NACE MR0175
DOES IT WORK FOR YOU?

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Abstract

NACE MR0175/ISO 15156 is the most used and recognised standard for material selection in sour oil and gas production. First published by NACE in 1975 as a sulphide stress cracking document, it has evolved into the more comprehensive ISO 15156 which now covers all forms of cracking that can be generated by wet hydrogen sulphide. This paper explores the standard and the current challenges for the Maintenance Panel and the Oversight Committee (STG299). There are a number of misconceptions which will be explained, in addition vital interpretations which affect the use of the standard will be highlighted. Finally, the relevance of particular test methods cited in the Standard will be explored.

Introduction

ISO15156/NACE MR0175 [1] was first issued in 2003, with its first full revision issued in 2009.

This is the Standard for Exploration and Production in the Oil and Gas Area. Since publication, the industry has varied views about the standard; the negative views are generally because time has not been spent reading and understanding the document. In addition, the standard requires prior knowledge of sour service corrosion and the cracking mechanisms that can be generated by wet hydrogen sulphide.

The standard is a working, evolving document providing the best knowledge that the industry can provide; it is not intended to be a “laundry list,” rather a tool for material selection and qualification by various methods accepted by the industry themselves.

Background

NACE MR0175 has been and still is the industry accepted Sour Service Material Selection Standard. First published in 1975, the standard was reviewed and re-issued annually, up until 2003.

During the 1990s, The European Federation of Corrosion (EFC) published Guideline Documents: - EFC 16 [2] in 1995 and EFC 17 [3], the former covering Carbon Steel in Sour Service and the latter covering Corrosion Resistant Alloys in Sour Service.

Thus in a way there were competing documents, although only one standard; a decision was made during the late 1990s to combine the three documents into one and make it an ISO standard.

In 2003, ISO15156 was issued with the dual nomenclature of NACE MR0175. Although this document is a standard, it is not considered totally prescriptive, there are many options for qualifying materials and many test methods are listed.

The standard is maintained by an ISO Maintenance Panel which reviews, ballots and answers questions and provides interpretations.

The standard now covers all forms of cracking that can be generated by wet hydrogen sulphide, ie Sulphide Stress Cracking (SSC), Hydrogen Induced Cracking (HIC) and Stress Orientated Hydrogen Induced Cracking (SOHIC). In addition, both Galvanically Induced Hydrogen Stress Cracking (GHSC) and Stress Corrosion Cracking (SCC) are also included.

Now that the document is an ISO standard, acceptance criteria and test stress levels are included. Some of these criteria and levels are part of the discussion in this paper and the concept of qualification by Field Experience has been introduced.

The Basic Rules

Set out below are the basic rules/assumptions for this standard:

- The standard only applies to equipment designed to elastic criteria;
- The environments considered are oxygen free;
- The standard applies to upstream oil and gas exploration and production;
- It is the user's responsibility to ensure the correct material is used;
- There is no lower limit of hydrogen sulphide for Corrosion Resistant alloys;
- The domain diagram (see later section) only applies to carbon and low alloy steels and for sulphide stress cracking.

The Standard [1]

<u>Part 1</u>

- Petroleum and Natural Gas Industries - Materials for use in H_2S-containing environments in oil and gas production;
- General principles for selection of cracking resistant materials;
- Important extract: "The equipment user shall determine whether or not the service conditions are such that the ISO standard applies."

Part 2

- Petroleum and Natural Gas Industries - Materials for use in H_2S-containing environments in oil and gas production;
- Cracking-resistant carbon and low alloy steels, and the use of cast irons;
- Cracking mechanisms considered include HIC, SOHIC and SSC, Figure 1.

