; effects of operating practices on coke drum reliability, in-service inspection and monitoring, condition assessment, repairs, and peripheral equipment.
User:	Purchaser: **P** Manufacturer: **P** Owner: **S** Inspector: **S** Regulator: P – Primary User S – Secondary User

A-65 API Std 936 *Refractory Installation Quality Control—Inspection and Testing Monolithic Refractory Linings and Materials*

Current Edition:	Fourth Edition, June 2014 (60 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard provides installation quality control procedures for monolithic refractory linings and may be used to supplement owner specifications. Materials, equipment, and personnel are qualified by the methods described, and applied refractory quality is closely monitored, based on defined procedures and acceptance criteria. The responsibilities of inspection personnel who monitor and direct the quality control process are also defined. In addition, this standard provides guidance for the establishment of quality control elements necessary to achieve the defined requirements.
Application:	This standard may be used as a basis for owners to develop their refractory installation procedures.
Comments:	The main parts of this standard are quality control elements, responsibilities (or owner, contractor, inspector and manufacturer), inspector qualifications, materials, qualification and testing, installation/execution, and dryout. Three annexes are provided; a glossary, refractory compliance datasheet, and a framework for certification for refractory personnel.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-66 API RP 939C *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*

Current Edition:	Second Edition, January 2019 (59 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	The objective of this recommended practice (RP) is to provide a better understanding of sulfidation corrosion characteristics and give practical guidance to inspectors and maintenance, reliability, project, operations, and corrosion personnel on how to address sulfidation corrosion in petroleum refining operations.
Application:	Owner/operators may use this RP to create and implement an inspection plan for components in sulfidation corrosion service. Such a plan could include performing inspections, evaluating thickness readings, performing retrospective PMI/verification, perform a low-Si carbon steel inspection program, define operating envelopes, institute corrosion monitoring, use of inhibitors for corrosion control, or materials replacement/upgrading.
Comments:	Included in this RP are: • Background to damage mechanisms. • The most common types of damage observed. • Root causes of sulfidation corrosion. • Methods to predict and monitor the corrosivity of systems. • Materials selection for new and revamped processes. • Inspection and nondestructive examination (NDE) methods used for detecting sulfidation corrosion.
User:	Purchaser: **S**; Manufacturer: (blank); Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-67 API RP 941 *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*

Current Edition:	Eighth Edition, February 2016 through Addendum 1, August 2020 (66 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP summarizes the results of experimental tests and actual data acquired from operating plants to establish practical operating limits for carbon and low alloy steels in hydrogen service at elevated temperatures and pressures. The effects on the resistance of steels to hydrogen at elevated temperature and pressure that result from high stress, heat treating, chemical composition, and cladding are discussed. This RP does not address the resistance of steels to hydrogen at lower temperatures [below about 400°F (204°C)], where atomic hydrogen enters the steel as a result of an electrochemical mechanism. This RP applies to equipment in refineries, petrochemical facilities, and chemical facilities in which hydrogen or hydrogen-containing fluids are processed at elevated temperature and pressure. The guidelines in this RP can also be applied to hydrogenation plants such as those that manufacture ammonia, methanol, edible oils, and higher alcohols. Hydrogenation processes require standards and materials that may not be warranted in other operations of the petroleum industry. At certain combinations of elevated temperature and hydrogen partial pressure, both chemical and metallurgical changes occur in carbon steel, which, in advanced stages, can render it unsuitable for safe operation. Alloy steels containing chromium and molybdenum can be used under such conditions. The steels discussed in this RP resist high temperature hydrogen attack (HTHA) when operated within the guidelines given. However, they may not be resistant to other corrosives present in a process stream or to other metallurgical damage mechanisms operating in the HTHA range. This RP also does not address the issues surrounding possible damage from rapid cooling of the metal after it has been in high temperature, high pressure hydrogen service (e.g., possible need for outgassing hydroprocessing reactors). This RP will discuss in detail only the resistance of steels to HTHA.
Application:	This RP can be used by pressure vessel designers as an aid in selecting steels for new pressure vessels at elevated temperature and pressure. It can also be used by pressure vessel fabricators to assess the adequacy of the materials specified by the purchaser. It can also be used by inspectors as an aid in selecting an inspection method(s) for detecting high temperature hydrogen attack in existing pressure vessels.

<table>
<tr><td>Comments:</td><td>
Presented in this document are curves that indicate the operating limits of temperature and hydrogen partial pressure for satisfactory performance of carbon steel and Cr-Mo steels in elevated temperature, hydrogen service. In addition, it includes a summary of inspection methods to evaluate equipment for the existence of HTHA.
At normal atmospheric temperatures, gaseous molecular hydrogen does not readily permeate steel, even at high pressures. Carbon steel is the standard metal for cylinders that are used to transport hydrogen at pressures of 2000 psi (14 MPa). Many postweld heat treated carbon steel pressure vessels have been used successfully in continuous service at pressures up to 10,000 psi (69 MPa) and temperatures up to 430°F (221°C). However, under these same conditions, highly stressed carbon steels and hardened steels have cracked due to hydrogen embrittlement.
The recommended maximum hydrogen partial pressure at atmospheric temperature for carbon steel fabricated in accordance with the ASME Boiler and Pressure Vessel Code is 13,000 psia (90 MPa). Below this pressure, carbon steel equipment has shown satisfactory performance. Above this pressure, very little operating and experimental data are available. If plants are to operate at hydrogen partial pressures that exceed 13,000 psia (90 MPa), the use of an austenitic stainless steel liner with venting in the shell should be considered.
At elevated temperatures, molecular hydrogen dissociates into the atomic form, which can readily enter and diffuse through the steel. Under these conditions, the diffusion of hydrogen in steel is more rapid. As discussed in Section 4 of this RP, hydrogen reacts with the carbon in the steel to cause either surface decarburization or internal decarburization and fissuring, and eventually cracking. This form of hydrogen damage is called high temperature attack (HTHA) and this RP discusses the resistance of steels to HTHA.
The main topics covered by this RP are pressure/temperature operating limits for carbon and Cr-Mo steels; forms of HTHA; factors influencing HTHA; and inspection for HTHA. It also includes eight technical annexes: 1) High temperature attack (HTHA) of 0.5 Mo steels, 2) HTHA of 1.25 Cr-0.5 Mo steel, 3) HTHA of 2.25 Cr-0.5 Mo steel, 4) Effective pressures of hydrogen in steel covered by clad/overlay, 5) Summary of inspection methods, 6) HTHA of Non-PWHT'd carbon steels, 7) methodology for calculating H_2 partial pressure in liquid-filled piping, and internal company data collection (request for new information).
</td></tr>
<tr><td>User:</td><td>
<table>
<tr><th>Purchaser</th><th>Manufacturer</th><th>Owner</th><th>Inspector</th><th>Regulator</th></tr>
<tr><td>P</td><td>P</td><td></td><td>P</td><td></td></tr>
</table>
P – Primary User
S – Secondary User
</td></tr>
</table>

A-68 API RP 945 *Avoiding Environmental Cracking in Amine Units*

Current Edition:	Third Edition, June 2003, Reaffirmed, July 2020 (35 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This RP discusses environmental cracking problems of carbon steel equipment in amine units. Stress corrosion cracking of stainless steels in amine units is beyond the scope of this document, although there have been isolated reports of such problems. This practice does provide guidelines for carbon steel construction materials, including their fabrication, inspection, and repair to help assure safe and reliable operation. The steels referred to in this document are defined by the ASTM designation system, or are equivalent materials contained in other recognized codes or standards. Welded construction is considered the primary method of fabricating and joining amine unit equipment.
Application:	This RP can be used by process designers (owner or contractor) as an aid in specifying steels and fabrication requirements for new and replaced/repaired equipment in amine units. It can also be used for guidance for the inspection and repair of existing equipment used to handle amines.
Comments:	This document is based on current engineering practices and insights from recent industry experience. Older amine units may not conform exactly to the information contained in this RP, but this does not imply that such units are operating in an unsafe or unreliable manner. No two amine units are alike, and the need to modify a specific facility depends on its operating, inspection, and maintenance history. This RP presents information covering amine unit description and problems, construction materials and fabrication, inspection guidelines, repair guidelines, cracking mechanisms, and corrosion control.
User:	Purchaser: — ; Contractor: **P** ; Owner: **P** ; Inspector: **P** ; Regulator: — P – Primary User S – Secondary User

A-69 API RP 970 *Corrosion Control Documents*

Current Edition:	First Edition, December 2017 (59 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This recommended practice (RP) provides users with the basic elements for developing, implementing, and maintaining a Corrosion Control Document for refining, and at the owner's discretion, may be applied at petrochemical and chemical process facilities. A Corrosion Control Document (CCD) is a document or other repository or system that contains all the necessary information required to understand materials damage susceptibility issues in a specific type of operating process unit at a plant site. CCDs are a valuable addition to an effective Mechanical Integrity Program. They help to identify the damage mechanism susceptibilities of pressure-containing piping and equipment, factors that influence damage mechanism susceptibilities, and recommended actions to mitigate the risk of loss of containment or unplanned outages. Typical CCDs cover the pressure-containing components of fixed equipment. The types of equipment and associated components typically covered by CCDs are: pressure vessels, process piping, storage tanks (atmospheric and pressurized), process heater pressurized components, and heat exchangers. The scope of this standard includes: • Descriptions of CCDs and definitions of related terminology. • Creating, establishing, and maintaining CCDs. • Data and information typically needed to create CCDs. • Descriptions of the various types of CCDs needed for process units. • Documenting and implementing CCDs. • Reviewing, changing, and updating CCDs. • Integrating CCDs with other risk management practices. • Roles and responsibilities in the CCD work process. • Knowledge transfer to all stakeholders.
Application:	This RP is a guideline document for organizing Corrosion Control Documents. The owner/user of this RP may also develop internal documents that detail how their company will create and implement the processes suggested herein. Section 5 contains key points for establishing a site procedure that documents the CCD work process.
Comments:	This document provides the owner/user with information and guidance on the work processes for development and implementation of CCDs for the owners'/users' process units. While some generic examples are provided in the text and in 5.9, this document does not contain a complete list of unit-specific CCDs or operating plant variables for the numerous types of hydrocarbon processing units in the industry.
User:	Purchaser: — ; Manufacturer: — ; Owner: **P** ; Inspector: **S** ; Regulator: — P – Primary User S – Secondary User

A-70 API Std 976 *Refractory Installation Quality Control—Inspection and Testing of AES/RCF Fiber Linings and Materials*

Current Edition:	First Edition, March 2018 (34 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard provides installation quality control procedures and lining system design requirements for AES/RCF* fiber linings, and may be used to supplement owner specifications. Materials, equipment, and personnel are qualified by the methods described, and applied refractory quality is closely monitored, based on defined procedures and acceptance criteria. The responsibilities of inspection personnel who monitor and direct the quality control process are also defined. The lining described in this standard is for internal refractory linings on the process side of the equipment. External insulation and jacketing are not covered in this standard. *AES: Alkaline Earth Silicate fiber; RCF: Refractory Ceramic Fibers
Application:	This standard may be used as a basis for owners to develop their refractory installation procedures, along with a means to assess and verify competencies of refractory inspectors.
Comments:	The main parts of this standard are responsibilities (or owner, installer, inspector, refractory manufacturer, and fiber component fabricator); inspector qualifications; materials (including refractory and anchors); lining design; rigidized and surface-treated fiber; QA/QC; examination and testing; and preparation for shipping. Annexes consist of a refractory compliance datasheet and a listing of minimum competencies for refractory inspectors.
User:	Refractory Installer: **S**; Refractory Manufacturer: **S**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-71 API Std 1104 *Welding of Pipelines and Related Facilities*

Current Edition:	Twenty First Edition, September 2013 through Errata 5, September 2018 (130 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard covers the gas and arc welding of butt, fillet, and socket welds in carbon and low-alloy steel piping used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, nitrogen and, where applicable, covers welding on distribution systems. It applies to both new construction and in-service welding. The welding may be done by a shielded metal-arc welding, submerged arc welding, gas tungsten-arc welding, gas metal-arc welding, flux-cored arc welding, plasma arc welding, oxyacetylene welding or flash butt welding process, or by a combination of these processes using a manual, semi-automatic, mechanized or automatic welding technique, or a combination of these techniques. The welds may be produced by position or roll welding or by a combination of position and roll welding. This standard also covers the procedures for radiographic, magnetic particle, liquid penetrant and ultrasonic testing, as well as the acceptance standards to be applied to production welds tested to destruction or inspected by radiographic, magnetic particle, liquid penetrant, ultrasonic and visual testing methods.
Application:	Pipeline owners and operators can reference this standard in a purchase specification for new pipeline construction welding and for in-service pipeline welding. Pipeline construction contractors can refer to this document to ensure compliance when it is cited in the purchase specification. It can also provide guidance to inspectors.
Comments:	The purpose of this standard is to present methods for the production of high-quality welds through the use of qualified welders using approved welding procedures, materials, and equipment. Its purpose is also to present inspection methods to ensure the proper analysis of welding quality through the use of qualified technicians and approved methods and equipment. It applies to both new construction and in-service welding. The main topics covered in this standard are welding equipment; weld filler metal; weld shielding gases; qualification of welding procedures; qualification of welders; design and preparation of a joint for production welding; inspection and testing of production welds; certification of NDT personnel; acceptance standards for nondestructive testing; repair and removal of defects; procedures for nondestructive testing; mechanized welding with filler metal additions; automatic welding without filler-metal additions; alternative acceptance standards for girth welds; and in-service welding.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-72 API Std 2000 *Venting Atmospheric and Low-pressure Storage Tanks*

Current Edition:	Seventh Edition, March 2014, Reaffirmed April 2020 (94 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers the normal and emergency vapor venting requirements for aboveground nonrefrigerated liquid petroleum or petroleum products storage tanks and aboveground and underground refrigerated storage tanks designed for operation at pressures from vacuum through 15 pounds per square inch gauge (1.034 bar gauge). Engineering studies of a particular tank may indicate that the appropriate venting capacity for the tank is not the venting capacity estimated in accordance with this standard. The many variables associated with tank venting requirements make it impractical to set forth definite, simple rules that are applicable to all locations and conditions. Larger venting capacities may be required on tanks in which liquid is heated, on tanks that receive liquid from wells or traps, and on tanks that are subjected to pipeline surges. Larger venting capacities may also be required on tanks that use flame arresters or have other restrictions that may build up pressure under certain conditions. This standard does not apply to external floating roof tanks or free vented internal floating roof tanks.
Application:	This standard can be used by storage tank designers and/or instrument engineers as an aid in determining a tank's venting requirement, and also in selecting the type of venting device. It can also be used by a storage tank supplier to assess the adequacy of the venting device specified by the purchaser.
Comments:	The main topics covered in this standard are causes of overpressure or vacuum; determination of venting requirements; means of venting; considerations for tanks with potentially flammable atmospheres; relief-device specification, and installation of venting devices and open vents. These topics are presented separately for nonrefrigerated and refrigerated storage tanks. Annexes are provided on alternative calculation of normal venting requirements; basis of emergency venting for Tables 7 and 8; types and operating characteristics of venting devices; basics of sizing equations; basis for normal out-breathing and in-breathing; guidance for inert gas blanketing of tanks for flashback protection; and explanation of differences in thermal in-breathing using the general and Annex A methods.

User:

Designer/ Engineer	Manufacturer	Owner	Inspector	Regulator
P	**P**			

P – Primary User
S – Secondary User

A-73 API RP 2201 *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*

Current Edition:	Fifth Edition, June 2003, Reaffirmed March 2020 (40 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This publication provides information to assist in safely conducting hot tapping operations on equipment in service in the petroleum and petrochemical industries. No document can address all situations nor answer all potential questions; however, the understanding of potential hazards, and application of this knowledge, can help reduce the probability and severity of incidents.
Application:	Hot tapping is performed in refineries and chemical plants when it is impractical to shut down and de-inventory equipment to add a branch connection.
Comments:	The main topics covered in this publication are job analysis, hazard evaluation and risk reduction, metallurgy considerations, hot tapping machines, preparations, special conditions, and hot tap operations. Appendices include examples of hot tap checklists, request forms, welders instructions, and an in-service hot tap emergency action plan.
User:	Designer/ Engineer: — ; Manufacturer: — ; Owner: **P** ; Inspector: **S** ; Regulator: **S** P – Primary User S – Secondary User

A-74 API RP 2611 *Terminal Piping Inspection—Inspection of In-Service Terminal Piping Systems*

Current Edition:	First Edition, June 2011 (54 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This document covers the inspection of typical terminal piping systems within terminal boundaries, which includes off-plot piping. Off-plot piping includes, but is not limited to, piping between facilities, piping that comes from or goes to a refinery, or other type of facility, or piping that may cross a road, ditch, or other property outside the confines of a terminal facility. Piping for transportation of finished fuel products such as gasoline, diesel, lubricating oils, jet fuel, and aviation fuel are covered by the scope of this document. Also covered are piping systems for nonfuel-type fluids. The piping for other terminal nonfuel-type fluids typically found in terminals, include asphaltic products, process water, transmix, slop water and biofuels. The scope of this document does not include piping in a refinery facility, sanitary waste piping, cast iron piping, and nonmetallic gravity flow piping systems.
Application:	The purpose of this document is to align current terminal piping inspection practices with the appropriate and applicable elements of API 570. API 2611 covers the inspection of existing terminal piping systems. The document incorporates industry accepted practice for terminals as well as selected principles from API 570. This document addresses the piping and associated failure modes commonly found in terminals with piping systems operating at a maximum process design pressure of 300 psi at ambient temperature (an exception on design temperatures is made for asphaltic products). If any repair or alteration results in a change of design conditions, a rerating per API 570 shall be satisfied. For asphaltic products, this document covers the maximum process design pressure of 150 psi at a temperature range of 25°F to 450°F (–3.9°C to 232°C).
Comments:	The main topics covered in this document are: inspection of piping, frequency and extent of inspection of aboveground and belowground piping, repairs to piping systems, and marine facilities inspection/frequency. Annexes are provided covering inspector qualifications, a summary of cited inspections, guidance on pipe wall retirement thickness, and a sample inspection checklist for piping.
User:	Designer/ Engineer: [ ] — Manufacturer: [ ] — Owner: **P** — Inspector: **P** — Regulator: **S** P – Primary User S – Secondary User

A-75 API Std 2350 *Overfill Protection for Storage Tanks in Petroleum Facilities*

Current Edition:	Fifth Edition, September 2020 through Errata 1, April 2021 (75 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document applies to atmospheric storage tanks associated with refining, marketing, pipeline, and terminals that contain NFPA Class I or Class II liquids. This standard does not apply to: • Tanks of 1320 US gallons (5000 liters) or less, unless connected to a transporter or marine delivery system. • Tanks that are covered by PEI RP 600. • Tanks filled exclusively from wheeled vehicles (i.e., tank trucks or railroad tank cars), where the fill rate is less than 630 bbl/hr (440 gpm) (100m^3/hour). • Dedicated pipeline relief tanks. • Tanks storing LPG and LNG. The purpose of this standard is to assist owner/operators and operating personnel in the prevention of tank overfilling by implementation of a comprehensive overfill prevention system (OPS). The goal is to receive product into the intended storage tank without overfilling or mechanical damage.
Application:	The user or tank designer may use this standard to define/specify the overfill protection level (or volume requirement) and need for overflow indicators as required.
Comments:	This standard is one of minimum requirements. Alternate approaches or variations on the principles of this standard that provide equivalent or more robust overfill prevention are acceptable. Alternate approaches may be needed when the tank system varies from the typical configurations described in this standard. The rationale for the implementation of each overfill prevention process (OPP) should be documented and retained by the owner/operator. This standard is not intended to prevent the use of systems, methods, or devices of equivalent or superior quality, effectiveness, durability, and safety over those provided in this standard.
User:	Purchaser: **P**; Manufacturer: ; Owner: **P**; Inspector: ; Regulator: P – Primary User S – Secondary User

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE) STANDARDS

A-76 ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*

Current Edition:	2016 through Errata 3, January 2020 (923 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard may be used to determine the magnitude of wind and earthquake loadings to apply to structures, including pressure vessels and piping systems.
Application:	Designers of pressure equipment can use the methods in this standard to determine the appropriate design magnitude of wind and earthquake loadings for new construction. Owners and users of pressure equipment can use the methods for post-construction integrity assessments.
Comments:	Rules are provided for locating earthquake zones and for estimating maximum wind speeds depending on the location of the installation of the equipment.
User:	Purchaser: [ ] Consultant: [ ] Owner: [ ] Inspector: [ ] Regulator: [ ] P – Primary User S – Secondary User

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME) STANDARDS

A-77 ASME B16.1 *Gray Iron Pipe Flanges and Flanged Fittings (Classes 25, 125, and 250)*

