

Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

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Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration

1 Scope

1.1 General Application

1.1.1 Coverage

This inspection code covers the in-service inspection, repair, alteration, and rerating activities for pressure vessels and the pressure-relieving devices (PRDs) protecting these vessels. This inspection code applies to all hydrocarbon and chemical process vessels that have been placed in service unless specifically excluded per [1.2.2](#); however, it could also be applied to process vessels in other industries at owner-operator discretion. This includes:

- a) vessels constructed in accordance with an applicable construction code [e.g., ASME *Boiler and Pressure Vessel Code (BPVC)*]; where a pressure vessel has been constructed to the American Society of Mechanical Engineers (ASME) *Section VIII Code*, API 510 is intended to apply to Divisions 1 and 2 and not Division 3;
- b) vessels constructed without a construction code (noncode vessels);
- c) vessels constructed and approved as jurisdictional-special based upon jurisdiction acceptance of particular design, fabrication, inspection, testing, and installation;
- d) nonstandard vessels.

However, vessels that have been officially decommissioned (i.e. no longer are an asset of record from a financial/accounting standpoint) are no longer covered by this “in-service inspection” code. Abandoned-in-place vessels may still need some amount of inspection and/or risk mitigation to assure they do not become a hazard because of continuing deterioration. Pressure vessels temporarily out of service and preserved for potential future use are still covered by this code.

The ASME *BPVC* and other recognized construction codes are written for new construction; however, most of the technical requirements for design, welding, nondestructive examination (NDE), and materials can be applied to the inspection, rerating, repair, and alteration of in-service pressure vessels. If for some reason an item that has been placed in service cannot follow the construction code because of its new construction orientation, the requirements for design, material, fabrication, and inspection shall conform to API 510 rather than to the construction code. If in-service vessels are covered by requirements in the construction code and API 510 or if there is a conflict between the two codes, the requirements of API 510 shall take precedence. As an example of the intent of API 510, the phrase “applicable requirements of the construction code” has been used in API 510 instead of the phrase “in accordance with the construction code.”

1.1.2 Intent

The application of this inspection code is restricted to owner-operators that employ or have access to the following technically qualified individuals and organizations:

- a) an authorized inspection agency;
- b) a repair organization;
- c) an engineer;
- d) an inspector;

e) examiners.

Inspectors are to be certified as stated in this inspection code (see Annex B). Since other codes covering specific industries and general service applications already exist (e.g., NB-23), the refining and petrochemical industry has developed this inspection code to fulfill their own specific requirements for vessels and PRDs that fit within the restrictions listed in the scope.

The intent of this code is to specify the in-service inspection and condition-monitoring program needed to determine the integrity of pressure vessels and PRDs. The program should provide reasonably accurate and timely assessments to determine if any changes in the condition of pressure equipment could compromise continued safe operation. The owner-operators shall respond to any inspection results that require corrective actions to assure the continued safe operation of pressure vessels and PRDs.

This code does not cover source inspection of newly fabricated pressure vessels. Refer to API RP 588 *Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment* for guidance on the surveillance of supplier vendors fabricating and/or repairing pressure vessels that will be installed on site. Owner-operators may engage the services of individuals qualified and certified in accordance with API RP 588 or this code.

1.1.3 Limitations

Adoption and use of this inspection code does not permit its use in conflict with any prevailing regulatory requirements. However, if the requirements of this code are more stringent than the requirements of the regulation, then the requirements of this code shall govern.

1.2 Specific Applications

1.2.1 Exploration and Production (E&P) Vessels

All pressure vessels used for E&P service [e.g., drilling, producing, gathering, transporting, lease processing, and treating liquid petroleum, natural gas, and associated salt water (brine)] may be inspected under the alternative rules set forth in [Section 9](#). Except for [Section 6](#), all of the sections in this inspection code are applicable to pressure vessels in E&P service. The alternative rules in [Section 9](#) are intended for services that may be regulated under safety, spill, emission, or transportation controls by the U.S. Coast Guard; the Office of Hazardous Materials Transportation of the U.S. Department of Transportation (DOT), and other units of DOT; the Bureau of Ocean Energy Management, Regulation, and Enforcement, formerly the Minerals Management Service of the U.S. Department of the Interior; state and local oil and gas agencies; or any other regulatory commission.

1.2.2 Excluded and Optional Services

Vessels excluded from the specific requirements of this inspection code are listed in Annex A. However, each owner-operator has the option of including any excluded pressure vessel in their inspection program as outlined in this code.

Some vessels exempted in accordance with the criteria in ASME *BPVC, Section VIII, Division 1* should be considered for inclusion based on risk (probability and consequence of failure) as determined by the owner-operator. An example of such vessels might be vacuum flashers in refining service or other large vessels operating in vacuum service.

