

# Materials and Fabrication Requirements for Carbon Steel Pressure Vessels in Petroleum Refining Wet H<sub>2</sub>S Environments

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AMPP values your input. To provide feedback on this standard, please contact: [standards@ampp.org](mailto:standards@ampp.org)

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## Foreword

Many petroleum refining and oil and gas production services contain liquid water and hydrogen sulfide ( $H_2S$ ). Depending on the  $H_2S$  concentration and various other process conditions, the following damage mechanisms can become active:

- a) Sulfide stress cracking (SSC) of carbon steel welds or base materials that exceed certain strength or hardness levels
- b) Blistering
- c) Hydrogen Induced Cracking (HIC)
- d) Stress-oriented Hydrogen Induced Cracking (SOHIC)

Complementary AMPP standards with which this document is intended to comply, and which are referenced in specific sections, include:

- 1) ANSI/NACE MR0103/ISO 17945, "Petroleum, Petrochemical, and Natural Gas Industries – Metallic Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments"
- 2) NACE SP0472, "Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments."

ANSI/NACE MR0103/ISO 17945 provides product form heat treating requirements and hardness limits for preventing SSC in numerous alloys, but its scope does not address blistering, HIC, or SOHIC. NACE SP0472 provides guidance on controls to prevent hydrogen stress cracking (including SSC) and alkaline cracking mechanisms at carbon steel (CS) weldments.

Many practices discussed in the precursor to this standard, NACE Publication 8X194, were identified through informal industry surveys of petroleum refiners, process licensors, and engineering contractors conducted in 1991 by NACE Work Group (WG) T-8-16g and in 2004 by NACE Task Group (TG) 301. This information has been supplemented by the experiences of the work group and task group members and their colleagues and other industry publications like EEMUA Publication 179. The first edition of NACE Publication 8X194 was issued in June 1994, and a revision was issued in December 2006. TCRs are more tutorial in format, and present numerous options and experiences, and therefore are not intended to provide recommendations. The intent of issuing this document as an SP is to provide a tool for the procurement and fabrication of new equipment for petroleum refining wet  $H_2S$  services. The requirements outlined in the main body of the SP are in a specification format to allow direct use as a standard specification by users/owners.

Although this SP is specific to wet  $H_2S$  services, the requirements outlined herein may also be applicable to other hydrogen charging services (e.g., hydrofluoric acid services). It is then the owner's responsibility to define which specific requirements they will apply to these other hydrogen charging environments and the additional requirements for these other services.

## Scope

This AMPP standard defines standard practices for new carbon steel (CS) pressure vessels to be used in petroleum refining wet hydrogen sulfide ( $H_2S$ )-containing environments, with the recommended steps for resisting the damage mechanisms listed below. It covers materials, welding, testing, and other fabrication requirements. It is intended to be used by refiners, equipment fabricators, engineering contractors, and construction contractors.

## Rationale

This Standard Practice (SP) was developed as a result of a previous Technical Committee Report (TCR), NACE Publication 8X194, which was titled "Materials and Fabrication Practices for New Pressure Vessels Used in Wet  $H_2S$  Refinery Service." The objective of that TCR was to provide a state-of-the-art overview of the options for materials selection, fabrication, post-weld heat treatment (PWHT), inspection, and testing practices that have been applied to new pressure vessels (referred to in this document as equipment) intended for use in wet  $H_2S$  refinery service.

## Referenced Standards and Other Consensus Documents

Unless specifically dated, the latest edition, revision, or amendment of the documents listed in the table below shall apply.

### **AMPP/NACE/SSPC, [www.amp.org](http://www.amp.org):**

|                            |                                                                                                                                                             |
|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NACE SP0472                | Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments                    |
| ANSI/NACE MR0103/ISO 17945 | Petroleum, Petrochemical, and Natural Gas Industries – Metallic Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments |
| ANSI/NACE MR0175/ISO 15156 | Petroleum and Natural Gas Industries – Materials for Use in H <sub>2</sub> S Containing Environments in Oil and Gas Production                              |
| NACE SP0178                | Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service                                                   |
| NACE Publication 8X194     | Materials and Fabrication Practices for New Pressure Vessels Used in Wet H <sub>2</sub> S Refinery Service                                                  |
| ANSI/NACE TM0284           | Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking                                                               |

### **American Petroleum Institute (API), [www.api.org](http://www.api.org):**

|               |                                                                                           |
|---------------|-------------------------------------------------------------------------------------------|
| API RP 582    | Welding Guidelines for the Chemical, Oil, and Gas Industries                              |
| API Pub 939-B | Repair and Remediation Strategies for Equipment Operating in Wet H <sub>2</sub> S Service |
| API RP 945    | Avoiding Environmental Cracking in Amine Units                                            |