Current Edition:	2020 (49 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers Classes 25, 125, and 250 Gray Iron Pipe Flanges and Flanged Fittings. It includes pressure-temperature ratings; sizes and methods of designating openings of reducing fittings; marking; materials; dimensions and tolerances; bolting and gaskets; and pressure testing.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program.
Comments:	This standard covers flanges, 45 and 90 degree elbows, tees, crosses, 45 degree laterals, reducers and true Ys in sizes NPS 4 through 96 (Class 25), NPS 1 through 48 (Class 125) and NPS 1 through 30 (Class 250).
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-78 ASME B16.3 *Malleable Iron Threaded Fittings (Classes 150 and 300)*

Current Edition:	2016 (54 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers malleable iron threaded fittings, Class 150 and 300. It also contains provisions for using steel for caps and couplings in Class 150 for NPS ⅜ and smaller. This standard includes: a) pressure-temperature ratings; b) size and method of designating openings of reducing fittings; c) marking; d) material; e) dimensions and tolerances; f) threading; g) ribs; h) plugs, bushings, and locknuts; i) face bevel; and j) coatings.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program.
Comments:	This standard covers flanges, 45 and 90 degree elbows, tees, crosses, 45 degree Y branches, reducers, street tees and elbows, couplings, caps and return bends and generally in NPS sizes ⅛ through 6 (Class 150) and NPS ¼ through 3 (Class 300). There is some variation in the smallest and largest size based on the particular type of fitting (e.g., Class 300 return bend sizes are NPS 1 and 2).
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-79 ASME B16.4 *Gray Iron Threaded Fittings (Classes 125 and 250)*

Current Edition:	2016 (34 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard for gray iron threaded fittings, Classes 125 and 250, covers: a) pressure-temperature ratings; b) size and method of designating openings of reducing fittings; c) marking; d) material; e) dimensions and tolerances; f) threading; g) ribs; h) plugs, bushings, and locknuts; i) face bevel; and j) coatings.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program.
Comments:	This Standard covers Classes 125 and 250, 45 and 90 degree elbows, tees and crosses in sizes NPS ¼ through 12. It also covers Class 125, 90 degree reducing elbows (NPS ½ x ⅜ through 8 x 6), reducing crosses (NPS ¾ x ¾ x ½ x ½ through 8 x 8 x 4 x 4), reducing tees (NPS ½ x ½ x ⅜ through 6 x 6 x 8) and caps, reducing couplings and return bends (NPS ½ through 12).
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-80 ASME B16.5 *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*

<table>
<tr><td>Current Edition:</td><td>2020 (250 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>Yes</td></tr>
<tr><td>Scope:</td><td>This standard covers pressure-temperature ratings, materials, dimensions, tolerances, marking, testing, and methods of designating openings for pipe flanges and flanged fittings. Included are:
• Flanges with rating class designations 150, 300, 400, 600, 900, 1500, and 2500 in sizes NPS ½ through NPS 24, with requirements given in both metric and US customary units with diameter of bolts and flange bolt holes expressed in inch units.
• Flanged fittings with rating class designation 150 and 300 in sizes NPS ½ through NPS 24, with requirements given in both metric and US customary units with diameter of bolts and flange bolt holes expressed in inch units.
• Flanged fittings with rating class designations 400, 600, 900, 1500, and 2500 in sizes NPS ½ through NPS 24 that are acknowledged in Nonmandatory Appendix E in which only US customary units are provided.
This standard is limited to:
• Flanges and flanged fittings made from cast or forged materials.
• Blind flanges and certain reducing flanges made from cast, forged, or plate materials.
Also included in this standard are requirements and recommendations regarding flange bolting, flange gaskets, and flange joints.</td></tr>
<tr><td>Application:</td><td>Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. Manufacturers can also use this document as a reference for the required flange dimension details, including those applicable to welding.
Designers can use this standard to select the appropriate class flange or fitting based on the specific design conditions (pressure and temperature) and the material of construction.
In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. It can also be used as a reference for inspection at the manufacturer's plant.</td></tr>
<tr><td>Comments:</td><td>This is a comprehensive document that contains the pressure-temperature ratings for 44 groups of materials, with each group broken down according to forgings, castings, and plates.
The flanged fittings covered by this standard include 90 and 45 degree standard elbows, 90 degree long radius elbows, tees, crosses, true Ys and reducers.</td></tr>
<tr><td>User:</td><td><table><tr><td>Purchaser</td><td>Manufacturer</td><td>Owner</td><td>Inspector</td><td>Regulator</td></tr><tr><td>**P**</td><td>**P**</td><td>**P**</td><td>**S**</td><td></td></tr></table>P – Primary User
S – Secondary User</td></tr>
</table>

A-81 ASME B16.9 *Factory-Made Wrought Buttwelding Fittings*

Current Edition:	2018 (41 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers overall dimensions, tolerances, pressure ratings, testing, markings, material, and end preparation for factory-made wrought butt-welding fittings in sizes NPS ½ through NPS 48 (DN 15 through DN 1200).
Application:	Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met.
Comments:	This standard covers 45 and 90 degree long radius elbows (NPS ½ through 48), 90 degree long radius reducing elbows (NPS 2 x ½ through 24 x 12), long radius returns (NPS ½ through 24), short radius elbows (NPS 1 through 24), short radius 180 degree returns (NPS 1 through 24), 3D elbows (NPS ¾ through 48), straight tees and crosses (NPS ½ through 48), reducing outlet tees and crosses (NPS ½ x ½ x ⅜ through 48 x 48 x 22), lap joint stub ends (NPS ½ through 24), caps (NPS ½ through 48), and reducers (NPS ¾ x ½ through 48 x 40). The allowable pressure ratings for fittings designed in accordance with this standard may be calculated as for straight seamless pipe of equivalent material in accordance with the rules established in the applicable sections of ASME B31, *Code for Pressure Piping*. For the calculations, applicable data for the pipe size, wall thickness, and material that is equivalent to that of the fitting shall be used. Pipe size, wall thickness (or schedule number), and material identity on the fittings are in lieu of pressure rating markings.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: ; Regulator: P – Primary User S – Secondary User

A-82 ASME B16.10 *Face-to-Face and End-to-End Dimensions of Valves*

Current Edition:	2017 (57 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers face-to-face and end-to-end dimensions of straightway valves and center-to-face and center-to-end dimensions of angle valves. Its purpose is to assure installation interchangeability for valves of a given material, type, size, rating class, and end connection. Face-to-face and center-to-face dimensions apply to flanges end valves with facing defined in paragraph 2.3.1 of this standard and to other valves intended for assembly between flat face or raised face flanges. End-to-end dimensions apply to grooved end, butt-welding end, and flanged end valves with facing defined in paragraph 2.3.3 of this standard. Center-to-end dimensions apply to butt-welding end and to flanged end valves with facings defined in paragraph 2.3.3 of this standard. For cast iron and ductile iron valves, only flanged end valves (and others intended for assembly between flanges) are covered by this standard. For carbon, alloy and stainless steel valves, and nonferrous materials listed in ASME B16.34, this standard covers flanged, butt-welding and grooved ends, as well as the types of valves intended for assembly between flanges.
Application:	Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. Designers can reference this standard in preparing piping layout drawings. It can also be referenced for inspections at the manufacturer's plant.
Comments:	For cast iron valves, this standard covers: 1) Class 125 and 250 gate, plug, check, globe, angle, and wafer swing check valves and 2) Class 25 and 125 butterfly valves. For ductile iron valve, this standard covers Class 150 and 300 gate, plug, check, globe, and angle valves. For steel and alloy valves, this standard covers: 1) Class 150 through 2500 gate, globe, angle, check, plug, and ball valves; 2) Class 150 Y-pattern globe and Y-pattern swing check valves; 3) Class 150 and 300 wafer knife gate valves; 4) Class 150 through 2500 wafer swing check valves; and 4) Class 150, 300, and 600 butterfly valves. The sizes covered by this Standard are NPS ¼ through 72, but the range varies depending on class and valve type.
User:	Purchaser: **P**; Manufacturer: **P**; Designer: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-83 ASME B16.11 *Forged Fittings, Socket-Welding and Threaded*

Current Edition:	2016 through Errata, June 2017 (39 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers ratings, dimensions, tolerances, marking, material requirements, and testing for forged fittings, both socket-welding and threaded.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program.
Comments:	This standard covers 45 and 90 degree elbows, tees, crosses, couplings, half-couplings, caps, plugs, and bushings forged fittings in sizes NPS ⅛ through 4 and pressure classes 3000 through 9000 (welded) and 6000 (threaded). Standard dimensions are provided, as well as body thickness requirements.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-84 ASME B16.14 *Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads*

Current Edition:	2018 (26 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard for ferrous pipe plugs, bushings, and locknuts with pipe threads covers: a) pressure-temperature ratings; b) size; c) marking; d) materials: e) dimensions and tolerances; f) threading; and g) pattern taper.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspections at the manufacturer's plant.
Comments:	The types of components covered by this standard are solid and cored square head plugs; bar and slotted head plugs; countersunk plugs; outside head, inside head, and face bushings; and locknuts. The sizes covered are NPS ⅛ through 8, but the range varies depending on the type of component.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: (blank); Inspector: **S**; Regulator: **P** P – Primary User S – Secondary User

A-85 ASME B16.15 *Cast Copper Alloy Threaded Fittings (Classes 125 and 250)*

Current Edition:	2018 (34 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers cast Classes 125 and 250 copper alloy threaded pipe fittings with provisions for substituting wrought copper alloys for plugs, bushings, caps and couplings in small sizes. This standard includes: a) pressure-temperature ratings; b) size and method of designating openings of reducing pipe fittings; c) marking requirements; d) minimum requirements for casting quality and materials; e) dimensions and tolerances in SI (metric) and US customary units; f) threading requirements; and g) pressure test requirements.
Application:	Purchasers can reference this document in an equipment purchase specification and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. It can also be used as a reference for inspections in a manufacturer's plant.
Comments:	For Class 125 fittings, this standard covers 45 and 90 degree elbows, tees, crosses, 45 degree Y branches, reducers, street elbows, couplings, caps, reducing elbows and tees and return bands, and generally in NPS sizes ⅛ through 4. For Class 250 fittings, this standard covers 45 and 90 degree elbows, tees, crosses, couplings, bushings, plugs, and reducing elbows and tees, and generally in NPS sizes ¼ through 4.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-86 ASME B16.18 *Cast Copper Alloy Solder Joint Pressure Fittings*

Current Edition:	2018 (41 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard for cast copper alloy solder joint pressure fittings designed for use with copper water tube establishes requirements for: a) pressure-temperature ratings; b) abbreviations for end connections; c) sizes and methods of designating openings of fittings; d) marking; e) material; f) dimensions and tolerances; and g) tests.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspections at the manufacturer's plant.
Comments:	This standard covers various types of copper fittings, such as elbows, tees, return bends, plugs, caps, and couplings, in both straight and reducing styles, if applicable. Fittings with both soldered and threaded connections are also covered. The water tube sizes covered are ¼ through 12 inches, but the range varies depending on the type of fitting.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-87 ASME B16.20 *Metallic Gaskets for Pipe Flanges*

Current Edition:	2017 (66 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers materials, dimensions, tolerances and markings for metal ring-joint gaskets, spiral-wound metal gaskets metal-jacketed gaskets, and grooved metal gaskets with covering layers. These gaskets are dimensionally suitable for use with flanges described in reference flange standards ASME B16.5, ASME B16.47, API Specification 6A, and ISO 10423.
Application:	Purchasers (end users or fabricators) can reference this standard in a purchase specification. Manufacturers and fabricators need it to comply with the purchase specification when the standard is cited therein.
Comments:	Ring-joint gaskets shall be identified by an R, RX or BX number that relates to flange size (NPS), pressure class and appropriate flange standards (ASME B16.5, ASME B16.47, API Specification 6A or ISO 10423). The pipe sizes and pressure classes covered by this standard are:

	ASME B16.5					API 6B				
Gasket type	150	300-600	900	1500	2500	720-960(1)	2000	3000	5000	10000 (1)
R (min)	1	½	½	½	½	1	1	1	1	1
R (max)	24	24	24	24	12	20	20	20	10	10

	ASME B16.47 Series A		
Gasket type	150	300-600	900
R (min)	—	26	26
R (max)	—	36	36

	ASME B16.47 Series A			
Gasket type	720-960(1) and 2000	2900(1)	3000	5000
RX (min)	1 ½	1	1 ½	1 ½
RX (max)	20	10	20	14

	ASME B16.5					
Gasket type	2000	3000	5000	10000	1500	20000
BX (min)	26 ½	26 ¾	13 5/8	1 11/16	1 11/16	1 13/16
BX (max)	30	30	21 ¼	21 ¼	18 ¾	13 5/8

(1) Class 720, 960, 2900 and 10000 flanges to API 6B are obsolete. Data for information only.

User:	Purchaser	Manufacturer	Owner	Inspector	Regulator
	P	**P**	**P**	**S**	
	P – Primary User S – Secondary User				

A-88 ASME B16.21 *Nonmetallic Flat Gaskets for Pipe Flanges*

Current Edition:	2016 (29 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers types, sizes, materials, dimensions, tolerances, and markings for nonmetallic flat gaskets. These gaskets are dimensionally suitable for use with flanges described in the referenced flange standards: ASME B16.1, B16.5, B16.24, B16.47 (Series A & B) and MSS SP-51.
Application:	Purchasers (end users or fabricators) can reference this standard in a purchase specification. Manufacturers and fabricators need it to comply with the purchase specification when the standard is cited therein. It can also be used as a reference for inspections in a manufacturer's plant.
Comments:	The pressure classes and pipe sizes covered by this standard are ASME B16.1 Class 25 (NPS 4 to 96), Class 125 (NPS 1 to 48), Class 250 (NPS 1 to 48); ASME B16.5 Classes 150, 300, 400, 600, and 900 (NPS ½ to 24); ASME B16.24 Classes 150 and 300 (NPS ½ to 12); ASME B16.47 Series A Classes 150, 300, 400, and 600 (NPS 22 to 60); ASME B16.47 Series B Classes 75, 150, 300, 400, and 600 (NPS 26 to 60); and MSS SP-51 Class 150 LW (NPS ¼ to 24).
User:	Purchaser: **P**; Manufacturer: **P**; Fabricator: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-89 ASME B16.22 *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*

Current Edition:	2018 (26 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard establishes specifications for wrought copper and wrought copper alloy, solder-joint, seamless fittings, designed for use with seamless copper tube conforming to ASTM B 88 (water and general plumbing systems), B 280 (air conditioning and refrigeration service) and B 819 (medical gas systems), as well as fittings intended to be assembled with soldering materials conforming to ASTM B 32, brazing materials conforming to AWS A5.8 or with tapered pipe thread conforming to ASME B1.20.1. This standard is allied with ASME B16.18, which covers cast copper alloy pressure fittings. It provides requirements for fitting ends suitable for soldering. This standard covers: a) pressure-temperature ratings; b) abbreviations for end connections; c) size and method of designating openings of fittings; d) marking; e) material; f) dimensions and tolerances; and g) tests.
Application:	Purchasers can reference this document in an equipment purchase specification and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspection at the manufacturer's plant.
Comments:	This standard covers various types of copper fittings such as adapters, bushings, elbows, tees, return bends, plugs, caps, couplings, P-traps, in both straight and reducing styles, if applicable. Fittings are mostly soldered, but some with both soldered and threaded connections are also covered. The water tube and threaded pin sizes covered are ¼ through 8 inches. This standard states that, due to widely varying manufacturing processes, meaningful laying-length requirements of fittings cannot be established and to consult the manufacturer for these dimensions.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-90 ASME B16.24 *Cast Copper Alloy Pipe Flanges, Flanged Fittings, and Valves (Classes 150, 300, 600, 900, 1500, and 2500)*

Current Edition:	2016 (42 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers the following cast copper alloy components: a) threaded-joint pipe flanges and blind pipe flanges having rating class designations 150, 300, 600, 900, 1500, and 2500; flanged fittings having rating class designations 150 and 300; threaded and flanged valves having rating class designations 150, 300, 600, 1500, and 2500. It establishes requirements for: a) pressure-temperature ratings; b) size and method of designation openings for reduced fittings; c) markings; d) materials; e) dimensions; f) bolting and gaskets; g) tolerances; and h) tests. This standard also provides dimensional requirements for flanged ends of valves conforming to MSS SP-80.
Application:	Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. Designers can reference this standard in preparing piping layout drawings. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. It can also be used as a reference for inspection in the manufacturer's plant.
Comments:	This standard covers flanges, 45 and 90 degree elbows, tees, crosses, 45 degree laterals, reducers, and true Ys in sizes NPS ½ through 12 (Class 150) and NPS ½ through 8 (Class 300). The dimensions for the other classes of flanges **only** are by reference to ASME B16.5. The pressure-temperature ratings for Class 150 and 300 are provided for ASTM B61 Alloy C92200 and B62 Alloy C83600 for flanges and flanged fittings. The pressure-temperature ratings for Classes 150 through 2500 are provided for ASTM B148 Alloy C95200 for flanges only.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-91 ASME B16.25 *Buttwelding Ends*

Current Edition:	2017 (38 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers the preparation of butt-welding ends of piping components to be joined into a piping system by welding. It includes requirements for welding bevels, for external and internal shaping of heavy-wall components, and for preparation of internal ends (including dimensions and tolerances). Coverage includes preparation for joints with the following: a) no backing rings; b) split or noncontinuous backing rings; c) solid or continuous backing rings; d) consumable insert rings; e) gas tungsten arc welding (GTAW) of root pass. Details of preparation for any backing ring must be specified when ordering the component.
Application:	Purchasers can reference this standard in a purchase specification and fabricators, and field contractors require it to comply with the purchase specification when the standard is cited therein. It can also be used as a reference for shop or field inspection.
Comments:	The main topics covered by this standard are scope; transition contours; welding bevel design; preparation of inside diameter of welding end; and tolerances. Specific details are provided for maximum envelope for welding end transitions; bevels for wall thickness 3 mm (0.12 in) to 12 mm (0.88 in.); weld bevel details for wall thickness over 22 mm (0.88 in.); weld bevel details for GTAW root pass [wall thickness 3 mm (0.12 in.) to 10 mm (0.38 in.)]; weld bevel details for GTAW root pass [wall thickness 10 mm (0.38 in.) to 25 mm (1.0 in.)]; and weld bevel details for GTAW root pass [wall thickness over 25 mm (1.0 in.)].
User:	Purchaser: **P**; Fabricator: **P**; Contractor: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-92 ASME B16.26 *Cast Copper Alloy Fittings for Flared Copper Tubes*

Current Edition:	2018 (22 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard establishes specifications for cast copper alloy fittings and nuts used with flared seamless copper tube conforming to ASTM B 88 (water and general plumbing systems). Included are requirements for the following: (a) pressure rating; (b) size; (c) marking; (d) material; (e) dimensions; (f) threading; and (g) hydrostatic testing.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspections at the manufacturer's plant.
Comments:	This standard covers tees, 90 degree elbows, and 45 degree elbows in standard water tube sizes 3/8 through 2 inches. All fitting connections are threaded to accept flared copper tubes. The fittings covered by this standard are designed for a maximum cold water service-pressure of 1200 kPa (175 psig).
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-93 ASME B16.34 *Valves – Flanged, Threaded, and Welding End*

Current Edition:	2020 (229 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard applies to new construction and covers pressure-temperature ratings, dimensions, tolerances, materials, nondestructive examination requirements, testing, and marking for cast, forged, and fabricated flanged, threaded, and welding end and wafer or flangeless valves of steel, nickel-base alloys and other alloys. Wafer or flangeless valves, bolted or through-bolt types, which are installed between flanges or against a flange, are treated as flanged-end valves. Alternative rules for NPS 2 ½ and smaller valves are given in Mandatory Appendix V.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspection at the manufacturer's plant. In addition, the thickness requirements may be useful in evaluating the results of an in-service examination program.
Comments:	This standard covers Pressure Classes 150, 300, 400, 600, 900, 1500, 2500, and 4500 (4500 applies only to welding end valves). The range of inside valve diameters covered is 3 mm to 1500 mm (0.12 in, to 60 in.).
User:	Purchaser: P; Manufacturer: P; Owner: ; Inspector: S; Regulator: P – Primary User S – Secondary User

A-94 ASME B16.36 *Orifice Flanges*

Current Edition:	2020 (42 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers pressure-temperature ratings, materials, dimensions, tolerances, testing, and making of flanges (similar to those covered in ASME B16.5) that have orifice pressure differential connections. Coverage is limited to the following: a) welding neck flanges Classes 300, 600, 900, 1500, and 2500; b) slip-on and threaded Class 300.
Application:	Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. Manufacturers can also use this document as a reference for the required flange dimension details, including those applicable to welding. Designers can use this standard to select the appropriate class flange based on the specific design conditions (pressure and temperature) and the material of construction. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. It can also be used as a reference for inspection at the manufacturer's plant.
Comments:	This standard references ASME B16.5 in regard to pressure-temperature ratings and materials. B16.5 contains the pressure-temperature ratings for 44 groups of materials, with each group broken down according to forgings, castings and plates. The sizes covered by this standard are NPS 1 through 24 (Classes 300, 400, 600, 900, and 1500) and NPS 1 through 12 (Class 2500).
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-95 ASME B16.39 *Malleable Iron Threaded Pipe Unions Classes 150, 250, and 300*

