Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration

API 510
EIGHTH EDITION, JUNE 1997
ADDENDUM 1, DECEMBER 1998
ADDENDUM 2, DECEMBER 2000
ADDENDUM 3, DECEMBER 2001

American
Petroleum
Institute

Helping You
Get The Job
Done Right.SM

Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration

Downstream Segment

API 510
EIGHTH EDITION, JUNE 1997
ADDENDUM 1, DECEMBER 1998
ADDENDUM 2, DECEMBER 2000
ADDENDUM 3, DECEMBER 2001

American Petroleum Institute

Helping You Get The Job Done Right.SM

SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Standards Department [telephone (202) 682-8000]. A catalog of API publications and materials is published annually and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the director of the Standards Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the general manager.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

FOREWORD

In December 1931, API and the American Society of Mechanical Engineers (ASME) created the Joint API/ASME Committee on Unfired Pressure Vessels. This committee was created to formulate and prepare for publication a code for safe practices in the design, construction, inspection, and repair of pressure vessels to be used in the petroleum industry. Entitled API/ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases* (commonly called the API/ASME *Code for Unfired Pressure Vessels* or API/ASME Code), the first edition of the code was approved for publication in 1934.

From its inception, the API/ASME Code contained Section I, which covered recommended practices for vessel inspection and repair and for establishing allowable working pressures for vessels in service. Section I recognized and afforded well-founded bases for handling various problems associated with the inspection and rating of vessels subject to corrosion. Although the provisions of Section I (like other parts of the API/ASME Code) were originally intended for pressure vessels installed in the plants of the petroleum industry, especially those vessels containing petroleum gases and liquids, these provisions were actually considered to be applicable to pressure vessels in most services. ASME's Boiler and Pressure Vessel Committee adopted substantially identical provisions and published them as a nonmandatory appendix in the 1950, 1952, 1956, and 1959 editions of Section VIII of the ASME *Boiler and Pressure Vessel Code.*

After the API/ASME Code was discontinued in 1956, a demand arose for the issuance of Section I as a separate publication, applicable not only to vessels built in accordance with any edition of the API/ASME Code but also to vessels built in accordance with any edition of Section VIII of the ASME Code. Such a publication appeared to be necessary to assure industry that the trend toward uniform maintenance and inspection practices afforded by Section I of the API/ASME Code would be preserved. API 510, first published in 1958, is intended to satisfy this need.

The procedures in Section I of the 1951 edition of the API/ASME Code, as amended by the March 16, 1954 addenda, have been updated and revised in API 510. Section I of the API/ASME Code contained references to certain design or construction provisions, so these references have been changed to refer to provisions in the ASME Code. Since the release of the 1960 edition of the *National Board Inspection Code*, elements of the API/ASME Code have also been carried by the *National Board Inspection Code*.

It is the intent of API to keep this publication up to date. All pressure vessel owners and operators are invited to report their experiences in the inspection and repair of pressure vessels whenever such experiences may suggest a need for revising or expanding the practices set forth in API 510.

This edition of API 510 supersedes all previous editions of API 510, *Pressure Vessel Inspection Code: Maintenance Inspection, Rating, and Repair of Pressure Vessels*. Each edition, revision, or addenda to this API standard may be used beginning with the date of issuance shown on the cover page for that edition, revision, or addenda. Each edition, revision, or addenda to this API standard becomes effective 6 months after the date of issuance for
98 equipment that is rerated, reconstructed, relocated, repaired, modified (altered), inspected, and tested per this standard. During the 6-month time between the date of issuance of the edition, revision, or addenda and the effective date, the user shall specify to which edition, revision, or addenda, and the equipment is to be rerated, reconstructed, relocated, repaired, modified (altered), inspected and tested.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to the director of the Standards Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C.
01 20005-4070, standards@api.org.

IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of extreme usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products, published at 54 *Federal Register* 29460 (July 12, 1989).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

CONTENTS

Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration

1 Scope

1.1 GENERAL APPLICATION

This inspection code covers the maintenance inspection, repair, alteration, and rerating procedures for pressure vessels used by the petroleum and chemical process industries. The application of this inspection code is restricted to organizations that employ or have access to an authorized inspection agency as defined in 3.4. Except as provided in 1.2, the use of this inspection code is restricted to organizations that employ or have access to engineering and inspection personnel or organizations that are technically qualified to maintain, inspect, repair, alter, or rerate pressure vessels. Pressure vessel inspectors are to be certified as stated in this inspection code. Since other codes that cover specific industries and general service applications already exist (for example, Sections VI, VII, and XI of the ASME *Boiler and Pressure Vessel Code* and the *National Board Inspection Code*), the industries that fit within the restrictions above have developed this inspection code to fulfill their own specific requirements.

This inspection code applies to vessels constructed in accordance with the API/ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*, Section VIII of the ASME Code, and other recognized pressure vessel codes; to nonstandard vessels; and to other vessels constructed non-code or approved as jurisdictional special. This inspection code is only applicable to vessels that have been placed in service (including items further described in 1.2) and have been inspected by an authorized inspection agency or repaired by a repair organization as defined in 3.15.

Adoption and use of this inspection code does not permit its use in conflict with any prevailing regulatory requirements.

1.2 SPECIFIC APPLICATIONS

1.2.1 All pressure vessels used for Exploration and Production (E&P) service [for example, 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 8. 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 8 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 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 The following are excluded from the specific requirements of this inspection code:

a. Pressure vessels on movable structures covered by other jurisdictional regulations (see Appendix A).

b. All classes of containers listed for exemption from construction in the scope of Section VIII, Division 1, of the ASME Code (see Appendix A).

c. Pressure vessels that do not exceed the following volumes and pressures:

1. Five cubic feet (0.141 cubic meters) in volume and 250 pounds per square inch (1723.1 kilopascals) design pressure.
2. One and a half cubic feet (0.042 cubic meters) in volume and 600 pounds per square inch (4136.9 kilopascals) design pressure (see Appendix A).

1.3 FITNESS-FOR-SERVICE

This inspection code recognizes fitness-for-service concepts for evaluating in-service degradation of pressure-containing components. API RP 579 provides detailed 01
assessment procedures for specific types of degradation that are referenced in this code.

SECTION 2—REFERENCES

The most recent editions of the following standards, codes, and specifications are cited in this inspection code.

API

RP 572 *Inspection of Pressure Vessels*

RP 574 *Inspection of Piping System Components*

98 RP 576 *Inspection of Pressure-Relieving Devices*

RP 579 *Fitness-For-Service*

00 Publ 2201 *Procedures for Welding or Hot Tapping on Equipment in Service*

98 API 510 *Inspector Certification Examination Body of Knowledge*

Guide for Inspection of Refinery Equipment, Chapter II, "Conditions Causing Deterioration or Failures"

Note: This publication is out of print. To obtain a copy please inform the person taking your order that you require this publication for the API 510 Inspector Certification Exam.

ASME[1]

Boiler and Pressure Vessel Code, Section V, Section VI, Section VII, Section VIII, Section IX, and Section XI

NACE[2]

RP 0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments In Corrosive Petroleum Refining Environments* 00

MR 0175 *Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment* 01

National Board[3]

NB-23 *National Board Inspection Code*

WRC[4]

Bulletin 412 *Challenges and Solutions in Repair Welding for Power and Processing Plants*

ASNT[5] 00

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

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

---

[1]ASME International, Three Park Avenue, New York, NY 10016-5990, www.asme.org.

[2]NACE International, P.O. Box 218340, Houston, Texas, 77218-8340, www.nace.org.

[3]National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43229, www.nationalboard.com.

