MECHANICAL INTEGRITY:

FIXED EQUIPMENT STANDARDS & RECOMMENDED PRACTICES

JANUARY 2019

CONTENTS

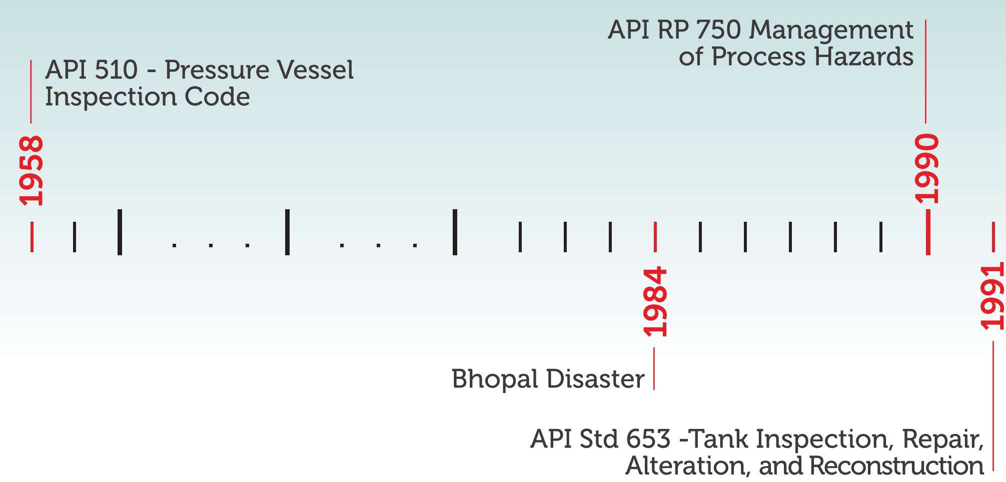
AN INTRODUCTION TO MECHANICAL INTEGRITY: FIXED EQUIPMENT

Mechanical Integrity (MI) can be defined as the management of critical process equipment to ensure it is designed and installed correctly and that it is operated and maintained properly. MI is 1 of the 14 elements included in the OSHA Process Safety Management standard. MI includes equipment/assets such as pressure vessels, storage tanks, piping systems, and associated hardware (valves, fittings, etc.), relief devices, and emergency shutdown/control systems

MI encompasses the activities necessary to ensure that equipment/assets are designed, fabricated, installed, operated and maintained in a way that provides the desired performance in a safe, environmentally protected, and reliable fashion.

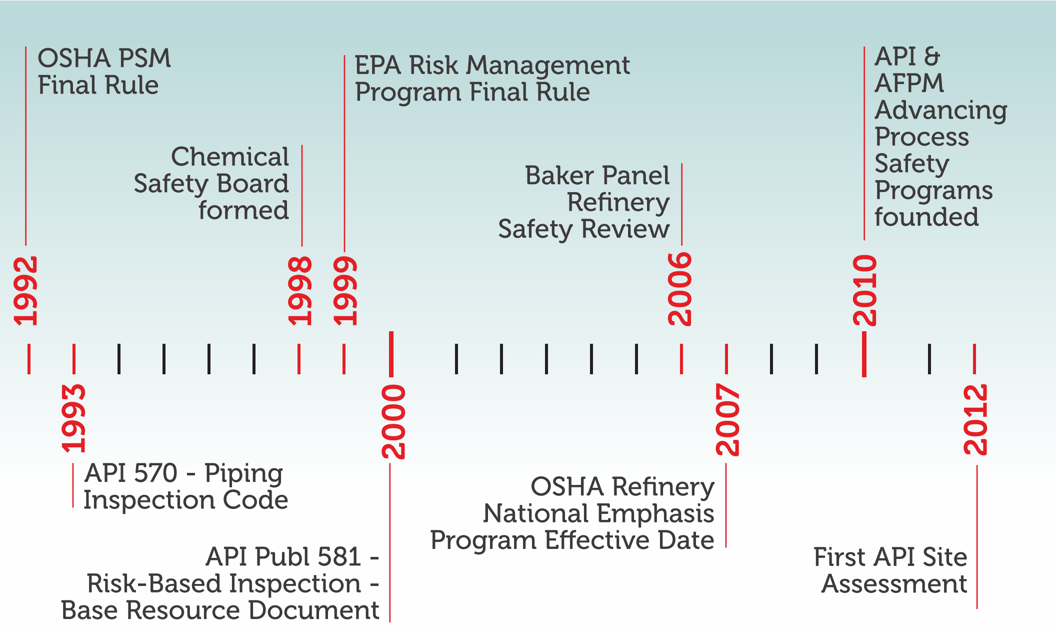
In the early 1900s, the need to protect workers and the public from the hazards of boilers and pressurized equipment became apparent, so the industry began to develop design standards. After World War II, a number of industry consensus standards were developed by the National Board Inspection Code

TIMELINE OF IMPORTANT MI EVENTS



(NBIC). By the 1980s, the American Petroleum Institute (API) led industry efforts to develop and implement important MI standards, while the federal government also turned its regulatory attention to MI. API, industry, and the regulators have addressed MI head-on since the early-90s, particularly through the Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) program and the Environmental Protection Agency's (EPA) Risk Management Program (RMP), as well as many additional Standards and Recommended Practices (RPs) published by API.

API and AFPM jointly manage the Advancing Process Safety Initiative which is a joint effort to further advance process safety improvements in refineries and petrochemical plants by providing industry with more opportunities to communicate and share experiences and knowledge. Through this partnership, API and AFPM collect process safety performance metrics, share process safety event information, produce and share Practices Sharing and Hazard Identification documents, host Regional Networks meetings, address issue-specific topics such as



Mechanical Integrity and Human Reliability. API also operates a program that assesses a site's Process Safety systems using independent and credible third party teams of industry-qualified process safety expert assessors. Through the use of industry developed protocols, the assessments evaluate both the quality of the written programs and the effectiveness of field implementation, including a site's Mechanical Integrity program.