1.2.3 Recognized Technical Concepts

For inspection planning and engineering assessment of in-service pressure vessels, this inspection code recognizes the applicability of fitness-for-service (FFS) assessment and risk-based inspection (RBI) methodologies. API 579-1/ ASME FFS-1 provides detailed assessment procedures for specific types of damage referenced in this code. API RP 580 provides guidelines for conducting a risk-based assessment program. API RP 581 provides a method of conducting RBI in accordance with the principles in API RP 580.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API 510, *Inspector Certification Examination Body of Knowledge*

API Recommended Practice 571, *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry*

API Recommended Practice 572, *Inspection of Pressure Vessels*

API Recommended Practice 576, *Inspection of Pressure-relieving Devices*

API Recommended Practice 577, *Welding Inspection and Metallurgy*

API Recommended Practice 578, *Material Verification Program for New and Existing Alloy Piping Systems*

API Standard 579-1/ASME FFS-1, *Fitness-For-Service*

API Recommended Practice 580, *Risk-Based Inspection*

API Recommended Practice 581, *Risk-Based Inspection Methodology*

API Recommended Practice 582, *Welding Guidelines for the Chemical, Oil, and Gas Industries*

API Recommended Practice 583, *Corrosion Under Insulation and Fireproofing*

API Recommended Practice 584, *Integrity Operating Windows*

API Recommended Practice 585, *Pressure Equipment Integrity Incident Investigations*

API Recommended Practice 751, *Safe Operation of Hydrofluoric Acid Alkylation Units*

API Recommended Practice 939-C, *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*

API Recommended Practice 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*

API Recommended Practice 2201, *Safe Hot Tapping Practices for the Petroleum and Petrochemical Industries*

ASME PCC-1,¹ *Guidelines for Pressure Boundary Bolted Flange Joint Assembly*

ASME PCC-2, *Repair of Pressure Equipment and Piping*

ASME *Boiler and Pressure Vessel Code, Section II: Materials*

ASME *Boiler and Pressure Vessel Code, Section V: Nondestructive Examination*

ASME *Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels; Division 1*

ASME *Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels; Division 2: Alternative Rules*

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME Boiler and Pressure Vessel Code, Section IX: Welding and Brazing Qualifications

ASNT CP-189,² *Standard for Qualification and Certification of Nondestructive Testing Personnel*

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this code, the following terms and definitions apply.

3.1.1

abandoned-in-place

A pressure vessel meeting all of the following: has been decommissioned with no intention for future use; has been completely de-inventoried/purged of hydrocarbon/chemicals; and is physically disconnected (e.g., air-gapped) from all energy sources and/or other piping/equipment but remains in place.

3.1.2

alteration

A physical change in any component that has design implications that affect the pressure-containing capability of a pressure vessel beyond the scope described in existing data reports. The following should not be considered alterations: any comparable or duplicate replacement; the addition of any reinforced nozzle less than or equal to the size of existing reinforced nozzles; and the addition of nozzles not requiring reinforcement.

3.1.3

applicable construction code

The code, code section, or other recognized and generally accepted engineering standard or practice to which the pressure vessel was built or deemed by the owner-operator or the engineer to be most appropriate for the situation.

3.1.4

authorization

Approval/agreement to perform a specific activity (e.g., repair) prior to the activity being performed.

3.1.5

authorized inspection agency

Any one of the following:

- a) the inspection organization of the jurisdiction in which the pressure vessel is used;
- b) the inspection organization of an insurance company licensed or registered to write pressure vessel insurance;
- c) the inspection organization of an owner-operator of pressure vessels who maintains an inspection organization for his/her equipment only and not for vessels intended for sale or resale;
- d) an independent organization or individual under contract to and under the direction of an owner-operator and recognized or otherwise not prohibited by the jurisdiction in which the pressure vessel is used. The owner-operator's inspection program shall provide the controls necessary when contract inspectors are used.

² American Society for Nondestructive Testing International Service Center, PO Box 28518, 1711 Arlingate Lane, Columbus, Ohio, 43228-0518, www.asnt.org.

3.1.6

authorized pressure vessel inspector

An employee of an authorized inspection agency who is qualified and certified to perform inspections under this inspection code, including Annex B. Whenever the term “inspector” is used in API 510, it refers to an authorized pressure vessel inspector.

3.1.7

condition-monitoring location

CML

A designated area on pressure vessels where periodic examinations are conducted to directly assess and monitor the condition of the vessel using a variety of examination methods and techniques based on damage mechanism susceptibility. CMLs may contain one or more examination points and can be a single small area on a pressure vessel, e.g., a 50 mm (2 in.) diameter spot or plane through a section of a nozzle where recording points exist in all four quadrants of the plane.

NOTE CMLs include but are not limited to what were previously called thickness-monitoring locations (TMLs).

3.1.8

construction code

The code or standard to which a vessel was originally built, such as API/ASME (now out of date), ASME *BPVC*, state special/non-ASME, or any other construction code to which the vessel was built.

3.1.9

controlled-deposition welding

CDW

Any welding technique used to obtain controlled grain refinement and tempering of the underlying heat-affected zone in the base metal. Various controlled-deposition techniques, such as temper bead (tempering of the layer below the current bead being deposited) and half bead (requiring removal of one-half of the first layer), are included (see [8.6](#)).

3.1.10

corrosion allowance

Additional material thickness available to allow for metal loss during the service life of the vessel component.

3.1.11

corrosion rate

The rate of metal loss due to erosion, erosion/corrosion, and/or the chemical reaction(s) with the environment, either internal and/or external.

