

## Sulfide Stress Cracking --NACE MR0175-2002, MR0175/ISO 15156

### The Details

NACE MR0175, "Sulfide Stress Corrosion Cracking Resistant Metallic Materials for Oil Field Equipment" is widely used throughout the world. In late 2003, it became NACE MR0175/ISO 15156, "Petroleum and Natural Gas Industries - Materials for Use in H<sub>2</sub>S-Containing Environments in Oil and Gas Production." These standards specify the proper materials, heat treat conditions and strength levels required to provide good service life in sour gas and oil environments.

NACE International (formerly the National Association of Corrosion Engineers) is a worldwide technical organization which studies various aspects of corrosion and the damage that may result in refineries, chemical plants, water systems and other types of industrial equipment. MR0175 was first issued in 1975, but the origin of the document dates to 1959 when a group of engineers in Western Canada pooled their experience in successful handling of sour gas. The group organized as a NACE committee and in 1963 issued specification 1B163, "Recommendations of Materials for Sour Service." In 1965, NACE organized a nationwide committee, which issued 1F166 in 1966 and MR0175 in 1975. Revisions were issued on an annual basis as new materials and processes were added. Revisions had to receive unanimous approval from the responsible NACE committee.

In the mid-1990's, the European Federation of Corrosion (EFC) issued 2 reports closely related to MR0175; Publication 16, "Guidelines on Materials Requirements for Carbon and Low Alloy Steels for H<sub>2</sub>S-Containing Environments in Oil and Gas Production" and Publication 17, "Corrosion Resistant Alloys for Oil and Gas Production: Guidance on General Requirements and Test Methods for H<sub>2</sub>S Service." EFC is located in London, England.

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from more than 140 countries. One organization from each country acts as the representative for all organizations in that country. The American National Standards Institute (ANSI) is the USA representative in ISO. Technical Committee 67, "Materials, Equipment and Offshore Structures for Petroleum, Petrochemical and Natural Gas Industries," requested that NACE blend the different sour service documents into a single global standard.

This task was completed in late 2003 and the document was issued as ISO standard, NACE MR0175/ISO 15156. It is now maintained by ISO/TC 67, Work Group 7, a 12-member "Maintenance Panel" and a 40-member Oversight Committee

under combined NACE/ISO control. The three committees are an international group of users, manufacturers and service providers. Membership is approved by NACE and ISO based on technical knowledge and experience. Terms are limited. Previously, some members on the NACE Task Group had served for over 25 years.

NACE MR0175/ISO 15156 is published in 3 volumes.

**Part 1:** General Principles for Selection of Cracking-Resistant Materials

**Part 2:** Cracking-Resistant Carbon and Low Alloy Steels, and the Use of Cast Irons

**Part 3:** Cracking-Resistant CRA's (Corrosion-Resistant Alloys) and Other Alloys

NACE MR0175/ISO 15156 applies only to petroleum production, drilling, gathering and flow line equipment and field processing facilities to be used in H<sub>2</sub>S bearing hydrocarbon service. In the past, MR0175 only addressed sulfide stress cracking (SSC). In NACE MR0175/ISO 15156, however, both SSC and chloride stress corrosion cracking (SCC) are considered. While clearly intended to be used only for oil field equipment, industry has applied MR0175 in to many other areas including refineries, LNG plants, pipelines and natural gas systems. The judicious use of the document in these applications is constructive and can help prevent SSC failures wherever H<sub>2</sub>S is present. Saltwater wells and saltwater handling facilities are not covered by NACE MR0175/ISO 15156. These are covered by NACE Standard RP0475, "Selection of Metallic Materials to Be Used in All Phases of Water Handling for Injection into Oil-Bearing Formations."

When new restrictions are placed on materials in NACE MR0175/ISO 15156 or when materials are deleted from this standard, materials in use at that time are in compliance. This includes materials listed in MR0175-2002, but not listed in NACE MR0175/ISO 15156. However, if this equipment is moved to a different location and exposed to different conditions, the materials must be listed in the current revision. Alternatively, successful use of materials outside the limitations of NACE MR0175/ISO 15156 may be perpetuated by qualification testing per the standard. The user may replace materials in kind for existing wells or for new wells within a given field if the environmental conditions of the field have not changed.