API has taken an active role in the creation and propagation of MI information and materials. API committees create Standards and RPs that address MI, largely in the areas of inspection and repair of pressure vessels, aboveground storage tanks, equipment reliability, corrosion, mechanics, and reducing capital and maintenance costs.

These documents provide expectations on implementation and compliance, and many contain requirements in the form of "shall" statements, as determined by industry consensus committees. The creation of these industry-wide standards allows for procedures and practices to seamlessly continue at a company despite challenges presented by a dynamic and changing workforce. Institutional knowledge is no longer limited to a few senior employees, and "gut feeling" is replaced with tried-and-true methods contained in the Standards and RPs. Because they must be applicable to many different sites, API committees write their documents in a way that still allows managers to operate in the most safe and efficient manner as dictated by their own facility's needs.

The motivation for writing API MI Standards and RPs was based on safety, competition, and budgeting challenges, as well as myriad external pressures, but the adoption of these documents has led to more valuable inspection data, increased ability to handle changing process conditions, and the scheduling and budgeting benefit of planned inspections, among other things. API Standards and RPs are periodically reviewed so that they remain relevant and valuable to the industry, and a review of past standards and updates shows how well the industry has adapted to changing times and MI science.

This brochure is designed to acquaint the reader with the MI resources available in API Standards, Recommended Practices, and other helpful resources. The information is organized topically, and "companion" documents meant to complement one another are highlighted and listed together.

EQUIPMENT

Pressure Vessels

API 510

Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration
(Includes Addendum 1 (2017) and Addendum 2 (2018))

Covers the in-service inspection, repair, alteration, and rerating activities for pressure vessels and the pressure-relieving devices protecting these vessels.

This inspection code applies to most refining and chemical process vessels that have been placed in service. This includes:

- vessels constructed in accordance with an applicable construction code;
- vessels constructed without a construction code (non-code)—a vessel not fabricated to a recognized construction code and meeting no known recognized standard;
- vessels constructed and approved as jurisdictional special based upon jurisdiction acceptance of particular design, fabrication, inspection, testing, and installation;
- non-standard vessels—a vessel fabricated to a recognized construction code but has lost its nameplate or stamping.

Companion document to RP 572

10th Edition | May 2014

RP 572

Inspection Practices for Pressure Vessels

Supplements API 510 by providing pressure vessel inspectors with information that can improve skills and increase basic knowledge of inspection practices. This recommended practice (RP) describes inspection practices for the various types of pressure vessels (e.g. drums, heat exchangers, columns, reactors, air coolers, spheres) used in petroleum refineries and chemical plants. This RP addresses vessel components, inspection planning processes, inspection intervals, methods of inspection and assessment, methods of repair, records, and reports. API 510 has requirements and expectations for inspection of pressure vessels.

Companion document to API 510

4th Edition | December 2016

Piping Systems

API 570

Piping Inspection Code: In-Service Inspection, Rating, Repair, and Alteration of Piping Systems

(Includes Addendum 1 (2017) and Addendum 2 (2018))

Covers inspection, rating, repair, and alteration procedures for metallic and fiberglass reinforced plastic (FRP) piping systems and their associated pressure relieving devices that have been placed in service. This inspection code applies to all hydrocarbon and chemical process piping covered in 1.2.1 that have been placed in service unless specifically designated as optional per 1.2.2. This publication does not cover inspection of specialty equipment including instrumentation, exchanger tubes, and control valves.

However, this piping code could be used by owner/users in other industries and other services at their discretion. Process piping systems that have been retired from service and abandoned in place are no longer covered by this "in-service inspection" Code. However abandoned in place piping may still need some amount of inspection and/or risk mitigation to assure that it does not become a process safety hazard because of continuing deterioration. Process piping systems that are temporarily out of service but have been mothballed (preserved for potential future use) are still covered by this Code.

Companion document to RP 574

4th Edition | February 2016

RP 574

Inspection Practices for Piping System Components

Supplements API 570 by providing piping inspectors with information that can improve skill and increase basic knowledge of inspection practices. This recommended practice describes inspection practices for piping, tubing, valves (other than control valves), and fittings used in petroleum refineries and chemical plants. Common piping components, valve types, pipe joining methods, inspection planning processes, inspection intervals and techniques, and types of records are described to aid the inspectors in fulfilling their role implementing API 570. This publication does not cover inspection of specialty items, including instrumentation, furnace tubulars, and control valves.

Companion document to API 570

4th Edition | November 2016

RP 578

Guidelines for a Material Verification Program (MVP) for New and Existing Areas

Provides the guidelines for a material and quality assurance system to verify that the nominal composition of alloy components within the pressure envelope of a piping system is consistent with the selected or specified construction materials to minimize the potential for catastrophic release of toxic or hazardous liquids or vapors.

This RP provides the guidelines for material control and material verification programs on ferrous and nonferrous alloys during the construction, installation, maintenance, and inspection of new and existing process piping systems covered by the ASME B31.3 and API 570 piping codes. This RP applies to metallic alloy materials purchased for use either directly by the owner/user or indirectly through vendors, fabricators, or contractors and includes the supply, fabrication, and erection of these materials. Carbon steel components specified in new or existing piping systems are not specifically covered under the scope of this document unless minor/trace alloying elements are critical to component corrosion resistance or similar degradation.

3rd Edition | February 2018

Heat Transfer Equipment

Std. 530

Calculation of Heater-Tube Thickness in Petroleum Refineries

Specifies the requirements and gives recommendations for the procedures and design criteria used for calculating the required wall thickness of new tubes and associated component fittings for fired heaters for the petroleum, petrochemical, and natural gas industries. These procedures are appropriate for designing tubes for service in both corrosive and non-corrosive applications. These procedures have been developed specifically for the design of refinery and related fired heater tubes (direct-fired, heat-absorbing tubes within enclosures). These procedures are not intended to be used for the design of external piping. This standard does not give recommendations for tube retirement thickness; Annex A describes a technique for estimating the life remaining for a heater tube.