[4]The Welding Research Council, 3 Park Avenue, 27th Floor, New York, NY 10016-5902, www.forengineers.org.

[5]American Society for Nondestructive Testing, Inc., 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio, 43228-0518, www.asnt.org.

SECTION 3—DEFINITIONS

For the purposes of this standard, the following definitions apply.

3.1 alteration: A physical change in any component or a rerating that has design implications that affect the pressure-containing capability of a pressure vessel beyond the scope of the items 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.

3.2 ASME Code*:* Abbreviation and shortened title for the ASME *Boiler and Pressure Vessel Code*. This abbreviated title includes the addenda and code cases of the ASME *Boiler and Pressure Vessel Code*.

The ASME Code is written for new construction; however, most of the technical requirements for design, welding, examination, and materials can be applied in the maintenance inspection, rating, repair, and alteration of operating pressure vessels. When the ASME Code cannot be followed because of its new construction orientation (new or revised material specifications, inspection requirements, certain heat treatments and pressure tests, and stamping and inspection requirements), the engineer or inspector shall conform to this inspection code rather than to the ASME Code. If an item is covered by requirements in the ASME Code and this inspection code or if there is a conflict between the two codes, for vessels that have been placed in service, the requirements of this inspection code shall take precedence over the ASME Code. As an example of the intent of this inspection code, the phrase “applicable requirements of the ASME Code” has been used in this inspection code instead of the phrase “in accordance with the ASME Code.”

3.3 authorized pressure vessel inspector: An employee of an authorized inspection agency who is qualified and certified to perform inspections under this inspection code.

3.4 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 that is licensed or registered to write and actually does write pressure vessel insurance.

c. The inspection organization of an owner or user of pressure vessels who maintains an inspection organization for his equipment only and not for vessels intended for sale or resale.

d. An independent organization or individual that is under contract to and under the direction of an owner-user and that is recognized or otherwise not prohibited by the jurisdiction in which the pressure vessel is used. The owner-user’s inspection program shall provide the controls that are necessary when contract inspectors are used.

3.5 construction code: The code or standard to which a vessel was originally built, such as API/ASME, API, or State Special/non-ASME.

3.6 inspection code: Shortened title for API 510 used in this publication.

3.7 inspector: Refers to an authorized pressure vessel inspector in this document. 98

3.8 jurisdiction: A legally constituted government administration that may adopt rules relating to pressure vessels.

3.9 maximum allowable working pressure: 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 loadings other than pressure.

3.10 minimum allowable shell thickness: The thickness required for each element of a vessel. The minimum allowable shell thickness is based on calculations that consider temperature, pressure, and all loadings.

3.11 on-stream inspection: The inspection used to establish the suitability of a pressure vessel for continued operation. Nondestructive examination (NDE) procedures are used to establish the suitability of the vessel, and the vessel may or may not be in operation while the inspection is being carried out. Because a vessel may be in operation while an on-stream inspection is being carried out, an on-stream inspection means essentially that the vessel is not entered for internal inspection.

3.12 pressure vessel: A container designed to withstand internal or external pressure. This pressure may be imposed by an external source, by the application of heat from a direct or indirect source, or by any combination thereof. This definition includes unfired steam generators and other vapor generating vessels which use heat from the operation of a processing system or other indirect heat source. (Specific limits and exemptions of equipment covered by this inspection code are given in Section 1 and Appendix A.)

3.13 pressure vessel engineer: Shall be one or more persons or organizations acceptable to the owner-user who are knowledgeable and experienced in the engineering disciplines associated with evaluating mechanical and material characteristics which 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.

3.14 quality assurance: All planned, systematic, and preventative actions required to determine if materials, equipment, or services will meet specified requirements so that equipment will perform satisfactorily in service. The contents of a quality assurance inspection manual are outlined in 4.3.

3.15 repair: The work necessary to restore a vessel to a condition suitable for safe operation at the design conditions. If any repair changes the design temperature or pressure, the requirements for rerating shall be satisfied. A repair can be the addition or replacement of pressure or nonpressure parts that do not change the rating of the vessel.

3.16 repair organization: Any one of the following:

a. The holder of a valid ASME Certificate of Authorization that authorizes the use of an appropriate ASME Code symbol stamp.

b. An owner or user of pressure vessels who repairs his or her own equipment in accordance with this inspection code.

c. A contractor whose qualifications are acceptable to the pressure-vessel owner or user and who makes repairs in accordance with this inspection code.

d. An individual or organization that is authorized by the legal jurisdiction.

3.17 rerating: A change in either the temperature ratings or the maximum allowable working pressure rating of a vessel, or a change in both. The maximum allowable working temperature and pressure of a vessel may be increased or decreased because of a rerating, and sometimes a rerating requires a combination of changes. Derating below original design conditions is a permissible way to provide for corrosion. When a rerating is conducted in which the maximum allowable working pressure or temperature is increased or the minimum temperature is decreased so that additional mechanical tests are required, it shall be considered an alteration.

3.18 examiner: A person who assists the API authorized pressure vessel inspector by performing specific NDE on pressure vessels 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 or user. The examiner need not be certified in accordance with API 510 or be an employee of the owner or user but shall be trained and competent in the applicable procedures in which the examiner is involved. In some cases, the examiner may be required to hold other certifications as necessary to satisfy the owner or user requirements. Examples of other certification that may be required are ASNT SNT-TC-1A, or CP189, or American Welding Society[6] Welding Inspector Certification. The examiner's employer shall maintain certification records of the examiners employed, including dates and results of personnel qualifications and shall make them available to the API authorized pressure vessel inspector.

3.19 controlled-deposition welding: Any welding technique used to obtain controlled grain refinement and tempering of the underlying heat affected zone (HAZ) in the base metal. Various controlled-deposition techniques, such as temper-bead (tempering of the layer below the current bead being 00
deposited) and half-bead (requiring removal of one-half of the first layer), are included. Controlled-deposition welding requires control of the entire welding procedure including the joint detail, preheating and post heating, welding technique, and welding parameters. Refer to supporting technical information found in Welding Research Council Bulletin 412.

3.20 fitness-for-service assessment: A methodology whereby flaws and conditions contained within a structure are assessed in order to determine the integrity of the equipment for continued service. 01

3.21 industry-qualified UT shear wave examiner: A person who possesses an ultrasonic shear wave qualification from API or an equivalent qualification approved by the owner/user.

[6]American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33135. www.aws.org.

SECTION 5—INSPECTION PRACTICES

5.1 PREPARATORY WORK

Safety precautions are important in pressure vessel inspection because of the limited access to and the confined spaces of pressure vessels. Occupational Safety and Health Administration (OSHA) regulations pertaining to confined spaces and any other OSHA safety rules should be reviewed and followed, where applicable.

For an internal inspection, the vessel should be isolated by blinds or other positive methods from all sources of liquids, gases, or vapors. The vessel should be drained, purged, cleaned, ventilated, and gas tested before it is entered. Where required, protective equipment should be worn that will protect the eyes, lungs, and other parts of the body from specific hazards that may exist in the vessel.

The nondestructive testing equipment used for the inspection is subject to the safety requirements customarily followed in a gaseous atmosphere. Before the inspection is started, all persons working around the vessel should be informed that people are going to be working inside it. People working inside the vessel should be informed when any work is going to be done on the exterior of it.

The tools and personnel safety equipment needed for the vessel inspection should be checked before the inspection. Other equipment that might be needed for the inspection, such as planking, scaffolding, bosun's chairs, and portable ladders, should be available if needed.