Current Edition:	2019 (22 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard for threaded malleable iron unions, Classes 150, 250, and 300 provides requirements for the following: a) design; b) pressure-temperature ratings; c) size; d) marking; e) materials; f) joints and seats; g) threads; h) hydrostatic strength; i) tensile strength; j) air pressure test; k) sampling for air pressure test; l) coatings; and m) dimensions.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspections at the manufacturer's plant.
Comments:	The sizes of the pipe unions covered by this standard are NPS 1/8 through 4.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-96 ASME B16.42 *Ductile Iron Pipe Flanges and Flanged Fittings (Classes 150 and 300)*

Current Edition:	2016 (50 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers minimum requirements for Class 150 and 300 cast ductile iron pipe flanges and flanged fittings. The requirements covered are as follows: a) pressure-temperature ratings; b) sizes and method of designating openings of reducing fittings; c) marking; d) materials; e) dimensions and tolerances; f) bolts, nuts and gaskets; and g) tests.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program.
Comments:	This standard covers flanges, 45 and 90 degree elbows, tees, crosses, 45 degree laterals, reducers, and true Ys in sizes NPS 1 through 24 in Classes 150 and 300.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-97 ASME B16.47 *Large Diameter Steel Flanges (NPS 26 through NPS 60 Metric/Inch Standard)*

Current Edition:	2020 (137 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers pressure-temperature ratings, materials, dimensions, tolerances, marking, and testing for pipe flanges in sizes NPS 26 through NPS 60. Included here are flanges with rating class designations 75, 150, 300, 400, 600, and 900 with requirements given in both SI (metric) and US customary units, with diameter of bolts and flange bolt holes expressed in inch units. This standard is limited to: • Flanges made from cast or forged materials. • Blind flanges made from cast, forged, or plate materials. Also, included in this standard are requirements and recommendations regarding flange bolting, flange gaskets, and flange joints.
Application:	Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. Manufacturers can also use this document as a reference for the required flange dimension details, including those applicable to welding. Designers can use this standard to select the appropriate class flange based on the specific design conditions (pressure and temperature) and the material of construction. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. It can also be used as a reference for inspection in a manufacturer's plant.
Comments:	This is a comprehensive document that contains the pressure-temperature ratings for 26 groups of materials, with each group broken down according forgings, castings and plates.
User:	Purchaser: **P** — Manufacturer: **P** — Designer: **P** — Inspector: **S** — Regulator: (blank) P – Primary User S – Secondary User

A-98 ASME B16.48 *Line Blanks*

Current Edition:	2020 (38 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers pressure-temperature ratings, materials, dimensions, tolerances, marking, and testing for operating line blanks in sizes NPS ½ through NPS 24 for installation between ASME B16.5 flanges in the 150, 300, 600, 900, 1500, and 2500 pressure classes.
Application:	Purchasers can reference this standard in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. Manufacturers can also use this document as a reference for the required flange dimension details. Designers can use this standard to select the appropriate class line blank based on the specific design conditions (pressure and temperature) and the material of construction. In addition, the thickness and dimensional requirements may be useful in evaluating the results of an in-service examination program. It can also be used as a reference for inspection in the manufacturer's plant.
Comments:	This standard covers figure-8 blanks, paddle blanks, and paddle spacers. Facings include raised face, female ring-joint facing, and male oval ring-joint facing. Materials and pressure-temperature ratings are by reference to ASME B16.5.
User:	Purchaser: **P**; Manufacturer: **P**; Designer: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-99 ASME B16.50 *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*

Current Edition:	2018 (26 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard establishes requirements for wrought copper and wrought copper alloy braze-joint seamless fittings designed for use with seamless copper tube conforming to ASTM Standard Specification B 88 (Water and General Plumbing Systems), B 280 (Air Conditioning and Refrigeration Service) and B 819 (Medical Gas Systems). This standard covers joints assembled with brazing materials conforming to AWS A5.8M/A5.8. This standard is allied to ASME Standards B16.18 and B16.22. It provides requirements for fitting-ends suitable for brazing. This standard covers: a) pressure-temperature ratings; b) abbreviations for end connections; c) size and method for designating openings for fittings; d) marking; e) materials; f) dimensions and tolerances; and g) testing.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspection at the manufacturer's plant.
Comments:	This standard covers various types of copper fittings, such as adapters, bushings, elbows, tees, return bends, plugs, cap, couplings, P-traps, in both straight and reducing styles, if applicable. Fittings are mostly soldered, but some with both soldered and threaded connections are also covered. The water tube and pipe thread sizes covered are 1/8 through 8 inches. This standard states that due to widely varying manufacturing processes, meaningful laying-length requirements of fittings cannot be established and to consult the manufacturer for these dimensions.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-100 ASME B16.52 *Forged Nonferrous Fittings, Socket-Welding and Threaded (Titanium, Titanium Alloys, Aluminum, and Aluminum Alloys)*

Current Edition:	2018 (28 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This Standard covers ratings, dimensions, tolerances, marking, and material requirements for titanium, titanium alloy, aluminum, and aluminum alloy forged fittings, both socket-welding and threaded ends.
Application:	Purchasers can reference this document in an equipment purchase specification, and manufacturers can use it to certify that requirements have been met. It can also be referenced for inspection at the manufacturer's plant.
Comments:	This standard covers 45- and 90-degree elbows, tees, crosses, couplings, half couplings, and caps in socket-welding and threaded configurations. Size range is NPS ⅛ through NPS 4 for threaded fittings and socket-welded fittings in pipe schedules 40 and 80. For socket-welded fittings in pipe schedule 160, the size range is NPS ⅛ through NPS 2.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: ; Inspector: **S**; Regulator: P – Primary User S – Secondary User

A-101 ASME B31.1 *Power Piping*

Current Edition:	2020 (393 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Rules for this code section have been developed considering the needs for application, which include piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems. This code prescribes requirements for the design, materials, fabrication, erection, examination, testing, inspection, operation, and maintenance of piping systems. Piping as used in this code includes pipe, flanges, bolting, gaskets, valves, relief devices, fittings, and the pressure-containing portions of other piping components, whether manufactured in accordance with standards listed in Table 126.1-1 or specifically designed. It also includes hangers and supports and other equipment items necessary to prevent overstressing the pressure containing components. Rules governing piping for miscellaneous appurtenances, such as water columns, remote water level indicators, pressure gages, gage glasses, etc., are included within the scope of this code, but the requirements for boiler appurtenances shall be in accordance with Section I of the ASME Boiler and Pressure Vessel Code, PG-60. Power piping systems as covered by this code apply to all piping and their component parts, except as excluded in paragraph 100.1.3. They include, but are not limited to, steam, water, oil, gas, and air services. This code covers boiler external piping for power boilers and high temperature, high pressure water boilers in which steam or vapor is generated at a pressure of more than 15 psig (100 kPag), and high temperature water generated at pressures exceeding 160 psig (1103 kPag) and/or temperature exceeding 250°F (120°C).
Application:	This code is intended for use by organizations that maintain or have access to engineering and inspection personnel technically trained and experienced in power boiler piping design, fabrication, repair, construction, and inspection. Regulators may use as desired.
Comments:	The general philosophy underlying this Power Piping Code is to parallel those provisions of Section I, Power Boilers, of the ASME Boiler and Pressure Vessel Code, as they can be applied to power piping systems. The allowable stress values for power piping are generally consistent with those assigned for power boilers. This code is more conservative than some other piping codes, reflecting the need for long service life and maximum reliability in power plant installations. The Power Piping Code as currently written does not differentiate between the design, fabrication, and erection requirements for critical and noncritical piping systems, except for certain stress calculations and mandatory nondestructive tests of welds for heavy wall, high temperature application.
User:	Manufacturer: **P** — Consultant: **P** — Owner: **P** — Inspector: **P** — Regulator: **S** P – Primary User S – Secondary User

A-102 ASME B31.3 *Process Piping*

<table>
<tr><td>Current Edition:</td><td>2020 (554 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>Yes</td></tr>
<tr><td>Scope:</td><td>Rules for the Process Piping Code Section B31.3 have been developed considering piping typically found in petroleum refineries; onshore and offshore petroleum and natural gas production facilities; chemical, pharmaceutical, textile, paper, ore processing, semiconductor, and cryogenic plants; food and beverage processing facilities; and related processing plants and terminals.
This code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.
This code applies to piping for all fluids, including:
• Raw, intermediate and finished chemicals.
• Petroleum products.
• Gas, steam, air, and water.
• Fluidized solids.
• Refrigerants.
• Cryogenic fluids.
Fig. 300.1.1 of this code illustrates the application of B31.3 piping at equipment. The joint connecting piping to equipment is within the scope of B31.3.
Also included within the scope of this code is piping which interconnects pieces or stages within a packaged equipment assembly.
This code excludes the following:
• Piping systems designed for internal gage pressures at or above zero but less than 105 kPa (15 psi), provided the fluid handled is nonflammable, nontoxic, and not damaging to human tissues.
• Power boilers in accordance with BPV Code Section I and boiler external piping, which is required to conform to B31.1.
• Tubes, tube headers, crossovers and manifolds of fired heaters, which are internal to the heater enclosure.
• Pressure vessels, heat exchangers, pumps, compressors, and other fluid handling or processing equipment, including internal piping and connection for external piping.</td></tr>
<tr><td>Application:</td><td>This code can be used by persons knowledgeable in the design, fabrication, erection, testing, and repair of piping components and systems.</td></tr>
<tr><td>Comments:</td><td>This is a comprehensive document intended for use by persons knowledgeable in stress calculations and materials properties. It covers metallic and nonmetallic piping. It has a part on piping for Category M (high pressure, toxic, flammable, damaging to human skin) fluid service. There is also information on interpretations and code cases relevant to B31.3.</td></tr>
<tr><td>User:</td><td><table><tr><td>Purchaser</td><td>Manufacturer</td><td>Owner</td><td>Inspector</td><td>Regulator</td></tr><tr><td>P</td><td>P</td><td>P</td><td>P</td><td>P</td></tr></table>P – Primary User
S – Secondary User</td></tr>
</table>

A-103 ASME B31.5 *Refrigeration Piping and Heat Transfer Components*

Current Edition:	2020 (105 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Rules for this code section have been developed considering the needs for applications that include piping and heat transfer components for refrigerants and secondary coolants. This code prescribes requirements for the materials, design, fabrication, assembly, erection, test, and inspection of refrigerant, heat transfer components, and secondary coolant piping for temperatures as low as –320°F (–196°C), whether erected on the premises or factory assembled, except as specifically excluded as noted. This code does not apply to any of the following: • Any self-contained or unit systems subject to the requirements of Underwriters Laboratories or other nationally recognized test laboratory. • Water piping, other than where water is used as a secondary coolant or refrigerant. • Piping designed for external or internal gage pressure not exceeding 15 psi (105 kPa) regardless of size. • Pressure vessels, compressors or pumps, but does include all connecting refrigerant and secondary coolant piping starting at the first joint adjacent to such apparatus.
Application:	This code can be used by persons knowledgeable in the design, fabrication, construction, and testing of piping components and systems.
Comments:	This document is intended for use by persons knowledgeable in stress calculations, materials properties, and mechanical engineering principles. It applies primarily to new construction using metallic components.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-104 ASME B31.9 *Building Services Piping*

Current Edition:	2020 (86 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This code section has rules for the piping in industrial, institutional, commercial, and public buildings and multi-unit residences, which do not require the range of sizes, pressures, and temperatures covered in ASME B31.1. This code prescribes requirements for the design, materials, fabrication, installation, inspection, examination, and testing of piping systems for building services. It includes piping systems for building services. It includes piping systems in the building or within the property limits. This code applies to the following building services: • Water and antifreeze solutions for heating and cooling. • Condensing water. • Steam or other condensate. • Other nontoxic liquids. • Steam. • Vacuum. • Compressed air. • Other nontoxic, nonflammable gases. • Combustible liquids including fuel oil. The scope of this code includes boiler external piping within the following limits: • For steam boilers, 15 psig (103 kPa gage) max. • For water heating units, 160 psig (1103 kPa gage) max. and 250°F (121°C) max. Boiler external piping above these pressure or temperature limits is within the scope of ASME B31.1. This code does not apply to economizers, heaters, pumps, tanks, heat exchangers, or equipment covered by the ASME Boiler and Pressure Vessel Code.
Application:	This code is intended for use by building designers, construction contractors and building inspectors. It can also be used as a resource by regulators and lawmakers for input into building codes.

<table>
<tr><td>Comments:</td><td>Piping systems of the following materials are within the scope of this code, through the indicated maximum size (and wall thickness if noted):
• Carbon steel: NPS 48 (DN 1200) and 0.50 in. (12.7 mm) wall.
• Stainless steel: NPS 24 (DN 600) and 0.50 in. (12.7 mm) wall.
• Aluminum: NPS 12 (DN 300).
• Brass and copper: NPS 12 (DN 300) and 12.125 in. (308 mm) O.D. for copper tubing.
• Thermoplastics: NPS 24 (DN 600).
• Ductile iron: NPS 48 (DN 1200).
• Reinforced thermosetting resin: 24 in. (DN 600) nominal.
Other materials may be used as noted in Chapter III of this code.
Piping systems with working pressure not in excess of the following limits are within the scope of this code:
• Steam and condensate: 150 psig (1034 kPa gage).
• Liquids: 350 psig (2413 kPa gage).
• Vacuum: 1 atm. external pressure.
• Compressed air and gas: 150 psig (1034 kPa gage).
Piping systems with working temperatures not in excess of the following limits are within the scope of this code:
• Steam and condensate: 366°F (186°C).
• Other gases and vapors: 200°F (93°C).
• Other nonflammable liquids: 250°F (121°C).
The minimum temperature for all services is 0°F (-18°C).</td></tr>
<tr><td>User:</td><td>
<table>
<tr><th>Purchaser</th><th>Contractor</th><th>Designer</th><th>Inspector</th><th>Regulator</th></tr>
<tr><td></td><td>P</td><td>P</td><td>P</td><td>P</td></tr>
</table>
P – Primary User
S – Secondary User</td></tr>
</table>

A-105 ASME B31.12 *Hydrogen Piping and Pipelines*

Current Edition:	2019, Including Errata, February 2020 (280 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Rules for this code section are applicable to piping in gaseous and liquid hydrogen service and to pipelines in gaseous hydrogen service. This code is applicable up to and including the joint connecting the piping to associated pressure vessels and equipment but not to the vessels and equipment themselves. It is applicable to the location and type of support elements but not to the structure to which the support elements are attached. The design for pressure and temperature shall be in accordance with the requirements of Part IP for industrial piping and Part PL for pipelines. This code is presented in the following parts and appendices: (a) Part GR—General Requirements. Part GR contains requirements applicable to and referenced by other parts. It contains definitions and requirements for materials, welding, brazing, heat treating, forming, testing, inspection, examination, operation, and maintenance. It also contains quality system topics common to the other parts. (b) Part IP—Industrial Piping. Part IP includes requirements for components, design, fabrication, assembly, erection, inspection, examination, and testing of piping. (c) Part PL—Pipelines. Part PL sets forth requirements for components, design, installation, and testing of hydrogen pipelines. (d) Mandatory Appendices I through IX. (e) Nonmandatory Appendices A through F. Each part defines requirements for piping or pipelines, as applicable, within its scope. The requirements are different for different aspects of components, design, fabrication, installation, assembly, erection, inspection, examination, and testing. It is required that each part be used in conjunction with the General Requirements section but independent of the other parts. The joint connecting piping governed by two different parts shall be subject exclusively to the requirements of one of the two parts. It is not intended that this edition of this Code be applied retroactively to existing hydrogen systems.
Application:	This code can be used by persons knowledgeable in the design, fabrication, construction, and testing of piping components and systems.
Comments:	The rules of Part IP, Industrial Piping, have been developed for hydrogen service included in petroleum refineries, refueling stations, chemical plants, power generation plants, semiconductor plants, cryogenic plants, hydrogen fuel appliances, and related facilities.
User:	Purchaser: **P**; Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: (blank) P – Primary User S – Secondary User

A-106 ASME B31E *Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems*

Current Edition:	2008, including Addenda-a, July 2010 (34 pages)
Alt. Number:	No
ANSI Approved?	Yes
Scope:	This standard establishes a method for the seismic design of above-ground piping systems in the scope of the ASME B31 Code for Pressure Piping. This standard applies to above-ground, metallic piping systems in the scope of the ASME B31 Code for Pressure Piping (B31.1, B31.3, B31.4, B31.5, B31.8, B31.9 and B31.11). The requirements described in this standard are valid when the piping system complies with the materials, design, fabrication, examination, testing, and inspection requirements of the applicable ASME B31 Code section.
Application:	This standard can be used by piping and/or mechanical designers as an aid in designing new or retrofitting existing piping systems to withstand seismic loads.
Comments:	This standard provides guidance on the design method that should be used based on: a) the classification of the piping system (critical or noncritical); b) the magnitude of the seismic input; and c) the pipe size. This standard can be used by persons knowledgeable in the design of piping systems.
User:	Purchaser: — ; Designer: **P** ; Owner: **P** ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-107 ASME B31G *Manual for Determining the Remaining Strength of Corroded Pipelines*

Current Edition:	2012, Reaffirmed 2017 (64 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document provides guidance in the evaluation of metal loss in pressurized pipelines and piping systems. The scope of this manual includes all pipelines within the scope of the pipelines codes that are part of ASME B31 Code for Pressure Piping (i.e., ASME B31.4, Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia and Alcohols); ASME B31.8, Gas Transmission and Distribution Piping Systems; and ASME B31.11, Slurry Transportation Piping Systems. Parts 2, 3 and 4 are based on material included in ASME Guide for Gas Transmission and Distribution Piping Systems, 1983 Edition. This manual is not applicable to new construction covered under the B31 Code sections. That is, it is not intended for this manual be used to establish acceptance standards for pipe that may have become corroded prior to or during fabrication and/or installation. The limitations of this manual are: • This manual is limited to corrosion on weldable pipeline steels categorized as carbon steels or high strength low alloy steels. Typical of these materials are those described in ASTM A 53, A 106, A 381, and API 5L. • This manual applies only to defects in the body of line pipe which have relatively smooth contours and cause low stress concentrations (e.g., electrolytic or galvanic corrosion, loss of wall thickness due to erosion). • This procedure should not be used to evaluate the remaining strength of corroded girth or longitudinal welds or related heat affected zones, defects caused by mechanical damage, such as gouges and grooves or defects introduced during pipe and plate manufacture, such as seams, laps, rolled ends, scabs, or slivers. • The criteria for corroded pipe to remain in service presented in this manual are based only upon the ability of the pipe to maintain structural integrity under internal pressure. It should not be the sole criterion when the pipe is subject to significant secondary stresses (e.g., bending), particularly if the corrosion has a significant transverse component. • This procedure does not predict leaks or rupture failures.
Application:	This manual is intended for the purpose of providing guideline information for the designer/owner/operator. The specific use of this manual is the responsibility of the designer/owner/operator. This manual can also be used by consultants who are contracted by pipeline owners/operators.
Comments:	The development of the procedure presented in this manual began in the early 1970s and is based on pressurizing to failure tests on full-size corroded pipes. These tests led to mathematical expressions to calculate the pressure strength of corroded pipe. Based on the table in Part 3 of this manual, the range of pipe sizes covered is NPS 2 (DN 50) and 0.083 in. (2.1 mm) wall thickness through NPS 60 (DN 1500) and 1.250 in. (31.8 mm) wall thickness. Although the Scope states that this manual is applicable to ASME B31.4, B31.8 and B31.11 pipelines, it can be used to assess other piping systems constructed of the same steels as used for pipelines.