3.1.12

corrosion specialist

A person acceptable to the owner-operator, who is knowledgeable and experienced in the specific process chemistries, damage mechanisms, materials selection, corrosion mitigation methods, corrosion-monitoring techniques, and their impact on equipment.

3.1.13

corrosion under fireproofing

CUF

Corrosion of piping, pressure vessels, and structural components resulting from water trapped under fireproofing.

3.1.14

corrosion under insulation

CUI

External corrosion of piping, pressure vessels, and structural components resulting from water trapped under insulation. External chloride stress corrosion cracking (ECSCC) of austenitic and duplex stainless steel under insulation is also classified as CUI damage.

3.1.15**cyclic service**

Refers to service conditions that could result in cyclic loading and produce fatigue damage or failure (e.g., cyclic loading from pressure, thermal, and/or mechanical loads). Other cyclic loads associated with vibration could arise from such sources as impact, turbulent flow vortices, resonance in compressors, and wind, or any combination thereof (see [5.4.4](#)).

3.1.16**damage mechanism**

Any type of deterioration encountered in the refining and chemical process industry that can result in flaws/defects that can affect the integrity of vessels (e.g., corrosion, cracking, erosion, dents, and other mechanical, physical, or chemical impacts). See API RP 571 for a comprehensive list and description of damage mechanisms.

3.1.17**decommissioned**

Termination of pressure vessel from its service. A pressure vessel at this stage of its life-cycle is permanently removed from service, and either removed from the process unit or abandoned-in-place.

3.1.18**defect**

A discontinuity or discontinuities that by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications (e.g., total crack length). The term designates rejectability.

3.1.19**deferral**

An approved and documented postponement of an inspection, test, or examination (see [6.6.3.5](#)).

3.1.20**design temperature**

The temperature used for the design of the pressure vessel per the applicable construction code.

3.1.21**documentation**

Records containing descriptions of specific vessel design, personnel training, inspection plans, inspection results, NDE, repair, alteration, rerating and pressure-testing activities, FFS assessments, procedures for undertaking these activities, or any other information pertinent to maintaining the integrity and reliability of vessels.

3.1.22**due date**

The date established by the owner-operator in accordance with this code, whereby an inspection, test, examination, or inspection recommendation falls due. The date may be established by rule-based inspection methodologies (e.g., fixed intervals, retirement half-life interval, retirement date), risk-based methodologies (e.g., RBI target date), FFS analysis results, owner-operator inspection agency practices/procedures/guidelines, or any combination thereof.

3.1.23**engineer**

Pressure vessel engineer.

3.1.24**examination point****recording point****measurement point****test point**

A more specific location within a CML. CMLs may contain multiple examination points, for example, a vessel nozzle may be a CML and have multiple examination points (e.g., an examination point in all four quadrants of the CML on the nozzle).

NOTE The term “test point” is no longer in use, as “test” refers to mechanical or physical tests, e.g. tensile tests or pressure tests.

3.1.25**examinations**

A process by which an examiner or inspector investigates a component of the pressure vessel using NDE in accordance with approved NDE procedures (e.g., inspection of a CML, quality control (QC) of repair areas).

3.1.26**examiner**

A person who assists the inspector by performing specific NDE on pressure vessel components and evaluates to the applicable acceptance criteria but does not evaluate the results of those examinations in accordance with API 510 unless specifically trained and authorized to do so by the owner-operator.

3.1.27**external inspection**

A visual inspection performed from the outside of a pressure vessel to find conditions that could impact the vessel's ability to maintain pressure integrity or conditions that compromise the integrity of the supporting structures (e.g., ladders, platforms, supports). The external inspection may be done either while the vessel is operating or while the vessel is out of service and can be conducted at the same time as an on-stream inspection.

3.1.28**fitness-for-service evaluation****FFS evaluation**

A methodology whereby flaws and other deterioration/damage or operating conditions contained within a pressure vessel are assessed in order to determine the integrity of the vessel for continued service.

3.1.29**general corrosion**

Corrosion distributed approximately uniform over the surface of the metal.

3.1.30**heat-affected zone****HAZ**

The portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding or thermal cutting.

3.1.31**hold point**

A point in the repair or alteration process beyond which work may not proceed until the required inspection or NDE has been performed.

3.1.32**idle**

Pressure vessel not currently operating, but remains connected to piping, electrical or instrumentation (may be blinded or blocked in).

NOTE An idled pressure vessel is considered in-service and is still subject to the requirements of this code.

3.1.33**imperfection**

Flaws or other discontinuities noted during inspection or examination that may or may not exceed the applicable acceptance criteria.

3.1.34**indication**

A response or evidence resulting from the application of an NDE that may be nonrelevant, flawed, or defective upon further analysis.

3.1.35**industry-qualified UT angle beam examiner**

A person who possesses an ultrasonic angle beam qualification from API (e.g., API QUTE/QUSE detection and sizing tests) or an equivalent qualification approved by the owner-operator.

NOTE Rules for equivalency are defined on the API ICP website.

3.1.36**in-service**

The life-cycle stage of a pressure vessel that begins after initial installation (where typically initial commissioning or placing into active service follows) and ends at decommissioning. Pressure vessels that are idle in an operating site and vessels that are not currently in operation because of a process outage are still considered in-service pressure vessels.