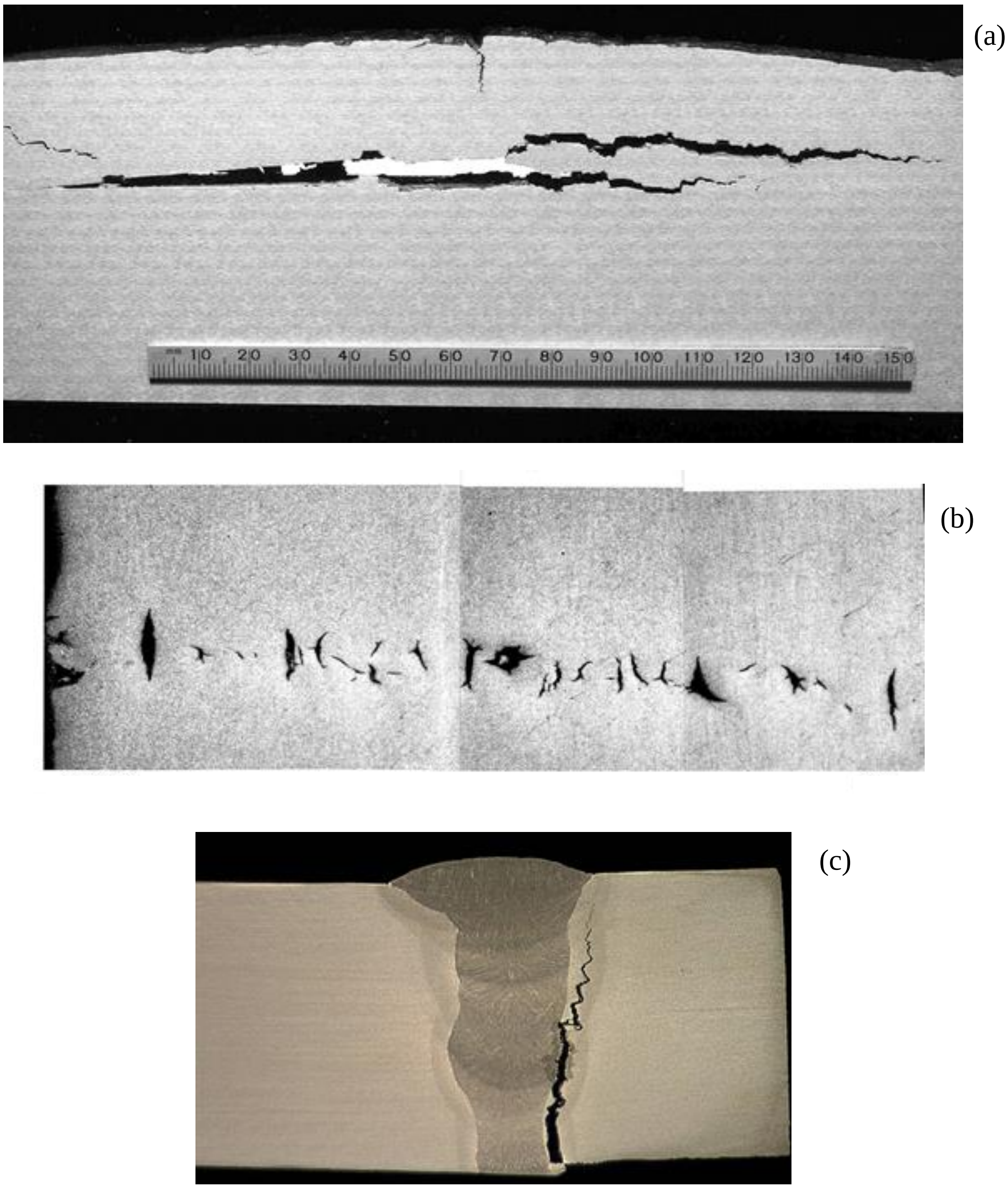

Figure 1. Examples of HIC (a), SOHIC (b) and SSC (c).