7th Edition | April 2015

RP 538

Industrial Fired Boilers for General Refinery and Petrochemical Service

Specifies requirements and gives recommendations for design, operation, maintenance, and troubleshooting considerations for industrial fired boilers used in refineries and chemical plants. It covers waterside control, combustion control, burner management systems (BMSs), feedwater preparation, steam purity, emissions, etc.

1st Edition | October 2015

Std. 560

Fired Heaters for General Refinery Service

Specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing, preparation for shipment, and erection of fired heaters, air preheaters (APHs), fans, and burners for general refinery service. Covered sections include Purchaser's and Vendor's Responsibilities; Design Considerations (Process, Combustion and Mechanical); Materials of Construction; Tubes and Tube Supports; Headers, Piping, Terminals, and Manifolds; Loads and Allowable Stress; Refractory Linings and Castable Design and Construction; Structures and Appurtenances; Stacks, Ducts and Breeching; Burners, Dampers and Controls; Fan Drives; Sootblowers; Instruments and Connections; Shop Fabrication and Field Erection; Inspection and Testing; Air Preheat Systems; Efficiency Measurement; and Noise Measurement.

5th Edition | February 2016

RP 573

Inspection of Fired Boilers and Heaters

Covers the inspection practices for fired boilers and process heaters (furnaces) used in petroleum refineries and petrochemical plants. The practices described in this document are focused to improve equipment reliability and plant safety by describing the operating variables which impact reliability and to ensure that inspection practices obtain the appropriate data, both on-stream and off-stream, to assess current and future performance of the equipment.

3rd Edition | October 2013

RP 575

Inspection Practices for Atmospheric and Low-Pressure Storage Tanks

Covers the inspection of atmospheric and low-pressure storage tanks that have been designed to operate at pressures from atmospheric to 15 psig.

Includes reasons for inspection, frequency and methods of inspection, methods of repair, and preparation of records and reports. This recommended practice is intended to supplement Std. 653, which covers the minimum requirements for maintaining the integrity of storage tanks after they have been placed in service.

Companion document to Std. 653

3rd Edition | April 2014

Std. 660

Shell-and-Tube Heat Exchangers

Specifies requirements and gives recommendations for the mechanical design, material selection, fabrication, inspection, testing, and preparation for shipment of shell-and-tube heat exchangers for the petroleum, petrochemical, and natural gas industries. This standard is applicable to the following types of shell-and-tube heat exchangers: heaters, condensers, coolers, and reboilers. It is not applicable to vacuum-operated steam surface condensers and feed-water heaters.

9th Edition | March 2015

Std. 661

Petroleum, Petrochemical, and Natural Gas Industries Air-cooled Heat Exchangers

Gives requirements and recommendations for the design, materials, fabrication, inspection, testing, and preparation for shipment of air-cooled heat exchangers for use in the petroleum, petrochemical, and natural gas industries. This standard is applicable to air-cooled heat exchangers with horizontal bundles, but the basic concepts can also be applied to other configurations.

7th Edition | July 2013 | Reaffirmed June 2018

Std. 663

Hairpin-type Heat Exchangers

Specifies requirements and gives recommendations for the mechanical design, materials selection, fabrication, inspection, testing and preparation for shipment of hairpin heat exchangers for use in the petroleum, petrochemical and natural gas industries. Hairpin heat exchangers include double-pipe and multitube type heat exchangers.

1st Edition | May 2014

Std. 664

Spiral Plate Heat Exchangers

Specifies requirements and gives recommendations for the mechanical design, materials selection, fabrication, inspection, testing, and preparation for shipment of spiral plate heat exchangers for the petroleum, petrochemical, and natural gas industries. It is applicable to standalone spiral plate heat exchangers and those integral with a pressure vessel.

1st Edition | March 2014

Storage Tanks

Std. 620

Design and Construction of Large, Welded, Low-pressure Storage Tanks

This standard covers the design and construction of large, welded, low-pressure carbon steel above ground storage tanks (including flat-bottom tanks) that have a single vertical axis of revolution. This standard does not cover design procedures for tanks that have walls shaped in such a way that the walls cannot be generated in their entirety by the rotation of a suitable contour around a single vertical axis of revolution.

The tanks described in this standard are designed for metal temperatures not greater than 250 °F and with pressures in their gas or vapor spaces not more than 15 lbf/in.2 gauge.

12th Edition | October 2013

Std. 650

Welded Tanks for Oil Storage
(Includes Addendum 1 (2014) and Addendum 2 (2016))

This standard establishes minimum requirements for material, design, fabrication, erection, and inspection for vertical, cylindrical, aboveground, closed- and open-top, welded storage tanks in various sizes and capacities for internal pressures approximating atmospheric pressure (internal pressures not exceeding the weight of the roof plates), but a higher internal pressure is permitted when additional requirements are met. This standard applies only to tanks whose entire bottom is uniformly supported and to tanks in non-refrigerated service that have a maximum design temperature of 93 °C (200 °F) or less.

12th Edition | March 2013

RP 651

Cathodic Protection of Aboveground Petroleum Storage Tanks

Presents procedures and practices for achieving effective corrosion control on aboveground storage tank bottoms through the use of cathodic protection. This RP contains provisions for the application of cathodic protection to existing and new aboveground storage tanks. Corrosion control methods based on chemical control of the environment or the use of protective coatings are not covered in detail.

When cathodic protection is used for aboveground storage tank applications, it is the intent of this RP to provide information and guidance specific to aboveground metallic storage tanks in hydrocarbon service. Certain practices recommended herein may also be applicable to tanks in other services. It is intended to serve only as a guide to persons interested in cathodic protection. Specific cathodic protection designs are not provided. Such designs should be developed by a person thoroughly familiar with cathodic protection practices for aboveground petroleum storage tanks.