NOTE Does not include pressure vessels that are still under construction or in transport to a site prior to being placed in operation nor does it include pressure vessels that have been decommissioned.

3.1.37**in-service inspection**

All inspection activities associated with an in-service pressure vessel (after installation, but before it is decommissioned).

3.1.38**inspection**

The external, internal, or on-stream evaluation (or any combination of the three) of the condition of a vessel conducted by the authorized inspector or his/her designee in accordance with this code.

3.1.39**inspection code**

A reference to the API 510 code.

3.1.40**inspection plan**

A strategy defining how and when a pressure vessel or PRD will be inspected, examined, repaired, and/or maintained (see [5.1](#)).

3.1.41**inspector**

A shortened title for an authorized pressure vessel inspector qualified and certified in accordance with this code.

3.1.42**integrity operating window****IOW**

Established limits for process variables (parameters) that can affect the integrity of the equipment if the process operation deviates from the established limits for a predetermined amount of time (see [4.1.4](#)).

3.1.43**internal inspection**

An inspection performed from the inside of a pressure vessel using visual and/or NDE techniques.

3.1.44**jurisdiction**

A legally constituted governmental administration that may adopt rules relating to pressure vessels.

3.1.45**localized corrosion**

Corrosion that is typically confined to a limited or isolated area(s) of the metal surface of a pressure vessel.

3.1.46**major repair**

Any work not considered an alteration that removes and replaces a major part of the pressure boundary other than a nozzle (e.g., replacing part of the shell or replacing a vessel head). If any of the restorative work results in a change to the design temperature, minimum allowable temperature (MAT), or maximum allowable working pressure (MAWP), the work shall be considered an alteration, and the requirements for rerating shall be satisfied.

3.1.47**management of change****MOC**

A documented management system for review and approval of changes (both physical and process) to pressure vessels prior to implementation of the change. The MOC process includes involvement of inspection personnel who may need to alter inspection plans as a result of the change.

3.1.48**manufacturer's data report**

A document that contains data and information from the manufacturer of the pressure vessel that certifies the materials of construction contained in the vessel meet certain material property requirements, tolerances, etc. and are in accordance with specified standards.

3.1.49**maximum allowable working pressure****MAWP**

The maximum gauge pressure permitted at the top of a pressure vessel in its operating position for a designated temperature. This pressure is based on calculations using the minimum (or average pitted) thickness for all critical vessel elements (exclusive of thickness designated for corrosion) and adjusted for applicable static head pressure and nonpressure loads (e.g., wind and seismic). The MAWP may refer to either the original design or a rerated MAWP obtained through an FFS assessment.

3.1.50**minimum design metal temperature/minimum allowable temperature****MDMT/MAT**

The lowest permissible metal temperature for a given material at a specified thickness based on its resistance to brittle fracture. In the case of MAT, it may be a single temperature or an envelope of allowable operating temperatures as a function of pressure. It is generally the minimum temperature at which a significant load can be applied to a pressure vessel as defined in the applicable construction code, e.g., ASME *BPVC, Section VIII, Division 1*, Paragraph UG-20(b). It might also be obtained through an FFS evaluation.

3.1.51**National Board**

The National Board of Boiler and Pressure Vessel Inspectors.

3.1.52**noncode vessel**

A vessel not fabricated to a recognized construction code and meeting no known recognized standard.

3.1.53**nonpressure boundary**

Components of the vessel that do not contain the process pressure (e.g., trays, tray rings, distribution piping, baffles, nonstiffening insulation support rings, clips, and davits).

3.1.54**nonstandard vessel**

A vessel fabricated to a recognized construction code but that has lost its nameplate or stamping.

3.1.55**on-stream**

A condition in which a pressure vessel has not been prepared for an internal inspection (see “on-stream inspection”).

3.1.56**on-stream inspection**

An inspection performed from the outside of a pressure vessel while it is on-stream using NDE procedures to establish the suitability of the pressure boundary for continued operation.

3.1.57**overdue inspections**

Inspections for in-service vessels still in operation that have not been performed by their documented due dates documented in the inspection plan and have not been deferred by a documented deferral process (see [6.7](#)).

3.1.58**overdue inspection recommendations**

Recommendations for repair or other mechanical integrity purposes for vessels still in operation that have not been completed by their documented due dates, which have not been deferred by a documented deferral process (see [6.8](#)).

3.1.59**owner-operator**

An owner or operator of pressure vessels who exercises control over the operation, engineering, inspection, repair, alteration, maintenance, pressure testing, and rerating of those pressure vessels.

3.1.60**plate lining**

Metal plates welded to the inside of the pressure vessel wall for the purpose of protecting the vessel construction material from interaction with process fluids. Normally, plates are of a more corrosion-resistant or erosion-resistant alloy than the vessel wall and provide additional corrosion/erosion resistance. In some instances, plates of a material of construction similar to the vessel wall are used for specific operating periods in which corrosion and/or erosion rates are predictable.

3.1.61**postweld heat treatment****PWHT**

Treatment that consists of heating an entire weldment or vessel to a specified elevated temperature after completion of welding in order to relieve the effects of welding heat, such as to reduce residual stresses, reduce hardness, stabilize chemistry, and/or slightly modify properties.

