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PenTech FAQ # 6 by Gary G. Sanders, Vice President - Engineering

NACE Requirements (Revision A)

NACE International (formerly NACE which is the acronym for the National Association of Corrosion Engineers) is one of the standards providing member organizations of ANSI (American National Standards Institute). NACE International currently has in publication over 65 recommended procedures, over 30 test methods, 7 joint S.P.P.C. specifications, 4 standard material requirements and miscellaneous others. When NACE is mentioned in our industry the standard that is generally implied is MR0175. Properly, it is Material Requirements 0175-xx (01 = first publication of the year 1975 and the xx is the year of the revision – 99 being current as this FAQ is written). Its title is “*Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*”. It was written to provide guidelines and material requirements for equipment that is resistant to – but not necessarily immune to - the problem of sulfide stress cracking [SSC]. SSC is a type of brittle failure by cracking caused when metals are stressed (usually by pressure although occasionally by mechanical loading) *and* corroded by H_2S (hydrogen sulfide) in the presence of water. Other contributing factors are the chemistry and heat history of the metal, the pH of the environment, time and temperature. MR0175 addresses only SSC, not other metallic failure mechanisms such as: blister or stepwise cracking of steels in an H_2 environment (a.k.a. hydrogen embrittlement) or chloride stress corrosion cracking [CSCC] or intergranular corrosion in austenitic stainless steels. A prime requirement of MR0175 is based upon the chemical composition of the metallic alloy and its intrinsic ability to withstand SSC. It discusses iron, steel, nickel, copper, aluminum, tantalum and titanium metals/alloys.

This FAQ will be directed toward the steels since they are the most commonly used alloys for which NACE MR0175 is invoked for Penberthy’s products. Steel is iron alloyed with carbon and manganese plus other materials. It is the most versatile material of construction used in our industry. Aside from its very large base of alloying materials (which classifies it into a family; such as: carbon, alloy, free-machining, stainless, duplex, etc.), one of the reasons for its versatility is that most types are ‘hardenable’. Metallurgically, hardness is measured by various indenters (hardness testers). The two most common types are Rockwell and Brinell. The Rockwell type is subdivided into A through D scales. Standard abbreviations are, e.g., HRC (Hardness Rockwell C-scale) or HB (Hardness Brinell). Steel can attain a maximum hardness of about 67 HRC. For a given chemical composition, if steel is fully annealed (i.e., heat treated in such a way to relieve “all” stresses) then it is considered mild (or soft) steel. With mildness comes toughness (the ability to “take a beatin’ and keep on tickin’ ”[1]). The converse is hardened steel (by heat treatment [martensitic conversion] or other stress inducing mechanisms). It is very strong, but the strength has a consequence – brittleness (consider spring steel, piano wire or steel repeatedly flexed until it work hardens, becomes brittle and eventually breaks).

Some succinct generalities:

a) Toughness is a measure of the energy absorbed when a material fractures.
b) Hardness is resistance to plastic deformation.
c) Hardness is roughly proportional to strength.
d) Hardness is also related to wear and abrasion resistance.
e) Hard materials tend to be brittle.
f) Brittle materials are not tough.
g) For a given chemistry, mild steels tend to resist corrosion better than hard.

Other examples of tough vs. strong: Most rubber is tough but not hard. It can absorb tremendous blows and remain intact, consider the beating that a tire takes (you may elect to kick the tires but don't kick the quarter panel, although harder it is not tougher so it dents). Conversely, consider an eggshell, it is extremely hard but is brittle and breaks easily. Other examples: polymers: Tupperware® vs. Bakelite®, metals: 24k gold or lead vs. chromium.

For pressure vessel design, toughness tends to be a more important metal characteristic than strength. The vessel must retain the ability to absorb the stresses caused by pressurization without breaking. Low strength can be compensated for by geometry or by using thicker sections, etc. In general, brittleness cannot be compensated for but can sometimes be designed around with massively rigid structures which essentially do not flex (consider machine bases). This is not very practical for pressure vessels.

As we are all aware – much of the crude and other feedstocks for the hydrocarbon industry are called "sour" as compared to "sweet" (e.g., the benchmark "Texas light sweet crude"). In this use "sour" means a significant amount of hydrogen sulfide (H2S) is present along with the process fluids.

Relevance: H_2S in the presence of water forms reducing acids, hydrosulfuric and occasionally other polythionic acids. The corrosion products with iron/steel is ferrous sulfide and sulfur which are both cathodic to the base metal (graphitic corrosion is also a possibility under certain conditions). When steel is placed under tensile stress (think pressure) this corrosion, especially along grain boundaries is accelerated, thus the steel cracks. Tensile loading affects the more ductile mild steels less than hardened steels (grain boundaries are under less stress). Therefore, to aid resistance to SSC brittle fractures, the second prime requirement of MR0175 specifies using mild materials. Although there are many exceptions, the rule of thumb is – keep steels milder than 22 HRC for MR0175 acceptance. Design problem – by using mild steel (think low strength) pressure derating is required if the geometry of the product is to remain the same.

For Penberthy products, we add another dimension to our NACE MR0175 callouts. If the process fluids are the only source of H_2S contact, then only process "wetted parts" (think internal surfaces) need to meet MR0175 requirements. We add the abbreviation NW meaning <u>N</u>ACE <u>W</u>etted. If H_2S can make contact with all pressure boundary parts (think external and internal surfaces), then all parts will be specified to meet the requirements of MR0175 and we abbreviate it NE meaning <u>N</u>ACE <u>E</u>nvironmental.

A word of **CAUTION:**
Many Penberthy products are supplied with welding type connections. Welding - including the heat affected zone [HAZ] - changes the hardness of steels in a manner similar to that of heat treating. Weldment caused changes in hardness must be addressed to maintain the installed product's compliance with MR0175. Penberthy attaches a blue stainless steel tag with an informational warning (part # 16351-000) to such products.

For information about MR0175 and other NACE publications the reader is directed to:
NACE Publications Orders Department
National Association of Corrosion Engineers
P.O. Box 218340
Houston, TX 77218-8340
(713) 492-0535

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to Kitty Thornton – Houston, TX for suggesting the subject addressed by this FAQ.
to NACE International for their review.

[1] My apologies to the Timex Corporation and John Cameron Swayze for this application of their slogan.

Revision addenda

In the absence of any other recognized standard, historically MR0175, the widely accepted standard for sour service in oil fields, was specified for processing equipment orders although it was clearly written for the oil and gas production industries.

In 2003, NACE International revised MR0175 / ISO 15156 (in three parts) to encompass a more international market.
NACE International also released a new standard, MR0103 titled "*Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*". MR0103 directly addresses sour service at refineries and allied processing. All future references to NACE qualified Penberthy products will be assumed to be to MR0103 unless specifically stated otherwise.

For information about MR0103 (NACE item no. 21305) and other NACE publications the reader is directed to:
NACE International
1440 South Creek Drive
Houston, TX 77084-4906
(281) 228-6200