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Standard
Test Method

Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking

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Foreword

Absorption of hydrogen generated by corrosion of steel in a wet hydrogen sulfide (H_2S) environment can have several effects that depend on the properties of the steel, the characteristics of the environment, and other variables. One adverse effect observed in pipeline and pressure vessel steels is the development of cracks along the rolling direction of the steel. Cracks on one plane tend to link up with the cracks on adjacent planes to form steps across the thickness. The cracks can reduce the effective wall thickness until the pipe or pressure vessel becomes overstressed and ruptures. Cracking is sometimes accompanied by surface blistering. Several service failures attributed to such cracking have been reported.[1,2]

The terms *stepwise cracking* (SWC), *hydrogen pressure cracking*, *blister cracking*, and *hydrogen-induced stepwise cracking* have been used in the past to describe cracking of this type in pipeline and pressure vessel steels, but are now considered obsolete. The term *hydrogen-induced cracking* (HIC) has been widely used for describing cracking of this type, and has been adopted by NACE International. Therefore, it is used throughout this standard test method.

HIC is related to hydrogen blistering, which has been recognized since the 1940s as a problem in vessels handling sour products.[3] It was not until much later, however, that HIC gained wide recognition as a potential problem in pipelines. As a result of pipeline failures experienced by two companies in the early 1970s, several companies began investigating the cracking and publishing results of tests on various steels. Many investigators found, however, that they could not reproduce published test results. It was eventually determined that lack of reproducibility resulted largely from differences in test procedures. Consequently, NACE Unit Committee T-1F on Metallurgy of Oilfield Equipment established Task Group T-1F-20 to study the problem and prepare a standard test method.

This standard was originally prepared in 1984 to provide a standard set of test conditions for consistent evaluation of pipeline steels and for comparison of test results from different laboratories. More recently, the concern for HIC damage has turned to plate steels for pressure vessels. Requirements for plate steels have included tests for resistance to HIC using this standard. Therefore, the scope of this standard was revised to include the testing of pressure vessel plate steels.

Test conditions are not designed to simulate any particular pipeline or process operation. The test is intended to evaluate resistance to HIC only, and not other adverse effects of sour environments such as sulfide stress cracking, pitting, or weight loss from corrosion.

This test may be used for many purposes, and the applications of the results are beyond the scope of this standard. Those who use the test should be aware that in some cases test results can be influenced by variations in properties among different locations in a single length of line pipe or plate, as well as by variations within a heat of steel. When the test is used as a basis for purchasing, the number and location of test specimens must be carefully considered.[4] This standard is intended for end users, manufacturers, fabricators, and testing laboratories.

This standard was revised by Task Group T-1F-20 in 1996, and again in 2003 by Task Group 082 (formerly T-1F-20) on Stepwise Cracking of Pipeline Steels, and is published by NACE under the auspices of Specific Technology Group 32 on Oil and Gas Production—Metallurgy (formerly Unit Committee T-1F on Metallurgy of Oilfield Equipment).

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 good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

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Contents

Section 1: General

1.1 This standard establishes a test method for evaluating the resistance of pipeline and pressure vessel plate steels to HIC caused by hydrogen absorption from aqueous sulfide corrosion.

1.1.1 Special procedures or requirements for testing small-diameter (nominal pipe size [NPS] 2 through 6), thin-wall (up to 6-mm wall thickness), electric-resistance welded (ERW) and seamless line pipe are included. These small-diameter, thin-wall materials shall be tested in the same manner as other line pipe except as otherwise stated in this standard.

1.2 The test method consists of exposing unstressed test specimens to one of the two standard test solutions—either Solution A, a sodium chloride, acetic acid (NaCl, CH_3COOH) solution saturated with H_2S at ambient temperature and pressure, or Solution B, a synthetic seawater solution saturated with H_2S at ambient temperature and pressure. After a specified time the test specimens shall be removed and evaluated.

1.3 The test method is not intended to duplicate service conditions. It is intended to provide reproducible test environments capable of distinguishing the susceptibility of different steel samples to HIC in a relatively short time. NOTE: The length of the test may not be sufficient to develop maximum cracking in any given steel but has been found to be adequate for the purpose of this test.

1.4 This standard does not include acceptance or rejection criteria. The methods used for determining acceptance and rejection, for comparing different steels, for screening of steels, or for other purposes are beyond the scope of this standard.

Section 2: Reagents

2.1 The reagents for Solution A shall be nitrogen gas for purging, H_2S gas, NaCl, CH_3COOH, and distilled or deionized water. The reagents for Solution B shall be nitrogen gas for purging, H_2S gas, and synthetic seawater. NOTE: H_2S IS HIGHLY TOXIC AND MUST BE HANDLED WITH CAUTION (see Appendix A).

2.2 The NaCl and CH_3COOH shall be reagent grade chemicals.

2.3 The gases shall be reagent grade or chemically pure gases and the water shall be distilled or deionized (see Appendix B).

2.4 The synthetic seawater shall be prepared in accordance with ASTM[(1)] Standard D 1141,[5] Stock Solutions No. 1 and No. 2 (without heavy metal ions).

Section 3: Testing Apparatus

3.1 The test may be performed in any convenient airtight vessel large enough to contain the test specimens with provisions for purging and introduction of H_2S. None of the materials involved in the test set-up shall contaminate or react with the test environment. Figure 1 is a schematic diagram of a typical test assembly.

Section 4: Test Specimens—Pipeline Steels

4.1 Size

4.1.1 Each test specimen shall be 100 ±1 mm long by 20 ±1 mm wide.

4.1.2 The test specimen thickness shall be the full wall thickness of the pipe up to a maximum of 30 mm. For wall thickness greater than 30 mm, the test specimen thickness shall be either the full wall thickness of the pipe or limited to a maximum thickness of 30 mm as described in Section 5. A maximum of 1 mm may be removed from each of the surfaces (i.e., internal and external). Test specimen blanks shall not be flattened.

4.1.3 For small-diameter, thin-wall ERW and seamless line pipe, the test specimen thickness must be at least 80% of the full wall thickness of the pipe. In such cases, curved test specimens cut from the line pipe

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