3.1.62**pressure boundary**

That portion of the pressure vessel that contains the pressure retaining elements joined or assembled into a pressure-tight, fluid-containing vessel (e.g., typically the shell, heads, and nozzles) but excluding nonpressure boundary items (e.g., supports, skirts, and clips).

3.1.63**pressure test**

A test performed on pressure vessels that have been in service and that have undergone an alteration or repair to the pressure boundary(s) to indicate the integrity of the pressure components are still compliant with the original construction code. The pressure test can be hydrostatic, pneumatic, or a combination thereof.

3.1.64**pressure vessel**

A container designed to withstand internal and/or external pressure/loads. This pressure may be imposed by the application of heat from a direct or indirect source, or by any combination thereof. This definition includes heat exchangers, air coolers, columns, towers, unfired steam generators (boilers), and other vapor generating vessels that use heat from the operation of a processing system or other indirect heat source.

NOTE Specific limits and exemptions of equipment covered by this inspection code are provided in [Section 1](#) and Annex A.

3.1.65**pressure vessel engineer**

A person acceptable to the owner-operator who is knowledgeable and experienced in the engineering disciplines associated with evaluating mechanical and material characteristics that affect the integrity and reliability of pressure vessels. The pressure vessel engineer, by consulting with appropriate specialists, should be regarded as a composite of all entities needed to properly assess the technical requirements. Wherever the term “engineer” is used in this code, it refers to a pressure vessel engineer.

3.1.66**procedures**

A document that specifies or describes how an activity is to be performed. It may include methods to be employed, equipment or materials to be used, qualifications of personnel involved, and sequence of work.

3.1.67**quality assurance****QA**

All planned, systematic, and preventative actions specified to determine if materials, equipment, or services will meet specified requirements so that equipment will perform satisfactorily in service. The minimum contents of a QA inspection manual for in-service inspection are outlined in [4.1.2](#).

3.1.68**quality control****QC**

Those physical activities conducted to check conformance with specifications in accordance with the QA plan.

3.1.69**R-stamp**

An “R” Certificate of Authorization issued by the National Board.

3.1.70**repair**

The work necessary to restore a vessel to a condition suitable for safe operation at the design conditions. If any of the restorative work results in a change to the design temperature, minimum design metal temperature (MDMT), or MAWP, the work shall be considered an alteration, and the requirements for rerating shall be satisfied. Any welding, cutting, or grinding operation on a pressure-containing component not specifically considered an alteration is considered a repair.

3.1.71**repair organization**

An organization that is qualified to make the repair by meeting the criteria of [4.3](#).

3.1.72**required thickness**

The minimum thickness without corrosion allowance for each element of a pressure vessel based on the appropriate design code calculations and code allowable stress that consider internal and external pressure, mechanical, and structural loadings including the effects of static head. Alternately, required thickness can be reassessed and revised using FFS analysis in accordance with API 579-1/ ASME FFS-1.

3.1.73**rerating**

A change in either the design temperature rating, the MDMT rating, or the MAWP rating of a vessel. The design temperature and MAWP of a vessel may be increased or decreased because of a rerating. Derating (rerating below original design conditions) is a permissible way to provide for additional corrosion allowance.

3.1.74**risk-based inspection****RBI**

An inspection planning methodology that incorporates a risk assessment process that considers both the probability of failure and consequence of failure. The methodology is primarily aimed at managing unacceptable risks, reducing loss of containment failures, and optimization of the inspection strategy.

3.1.75**scanning nondestructive examination**

Examination methods designed to find the thinnest spot or all defects in a specified area of a pressure vessel such as profile radiography of nozzles, scanning ultrasonic techniques, and/or other suitable nondestructive examination (NDE) techniques that will reveal the scope and extent of localized corrosion or other deterioration.

3.1.76**same or similar service**

A designation in which two or more pressure vessels are installed in parallel, comparable, or identical service and their process and environmental conditions have been consistent over a period of years based on the inspection criteria being assessed such that the damage mechanisms and rates of damage are comparable.

EXAMPLE 1 Parallel service: A process or part of a process connected in parallel having comparable configuration with analogous and readily recognized similarities.

EXAMPLE 2 Identical service: A designation where there is agreement that the configuration, process, and operating regime, metallurgy, and environmental conditions are all the same, such that expected degradation characteristics are expected to be the same.

3.1.77**strip lining**

Strips of metal plates welded to the inside of the vessel wall for the purpose of protecting the vessel construction material from interaction with process fluids. Normally the strips are of a more corrosion-resistant or erosion-resistant alloy than the vessel wall and provide additional corrosion/erosion resistance. This is similar to plate lining except narrower strips are used instead of larger plates.

3.1.78**temper embrittlement**

The reduction in fracture toughness due to a metallurgical change that can occur in some low-alloy steels (e.g., 2 1/4Cr-1Mo) as a result of long-term exposure in the temperature range of about 345 °C to 575 °C (650 °F to 1070 °F).

3.1.79**temporary repair**

Repairs made to pressure vessels to restore sufficient integrity to continue safe operation until permanent repairs are conducted (see [8.2](#)).