5.2 MODES OF DETERIORATION AND FAILURE

Contaminants in fluids handled in pressure vessels, such as sulfur, chlorine, hydrogen sulfide, hydrogen, carbon, cyanides,
98 acids, water, or other corroding species may react with metals and cause corrosion. Significant stress fluctuations or reversals in parts of equipment are common, particularly at points of high secondary stress. If stresses are high and reversals are frequent, failure of parts may occur because of fatigue. Fatigue failures in pressure vessels may also occur because of cyclic temperature and pressure changes. Locations where metals with different thermal coefficients of expansion are welded together may be susceptible to thermal fatigue. API RP 579, Section 3 provides procedures for the assessment of equipment for resistance to brittle fracture.

01 Other forms of deterioration, such as stress corrosion cracking, hydrogen attack, carburization, graphitization, and erosion, may also occur under special circumstances. These forms of deterioration are more fully discussed in API RP 579, Appendix G.

Deterioration or creep may occur if equipment is subjected to temperatures above those for which it is designed. Since metals weaken at higher temperatures, such deterioration may cause failures, particularly at points of stress concentration. Creep is dependent on time, temperature, stress, and material creep strength, so the actual or estimated levels of these quantities should be used in any evaluations. At elevated temperatures, other metallurgical changes may also take place that may permanently affect equipment.

For developing an inspection plan for equipment operating at elevated temperatures [generally starting in the range of 750° – 1000°F (400° – 540°C), depending on operating conditions and alloy], the following should be considered in assessing the remaining life:

a. Creep deformation and stress rupture.
b. Creep crack growth.
c. Effect of hydrogen on creep.
d. Interaction of creep and fatigue. 98
e. Possible metallurgical effects, including a reduction in ductility.

Numerous NDE techniques can be applied to find and characterize elevated temperature damage. These techniques include visual, surface, and volumetric examination. Additionally, if desired or warranted, samples can be removed for laboratory analysis.

The inspection plan should be prepared in consultation with an engineer having knowledge of elevated temperature and metallurgical effects on pressure vessel materials of construction.

At subfreezing temperatures, water and some chemicals handled in pressure vessels may freeze and cause failure.

At ambient temperatures, carbon, low-alloy, and other ferritic steels may be susceptible to brittle failure. A number of failures have been attributed to brittle fracture of steels that were exposed to temperatures below their transition temperature and to pressures greater than 20 percent of the required hydrostatic test pressure; most brittle fractures, however, have occurred on the first application of a particular stress level (the first hydrotest or overload). Although the potential for a brittle failure because of excessive operating conditions below the transition temperature shall be evaluated, the potential for a brittle failure because of rehydrotesting or pneumatic testing of equipment or the addition of any other additional loadings shall also be evaluated. Special attention should be given to low-alloy steels (especially $2^1/_4$ Cr-1Mo) because they may be prone to temper embrittlement. [*Temper embrittlement* is a loss of ductility and notch toughness due to postweld heat treatment or high-temperature service (above 700°F) (370°C).]

Other forms of deterioration, such as stress corrosion cracking, hydrogen attack, carburization, graphitization, and erosion, may also occur under special circumstances. These forms of deterioration are more fully discussed in Chapter II of the API *Guide for Inspection for Refinery Equipment.*

5.3 CORROSION RATE DETERMINATION

For a new vessel or for a vessel for which service conditions are being changed, one of the following methods shall be employed to determine the vessel’s probable corrosion rate. The remaining wall thickness at the time of the next inspection can be estimated from this rate.

a. A corrosion rate may be calculated from data collected by the owner or user on vessels providing the same or similar service.

b. If data on vessels providing the same or similar service are not available, a corrosion rate may be estimated from the owner’s or user’s experience or from published data on vessels providing comparable service.

c. If the probable corrosion rate cannot be determined by either item a or item b above, on-stream determinations shall be made after approximately 1000 hours of service by using suitable corrosion monitoring devices or actual nondestructive thickness measurements of the vessel or system. Subsequent determinations shall be made after appropriate intervals until the corrosion rate is established.

If it is determined that an inaccurate corrosion rate has been assumed, the rate to be used for the next period shall be increased or may be decreased to agree with the actual rate.

5.4 MAXIMUM ALLOWABLE WORKING PRESSURE DETERMINATION

The maximum allowable working pressure for the continued use of a pressure vessel shall be based on computations that are determined using the latest edition of the ASME Code or the construction code to which the vessel was built. The resulting maximum allowable working pressure from these computations shall not be greater than the original maximum allowable working pressure unless a rerating is performed in accordance with 7.3.

Computations may be made only if the following essential details comply with the applicable requirements of the code being used: head, shell, and nozzle reinforcement designs; material specifications; allowable stresses; weld efficiencies; inspection acceptance criteria; and cyclical service requirements. In corrosive service, the wall thickness used in these computations shall be the actual thickness as determined by inspection (see 5.7) minus twice the estimated corrosion loss before the date of the next inspection, except as modified in
98 6.4. If the actual thickness determined by inspection is greater than the thickness reported in the material test report or the manufacturer’s data report, it must be confirmed by multiple thickness measurements, taken at areas where the thickness of
00 the component in question was most likely affected by the thinning due to forming. The thickness measurement procedure shall be approved by the authorized pressure vessel inspector. Allowance shall be made for other loads in accordance with the applicable provisions of the ASME Code.

5.5 DEFECT INSPECTION

Vessels shall be examined for visual indications of distortion. If any distortion of a vessel is suspected or observed, the overall dimensions of the vessel shall be checked to confirm whether or not the vessel is distorted and, if it is distorted, to determine the extent and seriousness of the distortion. The parts of the vessel that should be inspected most carefully depend on the type of vessel and its operating conditions. The authorized pressure vessel inspector should be familiar with the operating conditions of the vessel and with the causes and characteristics of potential defects and deterioration. (For recommended inspection practices for pressure vessels, see API RP 572.)

Careful visual examination is the most important and the most universally accepted method of inspection. Other methods that may be used to supplement visual inspection include (a) magnetic-particle examination for cracks and other elongated discontinuities in magnetic materials; (b) fluorescent or dye-penetrant examination for disclosing cracks, porosity, or pin holes that extend to the surface of the material and for outlining other surface imperfections, especially in nonmagnetic materials; (c) radiographic examination; (d) ultrasonic thickness measurement and flaw detection; (e) eddy current examination; (f) metallographic examination; (g) acoustic emission testing; hammer testing while not under pressure; and (h) pressure testing. (Section V of the ASME Code can be used as a guide for many of the nondestructive examination techniques.)

Adequate surface preparation is important for proper visual examination and for the satisfactory application of any auxiliary procedures, such as those mentioned above. The type of surface preparations required depends on the individual circumstances, but surface preparations such as wire brushing, blasting, chipping, grinding, or a combination of these preparations may be required.

If external or internal coverings, such as insulation, refractory protective linings, and corrosion-resistant linings, are in good condition and there is no reason to suspect that an unsafe condition is behind them, it is not necessary to remove them for inspection of the vessel; however, it may be advisable to remove small portions of the coverings to investigate their condition and effectiveness and the condition of the metal underneath them.

Where operating deposits, such as coke, are normally permitted to remain on a vessel surface, it is particularly important to determine whether such deposits adequately protect the vessel surface from deterioration. To determine this, spot examinations in which the deposit is thoroughly removed from selected critical areas may be required.

Where vessels are equipped with removable internals, the internals need not be removed completely as long as reasonable assurance exists that deterioration in regions rendered inaccessible by the internals is not occurring to an extent beyond that found in more accessible parts of the vessel.