User:	Purchaser	Designer	Owner/ Operator	Inspector	Regulator
		P	**P**	**P**	
	P – Primary User S – Secondary User				

A-108 ASME B31J *Stress Intensification Factors (i-Factors), Flexibility Factors (k-Factors), and Their Determination for Metallic Piping Components*

Current Edition:	2017 (64 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	The ASME B31 Code for Pressure Piping and the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Components, Subsections NC and ND piping rules require the use of stress intensification factors (SIFs or i-factors) and flexibility factors (k-factors) when checking the adequacy of components and joints (welded and nonwelded) in piping subject to various loads, including cyclic loads, that may produce fatigue failures. This standard provides a standardized method to develop the stress intensification factors (i-factors), flexibility factors (k-factors), and sustained stress factors used in ASME B31 piping analysis. Experimental methods to determine SIFs, flexibility factors, and sustained load factors are provided in the Nonmandatory Appendices. Compiled stress intensification and flexibility factor equations for common piping components are included in Table 1-1 of the standard.
Application:	This Standard sets forth stress intensification factors, flexibility factors, and engineering procedures deemed appropriate for the safe determination of the fatigue and sustained load capacity of metallic piping components or joints in typical services. The procedure cannot foresee all geometries and services possible, and the use of competent engineering judgment may be necessary to extend the procedure to cover unusual geometries and service conditions or to ensure a safe testing environment.
Comments:	Stress intensification and flexibility factor equations for common piping components are provided in Table 1-1 of this standard. The sustained load test procedure can be used to determine more applicable nominal stress multipliers for use in sustained and occasional ASME B31 analyses.
User:	Designer: **P**; Consultant: **P**; Owner: **P**; Inspector: ; Regulator: P – Primary User S – Secondary User

A-109 ASME B31P *Standard Heat Treatments for Fabrication Processes*

Current Edition:	2017 (41 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	In 2011, the B31 Standards Committee for Pressure Piping determined that more consistency was needed between the B31 Code Sections regarding preheat and postweld heat treatment (PWHT) rules. The B31 Fabrication & Examination Technical Committee decided that a B31 Standard covering these rules would be the best way to provide this consistency. This standard was written to meet that need. This standard is intended to provide requirements for preheating and PWHT when mandated by the applicable Code Section or by the engineering design being used. While the Code Sections provide only preheat and PWHT rules for ferrous materials, this Standard may provide expanded rules and alternatives for a wider variety of materials, although all materials that may be possible to use may not be covered.
Application:	This standard is intended to provide consistent code heat treatment rules. It may be incorporated by reference in a code, or it can become a basis for code or contract requirements.
Comments:	Appendices provide more-specific controls that may be needed or desired for specific applications. These specific controls are not mandatory unless specified. Appendices are also included that outline alternative methods to exempt PWHT of welds when PWHT is difficult or impossible. The alternatives are required to be addressed within Welding Procedure Specifications (WPS) qualified in accordance with ASME Boiler and Pressure Vessel Code (BPVC), Section IX. The requirements for the heat treatments done in accordance with material or product specifications are not addressed within this Standard. Such heat treatments are governed by those specifications.
User:	Designer: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-110 ASME B31T *Standard Toughness Requirements for Piping*

Current Edition:	2018 (59 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This Code provides requirements for evaluating the suitability of materials used in piping systems for piping that may be subject to brittle failure due to low-temperature service conditions. While low-temperature service is usually considered to be below ambient temperature, brittle failure can occur at temperatures above ambient temperature for certain combinations of materials, thicknesses, and stress levels. The definition of “low-temperature service” as used in this Code, therefore, varies widely across the many applications for which piping systems are used. For a building service air line, low temperature may be 0°C (32°F), whereas for a cryogenic piping system, it could easily be −185°C (−300°F). However, the principles used to evaluate the suitability of a piping system as related to service temperature by evaluating the toughness of the material can be applied across a wide temperature range, and this Code has been established to provide uniform guidance in this area.
Application:	This Code may be invoked in whole or in part by various piping codes and/or specifications and is only mandatory when so invoked.
Comments:	One objective of this Code is to provide a simple approach to evaluate whether additional consideration is necessary to evaluate suitability for low-temperature service. This is done by establishing a low-temperature service limit for various materials. Services at or warmer than this limit are not considered low temperature, and additional considerations relative to suitability are not required.
User:	Contractor: **P**; Designer: **P**; Owner: **P**; Inspector: ; Regulator: P – Primary User S – Secondary User

A-111 ASME B36.10M *Welded and Seamless Wrought Steel Pipe*

Current Edition:	2018 (36 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers the standardization of dimensions of welded and seamless wrought steel pipe for high or low temperatures and pressures. The word “pipe” is used, as distinguished from “tube,” to apply to tubular products of dimensions commonly used for pipeline and piping systems. Pipe NPS 12 (DN 300) and smaller have outside diameters numerically larger than their corresponding sizes. For pipes NPS 14 (DN 350) and larger, the outside diameter and size are numerically identical. In contrast, the outside diameters of tubes are numerically identical to the size number for all sizes.
Application:	Designers can use this standard to select an available standard pipe thickness after the minimum thickness for the required conditions has been determined. The standard provides a tabulation of pipe weight per unit of length, which can be used in determining piping support loads and shipping weights.
Comments:	This standard covers nominal pipe sizes from NPS ⅛ (DN 6) through 80 (DN 2000). This standard does not cover the possible variations in pipe dimensions. These tolerances are given in the individual pipe material specifications.
User:	Purchaser: — ; Manufacturer: — ; Designer: **P** ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-112 ASME B36.19M *Stainless Steel Pipe*

Current Edition:	2018 (18 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard covers the standardization of dimensions of welded and seamless wrought stainless steel pipe for high or low temperatures and pressures. The word "pipe" is used, as distinguished from "tube," to apply to tubular products of dimensions commonly used for pipeline and piping systems. Pipe NPS 12 (DN 300) and smaller have outside diameters numerically larger than their corresponding sizes. For pipes NPS 14 (DN 350) and larger, the outside diameter and size are numerically identical. In contrast, the outside diameters of tubes are numerically identical to the size number for all sizes. The wall thickness for NPS 14 through 22, inclusive (DN 350-550, inclusive), of Schedule 10S; NPS 12 (DN 300) of Schedule 40D; and NPS 10 and 12 (DN 250 and 300) of Schedule 80S are not the same as those of ASME B36.10M. The suffix "S" in the schedule number is used to differentiate B36.19M pipe from B36.10M pipe. ASME B36.10M includes other pipe thicknesses that are commercially available with stainless steel material.
Application:	Designers can use this standard to select an available standard pipe thickness after the minimum thickness for the required conditions has been determined. The standard provides a tabulation of pipe weight per unit of length, which can be used in determining piping support loads and shipping weights.
Comments:	This standard covers nominal pipe sizes from NPS ⅛ (DN 6) through 30 (DN 750). This standard does not cover the possible variations in pipe dimensions. These tolerances are given in the individual pipe material specifications.
User:	Purchaser: — ; Manufacturer: — ; Designer: **P** ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-113 ASME B40.100 *Pressure Gauges and Gauge Attachments*

Current Edition:	2013 (136 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard (B40.100) consolidates the following individual standards, which cover terminology and definitions, dimensions, safety, construction and installation issues, test procedures, and general recommendations. ASME B40.1–Gauges: Pressure Indicating Dial Type-Elastic Element • This standard is confined to analog, dial-type gauges, which, utilizing elastic elements, mechanically sense pressure and indicate it by means of a pointer moving over a graduated scale. • This standard does not include gauges of special configuration designed for specific applications, edge reading, deadweight or piston gauges, or any other gauges not using an elastic element to sense pressure. ASME B40.2–Diaphragm Seals • This standard is confined to mechanical separators utilizing diaphragms or bladders together with a fill fluid to transmit pressure from the medium to the pressure element assembly of pressure gauges or other pressure measuring instruments such as transducers, transmitters, and switches. • It does not include diaphragm actuated pressure instruments that employ mechanical linkages to transmit the applied pressure or other separation devices designed to protect the pressure element assembly. ASME B40.5–Snubbers • This standard is confined to devices that are installed between the pressure source and the pressure-sensing element and are used to minimize the effect of pressure surges on positive and negative pressure-sensing instruments. ASME B40.6–Pressure Limiter Valves • This standard is confined to devices that protect pressure-sensing instruments from pressure sources in the event of system pressure rising above the adjusted closing pressure of the device. These devices are not pressure regulators. Pressure limiter valves are designed only to prevent the passage of excessive pressure to downstream pressure-sensing instruments. Hereafter, pressure limiter valves may be referred to as "devices." ASME B40.7–Gauges: Pressure Digital Indicating • This standard is confined to digital gauges with integral pressure transducers, which respond to pressure and indicate numerically. • It does not include panel meters with remote mounted transducers, nonindicating pressure transmitters, or pressure switches.
Application:	This standard is an advisory document that can provide guidance to manufacturers, instrument engineers, and users. For manufacturers, it provides suggested configuration guidelines; for engineers, it can be a resource in preparing a specification; and, for users, it explains the construction, operation, application, and procedures associated with pressure gauges and attachments.
Comments:	This Standard can serve as a tutorial type reference for process and mechanical engineers.

	Engineer	Manufacturer	User	Inspector	Regulator
User:	**P**	**P**	**P**	**S**	
	P – Primary User S – Secondary User				

A-114 ASME BPE *Bioprocessing Equipment*

Current Edition:	2019 (381 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard provides the requirements applicable to the design of equipment used in the bioprocessing, pharmaceutical, and personal care product industries, including aspects related to sterility and cleanability, materials, dimensions and tolerances, surface finish, material joining, seals, examinations, inspections, testing, and certifications. These apply to: • Components that are in contact with the product, raw materials, or product intermediates during manufacturing, development, or scale-up. • Systems that are a critical part of product manufacture [e.g., water-for injection (WFI), clean steam, filtration, and intermediate product storage]. The main sections in this standard are: General requirements; Design for sterility and cleanability; Dimensions and tolerances for stainless steel automatic welding and hygienic clamp tube fittings and process components; Material joining; Stainless steel and higher alloy product contact surface finishes; Equipment seals; and Polymer-based materials.
Application:	This standard is intended for use by persons involved in the design and manufacture of bioprocessing equipment. It can also be used as a reference by shop inspectors, regulators, and owners.
Comments:	This standard does not apply to those components of the system that are not in contact with the finished product or are a part of the intermediate manufacturing stages (e.g., computer systems, electrical conduits, and external system support structures). Steam sterilized systems normally meet pressure vessel design codes. Other equipment or systems as agreed to by the manufacturer and owner/user may not require adherence to these codes.
User:	Purchaser: (blank); Designer/Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-115 BPVC Section I *Rules for Construction of Power Boilers*

Current Edition:	2021 (444 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This code covers rules for construction of power boilers, electric boilers, miniature boilers, high-temperature water boilers and heat recovery steam generators to be used in stationary service and includes those power boilers used in locomotive, portable, and traction service. The scope of jurisdiction of Section I applies to the boiler proper and to the boiler external piping. Superheaters, economizers, and other pressure parts connected directly to the boiler without intervening valves shall be considered as parts of the boiler proper, and their construction shall conform to Section I rules.
Application:	This standard is intended for use by organizations that maintain or have access to engineering and inspection personnel technically trained and experienced in boiler design, fabrication, repair, construction, and inspection. Regulators may use as desired.
Comments:	The first part of this document contains a section covering the general requirements for all methods of construction. Subsequent sections cover requirements for boilers fabricated by welding, requirements for boilers fabricated by riveting, requirements for boilers fabricated by brazing, requirements for watertube boilers, requirements for firetube boilers, optional requirements for feedwater heater, requirements for miniature boilers, requirements for electric boilers, requirements for organic fluid vaporizers and requirements for heat recovery steam generators. One significant change in the 2021 Edition is the transfer of pressure relief device capacity certification requirements to the new Section XIII on Overpressure Protection. The remaining overpressure protection requirements have been retained in their current locations. New Nonmandatory Appendix G provides a guide to the relocation of pressure relief device capacity certification requirements.
User:	Manufacturer: **P** Consultant: **P** Owner: **P** Inspector: **P** Regulator: **S** P – Primary User S – Secondary User

A-116 BPVC Section II–Materials–Part A *Ferrous Material Specifications*

Current Edition:	2021 (Approx. 1800 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document contains the individual specifications for the ferrous materials that are allowed to be used by the ASME Code, Sections I, II, III, IV, VIII-1, VIII-2, VIII-3, and XII. It also designates for each ferrous material the specific ASME Code that allows its use. The forms of ferrous material covered by this document are steel pipe; steel tubes; steel flanges, fittings, valves, and parts; steel plates, sheets, and strip for pressure vessels; structural steel; steel bars; steel bolting materials; steel billets and forgings; steel castings; corrosion-resisting and heat-resisting steels; and wrought iron, cast iron, and malleable iron. This document also has specifications covering test and examination methods.
Application:	This document can be used as an aid by pressure vessel, piping, and structural designers to select a ferrous material for a specific application. It can also be referenced by inspections and by persons involved in the review of equipment designs.
Comments:	The areas addressed by the individual specifications vary based on the characteristics of the ferrous material and the final use/form for which it is intended. Some examples are ordering information, heat treatment, chemical composition, mechanical properties, tests and examination, dimensions and tolerances, and steel making practice. In addition to the individual material specifications, there are several general requirement specifications (e.g., General Requirements for Steel Plate for Process Vessels). The general specification is referenced by the applicable individual specifications.
User:	Designer: **P**; Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: (blank) P – Primary User S – Secondary User

A-117 BPVC Section II–Materials–Part B *Nonferrous Material Specifications*

Current Edition:	2021 (1280 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document contains the individual specifications for the nonferrous materials that are allowed to be used by the ASME Code, Sections I, II, III, IV, VIII-1, VIII-2, VIII-3 and XII. It also designates for each nonferrous material the specific ASME Code that allows its use. The forms of ferrous material covered by this document are aluminum and aluminum alloys; cobalt alloys; copper and copper alloy plate, sheet, strip, and rolled bar; copper and copper alloy rod, bar, and shapes; copper and copper alloy pipe and tubes; copper alloy castings; nickel and nickel alloy plate, sheet and strip; nickel and nickel alloy rod, bar and wire; nickel and nickel alloy pipe and tubes; nickel alloy castings; nickel and nickel alloy fittings; titanium and titanium alloys; and zirconium and zirconium alloys. Test requirements are typically by reference to ASTM standards.
Application:	This document can be used as an aid by pressure vessel, piping, and structural designers to select a nonferrous material for a specific application. It can also be referenced by inspectors and by persons involved in the review of equipment designs.
Comments:	The areas addressed by the individual specifications vary based on the characteristics of the ferrous material and the final use/form for which it is intended. Some examples are ordering information, chemical composition, mechanical properties, tests and examination, and dimensions and tolerances. In addition to the individual material specifications, there are several general requirement specifications (e.g., General Requirements for Nickel and Nickel Alloy Welded Pipe). The general specification is referenced by the applicable individual specifications.
User:	Designer: **P**; Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: (blank) P – Primary User S – Secondary User

A-118 BPVC Section II–Materials–Part C *Specifications for Welding Rods, Electrodes, and Filler Metals*

Current Edition:	2021 (1016 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This is a service book to the other code sections providing material specifications for the manufacture, acceptability, chemical composition, mechanical usability, surfacing, testing requirements and procedures, operating characteristics and intended uses for welding rods, electrodes, and filler metals. These specifications are designated by SFA numbers and are derived from American Welding Society (AWS) specifications.
Application:	This document can be used by persons who are responsible for: 1) Developing welding procedures and 2) Purchasing welding materials. It can also be used as a reference by inspectors.
Comments:	This document only includes specifications that are applicable to the ASME B&PVC Code.
User:	Purchaser: **P**; Consultant: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-119 BPVC Section II–Materials–Part D *Properties (Customary)*

Current Edition:	2021 (1260 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This is a service book to other code sections providing tables of design stress values, tensile and yield strength values, and tables and charts of material properties. Part D facilitates ready identification of specific materials to specific sections of the Boiler and Pressure Vessel Code. Part D contains appendices which present criteria for establishing allowable stress, the bases for establishing external pressure charts, and information required for approval of new materials. Access to the online version of the Stress Tables is included with the purchase of this hard copy.
Application:	This standard is intended for use by organizations that maintain, or have access to, engineering and inspection personnel technically trained and experienced in ASME Code design, fabrication, repair, construction, and inspection.
Comments:	The three subparts in this document are: Subpart 1: Interactive Tables–Stress Tables, Subpart 2: Physical Properties Tables and Subpart 3: Charts and Tables for Determining Shell Thickness of Components Under External Pressure. The Subpart 1 Stress Tables are provided for ASME Code Sections I, III, VIII-1, VIII-2, VIII-3 and XII, and include all ferrous and nonferrous materials contained in Section II, Parts A and B.
User:	Designer: **P**; Consultant: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-120 BPVC Section II–Materials–Part D *Properties (Metric)*

Current Edition:	2021 (1268 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This is a service book to other code sections providing tables of design stress values, tensile and yield strength values, and tables and charts of material properties. Part D facilitates ready identification of specific materials to specific sections of the Boiler and Pressure Vessel Code. Part D contains appendices, which present criteria for establishing allowable stress, the bases for establishing external pressure charts and information required for approval of new materials. Access to the online version of the Stress Tables is included with the purchase of this hard copy.
Application:	This standard is intended for use by organizations that maintain or have access to engineering and inspection personnel technically trained and experienced in ASME Code design, fabrication, repair, construction, and inspection.
Comments:	The three subparts in this document are: Subpart 1: Interactive Tables–Stress Tables, Subpart 2: Physical Properties Tables and Subpart 3: Charts and Tables for Determining Shell Thickness of Components Under External Pressure. The Subpart 1 Stress Tables are provided for ASME Code Sections I, III, VIII-1, VIII-2, VIII-3 and XII, and include all ferrous and nonferrous materials contained in Section II, Parts A and B.
User:	Designer: **P**; Consultant: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-121 BPVC Section IV *Rules for Construction of Heating Boilers*

Current Edition:	2021 (280 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This section of the code covers rules for minimum construction requirements for the design, fabrication, installation, and inspection of steam heating, hot water heating, hot water supply boilers that are direction fired with oil, gas, electricity, coal, or other solid or liquid fuels, and for operation at or below the pressure and temperature limits set forth in this document. Similar rules for potable water heaters are also included. The scope of jurisdiction of Section IV applies to the boiler proper at the supply and return connections to the system or the supply and feedwater connections of a hot water supply boiler. Included within the scope of the boiler are pressure-retaining covers for inspection openings, such as manhole covers, handhold covers and plugs; and headers required to connect individual coils, tubes, or cast sections within a boiler.
Application:	This standard is intended for use by organizations that maintain or have access to engineering and inspection personnel technically trained and experienced in heating boiler design, fabrication, repair, construction, and inspection. Regulators may use as desired.
Comments:	The first part of this document contains a section covering the general requirements for all methods of construction. Subsequent sections cover requirements for boilers fabricated by welding, requirements for boilers fabricated by brazing, requirements for boilers constructed of cast iron, and requirements for boilers constructed of cast aluminum. There is also a section on the requirements for potable water heaters. One significant change in the 2021 Edition is the transfer of pressure relief device requirements from Article 4 to the new Section XIII on Overpressure Protection. The remaining overpressure protection requirements have been restructured within the new Article 4A. New Nonmandatory Appendix P provides a complete cross reference list between the previous requirements and the updated requirements and locations.
User:	Manufacturer: **P**; Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-122 BPVC Section V *Nondestructive Examination*

Current Edition:	2021 (1016 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This section of the code contains requirements and methods for nondestructive examination (NDE), which are code requirements to the extent they are specifically referenced and required by other code sections or referencing document. These NDE methods are intended to detect surface and internal imperfections in materials, welds, fabricated parts, and components. They include radiographic examination, ultrasonic examination, liquid radiographic examination, magnetic particle examination, liquid penetrant examination, magnetic particle examination, eddy current examination, visual examination, leak testing, and acoustic emission examination. Appendix A of Subsection A presents a listing of common imperfections and damage mechanisms and the NDE methods that are generally capable of detecting them.
Application:	This document can be used by owners, manufacturers, and inspection service companies as an aid in selecting an NDE method(s) and performing the test for inspecting new and existing equipment. It also presents guidance for the evaluation of the test results.
Comments:	This is a comprehensive guidance document intended for use by persons knowledgeable in inspection methods and procedures and in the types of defects and damage mechanisms.
User:	Consultant: **S**; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: (blank) P – Primary User S – Secondary User

A-123 BPVC Section VI *Recommended Rules for the Care and Operation of Heating Boilers*

Current Edition:	2021 (104 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This section of the ASME Code is intended to cover general descriptions, terminology and basic fundamentals of heating boilers, controls and automatic fuel burning equipment. Because of the wide variety of makes and types of equipment in use, it is general in scope. The boilers discussed in this section will be those limited to the operating ranges of Section IV, Heating Boilers, of the ASME Boiler and Pressure Vessel Code as follows. • Steam boilers for operation at pressure not exceeding 15 psi (100 kPa). • Hot water heating and hot water supply boilers for operation at pressures not exceeding 160 psi (1100 kPa) and/or temperatures not to exceed 250°F (120°C).
Application:	This section is intended to provide general guidance to owners in the care and operation of steam and hot water boilers. For detailed information on any specific unit, the manufacturer's information should be consulted. It also includes information on the periodic inspection of existing boilers.
Comments:	This section is a tutorial type document. The main topics covered are types of boilers; accessories and installation; fuels; fuel burning equipment and fuel burning controls; boiler room facilities; operation, maintenance, and repair–steam boilers; operation, maintenance, and repair–hot water boilers and hot water heating boilers; and water treatment. It also includes sample maintenance, testing, and inspection logs for steam heating boilers and hot water heater boilers.
User:	Purchaser: — ; Manufacturer: — ; Owner: **P** ; Inspector: **S** ; Regulator: — P – Primary User S – Secondary User