3.1.80 testing

Within this document, testing generally refers to either pressure testing, whether performed hydrostatically, pneumatically, or a combination hydrostatic/pneumatic, or mechanical testing to determine such data as material hardness, strength, and notch toughness. Testing, however, does not refer to examination using NDE techniques such as liquid penetrant examination (PT), magnetic particle examination (MT), ultrasonic examination (UT), radiographic examination (RT), etc.

3.1.81 tightness test

A pressure test conducted on pressure vessels after maintenance or repair activities to indicate the equipment is leak free and is conducted at a test pressure determined by the owner-operator that is not higher than the MAWP.

3.1.82 transition temperature

The temperature at which a material fracture mode changes from ductile to brittle.

3.1.83 VR-stamp

A "VR" Certificate of Authorization issued by the National Board.

3.2 Acronyms and Abbreviations

For the purposes of this code, the following acronyms and abbreviations apply.

ASME Code	ASME Boiler and Pressure Vessel Code, including its addenda and code cases
CCD	corrosion control document
CDW	controlled-deposition welding
CML	condition-monitoring location
CUF	corrosion under fireproofing
CUI	corrosion under insulation
DMW	dissimilar metal welds
E&P	exploration and production
ECSCC	external chloride stress corrosion cracking
ET	eddy current examination
FFS	fitness-for-service
GMAW	gas metal arc welding
GTAW	gas tungsten arc welding
IOW	integrity operating window
MAT	minimum allowable temperature
MAWP	maximum allowable working pressure
MDMT	minimum design metal temperature
MOC	management of change
MT	magnetic particle examination
NDE	nondestructive examination
PAUT	phased array ultrasonic examination

PEI	pressure equipment integrity
PMI	positive material identification
PQR	procedure qualification record
PRD	pressure-relieving device
PT	liquid penetrant examination
PWHT	postweld heat treatment
QA	quality assurance
QC	quality control
RBI	risk-based inspection
RT	radiographic examination
SMAW	shielded metal arc welding
TOFD	time-of-flight diffraction ultrasonic examination
UT	ultrasonic examination
WPQ	welder performance qualification
WPS	welding procedure specification

4 Owner-operator Inspections Organization

4.1 Owner-operator Organization Responsibilities

4.1.1 General

An owner-operator of pressure vessels shall exercise control of the vessel and pressure relief device inspection program, inspection frequencies, and maintenance. The owner-operator is responsible for the function of an authorized inspection agency in accordance with the provisions of this code. The owner-operator inspection organization shall also control activities relating to the rating, repair, alteration, and engineering assessments of its pressure vessels and relief devices.

4.1.2 Owner-operator Systems and Procedures

An owner-operator organization is responsible for developing, documenting, implementing, executing, and assessing pressure vessel/pressure-relieving device inspection systems, inspection/repair systems, and procedures that meet the requirements of this inspection code. These systems and procedures will be contained and maintained in a quality assurance (QA) inspection/repair management system and shall include at least the following:

- a) organization and reporting structure for inspection personnel;
- b) documenting of inspection and QA procedures;
- c) documenting and reporting inspection, examination, and test results;
- d) developing and documenting inspection plans;
- e) developing and documenting risk-based assessments applied to inspection activities;
- f) establishing and documenting the appropriate inspection intervals;
- g) corrective action for inspection and test results;

- h) internal auditing for compliance with the QA inspection manual;
- i) review and approval of drawings, design calculations, engineering assessments, and specifications for repairs, alterations, and reratings;
- j) ensuring all jurisdictional requirements for pressure vessel inspection, repairs, alterations, and rerating are continuously met;
- k) reporting to the inspector any process changes or other conditions that could affect pressure vessel integrity;
- l) training requirements for inspection personnel regarding inspection tools, techniques, and technical knowledge base;
- m) controls necessary such that only qualified welders and procedures are used for all repairs and alterations;
- n) controls necessary that all repairs and alterations are performed in accordance with this inspection code and applicable specifications;
- o) controls necessary that only qualified NDE personnel and procedures are used;
- p) controls necessary that only materials conforming to the applicable construction code are used for repairs and alterations through material verification and/or positive material identification;
- q) controls necessary that all inspection measurement, NDE, and testing equipment are properly maintained and calibrated;
- r) controls necessary that the work of contract inspection or repair organizations meets the same inspection requirements as the owner-operator organization;
- s) internal auditing requirements for the QC system for PRDs;
- t) management shall have an appropriate requirement and work process to increase the confidence that inspectors have an annual vision test and are capable of reading standard J-1 letters on standard Jaeger eye test type charts for near vision.

4.1.3 Management of Change (MOC)

The owner-operator is responsible for implementing and executing an effective MOC process that reviews and controls changes to either the process or to the hardware. An effective MOC review process is vital to the success of any pressure vessel integrity management program as it allows the inspection group to:

- 1) be able to address issues concerning the adequacy of the pressure equipment design and current condition for the proposed changes;
- 2) anticipate changes in corrosion or other types of damage; and
- 3) update the inspection plan and records to account for those changes.