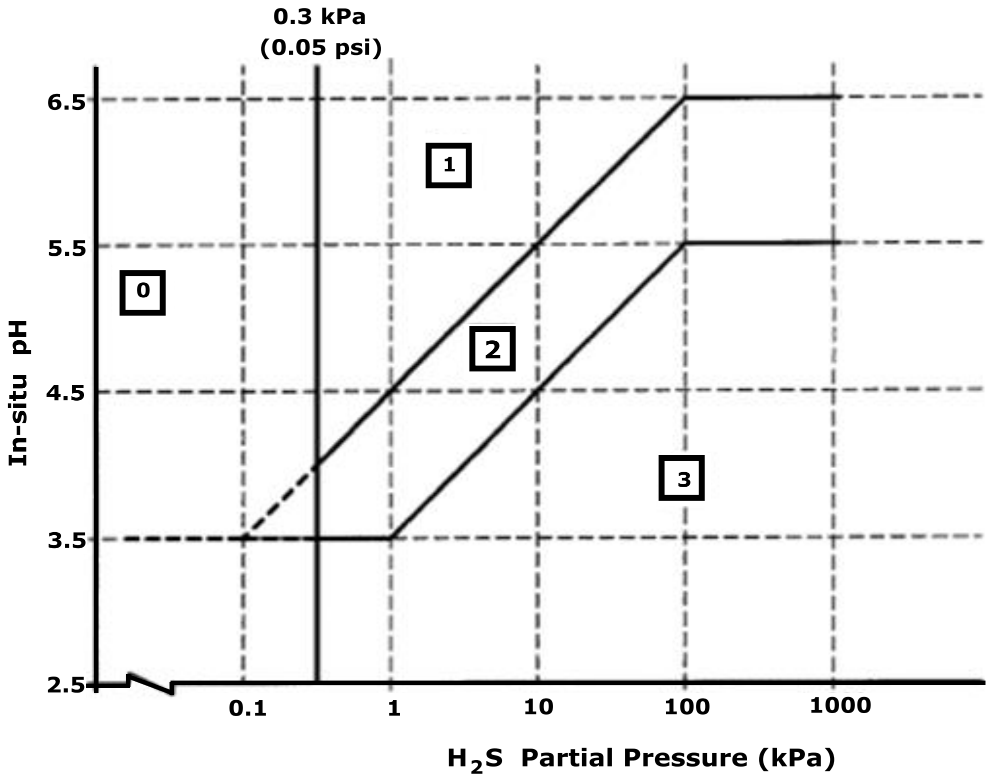

Figure 2. SSC regions of environmental severity [1].

As Figure 2 shows, the concept of pH is now recognised (this diagram is taken directly from ISO 15156/NACE MR0175). However, Figure 2 only applies to carbon and low alloy steels when considering SSC.

This domain diagram allows the qualification of material under representative field conditions rather than the fixed NACE condition:

- Region 3 represents fully sour conditions;
- Region 2 represents intermediate sour conditions;
- Region 1 represents mildly sour conditions.

Region 0 does not represent immunity from cracking; some high strength steels may still be susceptible in this region.

Qualification by Laboratory Testing. The following test methods are listed as acceptable for SSC:

- Uniaxial Tensile;
- Four Point Bend;
- Double Cantilever Bend;
- "C" Ring;
- Full size components by agreement between purchaser and supplier.

For qualification in all regions of the domain diagram the load shall be a minimum of 80% actual yield strength and tested in NACE TM0177 Solution A [4].

For qualification in specific regions (1 or 2) the load shall be a minimum of 90% actual yield strength.

However, what is the actual yield strength in a welded sample and what test protocol shall be followed for Four Point Bend testing? The loading levels were taken from EFC 16 [2] and were set to take into account the loss of residual stress when a small scale sample is machined from a pipe or plate.

But the residual stress is in many competing directions, thus is it correct to increase the load only in one direction? Currently there is no universally published Four Point Bend method; ASTM gives loading guidelines for a homogeneous prismatic sample, somewhat far away from a welded sample!

As the majority of pipeline welds are qualified by this method there is a gap in our guidance and documentation. To this end two working groups have been formed, one within EFC and one within NACE, to establish and write a Four Point Bend Test Method. These groups have now produced the first draft document, for review. All aspects of the test have been examined, from the load levels to the acceptance criteria.

The following test methods are listed as acceptable for SOHIC:

- Uniaxial Tensile specimens that are further loaded to failure;
- Four Point Bend Samples;
- The Full Ring Test Method OTI 95635 [5];
- Other test under development.

The author does not believe that the first two methods can determine susceptibility to SOHIC, unless they are loaded incorrectly.

The following test method is listed as acceptable for HIC:

- The NACE test method TM0284 [6] is cited as the method to be used. The additional information provided is acceptance criteria.