This RP does not designate specific practices for every situation because the varied conditions in which tank bottoms are installed preclude standardization of cathodic protection practices.

4th Edition | September 2014

RP 652

Linings of Aboveground Petroleum Storage Tank Bottoms

Provides guidance on achieving effective corrosion control by the application of tank bottom linings in aboveground storage tanks in hydrocarbon service. It contains information pertinent to the selection of lining materials, surface preparation, lining application, cure, and inspection of tank bottom linings for existing and new storage tanks. In many cases, tank bottom linings have proven to be an effective method of preventing internal corrosion of steel tank bottoms.

Provides information and guidance specific to aboveground steel storage tanks in hydrocarbon service. Certain practices recommended herein may also applicable to tanks in other services. This recommended practice is intended to serve only as a guide and detailed tank bottom lining specifications are not included. *

This recommended practice does not designate specific tank bottom linings for every situation because of the wide variety of service environments.

4th Edition | September 2014

Std. 653

Tank Inspection, Repair, Alteration, and Reconstruction
(Includes Addendum 1 (2018))

Covers steel storage tanks built to Std. 650 and its predecessor Spec 12C. It provides minimum requirements for maintaining the integrity of such tanks after they have been placed in service and addresses inspection, repair, alteration, relocation, and reconstruction.

The scope is limited to the tank foundation, bottom, shell, structure, roof, attached appurtenances, and nozzles to the face of the first flange, first threaded joint, or first welding-end connection. Many of the design, welding, examination, and material requirements of Std. 650 can be applied in the maintenance inspection, rating, repair, and alteration of in-service tanks. In the case of apparent conflicts between the requirements of this standard and Std. 650 or its predecessor Spec 12C, this standard shall govern for tanks that have been placed in service.

Companion document to RP 575

5th Edition | November 2014

Pressure Relief Devices

Std. 520, Part I

Sizing, Selection, and Installation of Pressure-Relieving Devices— Part I—Sizing and Selection

Applies to the sizing and selection of pressure relief devices used in refineries and related industries for equipment that has a maximum allowable working pressure of 15 psig (103 kPag) or greater. The pressure relief devices covered in this standard are intended to protect unfired pressure vessels and related equipment against overpressure from operating and fire contingencies.

9th Edition | July 2014

RP 520, Part II

Sizing, Selection, and Installation of Pressure-Relieving Devices— Part II—Installation

Covers the methods of installation for pressure relief devices for equipment that has a maximum allowable working pressure (MAWP) of 15 psig (1.03 bar g) or greater. Pressure relief valves or rupture disks may be used independently or in combination with each other to provide the required protection against excessive pressure accumulation. The term "pressure relief valve" includes safety relief valves used in either compressible or incompressible fluid service, and relief valves used in incompressible fluid service. Covers gas, vapor, steam, and incompressible fluid service.

6th Edition | March 2015

Std. 521

Pressure-Relieving and Depressuring Systems

Applies to pressure relieving and vapor depressuring systems. Although intended for use primarily in oil refineries, it is also applicable to petrochemical facilities, gas plants, liquefied natural gas (LNG) facilities, and oil and gas production facilities. The information provided is designed to aid in the selection of the system that is most appropriate for the risks and circumstances involved in various installations. This standard specifies requirements and gives guidelines for the following: examining the principal causes of overpressure; determining individual relieving rates; and selecting and designing disposal systems, including such component parts as piping, vessels, flares, and vent stacks. This standard does not apply to direct-fired steam boilers.

6th Edition | January 2014

RP 576

Inspection of Pressure-Relieving Devices

Describes the inspection and repair practices for automatic pressure relieving devices commonly used in the oil and petrochemical industries. As a guide to the inspection and repair of these devices in the user's plant, it is intended to ensure their proper performance. This publication covers such automatic devices as pressure-relief valves, pilot-operated pressure-relief valves, rupture disks, and weight-loaded pressure-vacuum vents.

The scope of this RP includes the inspection and repair of automatic pressure relieving devices commonly used in the oil and petrochemical industry. This publication does not cover weak seams or sections in tanks, explosion doors, fusible plugs, control valves, and other devices that either depend on an external source of power for operation or are manually operated. Inspections and tests made at manufacturers' plants, which are usually covered by codes or purchase specifications, are not covered by this publication.

4th Edition | May 2017

PROCESSES

Risk-Based Inspection

RP 580

Risk-Based Inspection

Provides users with the basic minimum and recommended elements for developing, implementing, and maintaining a risk-based inspection (RBI) program. It also provides guidance to owner-users, operators, and designers of pressure-containing equipment for developing and implementing an inspection program. These guidelines include means for assessing an inspection program and its plan. The approach emphasizes safe and reliable operation through risk-prioritized inspection. A spectrum of complementary risk analysis approaches (qualitative through fully quantitative) can be considered as part of the inspection planning process. RBI guideline issues covered include an introduction to the concepts and principles of RBI for risk management and individual sections that describe the steps in applying these principles within the framework of the RBI process.

3rd Edition | February 2016

RP 581

Risk-Based Inspection Methodology

Provides quantitative procedures to establish an inspection program using risk-based methods for pressurized fixed equipment including pressure vessel, piping, tankage, pressure relief devices (PRDs), and heat exchanger tube bundles. RP 580 provides guidance for developing Risk-Based Inspection (RBI) programs on fixed equipment in refining, petrochemical, chemical process plants, and oil and gas production facilities. The intent is for RP 580 to introduce the principles and present minimum general guidelines for RBI, while this recommended practice provides quantitative calculation methods to determine an inspection plan.