When pressure equipment integrity may be affected, the MOC process shall include the appropriate inspection, materials/corrosion, and mechanical engineering experience and expertise in order to effectively identify pressure equipment design issues and forecast what changes might affect pressure vessel integrity. The inspection group shall be involved in the approval process for changes that may affect pressure vessel integrity. Changes to the hardware and the process shall be included in the MOC process to improve its effectiveness in managing pressure equipment integrity.

4.1.4 Integrity Operating Windows (IOWs)

The owner-operator should implement and maintain an effective program for creating, establishing, and monitoring integrity operating windows. IOWs are implemented to avoid process parameter exceedances that may have an unanticipated impact on pressure equipment integrity. Future inspection plans and intervals have historically been based on prior measured corrosion rates resulting from past operating conditions. Without an effective IOW and process control program, there often is no warning of changing operating conditions that could affect the integrity of equipment or validation of the current inspection plan. Deviations from and changes of trends within established IOW limits should be brought to the attention of inspection/engineering personnel so they may modify or create new inspection plans depending upon the seriousness of the exceedance.

IOWs should be established for process parameters (both physical and chemical) that could impact equipment integrity if not properly controlled. Examples of the process parameters include temperatures, pressures, fluid velocities, pH, flow rates, chemical or water injection rates, levels of corrosive constituents, chemical composition, etc. IOWs for key process parameters may have both upper and lower limits established, as needed. Particular attention to monitoring IOWs should also be provided during start-ups, shutdowns, and significant process upsets. See API RP 584 for more information on issues that may assist in the development of an IOW program.

4.1.5 Pressure Equipment Integrity (PEI) Incident Investigations

The owner-operator should investigate PEI incidents and near-misses (near-leaks) to determine causes (root, contributing, and direct) that may result in updates to the associated inspection program, IOW, corrosion control document (CCD), etc. If PEI incidents and near-misses are recognized, investigated, and the causes identified, then future leaks and failures of pressure equipment can be minimized or prevented. API RP 585 covers PEI incident investigations and provides owner-operators with guidelines for developing, implementing, sustaining, and enhancing an investigation program for PEI incidents.

4.1.6 Corrosion Control Document (CCD)

The owner-operator may develop a CCD for each process unit in accordance with the work process contained in API RP 970 or alternate methodology outlining all the mechanical integrity damage mechanisms to which the equipment and piping in the process unit are susceptible. The CCDs or alternate documents identifying credible damage mechanisms should be available to stakeholders (e.g., inspectors, mechanical engineers, process engineers) that have a role in fixed equipment integrity.

4.2 Engineer

The pressure vessel engineer is responsible to the owner-operator to make certain that activities involving design, engineering review and analysis, or evaluation of pressure vessels and PRDs are as required in this inspection code and as specified by the owner-operator.

4.3 Repair Organization

The repair organization is responsible to the owner-operator and shall provide the materials, equipment, QC, and workmanship necessary to maintain and repair the vessel or PRD in accordance with the requirements of this inspection code. The repair organization shall meet one of the following criteria:

- a) the holder of a valid ASME Certificate of Authorization that authorizes the use of an appropriate ASME *BPVC* symbol stamp;
- b) the holder of another recognized code of construction certificate that authorizes the use of an appropriate construction code symbol stamp;
- c) the holder of a valid R-stamp issued by the National Board for repair of pressure vessels;
- d) the holder of a valid VR-stamp issued by the National Board for repair and servicing of relief valves;

- e) an owner-operator of pressure vessels and/or relief valves who repairs his or her own equipment in accordance with this code;
- f) a repair contractor whose qualifications are acceptable to the pressure vessel owner-operator;
- g) an individual or organization authorized by the legal jurisdiction to repair pressure vessels or service PRDs.

4.4 Inspector

The inspector is responsible to the owner-operator to assure the inspection, NDE, repairs, alterations, and pressure-testing activities meet API 510 code requirements. The inspector shall be directly involved in the inspection activities, especially visual inspections, which in most cases will require field activities to confirm procedures and inspection plans are followed. The inspector may be assisted in performing inspections by properly trained and qualified individuals acceptable to the owner-operator (e.g., examiners and operating or maintenance personnel). However, all NDE results shall be evaluated and accepted in accordance with API 510 by the inspector, who will then make appropriate recommendations for repairs, replacements, or fitness for continued service. Inspectors shall be certified in accordance with the provisions of Annex B. The inspector can be an employee of the owner-operator or be a contractor acceptable to the owner-operator.

4.5 Examiners

4.5.1 The examiner shall perform the NDE in accordance with job requirements, NDE procedures, and owner-operator specifications.

4.5.2 The examiner does not need API 510 inspector certification and does not need to be an employee of the owner-operator. The examiner does need to be trained and competent in the NDE procedures being used and may be required by the owner-operator to prove competency by holding certifications in those procedures. Examples of certifications that may be required include ASNT SNT-TC-1A, ASNT CP-189, CGSB, and AWS QC1. Inspectors conducting their own examinations with NDE techniques shall also be appropriately qualified in accordance with owner-operator requirements.

4.5.3 The examiner's employer shall maintain certification records of the examiners employed, including dates and results of personnel qualifications. These records shall be available to the inspector, who is responsible to the owner-operator to determine all NDE examiners are properly qualified for the work they perform.

