



NACE SP0403-2008
(formerly RP0403-2003)
Item No. 21102

Standard Practice

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

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Reaffirmed 2008-02-11
Approved 2003-11-14
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ISBN 1-57590-179-X
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Foreword

Caustic is used in many petroleum refinery applications in a wide range of concentrations and temperatures. This standard 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 guidance 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 produce the curves within the chart were developed 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 practice.

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

This standard practice was prepared by NACE Task Group (TG) 177 (formerly T-8-25)—Refineries, Environmental Cracking. TG 177 was formed in 1998 to disseminate information on environmental cracking in refineries. Work Group (WG) 177a was formed from that TG to survey the industry on practices to mitigate caustic SCC and to develop a standard practice for avoiding caustic SCC of CS refinery equipment and piping. This standard practice was originally published in 2003, and it was reaffirmed in 2008 by Specific Technology Group (STG) 34—Petroleum Refining and Gas Processing. TG 177 is administered by STG 34 and is sponsored by STG 60—Corrosion Mechanisms. This standard is issued by NACE 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 practice establishes guidelines 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 otherwise fall within area "A" of the Caustic Soda Service Chart shown in Figure 1.

1.2 The practices detailed below are specifically intended for handling aqueous solutions containing sodium hydroxide (NaOH). However, several companies extend these practices to include aqueous solutions of other strong alkali

compounds such as potassium hydroxide (KOH) and lithium hydroxide (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 herein may be conservative. The effectiveness of any inhibitors added to industrial caustic solutions should be evaluated before the guidelines set forth in this standard practice are implemented.

Section 2: Cracking Mechanism

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

2.2 Caustic SCC in CS is typically intergranular, although transgranular cracking occasionally occurs. These cracks are typically tight and filled with oxide. 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.^{1,3} Caustic SCC sometimes occurs 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 approximately 46°C (115°F) to boiling temperatures.

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. Sources of applied stress include the applied load and thermal stresses. Sources of residual stress include welding, bending, and forming. Corrosion products have often produced high stress in confined areas.

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

3.1 Based on the TG's review, this standard practice reaffirms the guidelines in the Caustic Soda Service Chart (see 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), cold-formed piping bends, and heat-exchanger-tube "U" bends in services that fall within area "B" and area "C" of the Caustic Soda Service Chart should be thermally stress relieved as outlined in Paragraph 3.2.