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Standard Practice

Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments

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Foreword

This NACE standard defines standard practices for producing weldments in P-No. 1 steels resistant to environmental cracking in corrosive petroleum refining environments. It is intended to be used by refiners, equipment manufacturers, engineering contractors, and construction contractors.

Most petroleum refining equipment are constructed from carbon steel having a minimum specified tensile strength of 485 MPa (70,000 psi) or less, and in almost every case, the equipment is fabricated by welding. The welds for refinery equipment are made to conform to various codes and standards, including the ASME(1) Boiler and Pressure Vessel Code, Section VIII[1] for pressure vessels, ASME/ANSI(2) B31.3[2] for process piping, or API(3) Standards 620[3] and 650[4] for tanks. According to these codes and standards, these carbon steels are classified as P-No. 1, Group 1 or 2, and in this standard, they are referred to as P-No. 1 steels.

Petroleum refineries as well as oil- and gas-processing plants have predominantly used P-No. 1 steels for services containing wet hydrogen sulfide (H_2S), or sour services. They are the basic materials of construction for pressure vessels, heat exchangers, storage tanks, and piping. Decades of successful service have shown them to be generally resistant to a form of hydrogen stress cracking (HSC) called sulfide stress cracking (SSC). HSC occurs in high-strength materials or zones of a hard or high-strength microstructure in an otherwise soft material. With commonly used fabrication methods, P-No. 1 steels should be below the strength threshold for this cracking.

NACE Standard MR0103[5] provides guidance for materials in sour oil and gas environments in refinery services, including limiting the hardness of P-No. 1 steels and reducing the likelihood of SSC. NACE MR0175/ISO 15156[6] provides additional guidance for materials in sour oil and gas environments in production services.

In the late 1960s, a number of SSC failures occurred in hard weld deposits in P-No. 1 steel refinery equipment. To detect hard weld deposits caused by improper welding filler metals or procedures, the petroleum refining industry began requiring hardness testing of production weld deposits under certain conditions and applied a criterion of 200 Brinell hardness (HBW) maximum. These requirements were given in previous editions of this standard and in API RP 942.[7]

In the late 1980s, instances of heat-affected zone (HAZ) cracking were reported in P-No. 1 steel equipment that met the 200 HBW weld deposit hardness limit. Some cases were determined to be SSC that was caused by high hardness in the HAZ. Some were identified as another form of hydrogen damage called stress-oriented hydrogen-induced cracking (SOHIC).[8] These cracks propagated primarily in the HAZs of weldments and were found in both high- and low-hardness HAZs. Other HAZ cracking instances in specific corrosive refinery process environments were attributed to alkaline stress corrosion cracking (ASCC), which can occur as a result of high residual stress levels.

HAZ hardness controls and reduction of residual stresses in weldments were outside the scope of early editions of this standard, which covered only weld deposit hardness limits. The 1995 revision of this standard was expanded to cover the entire weldment and the various in-service cracking mechanisms (HSC in the weld deposit, HSC in the weld HAZ, and ASCC) that can occur in corrosive petroleum refining environments.

This standard was originally prepared in 1972 by NACE Task Group (TG) T-8-7, which was composed of corrosion consultants, corrosion engineers, and other specialists associated with the petroleum refining industry. It was reaffirmed in 1974 and revised in 1987 and 1995. It was reaffirmed in 2000 by Specific Technology Group (STG) 34, "Petroleum Refining and Gas Processing," and revised in 2005, 2008, 2010, and 2015 by TG 326, "Weldments, Carbon Steel:

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(2) American National Standards Institute (ANSI), 25 West 43rd St., 4th Floor, New York, NY 10036.
(3) American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005-4070.

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Prevention of Environmental Cracking in Refining Environments." API previously published a standard, API RP 942, with similar objectives. The API standard has been discontinued with the intention of recognizing this NACE standard as the industry consensus standard. This standard is issued by NACE International under the auspices of STG 34.

In NACE standards, the terms *shall, must, should*, and *may* are used in accordance with the definitions of these terms in the *NACE Publications Style Manual*. The terms *shall* and *must* are used to state a requirement, and are considered mandatory. The term *should* is used to state something good and is recommended, but is not considered mandatory. The term *may* is used to state something considered optional.

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Section 1: General

1.1 This standard establishes guidelines to prevent most forms of environmental cracking of weldments in carbon steel refinery equipment, including pressure vessels, heat exchangers, piping, valve bodies, and pump and compressor cases. Weldments are defined to include the weld deposit, base metal HAZ, and adjacent base metal zones subject to residual stresses from welding.

1.1.1 Complete PWHT of field-fabricated storage tanks is impractical and sometimes impossible. Costly techniques of supporting tanks, insulating the outside, and applying gas burners to heat the inside gas have been attempted, but the effectiveness was questionable. Other protection steps such as alternative thermal methods, internal coatings, maintaining lower temperatures, etc., should be used.

1.2 This standard covers only carbon steels classified as P-No. 1, Group 1 or 2. These classifications can be found in the ASME Boiler and Pressure Vessel Code, Section IX[9] for pressure vessels, ASME/ANSI B31.3 for process piping, or API Standards 620 and 650 for tanks. It excludes steels with greater than 485 MPa (70,000 psi) minimum specified tensile strength. Other materials may be vulnerable to cracking, but these materials are outside the scope of this standard.

1.3 The types of equipment covered by this standard include pressure vessels, heat exchangers, piping, valve bodies, and pump and compressor cases. All pressure-containing weldments or internal attachment weldments to the pressure boundary are included. External attachment weldments are sometimes included. In addition, this standard may be applied to weldments in some non-pressure-containing equipment, such as atmospheric storage tanks.

1.4 Both new fabrication and repair welds are within the scope of this standard. The practices included herein are intended to prevent in-service cracking and are not intended to address cracking that can occur during fabrication, such as delayed hydrogen cracking. In most cases, however, these practices are also helpful in minimizing these fabrication problems. Useful information for preventing delayed hydrogen cracking is provided by F.R. Coe, et al.[10]

1.5 Welding processes covered by this standard include shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux-cored arc welding (FCAW); gas tungsten arc welding (GTAW); and submerged arc welding (SAW). Almost all types of weld configurations are included. For specific exceptions, such as hot taps, hardness limits and post weld heat treatment (PWHT) requirements should be reviewed on a case-by-case basis.

1.6 Corrosive refinery process environments covered by this standard can be divided into two general categories: services that could cause cracking as a result of hydrogen charging, and services that could cause ASCC. However, identification of the specific environments to which the guidelines set forth in this standard are to be applied to prevent various forms of in-service environmental cracking is the responsibility of the user. Figure 1 is a simplified schematic showing the interrelationships of the various cracking mechanisms discussed in this standard.