A-124 BPVC Section VII *Recommended Guidelines for the Care of Power Boilers*

Current Edition:	2021 (208 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document applies to the boiler proper and to pipe connections up to and including the valve or valves as required by the code. Superheaters, reheaters, economizers, or other pressure parts connected directly to the boiler without intervening valves should be considered as part of the boiler. Guidelines are also provided for operation of auxiliary equipment and appliances that affect the safe and reliable operation of power boilers. With respect to the application of this document, a power boiler is a pressure vessel constructed in compliance with Section 1 in which steam is generated for use external to the boiler at a pressure exceeding 15 psig (100 kPa) due to the application of heat. This heat may be derived from the combustion of fuel (solids, liquids, or gases), from hot waste gases or other chemical reactions or from the application of electrical energy.
Application:	The purpose of this document is to promote safety in the use of power boilers. This document is intended for use by those directly responsible for operating, maintaining, and inspecting power boilers. The difficulty in formulating a set of guidelines that may be applied to all sites and types of plants is recognized; therefore, it may be advisable to depart from them in specific cases. Manufacturer's operating instructions should always be followed. Other recommended procedures such as National Fire Protection Association codes covering prevention of furnace explosions are suggested for additional guidance.
Comments:	The main topics covered by this section are fundamentals; boiler operation; boiler auxiliaries; appurtenances; instrumentation, controls, and interlocks; inspection; repairs, alterations, and maintenance; control of internal chemical conditions; and preventing boiler failures. It also includes maintenance and operation checklists for watertube and firetube boilers.
User:	Contractor: — ; Manufacturer: — ; Owner: P ; Inspector: P ; Regulator: — P – Primary User S – Secondary User

A-125 BPVC Section VIII–Division 1 *Rules for Construction of Pressure Vessels*

Current Edition:	2021 (804 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	For the scope of this division, pressure vessels are containers for the containment of pressure, either internal or external exceeding 15 psig. This pressure may be obtained from an external source, by the application of heat by a direct or indirect source or through any combination thereof. This division contains mandatory requirements, specific prohibitions and nonmandatory guidance for pressure vessel materials, design, fabrication, examination, inspection, testing, certification, and pressure relief. The code does not address all aspects of these activities, and those aspects which are not specifically addressed should not be considered prohibited. This division is divided into three subsections, mandatory appendices, and non-mandatory appendices. Subsection A covers the general requirements applicable to all pressure vessels. Subsection B covers specific requirements that are applicable to the various methods used in the fabrication of pressure vessels. It deals with welded, forged, and brazed methods. Subsection C covers specific requirements applicable to the several classes of materials used in pressure vessel construction. It deals with carbon and low alloy steels, nonferrous metals, high alloy steels, cast iron, clad and lined material, cast ductile iron and ferritic steels, with properties enhanced by heat treatment, layered construction and low temperature materials, respectively. Section II, Part D contains tables of maximum allowable stress values for these classes of materials. The mandatory appendices address specific subjects not covered elsewhere in this division, and their requirements are mandatory when the subject covered is included in construction under this division. The non-mandatory appendices provide information and suggested good practices.
Application:	This division can be used by persons knowledgeable in the design, fabrication, testing, and repair of pressure vessels.
Comments:	This division is based on "Design by Rule" procedures. It is less rigorous than Division 2 but uses lower allowable stress values. One significant change in the 2021 Edition is the transfer of pressure relief device requirements to the new Section XIII on Overpressure Protection. The remaining overpressure protection requirements have been restructured into new paragraphs UG-150 through UG-156. New Nonmandatory Appendix PP provides a complete cross reference list between the previous requirements and the updated requirements and locations.
User:	Purchaser: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: **P** P – Primary User S – Secondary User

A-126 BPVC Section VIII–Division 2 *Rules for Construction of Pressure Vessels–Alternative Rules*

Current Edition:	2021 (872 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	In the scope of this division, pressure vessels are containers for the containment of pressure, either internal or external, exceeding 15 psig. This pressure may be obtained from an external source or by the application of heat from a direct or indirect source as a result of a process or through any combination thereof. The rules of this division may be used for the construction of the following pressure vessels: • Vessels to be installed at a fixed (stationary) location for a specific service where operation and maintenance control is retained during the useful life of the vessel by the user and is in conformance with the user's design specification. • Pressure vessels installed in ocean-going ships, barges, and other floating craft or used for motor vehicle or rail freight. • Pressure vessels or parts subject to direct firing from the combustion of fuel (solid, liquid, or gaseous) that are not within the scope of Sections I, III or IV may be constructed in accordance with the rules of this division. • The following pressure vessels in which steam is generated shall be constructed in accordance with the rules of Section VIII, Division 1 or this division: o Vessels known as evaporators or heat exchangers. o Vessels in which steam is generated by the use of heat resulting from operation of a processing system containing a number of pressure vessels such as used in the manufacture of chemical and petroleum products. o Vessels in which steam is generated but not withdrawn for external use. • Unfired steam boilers shall be constructed in accordance with the rules of Section I or Section VIII, Division 1. This division is divided into nine parts: general requirements, responsibilities and duties, materials requirements, design by rule requirements, design by analysis requirements, fabrication requirements, examination and inspection requirements, pressure testing requirements, and pressure vessel overpressure protection. Technical information previously placed in mandatory and non-mandatory appendices at the back of the document have been re-deployed as annexes to the nine parts. The 2017 Edition of Section VIII Division 2 introduced two vessel classes to attract more users to Section VIII Division 2. Class 1 vessels were introduced with the following limitations and relaxed rules when compared to a Class 2 vessel: • Class 1 vessels utilize a Design Margin of 3.0 on the material Ultimate Tensile Strength (compared to 2.4 for Class 2 vessels). • Certification of the User's Design Specification and Manufacturer's Design Report is required only when a formal fatigue analysis is required. Otherwise, these are not required (similar to that for a Section VIII Division 1 vessel). • For Class 1 vessels, the Design-by-Analysis rules of Part 5 may not be used in lieu of the Design-by-Rule requirements in Part 4. • All other aspects of construction including materials, fabrication, examination, and testing shall be in accordance with the applicable parts of ASME Section VIII Division 2.
Application:	This division can be used by persons knowledgeable in the design, fabrication, testing, repair, and approval of pressure vessels.
Comments:	This division is based on both "Design by Rule" and "Design by Analysis" procedures. It is more rigorous than Division 1 and uses higher allowable stress values. This division covers cyclic fatigue analysis.

	One significant change in the 2021 Edition is the transfer of pressure relief device requirements from Part 9 to the new Section XIII on Overpressure Protection. The remaining overpressure protection requirements have been restructured within Part 9. New Annex 9B provides a complete cross reference list between the previous requirements and the updated requirements and locations.
User:	Purchaser: **P** Manufacturer: **P** Owner: **P** Inspector: **P** Regulator: **P** P – Primary User S – Secondary User

A-127 BPVC Section VIII–Division 3 *Rules for Construction of Pressure Vessels–Alternative Rules for Construction of High Pressure Vessels*

Current Edition:	2021 (384 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	The rules of this division constitute requirements for the design, construction, inspection, and overpressure protection of metallic pressure vessels with design pressures generally above 10 ksi (70 MPa). However, it is not the intent of this division to establish maximum pressure limits for Section VIII, Division 1 or 2, nor minimum pressure limits for this division. Specific pressure limitations for vessels constructed to the rules of this division may be imposed elsewhere in this division for various types of fabrication. Pressure vessels within the scope of this division are pressure containers for the retainment of fluids, gaseous or liquid, under either internal or external pressure. This pressure may be generated by an external source, the application of heat from a direct or indirect source, a process reaction or through any combination thereof. This division is divided into eight parts and mandatory and nonmandatory appendices. The eight parts cover general requirements; material requirements; design requirements; fabrication requirements; pressure relief devices; examination requirements; testing requirements; and marking, stamping, reports, and records.
Application:	This division can be used by persons knowledgeable in the design, fabrication, testing, repair, and approval of high pressure vessels.
Comments:	One significant change in the 2021 Edition is the transfer of pressure relief device requirements from Part KR to the new Section XIII on Overpressure Protection. The remaining overpressure protection requirements have been restructured within a new Part KOP. New Nonmandatory Appendix M provides a complete cross reference list between the previous requirements and the updated requirements and locations.
User:	Designer: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: **P** P – Primary User S – Secondary User

A-128 BPVC Section IX *Welding, Brazing, and Fusing Qualifications*

Current Edition:	2021 (400 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This section of the ASME Boiler and Pressure Vessel Code relates to the qualifications of welders, welding operators, brazers and brazing operators, and the procedures that they employ in welding and brazing according to the ASME Boiler and Pressure Vessel Code and the ASME B31 Code for Pressure Piping. It is divided into two parts: Part QW gives requirements for welding and Part QB contains requirements for brazing. Others sections of the code may specify different requirements than those specified by this section. Such requirements take precedence over those of this section, and the manufacturer or contractor shall comply with them. The main topics in the welding Part QW are welding general requirements; welding procedure qualification; welding performance qualifications; welding data; and standard welding procedure specifications (SWPSs). The main topics in brazing Part QB are brazing general requirements; brazing procedure qualifications; brazing performance qualifications; and brazing data.
Application:	Purchasers can reference this section in purchase specifications for new equipment or repairs and modifications to existing equipment. Manufacturers and field contractors need it to comply with the purchase specification when the section is cited therein.
Comments:	This section provides detailed procedures to qualify welders and brazers (operate manual or semi-automatic equipment) and welding and brazing operators (operate machine or automatic equipment) and also the procedures employed. It also contains acceptance standards.
User:	Purchaser: **P**; Manufacturer: **P**; Field Contractor: **P**; Inspector: ; Regulator: P – Primary User S – Secondary User

A-129 BPVC Section X *Fiber-Reinforced Plastic Pressure Vessels*

<table>
<tr><td>Current Edition:</td><td>2021 (328 pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>Yes</td></tr>
<tr><td>Scope:</td><td>This section established the requirements for the fabrication of fiber-reinforced thermosetting plastic pressure vessels for general service, sets limitations on the permissible service conditions, and defines the types of vessels to which these rules are not applicable.
To assure that vessels fabricated according to these rules will be capable of safely withstanding the operating conditions specified by the design specification, this section:
• Gives minimum requirements for the materials of fabrication.
• Specifies test procedures for determining laminate mechanical properties.
• Defines two methods of design qualification:
o Class I Design–qualification of a vessel design through the destructive test of a prototype.
o Class II Design–mandatory design rules and acceptance testing by nondestructive methods.
• Suggests nonmandatory design procedures for Class I vessels.
• Provides mandatory design procedures and acceptance testing for Class II vessels.
• Defines the general methods of fabrications which may be used.
• Limits the types of end closures, connections and attachments which may be employed and the means used to join them to the vessels.
• Stipulates the procedures to be used in proving that prototype vessels will withstand specified operating and test conditions.
• Establishes rules under which fabricating procedures used for fabricating Class I prototype and production vessels are qualified, and defines what deviations from such procedures necessitate requalification.
• Sets forth requirements to assure that no essential variation in qualified fabrication procedures has occurred.
• Establishes rules for acceptance testing, inspection, and reporting.
• Gives requirements for stamping and marking.
For vessels fabricated in accordance with these rules, the provisions of Section X shall apply over any other sections of the code. When metallic components are part of fiber-reinforced plastic vessels, they shall meet the provisions of Section VIII, Division 1.
This section is divided into nine main parts and mandatory and nonmandatory appendices. The main parts are general requirements; material requirements; fabrication requirements; qualification requirements; pressure relief devices; rules governing testing; inspection requirements; and marking, stamping, and reports.</td></tr>
<tr><td>Application:</td><td>This section can be used by persons knowledgeable in the design, fabrication, testing, repair, and approval of fiber-reinforced plastic pressure vessels.</td></tr>
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<tr><td>Comments:</td><td>The use of fiber-reinforced plastics for the manufacture of pressure vessels presents unique materials considerations in the design, fabrication, and testing of these vessels. Metallic vessels, being made from materials which are normally isotropic and ductile, are designed by using well-established allowable stresses based on measured tensile and ductility properties. In contrast, fiber-reinforced plastics are usually anisotropic and the physical properties are dependent upon the fabrication process, the placement and orientation of the reinforcement and the resin matrix.

Adequacy of specific designs shall be qualified by one of two basic methods:
• Class I Design–qualification of a vessel design through the pressure testing of a prototype.
• Class II Design–mandatory design rules and acceptance testing by nondestructive methods.

These two methods shall not be intermixed.

These vessels are not permitted to store, handle, or process lethal fluids. Vessel fabrication is limited to the following processes: bag-molding, centrifugal casting and filament-winding, and contract molding. General specifications for the glass and resin materials and minimum physical properties for the composite materials are given.

One significant change in the 2021 Edition is the transfer of pressure relief device requirements from Part RR to the new Section XIII on Overpressure Protection. The remaining overpressure protection requirements have been restructured within the new Part ROP. New Nonmandatory Appendix AM provides a complete cross reference list between the previous requirements and the updated requirements and locations.</td></tr>
<tr><td>User:</td><td>Designer: P | Consultant: P | Owner: P | Inspector: S | Regulator: (blank)

P – Primary User
S – Secondary User</td></tr>
</table>

A-130 BPVC Section XIII *Rules for Overpressure Protection*

Current Edition:	2021 (128 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This Section (new in 2021) provides the requirements for the overpressure protection of pressurized equipment such as boilers, pressure vessels, and piping systems. Overpressure protection methods include: (1) Releasing excess pressure by use of pressure relief devices. (2) Applying controls to prevent an increase in pressure (overpressure protection by system design) (3) Using a combination of (1) and (2). The referencing Code or Standard specifies the objectives of the overpressure protection and acceptable methods to achieve it. Where a pressure-releasing overpressure protection method is specified, the referencing Code or Standard identifies the permissible devices based on this Section's rules for devices. This Section includes: (1) Requirements relating to pressure integrity and performance governing the construction and installation of pressure relief devices. Construction requirements include materials, design, manufacture, examination, inspection, production testing, and certification. Installation requirements address only the variables that affect the performance and pressure-relieving function of the devices, including the inlet and outlet piping. (2) Requirements for conducting tests and analyses to determine the performance of pressure relief devices. These include rules for device-type certification of relieving capacity and/or flow resistance and production testing for new pressure relief devices. (3) Requirements for the use of overpressure protection by system design. (4) Mandatory Appendices that address specific subjects not covered elsewhere in this Section. (5) Nonmandatory Appendices that provide information and suggested best practices.
Application:	The main Parts of this Section include: scope and general requirements; responsibilities for providing overpressure protection; five Parts describing requirements for the design, materials, inspection, testing, welding, and marking of pressure relief devices, rupture disk devices, pin devices, spring-actuated non-reclosing devices, and temperature and pressure relief valves; requirements for use and marking of devices in combination; requirements for capacity and flow resistance certification; requirements concerning the use of the Certification Mark; requirements for open flow paths and vents; requirements/guidelines for the installation of pressure relief devices (addressing only those variables that affect the performance and pressure-relieving function of the devices);. requirements for overpressure protection by system design.

Comments:	The ASME BPV Committee on Overpressure Protection was established in 2016 to establish, for publication in Section XIII of the Boiler and Pressure Vessel Code: (1) Rules relating to pressure integrity and performance governing the construction[1] and installation[2] of pressure relief devices. (2) Rules for device type certification of relieving capacity and flow resistance ratings including the rules for conducting the tests and analyses to determine the performance of pressure relief devices. (3) Rules for overpressure protection by system design. These rules are intended for use in the Sections of the Boiler and Pressure Vessel Code and other Standards, for the purpose of providing overpressure protection, to the extent that they are specified in those Sections or Standards. These rules are also to be suitable for reference by other national and international organizations involved with the application of overpressure protection. This committee shall also advise on overpressure protection rules that are proposed for construction and in-service integrity in the Boiler and Pressure Vessel and the B31 Codes. [1]Construction, as used here, is limited to materials, design, fabrication, examination, inspection, testing, and certification. [2]Installation, as here, is limited to the variables that affect the performance and safety function of pressure relief devices. The Committee worked in coordination with other BPV Construction Codes (I, III, IV, VIII-1/2/3, X) to publish the new Section XIII Code with corresponding revisions in each of the construction codes (see the respective code sections for a brief summary of relevant changes).
User:	Designer: **P** · Manufacturer: **P** · Owner: **P** · Inspector: **P** · Regulator: **P** P – Primary User S – Secondary User

A-131 BPVC Code Cases *Boilers and Pressure Vessels*

Current Edition:	2021 (No. of pages changes when periodic supplements are issued.)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document contains provisions which have been adopted by the Boiler and Pressure Vessel Committee that cover all the sections of the code other than Section III, Divisions 1, 2, and 3 and Section XI. Code cases provide rules that permit the use of materials and alternative methods of construction that are not covered by existing B&PVC rules. A Code case comes into existence when there is an inquiry to the ASME Boiler and Pressure Vessel Standards Committee on some aspect of design and/or construction that is not covered by the current code rules. The written response from the committee is assigned a number and it is published, along with the inquiry, in this document.
Application:	The initial user of a code case is typically the party that made the inquiry to the ASME Standards Committee. Once the committee responds, it is available for use by anyone involved in the use, design, and construction of boilers and pressure vessels.
Comments:	The code cases are indexed according to the: 1) ASME code section, 2) material specification, 3) AWS specifications, 4) international specifications designer and 5) charts for vessels under external pressure. There is also a numerical index that shows the approval date and annulled date, if applicable. The ASME Boiler and Pressure Vessel Standards Committee took action to eliminate code case expiration dates effective March 11, 2005. This means that all code cases listed after this date will remain available for use until annulled by the ASME Boiler and Pressure Vessel Standards Committee.
User:	Purchaser: ; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Regulator: **S** P – Primary User S – Secondary User

A-132 ASME NM.1 *Thermoplastic Piping Systems*

Current Edition:	2020 (179 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard prescribes requirements for the design, materials, fabrication, erection, examination, testing, and inspection of thermoplastic piping systems. Thermoplastic piping, as used in this Standard, includes pipe, flanges, bolting, gaskets, valves, fittings, special connecting components, and the pressure containing portions of other piping components, whether manufactured in accordance with standards referenced in this standard or specially designed. It also includes hangers and supports and other equipment items necessary to prevent overstressing the pressure containing components.
Application:	This standard can be used by persons knowledgeable in the design, fabrication, testing, and repair of thermoplastic piping systems.
Comments:	Thermoplastics are a specific group of nonmetallic materials that, for processing purposes, are capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.
User:	Purchaser: **P**; Designer: **P**; Owner: **P**; Inspector: **S**; Regulator: **S** P – Primary User S – Secondary User

A-133 ASME NM.2 *Glass-Fiber-Reinforced Thermosetting-Resin Piping Systems*

Current Edition:	2020 (138 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard provides requirements for the design, materials, manufacture, fabrication, installation, examination, and testing of glass-fiber-reinforced thermosetting-resin (FRP) piping systems. FRP piping, as used in this Standard, includes pipe, flanges, bolting, gaskets, valves, fittings, special connecting components, and the pressure-containing or pressure retaining portions of other piping components, whether manufactured in accordance with references cited in this Standard or specially designed. It also includes hangers and supports and other items necessary to prevent overstressing the pressure-containing components.
Application:	This standard can be used by persons knowledgeable in the design, fabrication, testing, and repair of glass-fiber-reinforced thermosetting-resin piping systems.
Comments:	This standard addresses pipe and piping components that are produced as standard products, as well as custom products that are designed for a specific application. It covers FRP pipe and piping components manufactured by contact molding, centrifugal casting, filament winding, and other methods. Its intent is to provide a uniform set of requirements for FRP pipe and piping components that can be adopted by reference in the various piping codes, including sections of the ASME B31 Code for Pressure Piping. This standard is published as a separate document to reduce duplication between piping codes.
User:	Purchaser: **P**; Designer: **P**; Owner: **P**; Inspector: **S**; Regulator: **S** P – Primary User S – Secondary User

A-134 ASME NM.3.1 *Nonmetallic Materials Part 1—Thermoplastic Material Specifications*

Current Edition:	2020 (555 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This Part is one of three contained in the Standard that includes specifications for nonmetallic materials (except wood, nonfibrous glass, and concrete) and, in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. This Part contains thermoplastic material specifications identical to or similar to those published by the American Society for Testing and Materials (ASTM International) and other recognized national or international organizations.
Application:	This document can be used as an aid by piping designers to select a thermoplastic material for a specific application. It can also be referenced by inspectors and by persons involved in the review of equipment designs.
Comments:	This document is similar to ASME Section II, Parts A and B for metallic materials.
User:	Designer: **P**; Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: (blank) P – Primary User S – Secondary User

A-135 ASME NM.3.2 *Nonmetallic Materials Part 2 — Reinforced Thermoset Plastic Material Specifications*

Current Edition:	2020 (191 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This Part is one of three contained in the Standard that includes specifications for nonmetallic materials (except wood, nonfibrous glass, and concrete) and, in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. This Part contains reinforced thermoset plastic material specifications identical to or similar to those published by ASTM and other recognized national or international organizations.
Application:	This document can be used as an aid by piping designers to select a reinforced thermoset plastic material for a specific application. It can also be referenced by inspectors and by persons involved in the review of equipment designs.
Comments:	This document is similar to ASME Section II, Parts A and B for metallic materials.
User:	Purchaser: **P**; Consultant: **P**; Owner: **P**; Inspector: **P**; Regulator: P – Primary User S – Secondary User