The owner/user shall specify industry-qualified UT shear wave examiners when the owner/user requires the following: (a) detection of interior surface (ID) breaking planar flaws when inspecting from the external surface (OD); or (b) where detection, characterization, and/or
01 through-wall sizing is required of planar defects. Application examples for the use of such industry-qualified UT shear wave examiners include fitness-for-service and future monitoring of known interior flaws from the external surface. The requirement for use of industry-qualified UT shear wave examiners becomes effective two years after publication in this code or addendum.

5.6 INSPECTION OF PARTS

The following inspections are not all inclusive for every vessel, but they do include the features that are common to most vessels and that are most important. Authorized pressure vessel inspectors must supplement this list with any additional items necessary for the particular vessel or vessels involved.

a. Examine the surfaces of shells and heads carefully for possible cracks, blisters, bulges, and other signs of deterioration. Pay particular attention to the skirt and to support-attachment and knuckle regions of the heads. If evidence of distortion is found, it may be necessary to make a detailed check of the actual contours or principal dimensions of the vessel and to compare those contours and dimensions with the original design details.
b. Examine welded joints and the adjacent heat-affected zones for service-induced cracks or other defects. On riveted vessels, examine rivet head, butt strap, plate, and caulked edge conditions. If rivet-shank corrosion is suspected, hammer testing or spot radiography at an angle to the shank axis may be useful.
c. Examine the surfaces of all manways, nozzles, and other openings for distortion, cracks, and other defects, paying particular attention to the welding used to attach the parts and their reinforcements. Normally, weep holes in reinforcing plates should remain open to provide visual evidence of leakage as well as to prevent pressure build-up in the cavity. Examine accessible flange faces for distortion and determine the condition of gasket-seating surfaces.

API Recommended Practice 574 provides more information on the inspection of piping, valves, and fittings associ-
98 ated with pressure vessels. API Recommended Practice 572 provides more information on pressure vessel inspection.

5.7 CORROSION AND MINIMUM THICKNESS EVALUATION

Corrosion may cause a uniform loss (a general, relatively even wastage of a surface area) or may cause a pitted appearance (an obvious, irregular surface wastage). Uniform corrosion may be difficult to detect visually, and thickness readings may be necessary to determine its extent. Pitted surfaces may be thinner than they appear visually, and when there is uncertainty about the original surface location, thickness determinations may also be necessary.

The minimum actual thickness and maximum corrosion rate for any part of a vessel may be adjusted at any inspection. When the minimum actual thickness or maximum corrosion rate is to be adjusted, one of the following should be considered:

a. Any suitable nondestructive examination, such as ultrasonic or radiographic examination, that will not affect the safety of the vessel may be used as long as it will provide minimum thickness determinations. When a measurement method produces considerable uncertainty, test holes may be drilled, or other nondestructive techniques, such as ultrasonic A-scan, B-scan, or C-scan, may be employed. Profile radiography may be also employed.
b. If suitable openings are available, measurements may be taken through them.
c. The depth of corrosion may be determined by gauging the uncorroded surfaces within the vessel when such surfaces are in the vicinity of the corroded area.
d. For a corroded area of considerable size in which the circumferential stresses govern, the least thickness along the most critical element of the area may be averaged over a length not exceeding the following:
   1. For vessels with inside diameters less than or equal to 60 inches (150 centimeters), one-half the vessel diameter or 20 inches (50 centimeters), whichever is less.
   2. For vessels with inside diameters greater than 60 inches (150 centimeters), one-third the vessel diameter or 40 inches (100 centimeters), whichever is less.

When the area contains an opening, the distance on either side of the opening within which the thicknesses are averaged shall not extend beyond the limits of the reinforcement as defined in the ASME Code. If, because of wind loads or other factors, the longitudinal stresses govern, the least thickness in a similarly determined length of arc in the most critical plane perpendicular to the axis of the vessel also shall be averaged for computation of the longitudinal stresses. The thickness used for determining corrosion rates at the respective locations shall be the average thickness determined as in the preceding. For the purposes of 5.4, the actual thickness as determined by inspection shall be understood to mean the most critical value of the average thickness that has been determined.

e. Widely scattered pits may be ignored as long as the following are true:
   1. No pit depth is greater than one-half the vessel wall thickness exclusive of the corrosion allowance.
   2. The total area of the pits does not exceed 7 square inches (45 square centimeters) within any 8-inch (20-centimeter) diameter circle.
   3. The sum of their dimensions along any straight line within the circle does not exceed 2 inches (5 centimeters).

f. As an alternative to the procedures just described, any components with thinning walls that, because of corrosion or other wastage, are below the minimum required wall thicknesses may be evaluated to determine if they are adequate for continued service. The thinning components may be evaluated by employing the design by analysis methods of Section VIII, Division 2, Appendix 4, of the ASME Code. These methods may also be used to evaluate blend ground areas where defects have been removed. It is important to ensure that there are no sharp corners in blend ground areas to minimize stress concentration effects.

When using this criteria, the stress value used in the original pressure vessel design shall be substituted for the S_m value of Division 2 if the design stress is less than or equal to ⅔-specified minimum yield strength (SMYS) at temperature. If the original design stress is greater than ⅔-specified minimum yield strength at temperature, then ⅔-specified minimum yield strength shall be substituted for S_m. When this approach is to be used, consulting with a pressure vessel engineer experienced in pressure vessel design is required.

g. When the surface at a weld with a joint factor of other than 1.0, as well as surfaces remote from the weld, is corroded, an independent calculation using the appropriate weld joint factor must be made to determine if the thickness at the weld or remote from the weld governs the allowable working pressure. For this calculation, the surface at a weld includes 1 inch (2.5 centimeters) on either side of the weld or twice the minimum thickness on either side of the weld, whichever is greater.

h. When measuring the corroded thickness of ellipsoidal and torispherical heads, the governing thickness may be as follows:

1. The thickness of the knuckle region with the head rating calculated by the appropriate head formula.

2. The thickness of the central portion of the dished region, in which case the dished region may be considered a spherical segment whose allowable pressure is calculated by the code formula for spherical shells.

The spherical segment of both ellipsoidal and torispherical heads shall be considered to be that area located entirely within a circle whose center coincides with the center of the head and whose diameter is equal to 80 percent of the shell diameter. The radius of the dish of torispherical heads is to be used as the radius of the spherical segment (equal to the diameter of the shell for standard heads, though other radii have been permitted). The radius of the spherical segment of ellipsoidal heads shall be considered to be the equivalent spherical radius K_1D, where D is the shell diameter (equal to the major axis) and K_1 is given in Table 5-1. In Table 5-1, h is one-half the length of the minor axis [equal to the inside depth of the ellipsoidal head measured from the tangent line (headbend line)]. For many ellipsoidal heads, $D/2h$ equals 2.0.

Table 5-1—Values of Spherical Radius Factor K_1

$D/2h$	K_1
3.0	1.36
2.8	1.27
2.6	1.18
2.4	1.08
2.2	0.99
2.0	0.90
1.8	0.81
1.6	0.73
1.4	0.65
1.2	0.57
1.0	0.50

Note: The equivalent spherical radius equals K_1D; the axis ratio equals $D/2h$. Interpolation is permitted for intermediate values.

5.8 ASSESSMENT OF INSPECTION FINDINGS

Pressure containing components found to have degradation that could affect their load carrying capability (pressure loads and other applicable loads, e.g., weight, wind, etc., per API RP 579) shall be evaluated for continued service. Fitness-for-service techniques, such as those documented in API RP 579, may be used for this evaluation. The fitness-for-service techniques used must be applicable to the specific degradation observed. The following techniques may be used as an alternative to the evaluation techniques in 5.7.

a. To evaluate metal loss in excess of the corrosion allowance, a fitness-for-service assessment may be performed in accordance with the following sections of API RP 579, as applicable. This assessment requires the use of a future corrosion allowance, which shall be established based on Section 6 of this inspection code.

