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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, manufacturing or forming processes, 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 pipeline 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 pressure 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, "Metallurgy of Oilfield Equipment," established Task Group (TG) 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 steel pipes and for comparison of test results from different laboratories. Subsequently, the concern for HIC damage turned to steel plates used for pressure vessels. Requirements for testing steel plates for resistance to HIC were included in this standard in 1996. More recently, concern for HIC damage in steel fittings and flanges used in pipelines and pressure vessels has led to their inclusion in the 2011 revision of this standard. Therefore, the scope of this standard now includes the testing of steels furnished in the form of pipes, plates, fittings, and flanges for use in fabricating pipelines and pressure vessels.

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 (SSC), pitting, or mass 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 pipe or individual plate, fitting, or flange, 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 originally prepared by Task Group T-1F-20 in 1984. It was revised by TG T-1F-20 in 1996, and in 2003 and 2011 by Task Group (TG) 082, "Stepwise Cracking of Pipeline Steels." This standard is published by NACE under the auspices of Specific Technology Group (STG) 32, "Oil and Gas Production—Metallurgy." It is issued by NACE under the auspices of STG 32.

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

1.1.1 Details are provided on the size, number, location, and orientation of test specimens to be taken from each steel product form—pipes, plates, fittings, and flanges.

1.1.2 Special procedures or requirements for testing small-diameter (nominal diameter [DN] 50 through 150, nominal pipe size [NPS] 2 through 6), thin-wall (up to 6 mm [0.2 in] wall thickness), electric-resistance welded (ERW) and seamless pipes are included. The test specimens taken from small-diameter, thin-wall pipes shall be tested in the same manner as the test specimens taken from other pipes 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—Test Solution A, a solution consisting of sodium chloride (NaCl) and acetic acid (CH_3COOH) dissolved in distilled or deionized water saturated with H_2S at ambient temperature and pressure; or Test Solution B, a synthetic seawater solution saturated with H_2S at ambient temperature and pressure. After a specified time the test specimens are 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; however, guidance is provided in NACE MR0175/ISO[(1)] 15156,[5] Part 2, Section 8 and Annex B of EFC[(2)] 16.[6]

Section 2: Reagents

2.1 The reagents for Test Solution A shall be nitrogen gas for purging, H_2S gas, NaCl, CH_3COOH, and distilled or deionized water. The reagents for Test 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 (nonmandatory).

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 (nonmandatory).

2.4 The synthetic seawater shall be prepared in accordance with ASTM[(3)] Standard D1141,[7] Stock Solutions No. 1 and No. 2 (without heavy metal ions).

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(2) European Federation of Corrosion, 1 Carlton House Terrace, London, SW1Y 5DB, U.K.
(3) ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.