A-136 ASME NM.3.3 *Nonmetallic Materials Part 3—Properties*

Current Edition:	2020 (191 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This Part provides tables and data sheets for allowable stresses, mechanical properties (e.g., tensile and yield strength), and physical properties (e.g., coefficient of thermal expansion and modulus of elasticity) for nonmetallic materials.
Application:	This document can be used as an aid by piping designers to select a nonmetallic material for a specific application. It can also be referenced by inspectors and by persons involved in the review of equipment designs.
Comments:	The subparts in this document are: Subpart 1: Stress Tables and Subpart 2: Physical Properties Tables. This document is similar to ASME Section II, Part D for metallic materials.
User:	Purchaser: **P**; Consultant: **P**; Owner: **P**; Inspector: **S**; Regulator: (blank) P – Primary User S – Secondary User

A-137 ASME RTP-1 *Reinforced Thermoset Plastic Corrosion-Resistant Equipment*

<table>
<tr><td>Current Edition:</td><td>2019 (357 Pages)</td></tr>
<tr><td>Alt. Number:</td><td>None</td></tr>
<tr><td>ANSI Approved?</td><td>Yes</td></tr>
<tr><td>Scope:</td><td>This standard applies to stationary vessels used for the storage, accumulation, or processing of corrosive or other substances at pressures not exceeding 15 psig external and/or 15 psig internal above any hydrostatic head.
In relation to the geometry of vessels, the scope of this standard shall include the following:
• Where external piping is to be connected to the vessel:
o The first threaded joint for screwed connections.
o The face of the first flange for bolted connections.
o The vessel side sealing surface for proprietary connections or fittings.
• The vessel attachment joint when an attachment is made to either the external or internal surface of the vessel.
• Covers for vessel openings, such as manhole and handhole covers.
• The vessel side sealing surface for proprietary fittings attached to vessels for which rules are not provided by this standard, such as gauges and instruments.
The following types of reinforced thermoset plastic equipment are excluded from the rules of the standard:
• Vessels with internal operating pressure in excess of 15 psig.
• Hoods, ducts, and stacks.
• Fans and blowers.
• Vessel internals such as entrainment separators, chevron blades, packing support plates, and liquid distribution plates.
• Pumps.
• Pipe or piping (see ASME B31.3).
• Fully buried underground closed vessels.
This standard is divided into eight main parts and mandatory and non-mandatory appendices. The main parts are: general requirements; materials; design; fabrication; over-pressure protection; inspection and testing; shop qualification; and certification.</td></tr>
<tr><td>Application:</td><td>This standard can be used by persons knowledgeable in the design, fabrication, testing, repair, and approval of reinforced thermoset plastic low pressure vessels.</td></tr>
</table>

Comments:	Design by formulas and by stress analysis are both included in this standard. Consideration is given both to ultimate strength and to limiting strain. Time and temperature dependence of RTP laminate properties is recognized. The ultimate stress consideration is required to assure safety against catastrophic failure over a reasonably long term. The strain considerations are required to assure long-term operation under cyclic stress (fatigue) without cracking the resin matrix of the composite laminate, thus maintaining maximum corrosion resistance. Vessels conforming to this standard shall be limited to the following pressure and temperature limits: • Maximum internal pressure: o With Proof Test. The internal operating pressure, measured at the top of the vessel, shall not be greater than 15 psig. o Without Proof Test. The internal operating pressure, measured at the top of the vessel, shall not be greater than 2 psig. • Maximum external pressure: o With Proof Test. The limit on external operating pressure is 15 psig. o Without Proof Test. The limit on external operating pressure is 2 psig. • Temperature limits. The operating temperature shall be limited to a value for which mechanical properties have been determined and the chemical resistance has been established.
User:	Designer: **P** ; Consultant: **P** ; Owner: **P** ; Inspector: **P** ; Regulator: **P** P – Primary User S – Secondary User

A-138 ASME PCC-1 *Guidelines for Pressure Boundary Bolted Flange Joint Assembly*

Current Edition:	2019 (114 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This document may be used to develop effective joint assembly procedures for flanged joints with ring type gaskets covering a broad range of sizing and service conditions.
Application:	Owners, users, and manufacturers of pressure equipment can use the methods in this document to optimize the assembly procedures for bolted flanged joints in order to minimize leaks.
Comments:	Detailed rules are provided for: • Examination of "working" surfaces. • Alignment of mating surfaces. • Installation of gaskets. • Lubrication of "working" surfaces. • Installation of bolts. • Number of bolts and tightening sequence. • Bolt tightening/tensioning methods and determination of the load achieved. • Tables of torque to achieve target bolt stress levels using the Target Torque Index (see Appendix O, "Determining the Target Bolt Stress"). The current edition contains 16 appendices covering topics such as training and qualification of bolted joint assembly personnel (Appendix A), alternative tightening patterns (Appendix F), assembly bolt stress determination (Appendix O), troubleshooting (Appendix P), and considerations for the use of powered equipment (Appendix Q).
User:	Purchaser: — ; Manufacturer: P ; Owner: P ; Inspector: — ; Regulator: — P – Primary User S – Secondary User

A-139 ASME PCC-2 *Repair of Pressure Equipment and Piping*

Current Edition:	2018 (294 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Provides methods for repairing pressure equipment after it has been placed into service. The methods include relevant design, fabrication, examination and testing of repairs, which may be temporary or permanent.
Application:	Owners and users of pressure equipment can use the methods in this standard to make repairs using the "best practices" provided in the document.
Comments:	Detailed rules are provided for the following general types of repairs: • Weld repairs, including insert plates, weld overlay, seal welds, leak boxes, flaw evacuation and weld repair, full encirclement reinforcing sleeves and lap patches, reinforcing plug welds, preheat alternatives, PWHT alternatives, weld buildup, fillet weld patches, and plug repairs. • Mechanical repairs, including replacement of components, freeze plugs, damaged threads, flange refinishing, mechanical leak clamps, pipe straightening and alignment, concrete anchors, bolting removal, and repair of heat exchangers. • Nonmetallic and bonded repairs. • Examination and testing.
User:	Purchaser: [ ] Contractor: [P] Owner: [P] Inspector: [P] Regulator: [ ] P – Primary User S – Secondary User

A-140 ASME PCC-3 *Inspection Planning Using Risk-Based Methods*

Current Edition:	2017 (94 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Provides guidance for developing and implementing an inspection program for fixed pressure-containing equipment and components. The approach emphasizes safe and reliable operation through cost-effective inspection.
Application:	Owners and users of pressure equipment can use the guidance in this standard to develop an in-service (post-construction) inspection program for their equipment. The guidance applies broadly to boilers, pressure vessels, piping, pipelines, and storage tanks. However, other standards that are specific to one or more of these equipment types should also be consulted in developing inspection plans. These include: • API RP 580 “Risk-Based Inspection.” This document is very similar to ASME PCC-3 but is focused on the hydrocarbon and chemical process industries. • API RP 581 “Risk Based Inspection Methodology.” This document provides specific, detailed guidance for risk-based inspection. • NB-23–“National Board Inspection Code” for boilers and pressure vessels that are not in refining and chemical process services. • API 510–“Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration” for pressure vessels in refining and chemical process services. • API 570–“Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems” for piping systems. Although developed for the refining and chemical process industries, it may be used, where practical, for any piping system.
Comments:	ASME PCC-3 should be used to help the owner or user of pressure equipment determine what areas of the equipment to inspect, what inspection techniques to use, and how frequently to do the inspection. Although basic guidance on these topics is provided in NB-23, API 510, and API 570 (described above), ASME PCC-3 provides for a more detailed analysis of inspection needs. This typically results in a reduction in the overall inspection effort, with increases in some areas offset by reductions in others. Most importantly, it provides for a systematic analysis to identify damage mechanisms that may affect particular material/process environment combinations to ensure that inspection/examination activities are focused on the areas that are important to pressure equipment integrity. ASME PCC-3 provides an overall methodology that can be used to develop an inspection plan using risk-based methods. It provides guidance and detailed tables to assist in defining the damage mechanisms that can affect pressure equipment, as well as inspection and monitoring methods to detect the damage. It provides methods for establishing RBI teams to determine the probability and consequence of failure and to calculate the risk of continued operation. The result of applying the process is an optimized, cost-effective inspection plan.
User:	Purchaser: [ ] Consultant: [P] Owner: [P] Inspector: [P] Regulator: [ ] P – Primary User S – Secondary User

A-141 ASME PTC 25 *Pressure Relief Devices (Performance Test Codes)*

Current Edition:	2018 (98 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This code provides standards for conducting and reporting tests on reclosing and nonreclosing pressure relief devices normally used to terminate an abnormal internal or external rise in pressure above a predetermined design value in boilers, pressure vessels, and related piping equipment. This code covers the methods and procedures to determine relieving capacity and additional operating characteristics, which may be required for certification or other purposes by other codes. This is accomplished by dividing the code into two parts following Sections 1 and 2: Part 1, “Flowing Capacity Testing,” and Part 2, “In-Service and Bench Testing.” This code provides instructions in Part 1 for flow capacity testing and in Part 2 for in-service and bench testing. Testing of reclosing and nonreclosing pressure relief devices is conducted under various inlet and outlet conditions using steam, gases, and liquids for which valid physical properties are known. The object of the test is to determine the performance of pressure-relief devices. These tests determine one or more of the following: a) dimensional, operational, and mechanical characteristics; b) relieving pressure; c) relieving flow capacity at test pressure; and d) individual flow resistance. Procedures for conducting the tests, calculating the results, and making corrections are defined. This code does not necessarily cover the methods and procedures to satisfy operating and other conditions as may be required by other codes. Establishment of pressure-relief device ratings and rules of safe construction do not fall within the province of this code.
Application:	This code is intended for use by pressure-relief device manufacturers and testing facilities for conducting and reporting tests on reclosing and nonreclosing pressure-relief devices. This code can also be used by owners as a reference for in-service and bench testing.
Comments:	This code is applicable to the following types of reclosing and nonreclosing pressure-relief devices: (A) Pressure relief valves, (B) Rupture disk devices (part 1 only), (C) Breaking/shear pin devices (part 1 only), and (D) Fusible plug devices (part 1 only). Other pressure relief devices may be tested provided all parties to the test agree to accept the provisions of this code.
User:	Test Facility: **P** Manufacturer: **P** Owner: **P** Inspector: **S** Regulator: P – Primary User S – Secondary User

AMERICAN SOCIETY OF NONDESTRUCTIVE TESTING (ASNT)STANDARDS

A-142 ASNT CP-189 *ASNT for Qualification and Certification of Nondestructive Testing Personnel*

Current Edition:	2020 (28 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	This standard specifies the procedures, essential factors, and minimum requirements for qualifying and certifying NDT personnel. The standard: • Establishes the minimum requirements for the qualification and certification of nondestructive testing (NDT) and Predictive Maintenance (PdM) personnel. • Details the minimum training, education, and experience requirements for NDT personnel and provides criteria for documenting qualifications and certification. • Requires the employer to establish a procedure for the certification of NDT personnel. • Requires that the employer incorporate any unique or additional requirements in the certification procedure.
Application:	This standard is intended for use by persons who are in charge of the training, qualification, and certification of the personnel who are responsible for, and perform, nondestructive testing.
Comments:	A complementary standard to ANSI/ASNT CP-189 is ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel (Document No. ANSI/ASNT CP-105). This standard specifies the body of knowledge to be used as part of a training program qualifying and certifying NDT personnel. The scope of ANSI/ASNT CP-105: • Establishes the minimum topical outline requirements for the qualifications of nondestructive testing (NDT) personnel. • Details the minimum training course content for NDT personnel. • Specifies that the amount of time spent on each topic in each method should be determined by the NDT Level III and the applicable certification document. • These topical outlines are progressive (i.e., consideration as Level I is based on satisfactory completion of Level I training course; consideration as Level II is based on satisfactory completion of both Level I and Level II training courses). • Topics in the outlines may be deleted or expanded to meet the employer's specific applications or for limited certification, unless stated otherwise by the applicable certification procedure or written practice.
User:	Company: **P** — Instructor: **P** — Owner: **P** — Inspector: **S** — Regulator: (blank) P – Primary User S – Secondary User

A-143 ASNT RP SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*

Current Edition:	2020 (44 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This recommended practice establishes the general framework for a qualification and certification program for nondestructive testing. In addition, the document provides recommended educational experience and training requirements for the different test methods. Supplementary documents include question and answer lists, which may be used in composing examinations for nondestructive testing personnel. The following apply to this recommended practice: • It is recognized that the effectiveness of nondestructive testing (NDT) applications depends upon the capabilities of the personnel who are responsible for, and perform, NDT. This recommended practice has been prepared to establish guidelines for the qualification and certification of NDT personnel whose specific jobs require appropriate knowledge of the technical principles underlying the nondestructive tests they perform, witness, monitor, or evaluate. • This document provides guidelines for the establishment of a qualification and certification program. • This document has been developed by The American Society for Nondestructive Testing Inc., to aid employers in recognizing the essential factors to be considered in qualifying personnel engaged in any of the NDT methods listed in Section 3 (Acoustic Emission Testing, Electromagnetic Testing, Laser Testing Methods, Leak Testing, Liquid Penetrant Testing, Magnetic Flux Testing, Neutron Radiographic Testing, Radiographic Testing, Thermal/Infrared Testing, Ultrasonic Testing, Vibration Analysis, Visual Testing). • It is recognized that this document may not be appropriate for certain employers' circumstances and/or application. In developing a written practice as required in Section 5, the employer should review the detailed recommendations presented herein and modify them, as necessary, to meet particular needs.
Application:	This recommended practice is intended for use by persons who are in charge of the training, qualification, and certification of personnel who are responsible for and perform nondestructive testing.
Comments:	A complementary standard to ASME RP SNT-TC-1A is ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel (Document No. ANSI/ASNT CP-105). This standard specifies the body of knowledge to be used as part of a training program qualifying and certifying NDT personnel. The scope of ANSI/ASNT CP-105: • Establishes the minimum topical outline requirements for the qualifications of nondestructive testing (NDT) personnel. • Details the minimum training course content for NDT personnel. • Specifies that the amount of time spent on each topic in each method should be determined by the NDT Level III and the applicable certification document. • These topical outlines are progressive (i.e., consideration as Level I is based on satisfactory completion of Level I training course; consideration as Level II is based on satisfactory completion of both Level I and Level II training courses). • Topics in the outlines may be deleted or expanded to meet the employer's specific applications or for limited certification, unless stated otherwise by the applicable certification procedure or written practice.

User:	Company	Instructor	Owner	Inspector	Regulator
	P	**P**	**P**	**S**	**S**
	P – Primary User S – Secondary User				

ELECTRIC POWER RESEARCH INSTITUTE (EPRI) STANDARDS

A-144 EPRI CS-4774 *Guidelines for the Evaluation of Seam-Welded High-Energy Piping*

Current Edition:	Fourth Edition, December 2003 (392 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This document offers remaining life estimation procedures that provide the engineering basis for making inspection or maintenance decisions. Seam weldment damage mechanisms and the influence of numerous operational and structural variables on performance are not currently understood quantitatively enough for developing a rigorous mechanistic-based evaluation procedure. Nevertheless, a significant body of laboratory and field experience acquired since the 1980s has been reviewed, consolidated, and incorporated into developing an alternative empirical procedure that is an effective piping integrity assurance tool. The main sections in this document are: 1) Industry Experience and Observations; 2) Technical Bases for Guidelines; 3) Overview of Approach to Pipe Evaluation; 4) Inspection Decision; 5) Inspection Methodology; 6) Serviceability Assessment; 7) Conclusions; and 8) References. The following supporting appendices are also included in the Guidelines: A) Cracking and Failure Experience; B) Ultrasonic Examination Procedure; C) Time-of-Flight Diffraction Examination Procedure; D) Automated Phased Array Examination Procedure; E) Ultrasonic Flaw Sizing Procedure; F) Bid Specification for Examination of Seam-Welded Steam Piping; G) Crack Growth Calculation Procedure; and H) Stress Rupture Testing.
Application:	This document can be used by plant owners and operators to assess the remaining life of seam-welded high-energy piping. It can also be used by inspectors as guidance on inspection procedures for obtaining information for a remaining life assessment. It can also be used by consultants and regulators in assessing the adequacy of a plant's inspection/remaining life assessment program.
Comments:	This fourth edition of the *Guidelines for Evaluation of Seam-Welded High-Energy Piping* updates the third edition by incorporating new cracking and failure data, observations of industry trends, and information on inspection and evaluation methods. Data on cracking and failure incidents reported since the third edition of the document–and recent EPRI reports on advances in applicable nondestructive evaluation methods–were reviewed to prepare the 2003 update (fourth edition) of the document. The document features an easy-to-use stepwise format with inspection and evaluation procedure details. EPRI's pipe integrity evaluation approach is based on a flaw or damage tolerance evaluation method in which the flaw or damage zone is detected by inspection. A reinspection interval is set on the basis of current flaw size (in the through-wall dimension) and the estimated rate of crack growth. The flaw size is the inspection-estimated value or an appropriately selected default size when inspection data show no indication of damage.
User:	Purchaser: — ; Consultant: **S** ; Owner: **P** ; Inspector: **P** ; Regulator: **S** P – Primary User S – Secondary User

A-145 EPRI CS-5208 *Life Extension and Assessment of Fossil Power Plants (Conference Proceedings)*

Current Edition:	1987 (1265 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This document consolidated the proceedings of a conference, which was held in Washington, DC, June 2-4, 1986, to review, document, and transfer technology on all aspects of life extension for fossil-fuel-firing power plants. It provided a unique opportunity for personnel involved with the development of life extension strategies to interface directly with personnel in the development and application of residual life assessment methodologies for major pieces of plant equipment. Participation was truly international, with more than 400 people in attendance representing 14 countries. Utility experience reports were presented from Australia, Canada, England, Germany, Japan, Italy, Holland, and the United States. In recognition of the fact that life extension is not only a technical issue but has broader implications with respect to economic, environmental, and regulatory issues, a comprehensive agenda was organized that included: • Programs and strategies for plant life extension. • Residual life estimation for boilers, turbines, and steam pipes. • Nondestructive examination techniques. • Environmental and regulatory issues.
Application:	These conference proceedings can be used as a reference by power plant owners and operators, and their engineering contractors and consultants, to develop and implement life extension methods as a possible way of retaining units in service for 50 to 60 years or longer. They can also be used by the power plant component suppliers of boilers and turbines.
Comments:	The conference was sponsored by Edison Electric Institute, the American Society of Mechanical Engineers, and the American Society of Metals. The presentations and discussions supplemented ongoing EPRI work on life extension and assessment and contributed to the development of the Generic Life Extension Guidelines (EPRI report CS-4778, out of print). Since many of the residual life techniques have usefulness above and beyond life extension, the information consolidated in these proceedings is expected to be of long-range value and even applicable to newer plants. In addition to the papers and presentations by individual authors, an overview of each subject area was presented by recognized experts in the field.
User:	Contractor/Consultant: **P**; Boiler Manufacturer: **S**; Owner/Operator: **P**; Inspector: **S**; Regulator: **S** P – Primary User S – Secondary User

A-146 EPRI CS-5235 *Recommended Practices for Operating and Maintaining Steam Surface Condensers*

Current Edition:	July 1987 (248 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This document is a guideline for the operation and maintenance of steam surface condensers. It was developed for the Electric Power Research Institute by Heat Exchange Systems, Inc. The document includes a primer on the theory of operation of steam surface condensers. Also included is a brief description of typical condenser problems. These introductory sections lay the groundwork for assisting operators and engineers in troubleshooting to maximize condenser performance and availability. The remaining sections concentrate on specific topics such as performance monitoring, lay-up, and corrective action. Corrosion monitoring and maintenance methods including cleaning, plugging, corrosion countermeasures, and other corrective actions are also addressed.
Application:	The document is intended to assist plant engineers, operators, and maintenance personnel in improving the availability and performance of the steam surface condenser.
Comments:	This document describes the theory of operation, related heat transfer principals, and a description of the steam surface condenser designs typically used in the electric utility industry. A section is also included that identifies condenser performance, structural designs, and materials of construction-related problems and their causes. This section also contains a table, which cross references the reader to other report sections and other Electric Power Research Institute reports for guidance in problem resolution. The document also identified methods of performance and condition monitoring. In addition, technologies for improving condenser performance and availability are also identified. Since there are many technologies and monitoring practices that apply to specific condenser problems, the report addresses all which were identified by the principal investigators and which are proven by past utility experience. The document identifies the advantages and disadvantages of the technologies and methods presented. This is done in a manner that will assist a utility's operation and maintenance personnel in selecting the best solution for a specific application.
User:	Purchaser: — ; Manufacturer: — ; Owner/Operator: **P** ; Inspector: **S** ; Regulator: — P – Primary User S – Secondary User

NATIONAL ASSOCIATION OF CORROSION ENGINEERS (NACE) STANDARDS

A-147 NACE MR0103/ISO 17945-2015 *Petroleum, petrochemical and natural gas industries–Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*