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### New Sulfide Stress Cracking Standard for Refineries

Don Bush, Principal Engineer - Materials, at Emerson Process Management Fisher Valves, is a member and former chair of a NACE task group that has written a document for refinery applications, NACE MR0103. The title is "Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments." The requirements of this standard are very similar to the pre-2003 MR0175 for many materials. When applying this standard, there are changes to certain key materials compared with NACE MR0175-2002.

### Responsibility

It has always been the responsibility of the end user to determine the operating conditions and to specify when NACE MR0175 applies. This is now emphasized more strongly than ever in NACE MR0175/ISO 15156. The manufacturer is responsible for meeting the metallurgical requirements of NACE MR0175/ISO 15156. It is the end user's responsibility to ensure that a material will be satisfactory in the intended environment. Some of the operating conditions which must be considered include pressure, temperature, corrosiveness, fluid properties, etc. When bolting components are selected, the pressure rating of flanges could be affected. It is always the responsibility of the equipment user to convey the environmental conditions to the equipment supplier, particularly if the equipment will be used in sour service.

The various sections of NACE MR0175/ISO 15156 cover the commonly available forms of materials and alloy systems. The requirements for heat treatment, hardness levels, conditions of mechanical work and post-weld heat treatment are addressed for each form of material. Fabrication techniques, bolting, platings and coatings are also addressed.

### Applicability of NACE MR0175/ISO 15156

Low concentrations of  $H_2S$  (<0.05 psi (0,3 kPa)  $H_2S$  partial pressure) and low pressures (<65 psia or 450 kPa) are considered outside the scope of NACE MR0175/ISO 15156. The low stress levels at low pressures or the inhibitive effects of oil may give satisfactory performance with standard commercial equipment. Many users, however, have elected to take a conservative approach and specify compliance to either NACE MR0175 or NACE MR0175/ISO 15156 any time a measurable amount of  $H_2S$  is present. The decision to follow these specifications must be made by the user based on economic impact, the safety aspects should a failure occur and past field experience. Legislation can impact the decision as well. Such jurisdictions include; the Texas Railroad Commission and the U.S. Minerals Management Service (offshore). The Alberta, Canada Energy Conservation Board recommends use of the specifications.

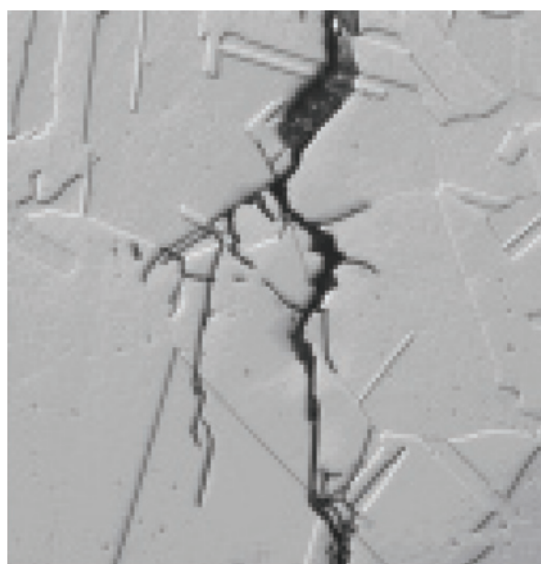


Figure 1. Photomicrograph Showing Stress Corrosion Cracking

### Basics of Sulfide Stress Cracking (SSC) and Stress Corrosion Cracking (SCC)

SSC and SCC are cracking processes that develop in the presence of water, corrosion and surface tensile stress. It is a progressive type of failure that produces cracking at stress levels that are well below the material's tensile strength. The break or fracture appears brittle, with no localized yielding, plastic deformation or elongation. Rather than a single crack, a network of fine, feathery, branched cracks will form (see Figure 1). Pitting is frequently seen, and will serve as a stress concentrator to initiate cracking.