1. Assessment of General Metal Loss—API RP 579, Section 4 01
2. Assessment of Local Metal Loss—API RP 579, Section 5
3. Assessment of Pitting Corrosion—API RP 579, Section 6

b. To evaluate blisters and laminations, a fitness-for-service assessment should be performed in accordance with API RP 579, Section 7. In some cases this evaluation will require the use of a future corrosion allowance, which shall be established based on Section 6 of this inspection code.

c. To evaluate weld misalignment and shell distortions, a fitness-for-service assessment should be performed in accordance with API RP 579, Section 8.

d. To evaluate crack-like flaws, a fitness-for-service assessment should be performed in accordance with API RP 579, Section 9.

e. To evaluate the effects of fire damage, a fitness-for-service assessment should be performed in accordance with API RP 579, Section 11.

should be calculated for the limiting component. A decision on the number and location of the thickness measurements should consider results from previous inspections, if available, and the potential consequence of loss of containment. Measurements at a number of thickness measurement locations (TMLs) are intended to establish general and localized corrosion rates in different sections of the vessel. A minimal number of TMLs are acceptable when the established rate of corrosion is low and not localized. For pressure vessels susceptible to localized corrosion, it is vital that those knowledgeable in localized corrosion mechanisms be consulted about the appropriate placement and number of TMLs. Additionally, for localized corrosion, it is important that inspections are conducted using scanning methods such as profile radiography, scanning ultrasonics, and/or other suitable NDE methods that will reveal the scope and extent of localized corrosion.

The remaining life of the vessel shall be calculated from the following formula:

$$\text{Remaining life (years)} = \frac{t_{actual} - t_{required}}{\text{corrosion rate}}$$

[inches (mm) per year]

where

t_{actual} = the actual thickness, in inches (millimeters), measured at the time of inspection for a given location or component.

$t_{required}$ = the required thickness, in inches (millimeters), at the same location or component as the t_{actual} measurement, computed by the design formulas (e.g., pressure and structural) before corrosion allowance and manufacturer's tolerance are added.

01 The long-term (LT) corrosion rate shall be calculated from the following formula:

$$\text{Corrosion rate (LT)} = \frac{t_{initial} - t_{actual}}{\text{time (years) between } t_{initial} \text{ and } t_{actual}}$$

The short-term (ST) corrosion rate shall be calculated from the following formula:

$$\text{Corrosion rate (ST)} = \frac{t_{previous} - t_{actual}}{\text{time (years) between } t_{previous} \text{ and } t_{actual}}$$

$t_{initial}$ = the thickness, in inches (millimeters), at the same location as t_{actual} measured at initial installation or at the commencement of a new corrosion rate environment.

$t_{previous}$ = the thickness, in inches (millimeters), at the same location as t_{actual} measured during a previous inspection.

Long-term and short-term corrosion rates should be compared as part of the data assessment. The authorized inspector, in consultation with a corrosion specialist, shall select the corrosion rate that best reflects the current process. 01

A statistical analysis may be used in the corrosion rate and remaining life calculations for the pressure vessel sections. This statistical approach may be applied for assessment of substituting an internal inspection (item b in the preceding), or for determining the internal inspection interval. Care must be taken to ensure that the statistical treatment of data results reflects the actual condition of the vessel section. Statistical analysis is not applicable to vessels with significant localized corrosion.

The determination of corrosion rate may include thickness data collected at more than two different times. Suitable use of short-term versus long-term corrosion rates shall be determined by the authorized pressure vessel inspector. When there is a discrepancy between short-term and long-term corrosion rates, a pressure vessel engineer experienced in corrosion may need to be consulted about the use of these rates, at the discretion of the inspector, for calculating the remaining life and next inspection date.

For a large vessel with two or more zones of differing corrosion rates, each zone may be treated independently regarding the interval between inspections or for substituting the internal inspection with an on-stream inspection. If a multi-zone analysis is used, the zone with the shortest remaining half-life shall be used as the limiting case for setting the internal inspection interval or for substituting the internal inspection with an on-stream inspection.

An alternative method to establish the required inspection interval based on remaining life is by calculation of the projected maximum allowable working pressure (MAWP) of each vessel component as described in 5.4. This procedure may be iterative involving selection of an inspection interval, determination of the corrosion loss expected over the interval, and calculation of the projected MAWP. The inspection interval is within the maximum permitted as long as the projected MAWP of the limiting component is not less than the lower of the name plate or rerated MAWP. The maximum inspection interval using this method is also 10 years.

When problems are experienced with external loading, faulty material, or fabrication the remaining life as determined above shall be reduced to recognize those conditions. If deterioration due to conditions such as those mentioned in 5.2 is detected, the inspection interval must be appropriately adjusted.

If the service conditions of a vessel are changed, the maximum operating pressure, the maximum and minimum operating temperature, and the period of operation until the next inspection shall be established for the new service conditions.

If both the ownership and the location of a vessel are changed, the vessel shall be internally and externally inspected before it is reused, and the allowable conditions of service and the next period of inspection shall be established for the new service.

98 6.5 PRESSURE TEST

When the authorized pressure vessel inspector believes that a pressure test is necessary or when, after certain repairs or alterations, the inspector believes that one is necessary (see 7.2.9), the test shall be conducted at a pressure in accordance with the construction code used for determining the maximum allowable working pressure. To minimize the risk of brittle fracture during the test, the metal temperature should be maintained at least 30°F (17°C) above the minimum
98 design metal temperature for vessels that are more than 2 inches (5 centimeters) thick, or 10°F (6°C) above for vessels that have a thickness of 2 inches (5 centimeters) or less. The test temperature need not exceed 120°F (50°C) unless there is information on the brittle characteristics of the vessel material indicating that a lower test temperature is acceptable or a higher test temperature is needed.[5]

Pneumatic testing may be used when hydrostatic testing is impracticable because of temperature, foundation, refractory lining, or process reasons; however, the potential personnel and property risks of pneumatic testing shall be considered before such testing is carried out. As a minimum, the inspection precautions contained in the ASME Code shall be applied in any pneumatic testing. Before applying a hydrostatic test to equipment, consideration should be given to the supporting structure and the foundation design.

When a pressure test is to be conducted in which the test pressure will exceed the set pressure of the safety relief valve with the lowest setting, the safety relief valve or valves should be removed. An alternative to removing the safety relief valves is to use test clamps to hold down the valve disks. Applying an additional load to the valve spring by turning the compression screw is not recommended. Other appurtenances, such as gauge glasses, pressure gauges, and rupture disks, that may be incapable of withstanding the test pressure should also be removed or should be blanked off or vented. When the pressure test has been completed, pressure relief devices of the proper settings and other appurtenances removed or made inoperable during the pressure test shall be reinstalled or reactivated.

98 6.6 PRESSURE-RELIEVING DEVICES

Pressure relief valves shall be tested and repaired by repair organizations experienced in valve maintenance. Each repair organization shall have a fully documented quality control system. As a minimum, the following requirements and pieces of documentation should be included in the quality control system:

a. Title page.
b. Revision log. 98
c. Contents page.
d. Statement of authority and responsibility.
e. Organizational chart.
f. Scope of work.
g. Drawings and specification controls.
h. Material and part control.
i. Repair and inspection program.
j. Welding, nondestructive examination, and heat treatment procedures.
k. Valve testing, setting, leak testing, and sealing.
l. General example of the valve repair nameplate.
m. Procedures for calibrating measurement and test gauges.
n. Controlled copies of the manual.
o. Sample forms.
p. Repair personnel training or qualifications.