The option to test in full NACE, low pH solution and field conditions is provided. However, for testing in field conditions no test duration is stated.

Part 3

- Petroleum and Natural Gas Industries - Materials for use in H_2S-containing environments in oil and gas production;
- Cracking-resistant CRAs (Corrosion Resistant Alloys) and other alloys.

This part of the standard groups the materials of each type in a table, thus Table A1 is effectively the index to Part 3. The intention was to make material selection simpler by having the alloys grouped together. However, this means a group of alloys have environmental limits that reflect the lowest form of the alloy. Thus, several ballots have now been received to increase the environmental limits of specific alloys within a table.

Currently Table A2 – Austenitic Stainless Steels is the subject of much discussion; particularly the definition of Cold Work and the effect thereof.

Each table sets the temperature, chloride level, partial pressure of H_2S and pH for the alloy grouping. Exceptions are then also listed; it is not the intention here to go through these groups.

The cracking mechanisms considered are:

- Sulphide Stress Cracking SSC;
- Stress Corrosion Cracking SCC (normally associated with chlorides);
- Galvanic Hydrogen Stress Cracking GHSC.

The available test methods are as per the carbon and low alloy steel section, with the addition of slow strain rate and interrupted slow strain rate. At this point it should be noted that virtually all the materials tested and balloted in Part 3 of the standard were tested as parent material only. Rarely, if ever, have welded samples been used. This begs the question – should welded samples be tested? The standard states that qualification of materials must be undertaken from material in its final product form – should this mean welded?

Test Methods. The comments pertaining to the carbon steel section are also relevant for CRAs (Excepting HIC and SOHIC).

Additionally, Slow Strain Rate (SSR) has been included; now this method, although of much less duration, has its own problems. In this method the sample is pulled to failure in the test environment. During the latter stages of the "pull", the sample will cold work and/or plastically deform, thus the material properties actually change. Therefore, qualification by this method must be considered carefully as a failure mechanism can be induced that would not occur in real life.

A good adage is that if a material passes the SSR test (SSRT) then it is acceptable, however if it fails the SSRT then try another test method!

What are missing from the standard are guidance notes on the use of each of the test methods.

The ISO Maintenance Panel

A cooperative ISO/NACE organisation was set up to maintain this document. Key groups representing the international oil and gas industries were established with a balance of USA and overseas members. Users, manufacturers, alloy suppliers, service companies and consultants are also represented. Membership is by nomination, not application, and there can only be one member per organisation. Qualification is reviewed and all members, including chairpersons, rotate. The aim of the maintenance panel is to be open to new ideas and perspectives. A single negative can no longer stop a ballot.

STG 299-The NACE Peer Review Panel

This group has a similar make up to the Maintenance Panel except they are approximately 45 in number. All ballots are critically reviewed by this committee.

The Challenges

The current challenges to the document are:

- Effect of Cold Work on Austenitic Stainless Steels;
- Hardness of test samples for Austenitic Stainless Steel;
- Low H_2S limit for 17-4PH;
- Inclusion of high strength Super 13%Cr Steels;
- The freedom to test and choose non-listed materials is outside comfort zone of many users;
- The wider availability of test results;
- Feedback of results of user sponsored tests to NACE for the benefit of all in the industry;
- Use of field experience;
- Consistency of definitions and alloy requirements across NACE, ISO and API;
- Both users and manufacturers need more training.

Reality Check

Does the Standard do what you want? Some parts of the industry say it is not prescriptive enough and that only experienced corrosion engineers can fully implement it.

Should more educational workshops be run? Should there be a working guide to the test methods employed?

The two Panels meet twice a year, once at the NACE Conference and once at EUROCORR. Why do the regulators and contractors not attend?

References

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3. European Federation of Corrosion Publications No. 17, *A Working Party Report on Corrosion Resistant Alloys for Oil and Gas Production – Guidance on General Requirements and Test Methods for H_2S Service* (London, UK: The Institute of Materials, 2nd edition, 2002).

4. NACE. "Standard Test Method Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments" 1996 (TM0177-96).

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6. NACE. "Standard Test Method Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen Induced Cracking" (TM0284-11).