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Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments

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Foreword

This standard addresses the testing of metals for resistance to cracking under the combined action of tensile stress and corrosion in aqueous environments containing hydrogen sulfide (H_2S). This phenomenon is generally termed sulfide stress cracking (SSC) when operating at temperatures near or below ambient and stress corrosion cracking (SCC) when operating at higher temperatures. In recognition of the variation in temperature and with different materials, this phenomenon is herein called environmentally assisted cracking (EAC). For the purposes of this standard, EAC includes only SSC, SCC, and hydrogen stress cracking (HSC).

SSC of metals exposed to oilfield environments containing H_2S was recognized as a materials failure problem by 1952. Laboratory data and field experience have demonstrated that even extremely low concentrations of H_2S may be sufficient to lead to SSC failure of susceptible materials. In some cases, H_2S can act synergistically with chlorides to produce corrosion and cracking (SSC and other mode) failures. However, laboratory and operating experiences have also indicated to materials engineers the optimum selection and specification of materials having minimum susceptibility to SSC. This standard covers test methods for SSC and SCC; other failure modes (e.g., hydrogen blistering, hydrogen-induced cracking [HIC], stress-oriented hydrogen-induced cracking [SOHIC], chloride SCC, pitting corrosion, and mass-loss corrosion) are not addressed. These tests are critical assessment tools for service in H_2S environments as referenced by international standards on materials for use in H_2S-containing environments in oil and gas production.[1,2]

The need for better understanding of the variables involved in EAC of metals in oilfield environments and better correlation of data has become apparent for several reasons. New design requirements by the oil and gas production industries call for higher-strength materials that, in general, are more susceptible to EAC than lower-strength alloys. These design requirements have resulted in extensive development programs to obtain more resistant alloys and/or better heat treatments. At the same time, users in the petroleum refining and synthetic fuels industries are pushing present materials much closer to their mechanical limits.

SSC failures in some alloys generally are believed to result from hydrogen embrittlement (HE). When hydrogen is cathodically evolved on the surface of a metal (as by corrosion or cathodic charging), the presence of H_2S (and other compounds, such as those containing cyanides and arsenic) tends to cause hydrogen atoms to enter the metal rather than form hydrogen molecules that cannot enter the metal. In the metal, hydrogen atoms diffuse to regions of high triaxial tensile stress or to some microstructural configurations where they become trapped and decrease the ductility of the metal. Although there are several kinds of cracking damage that can occur in metals, delayed brittle fracture of metals resulting from the combined action of corrosion in an aqueous sulfide environment and tensile stresses (failure may occur at stresses far below the yield stress) is the phenomenon known as SSC.

In some cases, however, failure may be the result of localized anodic corrosion processes that may or may not involve hydrogen. In such instances, failure is the result of anodic SCC. Such failures have historically been termed SSC even though their cause may not be hydrogen.

Scope

The primary purpose of this standard is to facilitate conformity in testing so that data from different sources can be compared on a common basis. Consequently, this standard aids the evaluation and selection of all types of metals and alloys, regardless of their form or application, for service in H_2S-containing environments. This standard contains methods for testing metals using uniaxial tensile, three-point bent-beam, C-ring, and double-cantilever-beam (DCB) test specimens. A separate standard, NACE TM0316,[3] contains a method for testing metals using four-point bend test specimens.

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