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**NACE International  
Standard  
Recommended Practice**

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

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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 and piping. Weldments are defined to include the weld deposit, base metal HAZs, and adjacent base metal zones subject to residual stresses from welding.

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,<sup>9</sup> ASME/ANSI B31.3 Code for process piping, or API Standards 620 and 650 for tanks. It excludes steels over 480 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, storage tanks, piping, valve bodies, and pump and compressor cases. All pressure-containing weldments or internal attachment weldments to the pressure boundary are included. In addition, weldments in some nonpressure-containing equipment, such as storage tanks, are included. External attachment weldments are sometimes included as discussed in Paragraph 6.4.6.

1.4 Both new fabrication and repair welds are within the scope of this standard. However, the practices recommended herein are intended to avoid *in-service* cracking, and are not intended to address cracking that can occur during fabrication, such as delayed hydrogen cracking. Useful information is provided by F.R. Coe et al.<sup>10</sup> In most cases, however, these practices are also helpful in minimizing these fabrication problems.

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. Some specific exceptions include hot taps, or weld build-ups. Hardness limits and PWHT requirements for these exceptions (i.e., weld configurations) should be reviewed on a case-by-case basis.

1.6 Corrosive refinery process environments covered by this standard can be divided into the two general services listed below. 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.

1.6.1 Services that could cause cracking due to hydrogen charging:

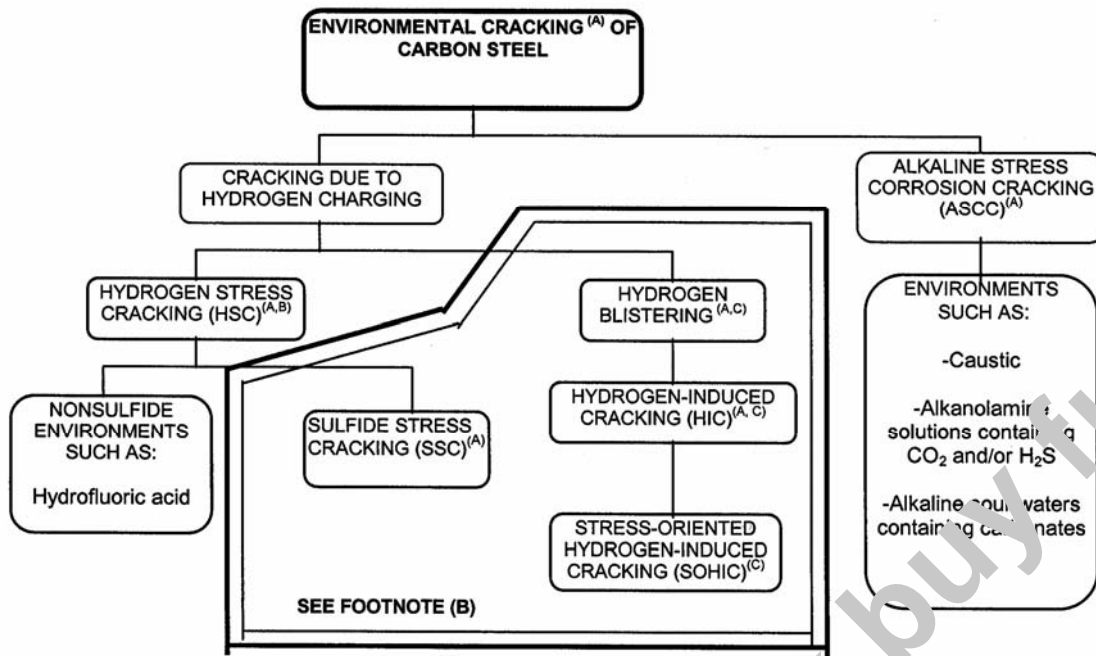
1.6.1.1 In these services, the environment or corrosion reactions result in diffusion of atomic hydrogen into the base metal and weldment. In high-strength or high-hardness areas, this hydrogen can result in HSC. In petroleum refining processes, the primary manifestation of HSC is SSC of hard weldments in process environments containing wet H<sub>2</sub>S. Information regarding the definition of wet H<sub>2</sub>S refinery services is given in NACE MR0103. However, other processes that promote aqueous corrosion of steel and promote hydrogen charging (such as hydrofluoric acid) can also cause HSC. Controlling both the weld deposit and HAZ hardness using the guidelines of Section 2 prevents HSC in most cases.