Current Edition:	November 2015 (52 pages)
Alt. Number:	ISO 17945
ANSI Approved?	Yes
Scope:	This document establishes material requirements for resistance to sulfide stress cracking (SSC) in sour petroleum refining and related processing environments containing H_2S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon. This document does not include and is not intended to include design specifications. Other forms of wet H_2S cracking, environmental cracking, corrosion, and other modes of failure are outside the scope of this International Standard.
Application:	This standard practice is intended to be used by refiners, equipment manufacturers, engineering contractors, and construction contractors.
Comments:	Specifically, this International Standard is directed at the prevention of SSC of equipment (including pressure vessels, heat exchangers, piping, valve bodies, and pump and compressor cases) and components used in the refining industry. Prevention of SSC in carbon steel categorized under P-No. 1 in Section IX of the ASME Boiler and Pressure Vessel Code (BPVC) is addressed by requiring conformance to NACE SP0472. This International Standard applies to all components of equipment exposed to sour refinery environments (see Factors contributing to SSC; Clause 6) where failure by SSC would (1) compromise the integrity of the pressure containment system, (2) prevent the basic function of the equipment, and/or (3) prevent the equipment from being restored to an operating condition while continuing to contain pressure.
User:	Construction Contractor: **P**; Engineering Contractor: **P**; Owner: **P**; Inspector: **P**; Consultant: **P** P – Primary User S – Secondary User

A-148 NACE SP0106-2018 *Control of Internal Corrosion in Steel Pipelines and Piping Systems*

Current Edition:	November 2018 (28 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard presents recommended practices for the control of internal corrosion in steel pipelines and piping systems used to gather, transport, or distribute crude oil, petroleum products, or gas. This standard serves as a guide for establishing minimum requirements for control of internal corrosion in the following systems: (a) crude oil gathering and flow lines; (b) crude oil transmission; (c) hydrocarbon products; (d) gas gathering and flow lines; (e) gas transmission; (f) gas distribution; (g) storage systems; (h) produced water lines; and (i) injection water lines.
Application:	This standard presents general practices and preferences in regard to control of internal corrosion in steel piping systems. This standard is intended for use by pipeline operators, pipeline service providers, government agencies, and any other persons or companies involved in planning, designing, or managing pipeline integrity.
Comments:	Because of the complex nature and interaction between constituents that are found in gas and liquid (e.g., oxygen, carbon dioxide, hydrogen sulfide, chloride, bacteria), certain combinations of these impurities being transported in the pipeline may affect whether a corrosive condition exists. Identification of corrosive gas and liquid in a pipeline can only be achieved by analysis of operating conditions, impurity content, physical monitoring, or other considerations. Therefore, gas, liquids, and operating conditions must be monitored and evaluated on an individual basis to accurately assess the effects of their presence or absence in the pipeline.
User:	Engineering Contractor: **P**; Field Contractor: **P**; Owner/ Operator: **P**; Inspector: **P**; Consultant: **P** P – Primary User S – Secondary User

A-149 NACE SP0169-2013 *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*

Current Edition:	October 2013 (60 pages)
Alt. Number:	Formerly RP0169-2002
ANSI Approved?	No
Scope:	This standard practice presents procedures and practices for achieving effective control of external corrosion on buried or submerged metallic piping systems. These recommendations are also applicable to many other buried or submerged metallic structures. This standard describes the use of electrically insulating coatings, electrical isolation, and cathodic protection (CP) as external corrosion control methods. It contains specific provisions for the application of CP to existing bare, existing coated, and new piping systems. Also included are procedures for control of interference currents on pipelines.
Application:	This standard practice is intended for use by corrosion control personnel concerned with the corrosion of buried or submerged piping systems, including oil, gas, water, and similar structures. It can also be used as a reference by field inspectors.
Comments:	This standard should be used in conjunction with the practices described in the following NACE standards and publications, when appropriate (use latest revisions): SP0572, RP0177, RP0285, SP0186, SP0286, SP0387, SP0188, TPC11, TM0497
User:	Construction Contractor: **P**; Engineering Contractor: **P**; Owner: **P**; Inspector: **P**; Consultant: **P** P – Primary User S – Secondary User

A-150 NACE SP0170-2018 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment*

Current Edition:	September 2018 (16 pages)
Alt. Number:	Formerly RP0169-2002
ANSI Approved?	No
Scope:	This standard practice provides mitigation methods to protect austenitic stainless steels and other austenitic alloys from polythionic acid (PTA) stress corrosion cracking (SCC) that can occur during a shutdown of refinery equipment. A shutdown includes the actual downtime period and the contiguous periods required to shut down and start up the equipment. This standard is directed toward preventing stress corrosion cracking (SCC) caused by polythionic acid (PTA) that can be formed by reaction of oxygen and water with sulfide corrosion products (i.e., metal sulfides) or with other oxidizable sulfur species (e.g., sulfur, hydrogen sulfide [H_2S]).
Application:	This standard is intended primarily for petroleum refinery materials and corrosion engineers as well as inspection, operations, and maintenance personnel. It can also be used as a reference by field inspectors.
Comments:	While the main focus of this standard is on equipment in refinery process units such as desulfurizing, hydrocracking, and hydrotreating, in which the incidence of PTA SCC has been comparatively high, it may be applied to equipment in other refinery process units that use austenitic stainless steels and other austenitic alloys, such as crude distillation units, lube distillation units, coking units, and fluid catalytic cracking units (FCCUs), when the user may have a concern for PTA SCC.
User:	Construction Contractor: **S**; Engineering Contractor: **S**; Owner: **P**; Inspector: **P**; Consultant: **P** P – Primary User S – Secondary User

A-151 NACE SP0288-2011 *Inspection of Lining Application in Steel and Concrete Equipment*

Current Edition:	November 2011 (12 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	The intent of this NACE standard recommended practice is to provide appropriate inspection requirements to verify conformance to the lining/coating specification. It is not intended to address the selection of a lining/coating or to specify surface preparation and application requirements.
Application:	This standard is intended for use by owners and their representatives, coating contractors, coating suppliers, and coating inspectors involved with the inspection of linings/coatings on steel and concrete.
Comments:	For further information on coatings for concrete, users of this standard should refer to NACE No. 6/SSPC-SP 13 and NACE Publication 02203/ICRI Technical Guideline 03741/SSPC-TR 5. For further information about selecting and specifying surface preparation methods for concrete before application of linings, users of this standard should refer to ICRI Technical Guideline 03732. For further information on the design, installation, and inspection of linings, users of this standard should refer to NACE No. 10/SSPC-PA 6 and NACE No. 11/SSPC-PA 8.
User:	Field Contractor: **P**; Coating Supplier: **P**; Owner: **P**; Inspector: **P**; Engineering Contractor: **S** P – Primary User S – Secondary User

A-152 NACE SP0296-2016–*Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H_2S Environments*

Current Edition:	January 2020 (26 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard practice is intended to be a primary source of information on cracking in wet H_2S petroleum refinery environments and provides guidelines on the detection, repair, and mitigation of cracking of existing carbon steel refinery equipment in wet H_2S environments.
Application:	This standard practice is intended for use primarily by refinery corrosion and materials engineers and inspection, operations, and maintenance personnel.
Comments:	For the purposes of this standard practice, the term equipment refers to pressure vessels and piping made of carbon steel plate material. Refinery pressure vessels include items such as, but not limited to, columns or towers, heat exchangers, drums, reboilers, and separators. Limited cracking has been noted in seamless piping; therefore, the information in this standard practice concentrates on longitudinally seam-welded pipe fabricated from plate.
User:	Construction Contractor: **S** Engineering Contractor: **S** Owner: **P** Inspector: **P** Consultant: **P** P – Primary User S – Secondary User

A-153 NACE SP0472-2020 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*

Current Edition:	August 2020 (32 pages)
Alt. Number:	Formerly RP0472
ANSI Approved?	No
Scope:	This standard establishes guidelines to prevent most forms of environmental cracking of weldments in carbon steel refinery equipment, including pressure vessels, heat exchangers, storage tanks, piping, valve bodies, and pump and compressor cases. Weldments are defined to include the weld deposit, base metal HAZ, and adjacent base metal zones subject to residual stresses from welding. This standard covers only carbon steels classified as P-No. 1, Group 1 or 2. These classifications can be found in the ASME Boiler and Pressure Vessel Code, Section IX for pressure vessels, ASME B31.3 for process piping, or API Standards 620 and 650 for tanks. It excludes steels with greater than 485 MPa (70,000 psi) minimum specified tensile strength. Other materials may be vulnerable to cracking, but these materials are outside the scope of this standard. All pressure-containing weldments or internal attachment weldments to the pressure boundary are included. In addition, weldments in some non-pressure-containing equipment, such as storage tanks, are included. External attachment weldments are sometimes included as discussed in paragraph 3.6.1. Both new fabrication and repair welds are within the scope of this standard. The practices included are intended to prevent in-service cracking and are not intended to address cracking that can occur during fabrication, such as delayed hydrogen cracking. In most cases, however, these practices are also helpful in minimizing these fabrication problems.
Application:	This standard is intended for use by persons involved in the design and repair of equipment that is susceptible to environmental cracking in corrosive petroleum refinery services. It can also be used as a reference by field and shop inspectors.
Comments:	Corrosive refinery process environments covered by this standard can be divided into two general categories: services that could cause cracking as a result of hydrogen charging and services that could cause alkaline stress corrosion cracking (ASCC). However, identification of the specific environments to which the guidelines set forth in this standard are to be applied to prevent various forms of in-service environmental cracking is the responsibility of the user.
User:	Engineering Contractor: **P**; Manufacturer: **P**; Owner: **P**; Inspector: **P**; Construction Contractor: **P** P – Primary User S – Secondary User

A-154 NACE SP0590-2015 *Prevention, Detection, and Correction of Deaerator Cracking*

Current Edition:	February 2015 (24 pages)
Alt. Number:	Formerly RP0590-96
ANSI Approved?	No
Scope:	This standard practice addresses: 1) procedures for inspection of deaerator heater and water storage vessel welds, including reinspection criteria and qualification of personnel; 2) factors influencing boiler feedwater deaerator cracking based on literature references and case history analyses; 3) standardized nomenclature of deaerator vessel welds and cracking; 4) guidelines for materials, design, fabrication, inspection, and acceptance criteria for new deaerator vessels and for repair of existing deaerator vessels; and 5) operational and water chemistry parameters that may influence deaerator deterioration.
Application:	This standard is intended to be the primary source of information on deaerator cracking and is directed toward owners, operators, and designers of deaerator equipment used in steam generation. It can also be used as a reference by field inspectors.
Comments:	Information presented in this standard reflects the work of the many individuals involved in documenting the deaerator cracking problem and is based on studies of carbon steel units. Similar cracking has been found in blowdown flash tanks, sedimentation tanks, hot water storage/disengaging vessels, and steam and feedwater piping.
User:	Purchaser: — ; Designer: **P** ; Owner/Operator: **P** ; Inspector: **S** ; Regulator: — P – Primary User S – Secondary User

NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS (NBBPVI) STANDARDS

A-155 NB-18 *National Board Pressure Relief Device Certifications*

Current Edition:	See note in Comments section below.
Alt. Number:	None
ANSI Approved?	No
Scope:	This National Board program provides for the certification of pressure-relief designs and the accreditation of organizations that manufacture or assemble these devices. Accredited organizations are issued a certificate of authorization to apply the National Board "NB" symbol to devices of certified designs. Technical requirements applied by this program to pressure-relief devices are contained in standards called "construction codes." These codes are: <u>Code Section</u> — <u>Construction Code</u> I — ASME Boiler & Pressure Vessel Code (BPVC) Section I III — ASME BPVC Section III IV — ASME BPVC Section IV VIII — ASME BPVC Section VIII Organizations which have met the program requirements and have paid the proper administrative fees will be granted permission to use the National Board "NB" mark on devices to denote certification by the National Board of the pressure relieving device design.
Application:	Manufacturers and assemblers of pressure relief devices can use this document to learn what is required to obtain National Board (NB) accreditation for the devices they manufacture or assemble. Owners, users, and designers of pressure vessels can reference this document to locate manufacturers and assemblers of National Board accredited pressure-relief devices. Owners and users of pressure vessels can also use it to locate repair firms who hold a National Board certificate of authorization to repair pressure relief valves.
Comments:	The steps presented in this document required for accreditation of pressure-relief devices are: a) administrative rules; b) quality system requirements; c) design review; d) initial testing; e) production testing for permission to apply the "NB" mark; f) 5 year repeat testing for "NB" mark permission extension; g) device marking requirements; h) permission to transfer the certification results of initial/production testing to a different/relocated facility; and i) test facility and test procedure requirements. This document presents two methods (coefficient and slope) to determine the relieving capacity which should appear on a valve set between the maximum and minimum listed set pressures. These methods are presented separately for the four ASME Codes (I, III, IV and VIII) to which this document applies. Although this document lists the repair firms who hold a National Board certificate of authorization to repair pressure relief valves, it does not address how that authorization is obtained (refer to the National Board Inspection Code, Part 3, Section 1). <u>Note:</u> This document is continuously updated and can be downloaded free of charge from the National Board website: www.nationalboard.org. (easiest way to find is to enter "NB-18" in the search field on the site.

	Purchaser	Designer	Owner/User	Manufacturer/ Assembler	Regulator
User:		**P**	**P**	**P**	

P – Primary User
S – Secondary User

A-156 NB-23 *National Board Inspection Code*

Current Edition:	2019 (1018 pages)
Alt. Number:	None
ANSI Approved?	Yes
Scope:	Provides basic rules that are required in many jurisdictions (see NB-370 for specific jurisdictional requirements) for installation, in-service inspection, repair and alteration of boilers, pressure vessels, piping, and pressure-relief devices. For pressure vessels, API 510, “Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration,” and for piping, API 570, “Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems,” are typically used in lieu of NB-23 in the petroleum and chemical process industries. Legal requirements for the use of these documents are determined by each jurisdiction. The four primary parts of NB-23 are: • Part 1–Installation • Part 2–Inspection • Part 3–Repairs and Alterations • Part 4–Pressure Relief Devices.
Application:	Owners and users of pressure equipment can use NB-23 to develop an in-service (post-construction) inspection program for their equipment. Although not specifically recognized by NB-23, other inspection planning documents, as listed below, can be used for inspection planning if permitted by local jurisdictional authorities: • ASME PCC-3 “Inspection Planning Using Risk-Based Methods”. • API RP 580 “Risk-based Inspection.” This document is very similar to ASME PCC-3, but is focused on the hydrocarbon and chemical process industries. • API RP 581 “Risk Based Inspection Methodology.” This document provides specific, detailed guidance for risk-based inspection. Owners and users of pressure equipment can use NB-23, in combination with other documents as listed below, to plan for repairs and alterations to pressure equipment. Other documents include: • ASME PCC-2 “Repair of Pressure Equipment and Piping.”
Comments:	NB-23 provides administrative requirements for accreditation of repair organizations and owner-user inspection organizations. Accredited organizations receive a Certificate of Authorization and can apply an “R” stamp to pressure equipment that they have repaired as an indication that the repairs conform to the requirements of NB-23. NB-23 also provides: • Installation requirements that impose requirements for new construction, such as accessibility for inspection. • Precautions for conducting inspections (e.g., vessel entry requirements). • General guidance on examination techniques and pressure testing Descriptions of a limited number of damage (deterioration) mechanisms. • Specific inspection requirements for boilers by boiler type. • General requirements for inspection of pressure vessels and piping. • Requirements for inspection and repair of overpressure protection devices. • Methods for determining inspection intervals. • General requirements for repairs and alterations and re-rating. • Repair, alteration, and inspection of fiber-reinforced plastic equipment.

	Field Contractor	Consultant	Owner	Inspector	Regulator
User:	**P**	**S**	**P**	**P**	

P – Primary User
S – Secondary User

A-157 NB-370 *National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations*

Current Edition:	A link to the Synopsis can be found within the Resources link on the home page (look for "NB-370, National Board Synopsis").
Alt. Number:	None
ANSI Approved?	No
Scope:	Provides a compilation of laws, rules, and regulations relating to boilers and pressure vessels in the 50 states in the US, 13 provinces and territories of Canada, and 17 US cities. Also provides a directory of code enforcement officials.
Application:	Owners and users of pressure equipment in the United States and Canada can use the guidance in this document to determine what state, provincial, and local laws and regulations apply to their boilers and pressure vessels for both new construction (e.g., code stamping requirements) and in-service inspection, alteration, and repair. It does not cover federal requirements, such as those of the Occupational Safety and Health Administration (OSHA).
Comments:	This document is updated frequently and can be downloaded free of charge from the National Board website: www.nationalboard.org
User:	Purchaser: – ; Consultant: **S** ; Owner: **P** ; Inspector: **P** ; Regulator: **P** P – Primary User S – Secondary User

TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION (TEMA) STANDARDS

A-158 *Standards of the Tubular Exchanger Manufacturers Association (TEMA)*

Current Edition:	Tenth Edition, 2019 (296 pages)
Alt. Number:	None
ANSI Approved?	No
Scope:	This standard covers the mechanical design, fabrication, and testing for shell and tube type heat exchangers. The main sections are: fabrication tolerances; general fabrication and performance information; installation, operation, and maintenance; mechanical standard TEMA Class RCB heat exchangers; flow induced vibration; thermal relations; physical properties of fluids; and general information. There is also a recommended practice section that covers: horizontal vessel supports; vertical vessel supports; lifting lugs; wind and seismic design; plugging tubes in tube bundles; entrance and exit areas; tubesheets; nozzles; end flanges and bolting; finite element analysis guidelines; and fouling. The TEMA mechanical standards are applicable to shell and tube heat exchangers, which do not exceed any of the following criteria: • Inside diameters of 100 in. • The product of nominal diameter, in., multiplied by design pressure, psi, of 100,000. • A design pressure of 3,000 psi. The intent of these parameters is to limit the maximum shell wall thickness to approximately 3 in. and the maximum stud diameter to approximately 4 in. Criteria contained in these standards may be applied to units which exceed the above parameters.
Application:	This standard is intended to be used by persons knowledgeable in the design, fabrication, operation, testing, and repair of shell and tube heat exchangers. This standard can be cited in a purchase specification.
Comments:	Three classes of mechanical standards, R, C, and B, reflecting acceptable designs for various service applications, are presented in this standard: • Class "R" covers unfired shell and tube heat exchangers for the generally severe requirements of petroleum and related processing applications. • Class "C" covers unfired shell and tube heat exchangers for the generally moderate requirements of commercial and general process applications. • Class "B" covers unfired shell and tube heat exchangers for chemical process service. Heat exchangers built to this standard shall comply with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
User:	Purchaser: **P** · Manufacturer: **P** · Owner: **P** · Inspector: **P** · Regulator: (blank) P – Primary User S – Secondary User

APPENDIX B ADDITIONAL REFERENCES

B-1 API 5UE *Recommended Practice for Ultrasonic Evaluation of Pipe Imperfections*

This RP describes procedures which may be used to “prove-up” the depth of imperfections. Included in this practice are the recommended procedures for ultrasonic prove-up inspection of new pipe using the Amplitude Comparison Technique and the Amplitude-Distance Differential Technique for evaluation of 1) surface breaking imperfections in the body of pipe, 2) surface breaking and subsurface imperfections in the weld area of electric resistance, electric induction or laser welded pipe, and 3) surface breaking and subsurface imperfections in the weld area of arc welded pipe. For the purpose of this document, pipe is defined as including casing, plain-end casing liners, tubing, plain-end drill pipe, line pipe, coiled line pipe, pup joints, coupling stock, and connector material.

Prove-up inspection is a method to evaluate the radial depth of imperfections detected by automated inspection equipment or other nondestructive testing (NDT) technique(s) to determine acceptance criteria compliance with the appropriate API specification.

This RP covers application, certification of testing personnel, a description of inspection methods, calibration and standardization procedures, testing procedures, and quantification of imperfections and testing record contents.

This RP was originally included in Appendix A as one of the standards to be considered for piping systems. Although developed primarily for application to drill pipe and casing in the petroleum and natural gas exploration and production industry, 5UE can be used for critical piping systems where detection and characterization of small flaws is important to integrity.

B-2 API Publication 327 *Aboveground Storage Tank Standards: A Tutorial*

This document is published to help owner/operators of aboveground storage tanks (ASTs) maintain ASTs in an environmentally safe manner.
This tutorial is applicable to both the design of new tanks and the evaluation of existing tanks.

This tutorial can be used by personnel involved with the design, fabrication, maintenance, and inspection of ASTs fabricated and/or maintained per the following standards:

- API SPEC 12B: Bolted Tanks for Storage of Production Liquids.
- API SPEC 12D: Field Welded Tanks for Storage of Production Liquids.
- API SPEC 12F: Shop Welded Tanks for Storage of Production Liquids.
- API RP 12R1: Setting, Maintenance, Operation, and Repair of Tanks in Production Service.
- API STD 650: Welded Steel Tanks for Oil Storage.
- API RP 651: Cathodic Protection of Aboveground Storage Tank Bottoms.
- API STD 653: Tank Inspection, Repair, Alteration, and Reconstruction.

Application of the principles discussed in this tutorial to ASTs constructed to differing design criteria should be based on sound engineering judgments. This tutorial does not attempt to address additional rules and requirements that may be imposed by individual jurisdictions or states.

