

## Standard Practice

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

This NACE International standard represents a consensus of those individual members who have reviewed this document, its scope, and provisions. Its acceptance does not in any respect preclude anyone, whether he or she has adopted the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not in conformance with this standard. Nothing contained in this NACE International standard is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This standard represents minimum requirements and should in no way be interpreted as a restriction on the use of better procedures or materials. Neither is this standard intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this standard in specific instances. NACE International assumes no responsibility for the interpretation or use of this standard by other parties and accepts responsibility for only those official NACE International interpretations issued by NACE International in accordance with its governing procedures and policies, which preclude the issuance of interpretations by individual volunteers.

Users of this NACE International standard are responsible for reviewing appropriate health, safety, environmental, and regulatory documents and for determining their applicability in relation to this standard prior to its use. This NACE International standard may not necessarily address all potential health and safety problems or environmental hazards associated with the use of materials, equipment, and/or operations detailed or referred to within this standard. Users of this NACE International standard are also responsible for establishing appropriate health, safety, and environmental protection practices, in consultation with appropriate regulatory authorities if necessary, to achieve compliance with any existing applicable regulatory requirements prior to the use of this standard.

**CAUTIONARY NOTICE:** NACE International standards are subject to periodic review, and may be revised or withdrawn at any time in accordance with NACE technical committee procedures. NACE International requires that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of initial publication and subsequently from the date of each reaffirmation or revision. The user is cautioned to obtain the latest edition. Purchasers of NACE International standards may receive current information on all standards and other NACE International publications by contacting the NACE International FirstService Department, 15835 Park Ten Place, Houston, Texas 77084-5145 (telephone +1 281-228-6200).

Approved 2015-03-14  
Revised 2010-03-13  
Revised 2008-11-07  
Revised 2005-12-02  
Reaffirmed 2000-09-13  
Revised October 1995  
Revised March 1987  
Reaffirmed 1974  
Approved April 1972  
NACE International  
15835 Park Ten Place  
Houston, Texas 77084-5145  
+1 281-228-6200

ISBN 1-57590-114-5  
© 2015 NACE International

---

## 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<sup>(1)</sup> Boiler and Pressure Vessel Code, Section VIII<sup>1</sup> for pressure vessels, ASME/ANSI<sup>(2)</sup> B31.3<sup>2</sup> for process piping, or API<sup>(3)</sup> Standards 620<sup>3</sup> and 650<sup>4</sup> 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<sub>2</sub>S), 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<sup>5</sup> 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<sup>6</sup> 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.<sup>7</sup>

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).<sup>8</sup> 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 caustic 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:

---

<sup>(1)</sup> ASME International (ASME), Two Park Avenue, New York, NY 10016-5990.

<sup>(2)</sup> American National Standards Institute (ANSI), 25 West 43rd St., 4th Floor, New York, NY 10036.

<sup>(3)</sup> American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005-4070.

Prevention of Environmental Cracking in Refining Environments.” A previously published 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.

---

## NACE International Standard Practice

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

#### Contents

1. General .....	1
2. Prevention of Hydrogen Stress Cracking .....	4
3. Prevention of Alkaline Stress Corrosion Cracking.....	9
References.....	11
Bibliography .....	13
Appendix A: Rationale for Guidelines for Prevention of Hydrogen Stress Cracking (Nonmandatory).....	13
Appendix B: Rationale for Guidelines for Prevention of Alkaline Stress Corrosion Cracking (Nonmandatory) .....	20
Appendix C: Summary of Cooling Time ( $t_{8/5}$ ) Concept (Nonmandatory).....	21
Appendix D: Guidance on Local PWHT (Nonmandatory).....	25
Figures	
Figure 1: Interrelationships of the Various Cracking Mechanisms .....	2
Figure C1: Types of Heat Flow During Welding .....	21
Figure C2: Transition Plate Thickness ( $d_t$ ) from Three-Dimensional to Two-Dimensional Heat Flow as a Function of Heat Input (Q) for Different Preheat Temperatures ( $T_p$ ).....	22
Figure C3: Cooling Time ( $t_{8/5}$ ) for Three-Dimensional Heat Flow as a Function of Heat input (Q) for Different Preheat Temperatures ( $T_p$ ).....	24
Figure C4: Cooling Time ( $t_{8/5}$ ) for Two-Dimensional Heat Flow as a Function of Heat Input (Q) for Different Preheat Temperatures ( $T_p$ ) and Plate Thicknesses ( $d$ ).....	25
Figure D1: Schematic Diagram for Description of Local 360° Band Heating <sup>14</sup> .....	27
Tables	
Table 1: “Road Map” of SP0472 Guidelines Applicable to Cracking Mechanisms.....	3
Table 2: Welding Process/Filler Metal Combinations Exempt from Weld Deposit Hardness Testing.....	4
Table 3: Minimum Recommendations for Local 360° Band PWHT on ASME B31.3 Piping <sup>(a)</sup> .....	10
Table 4: Minimum Recommendations for Local 360° Band PWHT on ASME Section VIII, Division 1 Vessels <sup>18</sup> .....	11
Table A1: Level of Base Metal Chemistry Control as a Function of Butt Weld Joint Configurations and HAZ Hardness Control Method Used.....	16
Table C1: Shape Factors for Influence of the Form of Weld on $t_{8/5}$ .....	23

---