Each repair organization shall also have a fully documented training program that shall ensure that repair personnel are qualified within the scope of the repairs.

Pressure relief valves shall be tested at intervals that are frequent enough to verify that the valves perform reliably. This may include testing pressure relief valves on newly installed equipment. Pressure-relieving devices should be tested and maintained in accordance with API Recommended Practice 576. Other pressure-relieving devices, such as rup- 98
ture disks and vacuum-breaker valves, shall be thoroughly examined at intervals determined on the basis of service.

The intervals between pressure-relieving-device testing or inspection should be determined by the performance of the devices in the particular service concerned. Test or inspection intervals on pressure-relieving devices in typical process services should not exceed 5 years, unless service experience indicates that a longer interval is acceptable. For clean (nonfouling), noncorrosive services, maximum intervals may be increased to 10 years. When service records indicate that a pressure-relieving device was heavily fouled or stuck in the last inspection or test, the service interval shall be reduced if the review shows that the device may not perform reliably in the future. The review should include an effort to determine the cause of the fouling or the reasons for the relief device not operating properly.

6.7 RECORDS 98

Pressure vessel owners and users shall maintain permanent and progressive records of their pressure vessels. Permanent records will be maintained throughout the service life of each vessel; progressive records will be regularly updated to include new information pertinent to the operation, inspection, and maintenance history of the vessel.

[5]For vessels without minimum design metal temperature, the minimum acceptable operating temperature should be used in lieu of the minimum design metal temperature.

01 Pressure vessel records shall contain four types of vessel information pertinent to mechanical integrity as follows:

a. Construction and design information. For example, equipment serial number or other identifier, manufacturers' data reports (MDRs), design specification data, design calculations (where MDRs are unavailable), and construction drawings. For pressure vessels that have no nameplate and minimal or no design and construction documentation, the following steps may be used to verify operating integrity:

i. Perform inspection to determine condition of the vessel. Make any necessary repairs.

ii. Define design parameters and prepare drawings and calculations.

iii. Base calculations on applicable codes and standards and condition of the vessel following any repairs. Do not use allowable stress values based on design factor of 3.5.

00 See ASME Code Section VIII, Division 1, paragraph UG-10(c) for guidance on evaluation of unidentified materials. If UG-10 (c) is not followed, then for carbon steels, use allowable stresses for SA-283 Grade C; and for alloy and nonferrous materials, use x-ray fluorescence analysis to determine material type on which to base allowable stress values.

When extent of radiography originally performed is not known, use joint factor of 0.7 for butt welds, or consider performing radiography if a higher joint factor is required. (Recognize that performing radiography on welds in a vessel with minimal or no design and construction documentation may result in the need for a fitness-for-service assessment and significant repairs.)

iv. Attach a nameplate or stamping showing the maximum allowable working pressure and temperature, minimum allowable temperature, and date. 00

v. Perform pressure test as soon as practical, as required by code of construction used for design calculations.

b. Operating and inspection history. For example, operating conditions, including process upsets that may affect mechanical integrity, inspection reports, and data for each type of inspection conducted (for example, internal, external, thickness measurements), and inspection recommendations for repair. See Appendix C for sample pressure vessel inspection records. Inspection reports shall document the date of each inspection and/or test, the date of the next scheduled inspection, the name of the person who performed the inspection and/or test, the serial number or other identifier of the equipment inspected, a description of the inspection and/or test performed, and the results of the inspection and/or test.

c. Repair, alteration, and rerating information. For example, (1) repair and alteration forms like that shown in Appendix D, (2) reports indicating that equipment still in-service with identified deficiencies or recommendations for repair are suitable for continued service until repairs can be completed, and (3) rerating documentation (including rerating calculations, new design conditions, and evidence of stamping).

d. Fitness-for-service assessment documentation requirements are described in API RP 579, Section 2.8. Specific documentation requirements for the type of flaw being assessed are provided in the appropriate section of API RP 01 579.

7.2.8 Material

The material used in making repairs or alterations shall conform to the applicable section of the ASME Code. The material shall be of known weldable quality and be compatible with the original material. Carbon or alloy steel with a carbon content over 0.35 percent shall not be welded.

7.2.9 Inspection

Acceptance criteria for a welded repair or alteration should include nondestructive examination techniques that are in accordance with the applicable sections of the ASME Code or another applicable vessel rating code. Where use of these nondestructive examination techniques is not possible or practical, alternative nondestructive examination methods may be used provided they are approved by the pressure vessel engineer and the authorized pressure vessel inspector.

For vessels constructed of materials that may be subject to brittle fracture (per API RP 579, or other analysis) from either normal or abnormal service (including startup, shutdown, and
01 pressure testing), appropriate inspection should be considered after welded repairs or alterations. Flaws, notches, or other stress risers could initiate a brittle fracture in subsequent pressure testing or service. Magnetic particle testing and other effective surface NDE methods should be considered. Inspection techniques should be designed to detect critical flaws as determined by a fitness-for-service assessment.

7.2.10 Testing

After repairs are completed, a pressure test shall be applied if the authorized pressure vessel inspector believes that one is necessary. A pressure test is normally required after an alteration. Subject to the approval of the jurisdiction (where the jurisdiction's approval is required), appropriate nondestructive examinations shall be required where a pressure test is not performed. Substituting nondestructive examination procedures for a pressure test after an alteration may be done only after a pressure vessel engineer experienced in pressure vessel design and the authorized pressure vessel inspector have been consulted.

For cases where UT is substituted for radiographic inspection, the owner/user shall specify industry-qualified UT shear wave examiners for closure welds that have not been pressure tested and for weld repairs identified by the
01 pressure vessel engineer or authorized inspector. The requirement for use of industry-qualified UT shear wave examiners becomes effective two years after publication in this code or addendum.

7.2.11 Filler Metal

The filler metal used for weld repairs should have minimum specified tensile strength equal to or greater than the minimum specified tensile strength of the base metal. If a filler metal is used that has a minimum specified tensile strength lower than the minimum specified tensile strength of the base metal, the compatibility of the filler metal chemistry with the base metal chemistry shall be considered regarding weldability and service degradation. In addition, the following shall be met:

a. The repair thickness shall not be more than 50 percent of the required base metal thickness, excluding corrosion allowance.
b. The thickness of the repair weld shall be increased by a ratio of minimum specified tensile strength of the base metal and minimum specified tensile of the filler metal used for the repair.
c. The increased thickness of the repair shall have rounded corners and shall be blended into the base metal using a 3-to-1 taper.
d. The repair shall be made with a minimum of two passes.

7.3 RERATING

Rerating a pressure vessel by changing its temperature ratings or its maximum allowable working pressure may be done only after all of the following requirements have been met:

a. Calculations from either the manufacturer or an owner-user pressure vessel engineer (or his designated representative) experienced in pressure vessel design, fabrication, or inspection shall justify rerating.
b. A rerating shall be established in accordance with the requirements of the construction code to which the pressure vessel was built or by computations that are determined using the appropriate formulas in the latest edition of the ASME Code if all of the essential details comply with the applicable requirements of the code being used. If the vessel was designed to an edition or addendum of the ASME Code earlier than the 1999 Addenda and was not designed to Code 00
Case 2290 or 2278, it may be rerated to the latest edition/addendum of the ASME Code if permitted by Figure 7-1.
c. Current inspection records verify that the pressure vessel is satisfactory for the proposed service conditions and that the corrosion allowance provided is appropriate. An increase in allowable working pressure or temperature shall be based on thickness data obtained from a recent internal or on-stream inspection.
d. If the pressure vessel has at some time been pressure tested to a test pressure equal to or higher than the pressure test pressure required by the latest edition or addendum of the ASME Code, or the vessel integrity is maintained by special nonde- 00
structive evaluation inspection techniques in lieu of testing, a pressure test for the rerated condition is not required.
e. The pressure vessel inspection and rerating is acceptable to the authorized pressure vessel inspector.