The calculation of risk outlined in RP 581 involves the determination of a probability of failure (POF) combined with the consequence of failure (COF). Failure is defined as a loss of containment from the pressure boundary resulting in leakage to the atmosphere or rupture of a pressurized component. Risk increases as damage accumulates during in-service operation as the risk tolerance or risk target is approached and an inspection is recommended of sufficient effectiveness to better quantify the damage state of the component. The inspection action itself does not reduce the risk; however, it does reduce uncertainty and therefore allows more accurate quantification of the damage present in the component.

3rd Edition | April 2016

Fitness-For-Service

Std. 579-1/ASME FFS-1

Fitness-For-Service

Fitness-For-Service (FFS) assessments are quantitative engineering evaluations that are performed to demonstrate the structural integrity of an in-service component that may contain a flaw or damage or that may be operating under a specific condition that might cause a failure. This standard provides guidance for conducting FFS assessments using methodologies specifically prepared for pressurized equipment.

The guidelines provided in this standard can be used to make run-repair- replace decisions to help determine if components in pressurized equipment containing flaws that have been identified by inspection can continue to operate safely for some period of time. These FFS assessments are currently recognized and referenced by the API Codes and Standards (510, 570, and 653), and by NB-23 as suitable means for evaluating the structural integrity of pressure vessels, piping systems, and storage tanks where inspection has revealed degradation and flaws in the equipment. The methods and procedures in this standard are intended to supplement and augment the requirements in API 510, API 570, Std. 653, and other post-construction codes that reference FFS evaluations such as NB-23.

3rd Edition | June 2016

Damage Mechanisms

RP 571

Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

Provides background information on damage that can occur to equipment in the refining process. It is intended to supplement Risk-Based Inspection (RP 580 and Publ. 581) and Fitness-for-Service (Std. 579-1/ASME FFS-1) technologies developed in recent years by API to manage existing refining equipment integrity. It is also an excellent reference for inspection, operations, and maintenance personnel. This RP covers over 60 damage mechanisms.

Each write-up consists of a general description of the damage, susceptible materials, construction, critical factors, inspection method selection guidelines, and control measures. Wherever possible, pictures are included and references are provided for each mechanism. In addition, generic process flow diagrams have been included that contain a summary of the major damage flow mechanism expected for typical refinery process units.

2nd Edition | April 2011

RP 585

Pressure Equipment Integrity Incident Investigation

Provides owner/users with guidelines and recommended practices for developing, implementing, sustaining, and enhancing an investigation program for pressure equipment integrity incidents. This recommended practice describes characteristics of an effective investigation and how organizations can learn from pressure equipment integrity incident investigations. This RP is intended to supplement and provide additional guidance for the OSHA Process Safety Management (PSM) Standard 29 CFR 1910.119 (m) incident investigation requirements, with a specific focus on incidents caused by integrity failures of pressure equipment.

1st Edition | April 2014

RP 970

Corrosion Control Documents

Provides users with the basic elements for developing, implementing, and maintaining a Corrosion Control Document (CCD) for refining, and at the owner's discretion, may be applied at petrochemical and chemical process facilities. A CCD is a document or other repository or system that contains all the necessary information to understand materials damage susceptibility issues in a specific type of operating process unit at a plant site.

CCDs are a valuable addition to an effective Mechanical Integrity Program. They help to identify the damage mechanism susceptibilities of pressure containing piping and equipment, factors that influence damage mechanism susceptibilities, and recommended actions to mitigate the risk of loss of containment or unplanned outages.

This recommended practice provides the owner/user with information and guidance on the work processes for development and implementation of CCDs for the owners'/users' process units.

1st Edition | December 2017

Integrity Operating Windows

RP 584

Integrity Operating Windows

Defines and explains the importance of IOWs for process safety management and to guide users in how to establish and implement an IOW program for refining and petrochemical process facilities for the express purpose of avoiding unexpected equipment degradation that could lead to loss of containment. It is not the intent of this document to provide a complete list of specific IOWs or operating variables that might need IOWs for the numerous types of hydrocarbon process units in the industry (though some generic examples are provided in the text and in Appendix A), but rather to provide the user with information and guidance on the work process for development and implementation of IOWs for each process unit.

1st Edition | May 2014

CORROSION AND MATERIALS

Welding

RP 577

Welding Processes, Inspection, and Metallurgy

Provides guidance to the API authorized inspector on welding inspection as encountered with fabrication and repair of refinery and chemical plant equipment and piping. Common welding processes, welding procedures, welder qualifications, metallurgical effects from welding, and inspection techniques are described to aid the inspector in fulfilling their role implementing API 510, API 570, Std. 653 and RP 582. The level of learning and training obtained from this document is not a replacement for the training and experience required to be an American Welding Society (AWS) Certified Welding Inspector (CWI).

2nd Edition | December 2013

RP 582

Welding Guidelines for the Chemical, Oil, and Gas Industries

Provides supplementary guidelines and practices for welding and welding related topics for shop and field fabrication, repair, and modification of the following:

- pressure-containing equipment, such as pressure vessels, heat exchangers, piping, heater tubes, and pressure boundaries of rotating equipment and attachments welded thereto;
- tanks and attachments welded thereto;
- non-removable internals for process equipment;
- structural items attached and related to process equipment;
- other equipment or component items, when referenced by an applicable purchase document.

This document is general in nature and augments the welding requirements of ASME BPVC Section IX and similar codes, standards, specifications, and practices, such as those listed in Section 2. The intent of this document is to be inclusive of chemical, oil, and gas industry standards, although there are many areas not covered herein, e.g. pipeline welding and offshore structural welding are intentionally not covered. This document is based on industry experience, and any restrictions or limitations may be waived or augmented by the purchaser.

