NACE SP0296-2020
Item ID No. SP0296-2020
Approved: 2020-01-08
Published 1996
Reaffirmed 2000
Revised 2004
Revised 2010
Reaffirmed 2016

Detection, Repair, and Mitigation of Cracking in Refinery Equipment in Wet H_2S Environments

ABSTRACT

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 equipment in wet H_2S environments.

KEYWORDS

H_2S, cracking, refining, developed by TG 268.

ISBN 1-57590-013-0

Foreword

NACE International Task Group (TG) T-8-16, "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 practice summarizes objectives (a), (c), and (d) listed above. A technical committee report (NACE Publication 8X294)[1] was issued to address objective (b). Finally, objective (e) was 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 (nonmandatory) 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 TG T-8-16, "Cracking in Wet H_2S Environments." It was reaffirmed in 2000 by Group Committee T-8, revised in 2004. TG 268 revised this standard in 2010 to address a number of items raised by Specific Technology Group (STG) 34 members as well as to respond to revisions in other applicable NACE standards, such as SP0472.[3] The original emphasis of this standard was on pressure vessels, and this emphasis remains; however, with this revision, some limited information on piping has been included at the request of TG 268 members and other members of STG 34. It was reaffirmed in 2016 and 2020 by TG 268, "Wet H_2S Cracking in Petroleum Refinery Pressure Vessels." TG 268 is administered by STG 34, "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. 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 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 equipment in wet H_2S environments.

1.1.1 For the purposes of this standard, the term equipment refers to pressure vessels and piping made of carbon steel plate material. Refinery pressure vessels include items such as, but not limited to, columns or towers, heat exchangers, drums, reboilers, and separators.

1.1.2 Limited cracking has been noted in seamless piping; therefore, the information in this standard concentrates on longitudinally seam-welded pipe fabricated from plate.

1.1.3 Information on fabrication and inspection practices for new pressure vessels (never in service) is in NACE Publication 8X194.

1.2 For the purposes of this standard, the term wet H_2S environments includes, but is not limited to, refinery process environments known to cause wet H_2S cracking resulting from hydrogen entry into the steel, as defined in NACE Standard MR0103.[4] Some environmental conditions known to cause wet H_2S cracking are those containing an aqueous phase and:

(a) > 50 ppmw total sulfide content in the aqueous phase; or

(b) ≥ 1 ppmw total sulfide content in the aqueous phase and pH < 4; or

(c) ≥ 1 ppmw total sulfide content and ≥ 20 ppmw free cyanide in the aqueous phase and pH > 7.6; or

(d) > 0.3 kPa absolute (0.05 psia) partial pressure H_2S in the gas phase associated with the aqueous phase of a process.

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

Alkaline environments such as alkanolamine solutions that contain sulfides and carbonate-containing sour waters also are included in the term wet H_2S environments and thus are within the scope of this standard. Two forms of alkaline stress corrosion cracking (ASCC) are commonly found in these alkaline wet H_2S environments. Amine stress corrosion cracking (commonly referred to as amine cracking) can occur in amine service under certain conditions, which are discussed in API[(1)] RP 945.[5] Alkaline carbonate stress corrosion cracking (commonly referred to as carbonate cracking) can occur in alkaline carbonate-containing sour waters under certain conditions. NACE Publication 34108[6] describes where carbonate cracking has occurred in process equipment in petroleum refining service, the refining community's current theory(ies) on the conditions and mitigation techniques that may have an impact on this type of cracking, and analytical and inspection techniques that have been used to address the issue.

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.[7] In response to this incident, NACE Task Group T-8-14, "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. The results of the T-8-14 effort have been reported separately.[8]

1.4 In 1988, some new results on vessel inspections and the cracking found were reported to the industry.[9] 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, "Cracking in Wet H_2S Environments," was formed in the spring of 1988. Work Group T-8-16a conducted a survey of cracking experiences in wet H_2S environments to better identify the extent of the problem. Appendix B (nonmandatory) summarizes the 1990 T-8-16a survey findings.

[(1)] American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005-4070.