Standard
Recommended Practice

Avoiding Caustic Stress Corrosion Cracking of Carbon Steel Refinery Equipment and Piping

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Foreword

Caustic is used in many petroleum refinery applications in a wide range of concentrations and temperatures. This standard recommended practice is intended to provide guidance to those designing, fabricating, and/or maintaining carbon steel (CS) equipment and piping that is exposed to caustic environments.

Caustic stress corrosion cracking (SCC) of CS equipment has been reported in industry since the 1930s (riveted steam boilers). NACE has published recommendations for handling sodium hydroxide (NaOH) in the form of a “Caustic Soda Service Chart” since at least the mid-1960s. It is believed that the majority of the data used to develop the curves within the chart came from work done by H.W. Schmidt, et. al.1 The Caustic Soda Service Chart is currently published in the *NACE Corrosion Engineer’s Reference Book*.2 A copy of the chart is included as Figure 1 in this standard.

An informal review of current industry caustic handling practices was completed in 1999. This standard incorporates the findings of that survey as they apply to refinery applications.

This standard was prepared by NACE Task Group (TG) 177 (formerly T-8-25) on Environmental Cracking in Refineries. TG 177 was formed in 1998 to disseminate information on environmental cracking in refineries. From that task group, a work group was formed to survey the industry on practices to mitigate caustic SCC and to develop a standard for avoiding caustic SCC of CS refinery equipment and piping. TG 177 is administered by Specific Technology Group (STG) 34 on Petroleum Refining and Gas Processing. It is also sponsored by STG 60 on Corrosion Mechanisms. This standard is issued by NACE under the auspices of STG 34.

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Section 1: General

1.1 This standard establishes recommended practices to avoid caustic SCC of CS refinery equipment and piping. It addresses applications that use “fresh” caustic. Caustic SCC has been observed in the presence of contaminated caustic (especially contaminated with sulfide) in services that would otherwise fall within “area A” of the Caustic Soda Service Chart.

1.2 The practices detailed below are specifically intended for handling aqueous solutions containing sodium hydroxide (NaOH). However, several companies extend these practices to other strong alkali compounds (i.e., KOH and LiOH).

1.3 Some proprietary caustic solutions used in the industry (e.g., for carbon dioxide removal in hydrogen manufacturing units) contain inhibitors that may mitigate caustic SCC. In these cases, the practices included in this standard may be conservative. The effectiveness of any inhibitors added to industrial caustic solutions should be evaluated before the recommendations set forth in this standard are implemented.

Section 2: Cracking Mechanism

2.1 Early cases of caustic SCC in CS were associated with steam boilers, in particular riveted boilers. In the riveted structures, cracks started in metal that was highly stressed in tension. The majority of more recent industry cases of caustic SCC in CS equipment are associated with nonstress-relieved welds, typically in the heat-affected zone (HAZ) and adjacent base metal. Although rare, cracking can also occur away from welds if high tensile stresses are present.

2.2 Caustic SCC in CS is typically intergranular, although transgranular cracking can also occur. These cracks are typically tight and oxide-filled. Often, multiple cracks are present. Cracking in weld metal is normally intergranular, following the ferrite constituent in the matrix. Caustic SCC in CS weld metal is shown in Figures A1 and A2 in Appendix A. Caustic SCC in CS base metal is shown in Figures A3, A4, and A5 in Appendix A.

2.3 Concentration and Temperature Effects on Cracking Probability

2.3.1 Caustic concentration greater than 5 wt% in the aqueous phase can produce SCC in CS. It is important to note that caustic SCC can occur in services with lower bulk fluid concentrations, usually in areas where local concentration effects occur.

2.3.2 Caustic SCC is known to occur over a wide range of temperatures from about 46°C (115°F) to boiling.

2.4 The level of tensile stress required to produce cracking is a function of metal temperature and caustic concentration. The source of stress may be applied or residual. Applied stress may come from applied load, thermal, or other sources. Sources of residual stress include welding, bending, forming, etc. Corrosion products have also been known to produce high stress in confined areas.

Section 3: Use of Thermal Stress Relief to Mitigate the Probability of Caustic SCC

3.1 Based on the task group’s review, this standard reaffirms the recommendations in the Caustic Soda Service Chart (Figure 1) for stress relief of CS based on the combination of metal temperature and caustic concentration. CS welds (including groove welds, socket welds, and seal welds) and cold-formed piping bends or heat-exchanger tube “U” bends that are in services that fall within “area B” and “area C” of this chart should be thermally stress relieved as outlined in Paragraph 3.2.