3rd Edition | May 2016

Corrosion and Materials

RP 932-B

Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems (includes Errata 1 dated January 2014)

Provides guidance to engineering and plant personnel on equipment and piping design, material selection, fabrication, operation, and inspection practices to manage corrosion and fouling in the wet sections of hydroprocessing reactor effluent systems. The reactor effluent system includes all equipment and piping between the exchanger upstream of the wash water injection point and the cold, low-pressure separator (CLPS). The majority of these systems have an air cooler; however, some systems utilize only shell-and-tube heat exchangers. Reactor effluent systems are prone to fouling and corrosion by ammonium bisulfide (NH4HS) and ammonium chloride (NH4Cl) salts.

2nd Edition | March 2012

RP 934-A

Materials and Fabrication of 2 1/4Cr-1Mo, 2 1/4Cr-1Mo-1/4V, 3Cr- 1Mo, and 3Cr-1Mo-1/4V Steel Heavy Wall Pressure Vessels for High-Temperature, High-Pressure Hydrogen Service
(includes Addendum 1 (2010) and Addendum 2 (2012))

Presents materials and fabrication requirements for new 2 1/4Cr and 3Cr steel heavy wall pressure vessels for high-temperature, high-pressure hydrogen service. It applies to vessels that are designed, fabricated, certified, and documented in accordance with ASME BPVC, Section VIII, Division 2, including Section 3.4, Supplemental Requirements for Cr-Mo Steels and ASME Code Case 2151, as applicable. This document may also be used as a resource when planning to modify an existing heavy wall pressure vessel.

Materials covered by this recommended practice are conventional steels, including standard 2 1/4Cr-1Mo and 3Cr-1Mo steels, and advanced steels, which include 2 1/4Cr-1Mo-1/4V, 3Cr-1Mo-1/4V-Ti-B, and 3Cr-1Mo-1/4V- Nb-Ca steels. This document may be used as a reference for the fabrication of vessels made of enhanced steels (steels with mechanical properties augmented by special heat treatments) at purchaser discretion. However, no attempt has been made to cover specific requirements for the enhanced steels.

2nd Edition | May 2008

RP 934-C

Materials and Fabrication of 1 1/4CR-1/2Mo Steel Heavy Wall Pressure Vessels for High Pressure Hydrogen Service Operating at or Below 825 °F (441 °C)

Presents materials and fabrication requirements for new 1 1/4Cr-1/2Mo steel heavy wall pressure vessels and heat exchangers for high-temperature, high- pressure hydrogen service. It applies to vessels that are designed, fabricated, certified, and documented in accordance with ASME BPVC, Section VIII, Division 1 or Division 2. This document may also be used as a resource for equipment fabricated using 1Cr-1/2Mo Steel. This document may also be used as a resource when planning to modify an existing heavy-wall pressure vessel. The interior surfaces of these heavy-wall pressure vessels may have an austenitic stainless steel or ferritic stainless steel weld overlay or cladding to provide additional corrosion resistance.

1st Edition | May 2008

RP 934-E

Recommended Practice for Materials and Fabrication of 11/4Cr-1/2Mo Steel Pressure Vessels for Service Above 825 °F (440 °C)

Includes materials and fabrication requirements for new 11/4Cr-1/2Mo steel and 1Cr-1/2Mo pressure vessels and heat exchangers for high temperature service. It applies to vessels that are designed, fabricated, certified and documented in accordance with ASME BPVC Section VIII, Division 1. This document may also be used as a resource when planning to modify existing pressure vessels. The interior surfaces of these pressure vessels may have an austenitic stainless steel, ferritic stainless steel, or nickel alloy weld overlay or cladding to provide additional corrosion resistance. This recommended practice is applicable to wall (shell) thicknesses from 1 in. (25 mm) to 4 in. (100 mm). Integrally reinforced nozzles, flanges, tubesheets, bolted channel covers, etc. can be greater than 4 in. (100 mm). At shell or head thicknesses greater than 4 in. (100 mm), 11/4Cr-1/2Mo and 1Cr-1/2Mo has been shown to have difficulty meeting the toughness requirements given in this document, but this does not preclude the use of this alloy if these properties can be met or if the equipment is designed with stresses below the threshold for brittle fracture.

2nd Edition | January 2018

TR 934-G

Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units

Includes information and guidance on the practices used by industry practitioners on the design, fabrication, operation, inspection, assessment, and repair of coke drums and peripheral components in delayed coking units. The guidance is general and does not reflect specific details associated with a design offered by licensors of delayed coking technology, or inspection tools, operating devices/components, repairs techniques, and/or engineering assessments offered by contractors. For details associated with the design offered by a licensor or services provided by contractors, the licensor or contractor should be consulted for guidance and recommendations for their design details and operating guidance. This document is a technical report and as such provides generally used practices in industry and is not an API recommended practice for coke drums in delayed coking units.

1st Edition | April 2016

RP 583

Corrosion Under Insulation and Fireproofing

Covers the design, maintenance, inspection, and mitigation practices to address external corrosion under insulation (CUI) and corrosion under fireproofing (CUF). The document discusses the external corrosion of carbon and low alloy steels under insulation and fireproofing, and external chloride stress corrosion cracking (ECSCC) of austenitic and duplex stainless steels under insulation. The document does not cover atmospheric corrosion or corrosion at uninsulated pipe supports, but does discuss corrosion at insulated pipe supports.

The purpose of this RP is to:

- help owner/users understand the complexity of the many CUI/CUF issues,
- provide owner/users with understanding the advantages and limitations of the various NDE methods used to identify CUI and CUF damage,
- provide owner/users with an approach to risk assessment (i.e. likelihood of failure, and consequence of failure) for CUI and CUF damage, and
- provide owner/users guidance on how to design, install, and maintain insulation systems to avoid CUI and CUF damage.

1st Edition | May 2014

RP 939-C

Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries

Applies to hydrocarbon process streams containing sulfur compounds, with and without the presence of hydrogen, which operate at temperatures above approximately 450 °F (230 °C) up to about 1000 °F (540 °C). A threshold limit for sulfur content is not provided because within the past decade significant corrosion has occurred in the reboiler/fractionator sections of some hydroprocessing units at sulfur or H2S levels as low as 1 ppm. Nickel based alloy corrosion is excluded from the scope of this document. While sulfidation can be a problem in some sulfur recovery units, sulfur plant combustion sections and external corrosion of heater tubes due to firing sulfur containing fuels in heaters are specifically excluded from the scope of this document.