The pressure vessel rerating will be considered complete when the authorized pressure vessel inspector oversees the attachment of an additional nameplate or additional stamping that carries the following information:

Rerated by ____
Maximum Allowable Working Pressure __________ psi at ____ F°
Date __________________

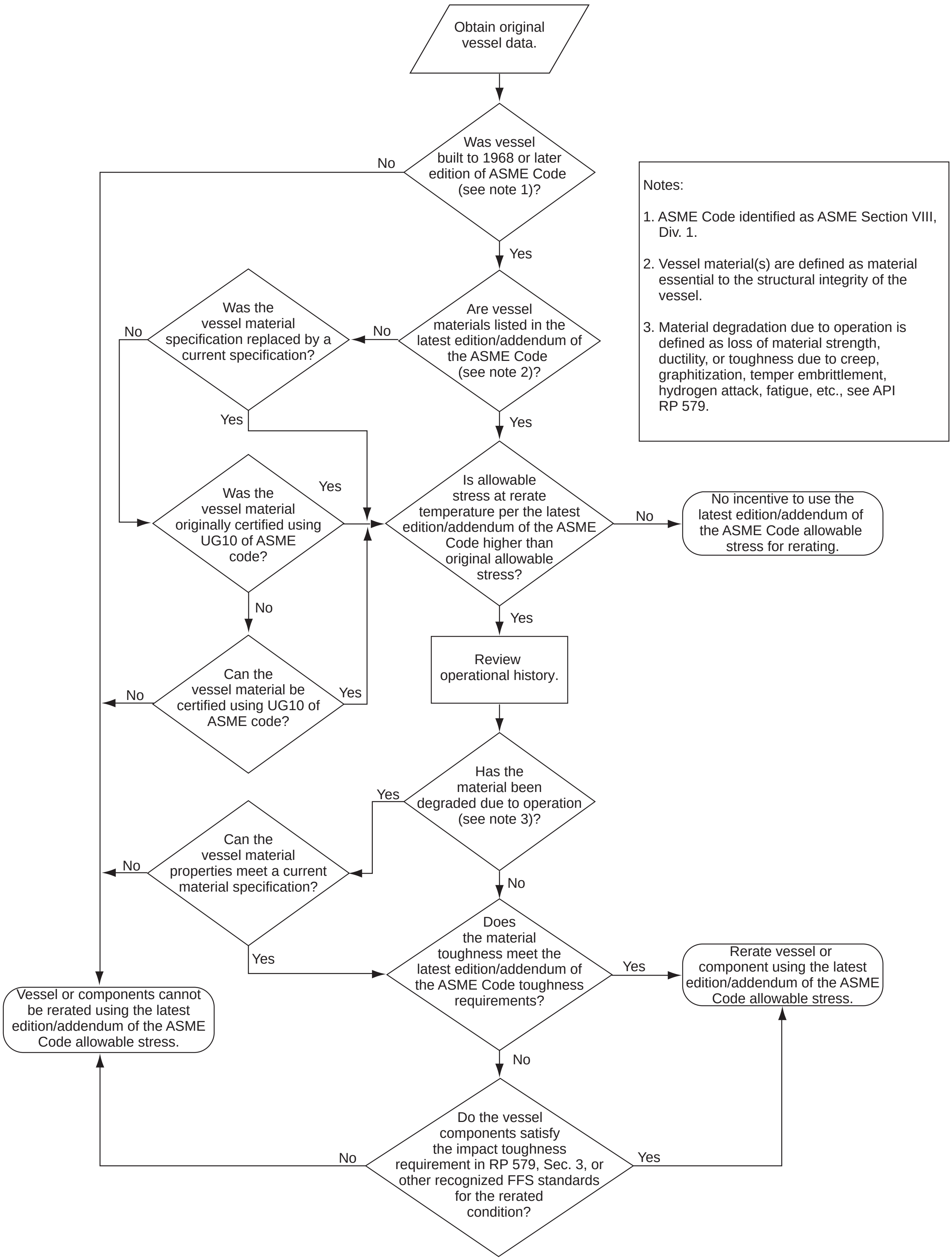

Figure 7-1—Rerating Vessels Using the Latest Edition or Addendum of the ASME Code Allowable Stresses

00

SECTION 8—ALTERNATIVE RULES FOR EXPLORATION AND PRODUCTION PRESSURE VESSELS

8.1 SCOPE AND SPECIFIC EXEMPTIONS

This section sets forth the minimum alternative inspection rules for pressure vessels that are exempt from the rules set forth in Section 6 except as referenced in paragraphs 8.4 and 8.5. Except for Section 6, all of the sections in this inspection code are applicable to Exploration and Production (E&P) pressure vessels. These rules are provided because of the vastly different characteristics and needs of pressure vessels used for E&P service. Typical E&P services are vessels associated with drilling, production, gathering, transportation, and treatment of liquid petroleum, natural gas, natural gas liquids, and associated salt water (brine).

The following are specific exemptions:

a. Portable pressure vessels and portable compressed gas containers associated with construction machinery, pile drivers, drilling rigs, well-servicing rigs and equipment, compressors, trucks, ships, boats, and barges shall be treated, for inspection and recording purposes, as a part of that machinery and shall be subject to prevailing rules and regulations applicable to that specific type of machine or container.
b. Pressure vessels referenced in Appendix A are exempt from the specific requirements of this inspection code.

8.2 GLOSSARY OF TERMS

8.2.1 class of vessels: Pressure vessels used in a common circumstance of service, pressure, and risk.

8.2.2 inspection: The external, internal, or on-stream evaluation (or any combination of the three) of a pressure vessel's condition.

a. **external inspection:** Evaluation performed from the outside of a pressure vessel using visual procedures to establish the suitability of the vessel for continued operation. The inspection may, or may not, be carried out while the vessel is in operation.
b. **internal inspection:** Evaluation performed from the inside of a pressure vessel using visual and/or nondestructive examination procedures to establish the suitability of the vessel for continued operation.

c. **on-stream inspection:** Evaluation performed from the outside of a pressure vessel using nondestructive examination procedures to establish the suitability of the vessel for continued operation. The vessel may, or may not, be in operation while the inspection is carried out.

d. **progressive inspection:** An inspection whose scope (coverage, interval, technique, and so forth) is increased as a result of inspection findings.

8.2.3 Section 8 vessel: A pressure vessel which is exempted from the rules set forth in Section 6 of this document.

8.3 INSPECTION PROGRAM

Each owner or user of Section 8 vessels shall have an inspection program that will assure that the vessels have sufficient integrity for the intended service. Each E&P owner or user shall have the option of employing, within the limitations of the jurisdiction in which the vessels are located, any appropriate engineering, inspection, classification, and recording systems which meet the requirements of this document.