### **American Society of Mechanical Engineers (ASME), [www.asme.org](http://www.asme.org):**

|                       |                                                                                                                     |
|-----------------------|---------------------------------------------------------------------------------------------------------------------|
| ASME B31.3            | Process Piping                                                                                                      |
| ASME BPVC Section IIA | Ferrous Material Specifications                                                                                     |
| SA-105                | Specification for Carbon Steel Forgings, for Piping Applications                                                    |
| SA-106                | Specification for Seamless Carbon Steel Pipe for High-Temperature Service                                           |
| SA-179                | Seamless Cold-Drawn Low Carbon Steel Heat Exchanger and Condenser Tubes                                             |
| SA-181                | Carbon Steel Forgings, for General-Purpose Piping                                                                   |
| SA-193                | Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service                                      |
| SA-194                | Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both      |
| SA-214                | Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes                                          |
| SA-216                | Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service                  |
| SA-234                | Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High-Temperature Service |

|                          |                                                                                                                                 |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| SA-266                   | Specification for Carbon Steel Forgings for Pressure Vessel Components                                                          |
| SA-320                   | Alloy Steel Bolting Materials for Low Temperature Service                                                                       |
| SA-333                   | Specification for Seamless and Welded Steel Pipe for Low-Temperature Service                                                    |
| SA-350                   | Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components                  |
| SA-352                   | Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service |
| SA-372                   | Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessel                                                                 |
| SA-420                   | Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service                           |
| SA-516                   | Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service                             |
| SA-578                   | Straight Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications                                    |
| SA-765                   | Carbon Steel and Low Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements                       |
| ASME BPVC Section IIC    | Welding Rods, Electrodes and Filler Metals                                                                                      |
| SFA-5.1                  | Covered Carbon Steel Arc Welding Electrodes                                                                                     |
| SFA-5.17                 | Carbon Steel Electrodes and Fluxes for Submerged Arc Welding                                                                    |
| SFA-5.18                 | Carbon Steel Filler Metals for Gas Shielded Arc Welding                                                                         |
| SFA-5.20                 | Carbon Steel Filler Metals for Flux Cored Arc Welding                                                                           |
| ASME BPVC Section VIII-1 | Rules for Construction of Pressure Vessels                                                                                      |
| ASME BPVC Section VIII-2 | Alternative Rules-Boiler and Pressure Vessel Code                                                                               |
| ASME BPVC Section IX     | Welding, Brazing, and Fusing Qualifications                                                                                     |

***ASTM International, [www.astm.org](http://www.astm.org):***

|           |                                                                                                    |
|-----------|----------------------------------------------------------------------------------------------------|
| ASTM A941 | Standard Terminology Relating to Steel, Stainless Steel, Related Alloys and Ferroalloys            |
| ASTM E92  | Standard Test Method for Vickers Hardness of Metallic Materials                                    |
| ASTM E10  | Standard Test Method for Brinell Hardness of Metallic Materials                                    |
| ASTM A833 | Standard Test Method for Indentation Hardness of Metallic Materials by Comparison Hardness Testers |

***European Standards, [www.en-standard.eu](http://www.en-standard.eu):***

|                   |                                                                               |
|-------------------|-------------------------------------------------------------------------------|
| EN 10204 Type 3.1 | Metallic Products – Types of Inspection Documents; Inspection Certificate 3.1 |
| EN 13445          | Unfired Pressure Vessels                                                      |

***Engineering Equipment and Materials Users Association (EEMUA), [www.eemua.org](http://www.eemua.org):***

|                       |                                                                            |
|-----------------------|----------------------------------------------------------------------------|
| EEMUA Publication 179 | A Working Guide for Carbon Steel Equipment in Wet H <sub>2</sub> S Service |
|-----------------------|----------------------------------------------------------------------------|

In AMPP standards, the terms *shall* and *must* are used to state requirements and are considered mandatory. The term *should* is used to state something that is recommended, but is not considered mandatory. The term *may* is used to state something considered optional.

## Section 1: General

- 1.1** Requirements described in this Standard Practice (SP) shall apply to new carbon steel pressure retaining equipment, such as pressure vessels and heat exchangers for operation in petroleum refining wet H<sub>2</sub>S environments defined herein.
- 1.1.1** Existing equipment already in service in older processing units may not conform to requirements in this SP, but this does not imply that such equipment is operating in an unsafe or unreliable manner. Industry practices are used to monitor operating conditions that could impact the severity of wet H<sub>2</sub>S exposure, which may necessitate specific inspection practices to monitor the equipment integrity of existing equipment. Each user/owner company is responsible for safe and reliable equipment operation. Repair or alteration of existing equipment to these requirements will depend on operating severity, historical inspection findings, and repair history.
- 1.1.2** This SP applies only to components in contact with the process environment that are within the pressure vessel code boundary (e.g., ASME Boiler and Pressure Vessel Code [BPVC] Section VIII, EN 13445). Piping, instrumentation, and internal components that are not part of the pressure vessel boundary are outside the scope of this SP.
- 1.1.3** Large-diameter piping components made from pressure vessel plate materials and welded from both sides in the same manner as pressure vessels are within the scope of this SP.
- 1.1.4** Base material requirements in this specification shall apply to pressure-retaining components that are in direct contact with the process environment, and not to the base metal of attachments welded to the pressure boundary or vessel internals, unless noted otherwise.
- 1.1.5** This SP provides minimum requirements derived from common industrial experience. User/owner companies may apply additional requirements to minimize the risk of wet H<sub>2</sub>S or other damage in specific refining processes based on their experience.
- 1.2** Pumps and other rotating equipment in wet H<sub>2</sub>S service are outside the scope of this standard.
- 1.3** Storage tanks and spheres are outside the scope of this standard.
- 1.4** Transmission pipelines are outside the scope of this standard.
- 1.5** The applications of this standard, and the “Severity Levels” (as defined herein) shall be specified for each equipment item on contract purchase orders, drawings, or data sheets.