1st Edition | May 2009

Bull. 939-E

Identification, Repair, and Mitigation of Cracking of Steel Equipment in Fuel Ethanol Service

Discusses stress corrosion cracking (SCC) of carbon steel tanks, piping, and equipment exposed to fuel ethanol as a consequence of being in the distribution system, at ethanol distribution facilities, or end user (EU) facilities where the fuel ethanol is eventually added to gasoline. Such equipment includes but is not limited to storage tanks, piping and related handling equipment, and pipelines

that are used in distribution, handling, storage, and blending of fuel ethanol. However, data for pipelines in ethanol service is limited and caution should be used when applying guidelines from this document that have been derived mainly from applications involving piping and tanks in ethanol storage and blending facilities. SCC of other metals and alloys is beyond the scope of this document, as is the corrosion of steel in this service.

2nd Edition | August 2013

RP 941

Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants

Summarizes the results of experimental tests and actual data acquired from operating plants to establish practical operating limits for carbon and low alloy steels in hydrogen service at elevated temperatures and pressures. The effects on the resistance of steels to hydrogen at elevated temperature and pressure that result from high stress, heat treating, chemical composition, and cladding are discussed. This recommended practice (RP) does not address the resistance of steels to hydrogen at lower temperatures [below about 400 °F (204 °C)], where atomic hydrogen enters the steel as a result of an electrochemical mechanism.

This RP applies to equipment in refineries, petrochemical facilities, and chemical facilities in which hydrogen or hydrogen-containing fluids are processed at elevated temperature and pressure. The guidelines in this RP can also be applied to hydrogenation plants such as those that manufacture ammonia, methanol, edible oils, and higher alcohols.

8th Edition | February 2016

RP 945

Avoiding Environmental Cracking in Amine Units

Discusses environmental cracking problems of carbon steel equipment in amine units. This publication provides guidelines for carbon steel construction materials, including, fabrication, inspection, and repair, to help ensure safe and reliable operation. The steels referred to in this document are defined by the ASTM designation system, or equivalent materials contained in other recognized codes or standards. This document is based on current engineering practices and insights from recent industry experience.

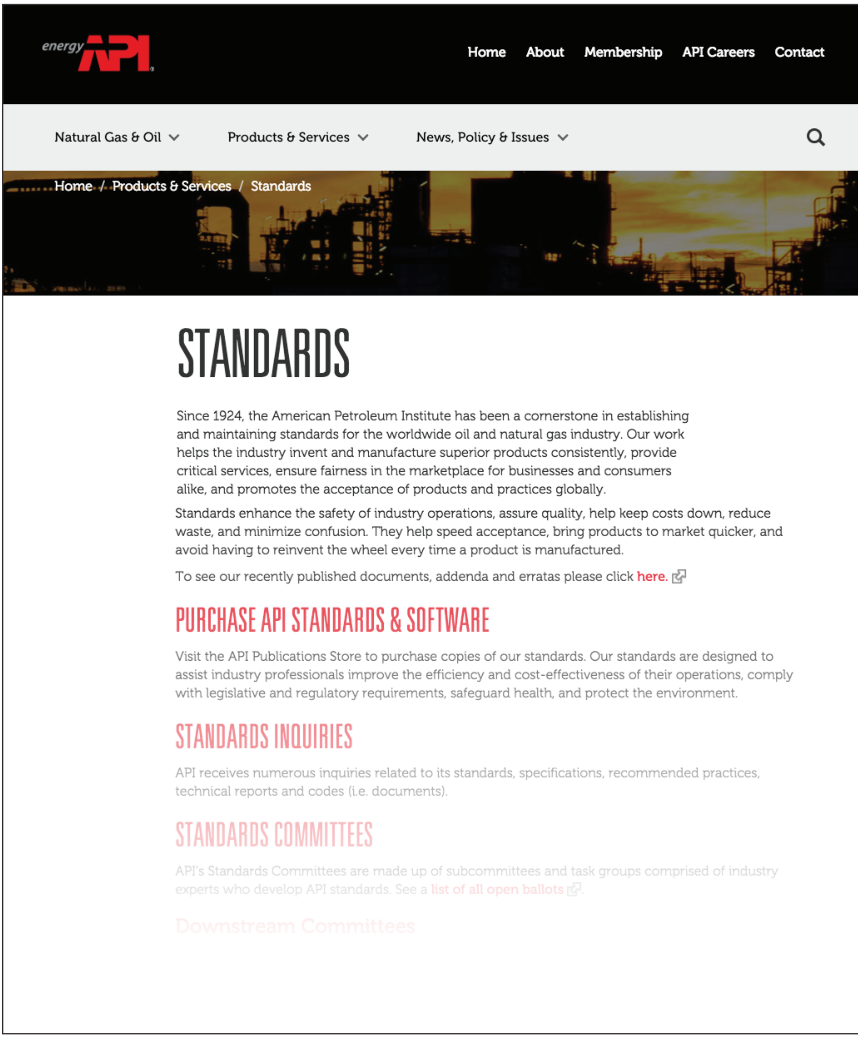
3rd Edition | June 2003 | Reaffirmed April 2008

TIMELINE OF FIRST EDITIONS OF API MECHANICAL INTEGRITY STANDARDS & RECOMMENDED PRACTICES

1950s	September **1955 RP 520** - Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries
	January 1956 **API 620** - Design and Construction of Large, Welded, Low-Pressure Storage Tanks
	July 1958 **API 510** - Pressure Vessel Inspection Code
	October 1958 **RP 530** - Calculation of Heater Tube Thickness in Petroleum Refineries
1960s	December 1961 **Std. 650** - Welded Tanks for Oil Storage
	January 1964 **Std. 660** - Shell-and-Tube Heat Exchangers
	August 1968 **Std. 661** - Petroleum, Petrochemical, and Natural Gas Industries Air-Cooled Heat Exchangers

