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Standard
Recommended Practice

Guidelines for Detection, Repair, and Mitigation of Cracking of Existing Petroleum Refinery Pressure Vessels in Wet H_2S Environments

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Foreword

NACE International Task Group T-8-16 on Cracking in Wet H_2S Environments was formed in 1988 to conduct an organized study on the incidence and mechanisms of cracking in pressure vessels operating in refinery wet hydrogen sulfide (H_2S) environments. Specific objectives were to (a) define the nature and extent of the problem by means of an industry survey; (b) define mechanisms for the type of cracking found, to be accomplished primarily through a literature survey; (c) establish inspection guidelines for existing vessels; and (d) develop repair and mitigation guidelines for cracked vessels. Four work groups were formed to address these tasks. In 1990, a fifth work group was formed with a fifth objective, (e) to investigate material specifications and fabrication practices for new pressure vessels.

This standard recommended practice summarizes objectives (a), (c), and (d) listed above. A technical committee report (NACE Publication 8X294)[1] has been issued to address objective (b). Finally, objective (e) has been handled by another technical committee report (NACE Publication 8X194).[2]

This standard is intended for use primarily by refinery corrosion and materials engineers and inspection, operations, and maintenance personnel. Information and guidance presented in this standard reflect the work of many individuals representing numerous companies worldwide.

The titles and source information of the codes, specifications, and standards referred to or discussed in this standard are provided in Appendix A rather than listed in footnotes throughout the standard. Confining this information to one appendix should help readers who have any interest in further research. This standard was originally prepared in 1996 by former Task Group T-8-16 on Cracking in Wet H_2S Environments. It was reaffirmed in 2000 by Group Committee T-8, and revised in 2004 by Task Group (TG) 268 on Wet H_2S Cracking in Petroleum Refinery Pressure Vessels. TG 268 is administered by Specific Technology Group (STG) 34 on Petroleum Refining and Gas Processing. 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, 4th ed., Paragraph 7.4.1.9. *Shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

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Section 1: General

1.1 This standard is intended to be a primary source of information on cracking in wet H_2S petroleum refinery environments and provides guidelines on the detection, repair, and mitigation of cracking of existing carbon steel refinery pressure vessels in wet H_2S environments. Refinery pressure vessels include items such as, but not limited to, columns, heat exchangers, drums, reboilers, and separators. All repairs should be conducted in accordance with API[(1)] 510[3] or another applicable industry code or standard. Limited cracking has been noted in piping and therefore, piping is not included in the scope of this standard. Information on inspection practices for new pressure vessels (never in service) is given in NACE Publication 8X194.

1.2 For the purposes of this standard, *wet H_2S service* is defined as refinery process environments containing free water as a liquid phase and in which

(a) the concentration of H_2S is >50 mg/L (50 ppmw) in the free water, or

(b) free water pH is <4 with some dissolved H_2S, or

(c) free water pH is >7.6 with at least 20 mg/L (20 ppmw) dissolved hydrogen cyanide (HCN) in the water with some dissolved H_2S, or

(d) >0.0003 MPa abs (0.05 psia) partial pressure of H_2S is present in the gas in processes with a gas phase.

However, the threshold concentration of H_2S in the aqueous phase required for cracking to occur has not been clearly established. Therefore, selective application of this standard may be appropriate when past experience has indicated the presence of cracking or blistering in comparable service, regardless of H_2S concentration.

1.3 Increased industry attention to the potential for cracking of carbon steel pressure vessels began in 1984 with the rupture of a monoethanolamine (MEA) absorber tower at a Lemont, Illinois, refinery. The ensuing explosion and fire resulted in fatalities and extensive damage to the facility.[4] In response to this incident, NACE Task Group T-8-14 on Stress Corrosion Cracking of Carbon Steel in Amine Solutions was formed in the fall of 1984. An industry survey to determine the nature and extent of the cracking problem was conducted by T-8-14. Appendix B presents a summary of the survey findings. The results of the T-8-14 effort have been reported separately.[5]

1.4 In 1988, some new results on vessel inspections and the cracking found were reported to the industry.[6] Among the significant findings was the observation that cracking problems were occurring in other wet H_2S environments, not just in MEA. It was further reported that inspection techniques commonly used at the time (visual, liquid penetrant, and dry magnetic particle testing) were not sensitive enough to find these cracks. In response to this new information, NACE Task Group T-8-16 on Cracking in Wet H_2S Environments was formed in the spring of 1988.

Section 2: Mechanisms of Cracking

2.1 The objective of this section is to define the terms used to describe cracks that occur because of exposure to wet H_2S environments and describe the mechanisms of cracking. Photographs of typical cracks found in wet H_2S environments are shown in Appendix C.

2.2 Definitions

2.2.1 Sulfide Stress Cracking (SSC): Cracking of a metal under the combined action of tensile stress and corrosion in the presence of water and H_2S. SSC is a form of hydrogen stress cracking resulting from absorption of atomic hydrogen that is produced by the sulfide corrosion process on the metal surface. SSC usually occurs more readily in high-strength steels or in hard weld zones of steels. (See Figure C1.)

2.2.2 Hydrogen Blistering: The formation of subsurface planar cavities, called hydrogen blisters, in a metal resulting from excessive internal hydrogen pressure. Growth of near-surface blisters in low-strength metals usually results in surface bulges. Hydrogen blistering in steel involves the absorption and diffusion of atomic hydrogen produced on the metal surface by the sulfide corrosion process. The development of hydrogen blisters in steels is caused by the accumulation of hydrogen that recombines to form molecular hydrogen at internal sites in the metal. In its molecular state, hydrogen is too large to diffuse through the steel. Typical sites for the formation of hydrogen blisters are large nonmetallic inclusions, laminations, or other discontinuities in the steel. This differs from the voids, blisters, and cracking associated with high-temperature hydrogen attack. (See Figure C2.)

(1) American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005.