8.3.1 On-Stream or Internal Inspections

a. Either an on-stream inspection or an internal inspection may be used interchangeably to satisfy inspection requirements. An internal inspection is required when the vessel integrity cannot be established with an on-stream inspection. When an on-stream inspection is used, a progressive inspection shall be employed.
b. In selecting the technique(s) to be utilized for the inspection of a pressure vessel, both the condition of the vessel and the environment in which it operates should be taken into consideration. The inspection may include any number of nondestructive techniques, including visual inspection, as deemed necessary by the owner-user.
c. At each on-stream or internal inspection, the remaining corrosion-rate life shall be determined as described in 8.3.2.

8.3.2 Remaining Corrosion Rate Life Determination

For a new vessel, a vessel for which service conditions are being changed, or existing vessels, the remaining corrosion rate life shall be determined for each vessel or estimated for a class of vessels based on the following formula:

$$\text{Remaining life (years)} = \frac{t_{\text{actual}} - t_{\text{required}}}{\text{corrosion rate}}$$

[inches (mm) per year]

where

t_{actual} = the actual thickness, in inches (millimeters), measured at the time of inspection for a given location or component used to determine the minimum allowable thickness, 01

$t_{required}$ = the required thickness, in inches (millimeters), at the same location or component as the t_{actual} measurement, obtained by one of the following methods:

a. The nominal thickness in the uncorroded condition, less the specified corrosion allowance.

b. The original measured thickness, if documented, in the uncorroded condition, less the specified corrosion allowance.
c. Calculations in accordance with the requirements of the construction code to which the pressure vessel was built, or by computations that are determined using the appropriate formulas in the latest edition of the ASME Code, if all of the essential details comply with the applicable requirements of the code being used.

corrosion rate = loss of metal thickness, in inches (millimeters), per year. For vessels in which the corrosion rate is unknown, the corrosion rate shall be determined by one of the following methods:

1. A corrosion rate may be calculated from data collected by the owner or user on vessels in the same or similar service.
2. If data on vessels providing the same or similar service is not available, a corrosion rate may be estimated from the owner's or user's experience or from published data on vessels providing comparable service.
3. If the probable corrosion rate cannot be determined by either item a or item b above, on-stream determination shall be made after approximately 1000 hours of service by using suitable corrosion monitoring devices or actual nondestructive thickness measurements of the vessel or system. Subsequent determinations shall be made after appropriate intervals until the corrosion rate is established.

The remaining life shall be determined by an individual experienced in pressure vessel design and/or inspection. If it is determined that an inaccurate assumption has been made for either corrosion rate or thickness, the remaining life shall be increased or decreased to agree with the actual rate or thickness.

Other failure mechanisms (stress corrosion, brittle fracture, blistering, and so forth,) shall be taken into account in determining the remaining life of the vessel.

8.3.3 External Inspections

The following apply to external inspections:

a. The external visual inspection shall, at least, determine the condition of the shell, heads, nozzles, exterior insulation, supports and structural parts, pressure-relieving devices, allowance for expansion, and general alignment of the vessel on its supports. Any signs of leakage should be investigated so that the sources can be established. It is not necessary to remove insulation if the entire vessel shell is maintained at a temperature sufficiently low or sufficiently high to prevent the condensation of moisture. Refer to API Recommended Practice 572 for guidelines on external vessel inspections.
b. Buried sections of vessels shall be monitored to determine their external environmental condition. This monitoring shall be done at intervals that shall be established based on corrosion-rate information obtained during maintenance activity on adjacent connected piping of similar material, information from the interval examination of similarly buried corrosion test coupons of similar material, information from representative portions of the actual vessel, or information from a sample vessel in similar circumstances.
c. Vessels that are known to have a remaining life of over 10 years or that are protected against external corrosion—for example, (1) vessels insulated effectively to preclude the entrance of moisture, (2) jacketed cryogenic vessels, (3) vessels installed in a cold box in which the atmosphere is purged with an inert gas, and (4) vessels in which the temperature being maintained is sufficiently low or sufficiently high to preclude the presence of water—do not need to have insulation removed for the external inspection; however, the condition of their insulating system or their outer jacketing, such as the cold box shell, shall be observed at least every 5 years and repaired if necessary.

8.3.4 Vessel Classifications

The pressure vessel owner or user shall have the option to establish vessel inspection classes by grouping vessels into common classes of service, pressure, and/or risk. Vessel classifications shall be determined by an individual(s) experienced in the criteria outlined in the following. If vessels are grouped into classes (such as lower and/or higher risk), at a minimum, the following shall be considered to establish the risk class:

a. Potential for vessel failure, such as, minimum design metal temperature; potential for cracking, corrosion, and erosion; and the existence of mitigation factors.
b. Vessel history, design, and operating conditions, such as, the type and history of repairs or alterations, age of vessel, remaining corrosion allowance, properties of contained fluids, operating pressure, and temperature relative to design limits.
c. Consequences of vessel failure, such as, location of vessel relative to employees or the public, potential for equipment damage, and environmental consequences.

8.3.5 Inspection Intervals

The following apply to inspection intervals:

a. Inspections shall be performed at intervals determined by the vessel's risk classification. The inspection intervals for the two main risk classifications (lower and higher) are defined below. When additional classes are established, inspection and sampling intervals shall be set between the higher risk and lower risk classes as determined by the owner or user. If the owner or user decides to not classify vessels into risk classes, the inspection requirements and intervals of higher-risk vessels shall be followed.
b. Lower-risk vessels shall be inspected as follows:
   1. Inspections on a representative sample of vessels in that class, or all vessels in that class, may be performed.

APPENDIX E—TECHNICAL INQUIRIES

E.1 Introduction

API will consider written requests for interpretations of API 510. API staff will make such interpretations in writing after consultation, if necessary, with the appropriate committee officers and the committee membership. The API committee responsible for maintaining API 510 meets regularly to consider written requests for interpretations and revisions and to develop new criteria as dictated by technological development. The committee's activities in this regard are limited strictly to interpretations of the standard or to the consideration of revisions to the present standard on the basis of new data or technology. As a matter of policy, API does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity; thus, accordingly, inquiries requiring such consideration will be returned. Moreover, API does not act as a consultant on specific engineering problems or on the general understanding or application of the rules. If, based on the inquiry information submitted, it is the opinion of the committee that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

All inquiries that cannot be understood because they lack information will be returned.

E.2 Inquiry Format

Inquiries shall be limited strictly to requests for interpretation of the standard or to the consideration of revisions to the standard on the basis of new data or technology. Inquiries shall be submitted in the following format:

a. Scope. The inquiry shall involve a single subject or closely related subjects. An inquiry letter concerning unrelated subjects will be returned.

b. Background. The inquiry letter shall state the purpose of the inquiry, which shall be either to obtain an interpretation of the standard or to propose consideration of a revision to the standard. The letter shall provide concisely the information needed for complete understanding of the inquiry (with sketches, as necessary). This information shall include reference to the applicable edition, revision, paragraphs, figures, and tables.

c. Inquiry. The inquiry shall be stated in a condensed and precise question format. Superfluous background information shall be omitted from the inquiry, and where appropriate, the inquiry shall be composed so that "yes" or "no" (perhaps with provisos) would be a suitable reply. This inquiry statement should be technically and editorially correct. The inquirer shall state what he believes the standard requires. If in his opinion a revision to the standard is needed, he shall provide recommended wording.

The inquiry should be typed; however, legible handwritten inquiries will be considered. The name and the mailing address of the inquirer must be included with the proposal. The proposal shall be submitted to the following address: director of the Standards Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005-4070, 01
standards@api.org.

Additional copies are available through Global Engineering Documents at (800) 854-7179 or (303) 397-7956

Information about API Publications, Programs and Services is available on the World Wide Web at: http://www.api.org

American
Petroleum
Institute

1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

Product No. C510A3