1.6.1.2 SOHIC can also occur in the services described above, but it does not require high strengths or high hardnesses. Hence, limiting weldment hardness does not prevent this form of cracking. Reducing weldment hardness and residual stress is believed to reduce the likelihood of this cracking, so the guidelines given in Sections 2 and 6 may still be helpful. However, additional steps, such as the use of special clean steels, water washing, corrosion inhibitors, or corrosion-resistant liners, may be needed for some services.<sup>11</sup> An overview of the materials selection, fabrication, PWHT, and testing practices that have been applied to new pressure vessels for mitigating SOHIC is provided in NACE Publication 8X194.<sup>11</sup>

1.6.1.3 Cases of cracking of hard welds have occurred as a result of short-term upset, start-up, or transient conditions in nonstress-relieved P-No. 1 carbon steel refinery equipment and piping in which hydrogen sulfide is not normally present. While this standard covers only P-No. 1 materials, it should be noted that welds have also cracked in tanks and pressure vessels constructed of nonstress-relieved P-No. 10A and 10C carbon-manganese steels.

1.6.2 Services that could cause alkaline stress corrosion cracking (ASCC):

1.6.2.1 Figure 1 provides examples of services that can cause ASCC, including caustic cracking, amine cracking, and carbonate cracking. Section 6 provides common practices used to avoid these types of ASCC. Severity of cracking is often dependent on temperature, concentration, level of residual tensile stresses, and other factors. Controlling weldment hardness does not prevent ASCC because high tensile stresses may still be present.



**FIGURE 1**  
**Interrelationships of the Various Cracking Mechanisms**

(A) Refer to the NACE Glossary of Corrosion-Related Terms for definitions (including stress corrosion cracking).

(B) The forms of environmental cracking included within the double lines are commonly referred to as “wet H<sub>2</sub>S cracking” when they occur in wet hydrogen sulfide environments.

(C) This form of environmental cracking can also occur in nonsulfide environments, such as hydrofluoric acid.

1.6.2.2 Further information about caustic cracking and its prevention can be found in NACE Standard RP0403.<sup>12</sup>

1.6.2.3 Further information about aniline cracking and its prevention can be found in API RP 945.<sup>13</sup>

1.6.2.4 Further information about carbonate cracking and its prevention will be forthcoming in a technical committee report currently being developed by NACE Task 3-7.

1.7 For most refinery services, weld deposit hardness should be controlled as discussed in Paragraph 2.2. This practice primarily helps avoid the use of improper welding materials, welding procedures, or heat treatment. It also minimizes the risk of HSC from external wet atmospheric corrodents, process upsets, or from future changes in services.

1.8 In some cases, environmental cracking (both HSC and ASCC) has initiated from pre-existing weldment fabrication defects. Hence, during original fabrication, weldments should be inspected for defects such as lack of fusion, delayed hydrogen cracking, or severe undercut. Any defects found should be removed.

1.9 One possible environmentally induced cracking mechanism in carbon steel weldments that is not addressed in this standard is high-temperature hydrogen attack. API RP 941<sup>15</sup> gives recommendations on materials selection to avoid this problem. Other types of in-service cracking not addressed by this standard are primarily mechanical in nature. Examples are fatigue, creep, and brittle fracture. Table 1 provides an overview (“road map”) of the guidelines applicable to the various types of cracking.