This tutorial presents a set of procedures and examples to aid in understanding and complying with API recommended practices, specifications, and standards regarding the prevention of leaks caused by bottom or shell corrosion, brittle fracture, and excessive settlement. Also, they show how the API inspection and maintenance documents influence the design of new or proposed tanks.

This tutorial is not meant to be used by itself; rather it is meant to be used as an aid in understanding the relevant Recommended Practices, Specifications, and Standards and to be used in conjunction with those documents.

B-3 API TR 654 *Aboveground Storage Tank Caulking or Sealing the Bottom Edge Projection to the Foundation*

The purpose of this technical report is to provide guidance to owner/operators who have tanks that are set on a foundation system with the goal to protect the asset from deterioration by minimizing corrosion and foundation deterioration and allowing for proper support of the tank shell. The asset includes the tank itself, as well as the foundation system.

This technical report does not require that caulking or sealants be installed at the bottom edge projection and the foundation of aboveground storage tanks. It provides guidance in situations in which caulking or sealants may be advantageous and should be considered.

This technical report applies to situations where an owner/operator is considering caulk or sealant in this area, or if any regulatory agency requires or recommends that an owner/operator installs some type of caulk or sealant. This document will also consider how to inspect existing caulk and sealant, including maintenance procedures, and includes a suggested inspection schedule.

This technical report does not offer guidance on tanks resting entirely on the ground or earth with no rigid foundation or foundation ring wall.

B-4 API Publication 932-A *A Study of Corrosion in Hydroprocess Reactor Effluent Air Cooler Systems*

This technical report provides the technical background for controlling corrosion in hydroprocessing reactor effluent systems based on industry experience and consensus practice. Information for this report has been gathered from open literature, private company reports, and interviews with representatives of major refining companies. The findings in this report are the basis for the guidance in API Recommended Practice 932-B.

B-5 API TR 934-D *Technical Report on the Materials and Fabrication Issues of 1 1/4Cr-1/2Mo and 1Cr-1/2Mo Steel Pressure Vessels*

This document provides background information and guidance on the implementation of *API 934-C, Materials and Fabrication of 1¼Cr-½Mo Steel Heavy Wall Pressure Vessels for High Pressure Hydrogen Service Operating at Temperatures at or Below 825°F (426°C)* and *API RP 934E, Materials and Fabrication of 1¼Cr-½Mo Steel Heavy Wall Pressure Vessels for High Temperature Service Operating Above 825°F (426°C)*, and should be used as a supplement to these recommended practices.

In recent years, it has been recognized that there are important distinctions that need to be considered for 1¼/1Cr-½Mo steels. Whereas API 934-A continues to provide materials and fabrication requirements for new 2¼/3Cr-1Mo and 2¼/3Cr-1Mo-¼V steel heavy wall pressure vessels in high temperature, high pressure hydrogen service, different material and fabrication requirements have been developed for 1¼/1Cr-½Mo steel heavy wall pressure vessels. These requirements are covered in API RP 934-C and API RP 934-E.

This document contains a description of key damage mechanisms that relate specifically to 1¼/1Cr-½Mo pressure vessels used in a variety of services. These damage mechanisms include elevated temperature damage mechanisms such as "reheat cracking" or "creep embrittlement" as well as other damage mechanisms that may occur at lower temperatures. Not all services are affected by the same damage mechanisms due to significant differences in service conditions. For example, Hydrofiner Reactors tend to operate at lower temperatures and higher pressures than Catalytic Reformer Reactors, and Coke Drums and FCC Reactors do not see hydrogen service. Also, as a result of the different services causing different damage mechanisms, the fabrication requirements also differ. To this end, API has developed two separate recommended practices to take this into account: API RP 934-C and API RP 934-E. Accordingly, background information and guidance on the implementation of these two new documents are needed.

This document provides information and guidance on successful practices for fabrication of 1¼/1Cr-½Mo steel heavy wall pressure vessels for the intended services of both API RP 934-C and API RP 934-E. The survey of steel producers and vessel fabricators (Annex 1) indicates that there is a need to evaluate the effect of heat treat cycles on materials properties (CVN toughness, tensile and yield strength). For this reason, the connection of the Larson-Miller parameter is emphasized to better align the user needs with fabrication requirements. However, detailed attention is still needed to implement this approach for individual cases, as there are many secondary variables, such as heating and cooling rates that need to be considered and discussed between the user and the fabricator. The areas of fabrication that are covered in this document include steel making as related to chemical composition, heat treatment, forming, and welding.

B-6 API TR 934-F, Part 1 *Impact of Hydrogen Embrittlement on Minimum Pressurization Temperature for Thick-Wall Cr-Mo Steel Reactors in High-Pressure H_2 Service—Initial Technical Basis for RP 934-F*

In support of API Recommended Practice 934-F [*Guidance for Establishing a Minimum Pressurization Temperature (MPT) for Heavy Wall Reactors in High Temperature Hydrogen Service During Startups and Shutdowns, not yet published*], the objective of this study is to establish the technical basis for determining a minimum pressurization temperature necessary to avoid Internal Hydrogen Assisted Cracking (IHAC) of weld metal and base plate of temper embrittled 2¼Cr-1Mo steel in high pressure H_2 service. The threshold condition for the onset of subcritical crack propagation—and its dependencies on dissolved hydrogen concentration, temperature, and steel purity/temper embrittlement—are targeted as particularly important to pressure vessel safe operations. A second objective is to improve the underlying database for fracture mechanics fitness-for-service (FFS) modeling of IHAC. Both analyses are built on the conservative rising displacement threshold stress intensity factor for IHAC (KIH).

This investigation has accomplished 5 tasks, leading to conclusions that are sufficient to establish RP 934-F on MPT to conservatively avoid IHAC in 2¼Cr-1Mo steel.

Task 1.0—Summarize and clarify the technical approach, assumptions, data, and modeling results used in Phase II JIP research to quantitatively establish the H concentration and temperature dependencies of the threshold stress intensity, KIH, for IHAC and the concentration dependence of MPT for moderate-impurity 2¼Cr-1Mo steel.

Task 2.0—Validate the Phase II correlation of KIH and critical temperature vs H concentration, based on new analyses of post-Phase-II IHAC data.

Task 3.0—Enhance the Phase II analysis of KIH vs crack tip H concentration, and thus MPT, by describing the interaction between temper embrittlement and IHAC using JIP Phase I data so as to predict the influence of modern steel purity.

Task 4.0—Build on the hydrogen-damage-mechanism-based master correlation between KIH and crack tip stress field/microstructure-trapped H to develop a H concentration similitude parameter that is useful in engineering analysis of thick-wall reactor FFS and MPT.

Task 5.0—Validate the empirically based trends and predictions of the effects of temperature and steel purity on the threshold stress intensity through consideration of state-of-the art theory and micromechanical modeling of IHAC.

B-7 API TR 934-F, Part 2 *Impact of Hydrogen Embrittlement on Minimum Pressurization Temperature for Thick-Wall Cr-Mo Steel Reactors in High-Pressure H_2 Service—Initial Technical Basis for RP 934-F*

This report documents a critical assessment of the existing literature on IHAC of V-modified Cr-Mo steels for use in interpreting the results of the present laboratory work (reported in *API TR 934-F, Part 3, Subcritical Cracking of Modern 2¼Cr-1Mo-¼V Steel due to Dissolved Hydrogen and H2 Environment*) so as to establish a definitive characterization of the H cracking resistance of this steel class. Since these modern Cr-Mo-V steels are of relatively high purity, and thus retain a low Fracture Appearance Transition Temperature (FATT) after laboratory simulation of in-service temper embrittlement, the data base for 2¼Cr- 1Mo shown in Figure 1 provides a context for assessment of the IHAC performance of V-modified grades. Hydrogen cracking of less pure V-modified Cr-Mo steels was not considered in this review. The content that follows is chronologically organized into initial and more modern works, as justified by improvement in test execution, data analysis and reporting, as well as the evolution from laboratory to commercial scale heats of Cr-Mo-V.

B-8 API TR 934-F, Part 3 *Subcritical Cracking of Modern 2¼Cr-1Mo-¼V Steel Due to Dissolved Internal Hydrogen and H_2 Environment, Research Report*

This report conveys the results of API-sponsored research to: (a) quantitatively characterize the internal hydrogen assisted cracking (IHAC) resistance of modern 2¼Cr-1Mo-¼V steel, in both base metal and weld metal product forms and including the effect of stressing temperature, (b) scope the hydrogen environment assisted cracking (HEAC) resistance of 2¼Cr-1Mo- ¼V base metal, (c) understand the mechanism(s) for the IHAC and HEAC behaviors of Cr-Mo and Cr-Mo-V steels, centered on H interactions with microstructure-scale trap sites, and (d) assess application of data and understanding of IHAC and HEAC to determine the role of subcritical H-assisted cracking on a minimum pressurization temperature estimate relevant to thick-wall hydro-treating reactor vessels.

B-9 API TR 934-F, Part 4 *The Effects of Hydrogen for Establishing a Minimum Pressurization Temperature (MPT) for Heavy Wall Steel Reactor Vessels*

Hydrogen, dissolved in the thick wall of a steel pressure vessel during steady state operation in elevated temperature, high-pressure H_2, can cause both slow-subcritical crack advance as well as unstable-catastrophic fracture during shutdown and startup. This behavior is defined in Section 2. It follows that modern fracture-mechanics assessments of the minimum pressurization temperature (MPT) and fitness for service (FFS) must include the deleterious effect of H on both subcritical and unstable internal hydrogen assisted cracking (IHAC). Two approaches are in draft stage to develop standard procedures that address this need; an API 934-F recommended practice and a WRC Bulletin 562 basis for API 579-1/ASME FFS-1. The objective of this technical report is to establish the technical basis necessary to enable and validate these best practices for quantifying the effects of hydrogen on (a) the MPT and (b) FFS of a thick wall hydroprocessing reactor.

B-10 API Publication 935 *Thermal Conductivity Measurement Study of Refractory Castables*

The refractory industry uses various methods for measuring and reporting thermal conductivity of refractory castables. The accuracy of reporting and understanding thermal conductivity are vital to developing the most cost effective, efficient, and reliable equipment. This study compares the differences between measurement techniques used to develop thermal conductivity of refractory castables. The following procedures were examined: Water Calorimeter, Calorimeter-Pilkington Method, Hot Wire Method, Comparative Thermal Conductivity Method, and Panel Test. The study makes no attempt to rank, classify, or assign accuracy to each of the measurement techniques.

B-11 API Publication 937-A *Study to Establish Relations for the Relative Strength of API 650 Cone Roof Roof-to-Shell and Shell-to-Bottom Joints*

This report documents an evaluation of the relative strengths of the roof-to-shell and shell-to-bottom joints in API 650 cone roof tanks. This information is supplied to the American Petroleum Institute as background material for development of design rules that govern frangible roof joints for API 650 tanks.

API 650 provides design criteria for fluid storage tanks used to store flammable products. Due to filling and emptying of the tanks, the vapor above the product surface inside the tank may be within its flammability limits. Ignition of this vapor can cause sudden over-pressurization and can lead to the catastrophic loss of tank integrity. To prevent shell or bottom failure, the rules in API 650 are intended to ensure that the frangible roof-to-shell joint fails before failure occurs in the tank shell or the shell-to-bottom joint. Failure of the frangible roof-to-shell joint provides a large venting area and reduces the pressure in the tank.

Although the criteria in API 650 function well for large tanks, small tanks designed to the API 650 rules have not always functioned as intended. Morgenegg, 1978, provides a description of a 20 foot diameter by 20 foot tall tank in which the shell-to-bottom failed. Other such failures have been noted by API, providing the incentive for this study.

As presently written, the API 650 rules do not address the strength of the shell-to-bottom joint directly. Instead, the present rule is intended to ensure that the roof-to-shell joint fails at a pressure lower than that required to lift the weight of tank. It is assumed that with no uplift, the shell-to-bottom joint will not have significant additional loads and that failure of the shell-to-bottom will be avoided.

A study of roof-to-shell joint failure (Swenson, et al., 1996) showed that for large tanks, the roof-to-shell joint did indeed fail before tank uplift, but that for smaller tanks uplift would occur before roof-to-shell joint failure. Since uplift occurs for small tanks, this increases the possibility of shell-to-bottom joint failure. The purpose of this study is to investigate the relative strengths of the roof-to-shell and shell-to-bottom joints, with the goal of providing suggestions for frangible roof design criteria applicable to smaller tanks.

B-12 API Publication 938-A *An Experimental Study of Causes and Repair of Cracking of 1¼Cr-1/2Mo Steel Equipment*

This 1996 publication gives the results of an experimental study conducted to provide the petroleum industry with solutions to recurring incidents of cracking in the application of welded 1¼Cr-1/2Mo steel for hydrogen processing equipment.

B-13 API TR 938-B *Use of 9Cr-1Mo-V (Grade 91) Steel in the Oil Refining Industry*

This report is only applicable to the 9Cr-1Mo-V alloy steel, Grade 91. There are newer, higher strength grades, namely 9Cr-2W (Grade P92) and 9Cr-1Mo-1W-Cb (Grade 911), however, because little fabrication and welding experience is available and application history for these grades is still evolving, they are not included in the scope of this report. Some data on these grades is included for comparison with Grade 91.

It covers the basic material and metallurgical properties of 9Cr-1Mo-V steel, including a summary of the physical and mechanical properties, corrosion and oxidation resistance, indicating possible corrosion and/or mechanical failure mechanisms and how to avoid them. The appropriate base metal heat treatment is also given.

This report provides guidelines on the proper specifications for base metal and welding consumables and successful fabrication, including welding and heat treatment requirements for use of 9Cr-1Mo-V alloy steel in the oil refinery services. This includes guidelines for preheat, postweld heat treatment, procedure qualification, and mechanical and nondestructive testing.

This document also defines hardness limits for the base material and welds in order to avoid cracking failures due to wet sulfide stress corrosion cracking or due to other possible failure mechanisms.

A discussion of both proper and improper refinery service applications for these steels is also provided.

B-14 API TR 938-C *Use of Duplex Stainless Steels in the Oil Refining Industry*

This report covers many of the "lean", "standard", "super", and "hyper" grades of duplex stainless steels (DSSs) most commonly used within refineries. The definitions of these terms have not been firmly established by the industry, and vary between literature references and materials suppliers. Table 1 shows how the various grades are being classified into "families" for the purposes of this report. The UNS numbers of the standard grades being used for corrosive refining services include:

- Lean DSSs: S32101, S32202, S32304, S32003, S82011, and S82441.
- Standard DSSs: S31803 and S32205.
- Super DSSs: S32520, S32550, S32750, S32760, and S32906.
- Hyper DSS: S32707.

The grades which are labeled as "lean" (including grades sometimes called "semi-lean") have either lower Cr, Ni, or Mo than the standard grades, and are used in some process services that are less aggressive (primarily in corrosive environments to replace 304L SS). These alloys have also been used for storage tanks and structural applications, primarily for their higher strength as compared to carbon steel (CS). It is observed that new DSS alloys are being introduced and are likely to continue to be introduced. These new grades can be reasonably placed in the context of this discussion based on their composition.

The product forms within the scope are tubing, plate, sheet, forgings, pipe, and fittings for piping, vessel, exchanger, and tank applications. The use of DSSs for tanks is also addressed by API 650, Annex X. The Third Edition of this report (API 938-C) has added sections covering castings and hot isostatically-pressed (HIP) components for pumps, valves, and other applications. The limited use of DSSs as a cladding is also briefly covered within this document.

The majority of refinery services where DSSs are currently being used or being considered in the refining industry contain at least one of the following:

(a) A wet, sour (H_2S) environment, which may also contain hydrogen, ammonia, carbon dioxide, chlorides, and/or hydrocarbons, which typically has a pH greater than 7.

(b) Water containing chlorides, with or without hydrocarbons—this includes many fresh water cooling water systems, and some salt water systems with higher alloy grades.

(c) Hydrocarbons with naphthenic acids at greater than 200°C (400°F), but below the maximum allowable temperatures in the ASME Code for DSSs (260°C to 343°C [500°F to 650°F], depending on the grade).

(d) Amines, such as MEA, MDEA, DEA, etc.

(e) Other environments, such as those containing caustic conditions.

The specific plant locations containing these services are described in a later section, and the report scope will be limited to the first four environments. Although DSSs have good resistance to caustic environments, this service is not unique to or widespread in refining, and hence is not covered in detail in this report.

B-15 API Publication 939-A *Research Report on Characterization and Monitoring of Cracking in Wet H_2S Service*

Demonstrates the ability to characterize and monitor various aspects of crack propagation in pressurized process equipment exposed to wet hydrogen sulfide environments. It represents one of several significant industry-wide efforts to study and to better understand this phenomenon.

B-16 API Publication 939-B *Repair and Remediation Strategies for Equipment Operating in Wet H_2S Service*

This publication presents data relative to the fabrication requirements for 2¼ 3Cr alloy steel heavy wall pressure vessels for high temperature, high pressure hydrogen services. It summarizes the results of industry experience, experimentation, and testing conducted by independent manufacturers, fabricators, and users of heavy wall pressure vessels. This recommended practice applies to equipment in refineries, petrochemical, and chemical facilities in which hydrogen or hydrogen-containing fluids are processed at elevated temperature and pressure.

B-17 API TR 939-D *Stress Corrosion Cracking of Carbon Steel in Fuel-Grade Ethanol: Review, Experience Survey, Field Monitoring, and Laboratory Testing*

Addresses stress corrosion cracking (SCC) in carbon steel equipment used in distribution, transportation, storage, and blending of denatured fuel ethanol. API, with assistance from the Renewable Fuels Association (RFA), conducted research on the potential for metal cracking and product leakage in certain portions of the fuel ethanol distribution system. API TR 939-D contains a review of existing literature, results of an industry survey on cracking events and corrosion field monitoring, and information on mitigation and prevention.

B-18 API Bulletin 939-E *Identification, Repair, and Mitigation of Cracking of Steel Equipment in Fuel Ethanol Service*

Usage of fuel ethanol as an oxygenate additive in gasoline blends is increasing both in the United States and internationally. This document discusses stress corrosion cracking (SCC) of carbon steel tanks, piping, and equipment exposed to fuel ethanol as a consequence of being in the distribution system, at ethanol distribution facilities, or end user (EU) facilities where the fuel ethanol is eventually added to gasoline. Such equipment includes but is not limited to the following when used in distribution, handling, storage, and blending of fuel ethanol:

- Storage tanks.
- Piping and related handling equipment.
- Pipelines.

However, data for pipelines in ethanol service is limited and caution should be used when applying guidelines from this document that have been derived mainly from applications involving piping and tanks in ethanol storage and blending facilities. SCC of other metals and alloys is beyond the scope of this document, as is the corrosion of steel in this service.

It is realized that SCC of steel in fuel ethanol is a topic where knowledge of the subject is actively growing through documentation of recent experience and through research in progress. This document deals with handling of cracks in existing equipment and reduction of SCC occurrence in new equipment as a result of exposure to fuel ethanol per ASTM D4806 (or other international specifications), ethanol fuel blends, and pipeline transmixes involving fuel ethanol and conventional hydrocarbon fuels (gasoline, diesel, or jet fuel). It includes guidelines for carbon steel construction materials, including their fabrication, inspection, and repair to help assure safe and reliable operations.

This document is based on current engineering practices and insights from recent industrial experience and research. Older equipment may not conform exactly to the information contained herein, but this does not imply that such equipment is being operated in an unsafe or unreliable manner. It is also recognized that facilities may vary and may need to be modified depending on specific operating conditions, inspection, and maintenance experience. Each user company is ultimately responsible for its own safe and reliable operations.

The steels referred to in this document are defined by the ASTM or API designation systems or equivalent steel grades contained in other recognized codes or standards. Welded construction is considered the primary method of fabrication in equipment exposed to fuel ethanol.

B-19 API TR 942-A *Materials, Fabrication, and Repair Considerations for Hydrogen Reformer Furnace Outlet Pigtails and Manifolds*

The API Committee on Refinery Equipment, Subcommittee on Corrosion and Materials undertook a project to develop this technical report on materials, fabrication, and repair issues related to hydrogen and syngas reformer furnace outlet pigtails and manifolds. High reliability of outlet pigtails and manifold components, such as headers, tees, and fittings, is important to the successful long-term operation of hydrogen and syngas reformer furnaces. These components typically operate at high temperatures in the range of 750°C to 950°C (1382°F to 1742°F) where they are potentially subject to high-temperature creep, stress relaxation, hot corrosion, and thermal fatigue damage.

In recent years, a number of reformer furnace operators have encountered problems of in-service degradation and cracking of outlet pigtails and manifold components, while others have had little or no problems of this type. Both direct experience in addressing specific cases of outlet pigtail and manifold cracking problems and indirect experience gained from surveying industry with regard to these problems were used in preparing this report.

The objective of the project was to develop an understanding, based on published literature and industry experience, of why some reformer furnaces have had problems with embrittlement and cracking of outlet pigtails and manifold components in service, while others have not had such problems.