4.6 Other Personnel

Operating, maintenance, engineering (process and mechanical), or other personnel who have special knowledge or expertise related to particular pressure vessels and/or PRDs shall be responsible for timely notification to the inspector or engineer of potential issues that may affect vessel integrity such as the following:

- a) any action that requires MOC;
- b) operations outside defined IOW;
- c) changes in source of feedstock and other process fluids that could increase process-related corrosion rates or introduce new damage mechanisms;
- d) vessel failures, repair actions conducted, and failure analysis reports;
- e) cleaning and decontamination methods used or other maintenance procedures that could affect pressure vessel integrity;
- f) reports that may come to their attention of other plants' experiences with similar or same service pressure vessel failures;

- g) any unusual conditions that may develop (e.g., noises, leaks, vibration, movements, insulation damage, external vessel deterioration, support structure deterioration, and significant bolting corrosion);
- h) any engineering evaluation, including FFS assessments, that might require current or future actions to maintain mechanical integrity until next inspection.

4.7 Inspection Organization Audits

Each owner-operator organization should be audited periodically to determine if the authorized inspection agency is meeting the requirements of this inspection code. The audit team should consist of people experienced and competent in the application of this code. The audit team should typically be from another owner-operator plant site or central office or from a third-party organization experienced and competent in refining and/or petrochemical process plant inspection programs or a combination of third-party and other owner-operator sites. However, periodic self-auditing by those directly involved in the site inspection organization is also recommended.

The audit team should determine in general whether:

- a) the requirements and intent of this inspection code are being met;
- b) owner-operator responsibilities are being properly discharged;
- c) documented inspection plans are in place for covered pressure vessels;
- d) intervals and extent of inspections are adequate for covered pressure vessels;
- e) general types of inspections and surveillance are being adequately applied;
- f) inspection data analysis, evaluation, and recording are adequate;
- g) repairs, reratings alterations, and engineering assessments comply with this code.

The owner-operator should receive a report of the audit team's findings. When nonconformances are found, the owner-operator authorized inspection agency shall take the necessary corrective actions. Each organization needs to establish a system for tracking and completion of corrective actions generated from audit findings. The resolution of the audit findings should be made available to the audit team for review. This information should also be reviewed during subsequent audits.

5 Inspection, Examination, and Pressure-testing Practices

5.1 Inspection Plans

5.1.1 General

An inspection plan shall be established for all pressure vessels and PRDs within the scope of this code. Inspection plans should be developed to cover all credible damage mechanisms, as well as code and jurisdictional requirements and may include multiple types of inspections such as: internal, on-stream, external, and thickness examinations.

5.1.2 Development of an Inspection Plan

5.1.2.1 The inspection plan shall be developed by the inspector and/or engineer. A corrosion specialist shall be consulted to identify credible damage mechanisms and susceptible areas for localized corrosion, cracking, corrosion under insulation/corrosion under fireproofing (CUI/CUF) and metallurgical damage. See [5.4.1](#).

5.1.2.2 The inspection plan is developed from the analysis of several sources of data. Equipment shall be evaluated based on present or credible types of damage mechanisms. The methods and the extent of NDE shall

be evaluated to assure the specified techniques can adequately identify the damage mechanism and the extent and severity of damage. Examinations shall be scheduled at intervals that consider the following:

- a) type of damage mechanism;
- b) rate of damage progression;
- c) tolerance of the equipment to the type of damage;
- d) probability of the NDE method to identify the damage;
- e) maximum intervals as defined in codes and standards;
- f) extent of previous examination (equipment history);
- g) recent operating history, including IOW exceedances;
- h) MOC records that may impact inspection plans;
- i) RBI assessments (where available).

5.1.2.3 The inspection plan shall be developed using the most appropriate sources of information. Inspection plans shall be reviewed and amended as needed. Sources of information may include process unit CCDs, RBI assessments, IOWs, past inspections, past failures (industry, company and site) and risk analysis on vessels in similar service, MOC documents, or documents referenced in [Section 2](#) of this code. See API RP 571, API RP 572, and API RP 583 for more information on issues that may assist in the development of inspection plans.

5.1.3 Contents of an Inspection Plan

The inspection plan shall contain the inspection tasks and schedule required to monitor damage mechanisms and assure the mechanical integrity of the equipment (pressure vessel or PRD). The plan should:

- a) define the type(s) of inspection needed (e.g., internal, external, etc);
- b) identify the next inspection date for each inspection type;
- c) describe the inspection and NDE techniques;
- d) describe the extent and locations of inspection and NDE;
- e) describe the surface-cleaning requirements needed for inspection and examinations;
- f) describe the requirements of any needed pressure test (e.g., type of test, test pressure, and duration);
- g) describe any previously planned repairs;
- h) describe specific considerations due to process or mechanical changes (e.g., MOCs), IOW exceedances, and other operating deviations that occurred since the prior inspection.

Generic inspection plans based on industry standards and practices may be used as a starting point but should be developed to provide sufficient detail to direct the designated inspector to examine all areas of potential concern as indicated by the corrosion specialist and/or process unit CCD as well as historic inspection and maintenance records for the vessel. The inspection plan may include historical and design documents. The contents of the plan should be readily accessible from inspection data systems.