1970s	July 1970 **RP 941** - Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants
1980s	January 1986 **Std. 560** - Fired Heaters for General Refinery Services
1990s	January 1990 **RP 574** - Inspection of Piping System Components
	August 1990 **RP 945** - Avoiding Cracking in Amine Units
	January 1991 **Std. 653** - Tank Inspection, Repair, Alteration, and Reconstruction
	April 1991 **RP 651** - Cathodic Protection of Aboveground Petroleum Storage Tanks
	April 1991 **RP 652** - Linings of Aboveground Petroleum Storage Tank Bottoms
	October 1991 **RP 573 -** Inspection of Fired Boilers and Heaters
	January 1992 **RP 576** - Inspection of Pressure-Relieving Devices
	February 1992 **RP 572** - Inspection of Pressure Vessels
	June 1993 **API 570** - Piping Inspection Code
	October 1995 **RP 575** - Inspection of Aboveground Storage Tanks
	March 1997 **Std. 521** - Guide for Pressure-Relieving and Depressuring Systems
	May 1999 **RP 578** - Material Verification Program for New and Existing Alloy Piping Systems
2000s	January 2000 **RP 579** - Fitness-For-Service
	May 2000 **Publ. 581** - Risk-Based Inspection - Base Resource Document
	March 2001 **RP 582** - Welding Guidelines for the Chemical, Oil, and Gas Industries 2001 Edition
	May 2002 **RP 580** - Risk-Based Inspection
	December 2003 **RP 571** - Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

2000s cont.	July 2004 **RP 932-B** - Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems
	October 2004 **RP 577** - Inspection of Welding and Metallurgy
	June 2007 **Std. 579-1/ASME FFS-1** - Fitness-For-Service
	May 2009 **RP 939-C** - Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries
	May 2008 **RP 934-A** - Materials and Fabrication of 2 1/4Cr-1Mo, 2 1/4Cr-1Mo-1/4V, 3Cr- 1Mo, and 3Cr-1Mo-1/4V Steel Heavy Wall Pressure Vessels for High-Temperature, High-Pressure Hydrogen Service
	May 2008 **RP 934-C** - Materials and Fabrication of 1 1/4CR-1/2Mo Steel Heavy Wall Pressure Vessels for High Pressure Hydrogen Service Operating at or Below 825 °F (441 °C)
	November 2008 **Bull. 939-E** - Identification, Repair, and Mitigation of Cracking of Steel Equipment in Fuel Ethanol Service
2010s	August 2010 **RP 934-E** - Recommended Practice for Materials and Fabrication of 11/4Cr-1/2Mo Steel Pressure Vessels for Service Above 825 °F (440 °C)
	April 2014 **RP 585** - Pressure Equipment Failure Investigations
	March 2014 **Std. 664** - Spiral Plate Heat Exchangers
	May 2014 **RP 583** - Corrosion Under Insulation
	May 2014 **Std. 663** - Hairpin-type Heat Exchangers
	October 2015 **RP 538** - Industrial Fired Boilers for General Refinery and Petrochemical Service
	April 2016 **RP 934-G** - Design, Fabrication, Operational Effects, Inspection, Assessment, and Repair of Coke Drums and Peripheral Components in Delayed Coking Units
	December 2017 **RP 970** - Corrosion Control Documents



To order copies of the publications listed in this catalog and for more information, visit **www.api.org/standards**.

OTHER NON-API MECHANICAL INTEGRITY RESOURCES

NACE Documents

Corrosion & Material Documents

- MR0103 Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments
- SP0114 Refinery Injection and Process Mix Points
- SP0169 Control of External Corrosion on Underground or Submerged metallic Piping Systems
- SP0170 Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment
- SP0296 Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H2S Environments
- SP0403 Avoiding Caustic Stress Corrosion Cracking of Refinery Equipment and Piping
- SP0472 Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments
- Publication 34103 Overview of Sulfidic Corrosion in Petroleum Refining
- Publication 34108 Carbonate SCC
- Publication 34109 Crude Distillation Unit—Distillation Tower Overhead System Corrosion

Tanks

- SP0205 Recommended Practice for the Design, Fabrication, and Inspection of Tanks for the Storage of Petroleum Refining Alkylation Unit Spent Sulfuric Acid at Ambient

Pressure Vessels

- SP0590 Prevention, Detection & Correction of Deaerator Cracking

ASME Documents

- ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly
- ASME PCC-2 Repair of Pressure Equipment and Piping

UPCOMING EVENTS

To learn more about API standards in person or get involved with a standards committee, consider attending one of API's semiannual refining conferences.

http://www.api.org/products-and-services/events/calendar

2019 Spring Refining and Equipment Standards Meeting

May 06, 2019 to May 09, 2019
Grand Hyatt San Antonio, San Antonio, Texas

2019 Fall Refining and Equipment Standards Meeting

November 18, 2019 to November 21, 2019
Hyatt Regency Atlanta, Atlanta, Georgia

AFPM also holds 11 to 12 meetings and conferences annually, covering many aspects of the hydrocarbon processing industries as well as several "hot topic" workshops.

https://www.afpm.org/Conferences/

NOTE: All API standards and recommended practices undergo periodic maintenance to ensure they are up to date with the latest industry engineering practices and technological changes. API's procedures require that API RPs/standards be reviewed at least once every 5 years to determine if the document should be reaffirmed (i.e., kept as currently written), revised to reflect needed changes or withdrawn (i.e., document is no longer needed by industry). Therefore, in addition to this brochure, please refer to the API website (www.api.org) for the latest information on new or updated standards, recommended practices, and other documents that may be of interest.

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