With SSC, hydrogen ions are a product of the corrosion process (Figure 2). These ions pick up electrons from the base material producing hydrogen atoms. At that point, two hydrogen atoms may combine to form a hydrogen molecule. Most molecules will eventually collect, form hydrogen bubbles and float away harmlessly. However, some percentage of the hydrogen atoms will diffuse into the base metal and embrittle the crystalline structure. When a certain critical concentration of hydrogen is reached and combined with a tensile stress exceeding a threshold level, SSC will occur.  $H_2S$  does not actively participate in the SSC reaction; however, sulfides act to promote the entry of the hydrogen atoms into the base material.

As little as 0.05 psi (0,3 kPa)  $H_2S$  partial pressure in 65 psia (450 kPa) hydrocarbon gas can cause SSC of carbon and low alloy steels. Sulfide stress cracking is most severe at ambient temperature, particularly in the range of 20° to 120°F (-6° to 49°C). Below 20°F (-6°C) the diffusion rate of the hydrogen is

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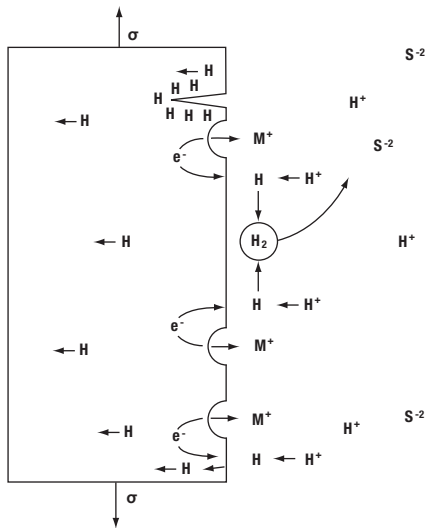


Figure 2. Schematic Showing the Generation of Hydrogen Producing SSC

so slow that the critical concentration is never reached. Above 120°F (49°C), the diffusion rate is so fast that the hydrogen atoms pass through the material in such a rapid manner that the critical concentration is not reached.

Chloride SCC is widely encountered and has been extensively studied. Much is still unknown, however, about its mechanism. One theory says that hydrogen, generated by the corrosion process, diffuses into the base metal in the atomic form and embrittles the lattice structure. A second, more widely accepted theory proposes an electrochemical mechanism. Stainless steels are covered with a protective, chromium oxide film. The chloride ions rupture the film at weak spots, resulting in anodic (bare) and cathodic (film covered) sites. The galvanic cell produces accelerated attack at the anodic sites, which when combined with tensile stresses produces cracking. A minimum ion concentration is required to produce SCC. As the concentration increases, the environment becomes more severe, reducing the time to failure.

Temperature also is a factor in SCC. In general, the likelihood of SCC increases with increasing temperature. A minimum threshold temperature exists for most systems, below which SCC is rare. Across industry, the generally accepted minimum temperature for chloride SCC of the 300 SST's is about 160°F (71°C). NACE MR0175/ISO 15156 has set a very conservative limit of 140°F (60°C) due to the synergistic effects of the chlorides, H<sub>2</sub>S and low pH values. As the temperature increases above these values, the time to failure will typically decrease.

Resistance to chloride SCC increases with higher alloy materials. This is reflected in the environmental limits set by NACE

MR0175/ISO 15156. Environmental limits progressively increase from 400 Series SST and ferritic SST to 300 Series, highly alloy austenitic SST, duplex SST, nickel and cobalt base alloys.

### Carbon Steel

Carbon and low-alloy steels have acceptable resistance to SSC and SCC however; their application is often limited by their low resistance to general corrosion. The processing of carbon and low alloy steels must be carefully controlled for good resistance to SSC and SCC. The hardness must be less than 22 HRC. If welding or significant cold working is done, stress relief is required. Although the base metal hardness of a carbon or alloy steel is less than 22 HRC, areas of the heat affected zone (HAZ) will be harder. PWHT will eliminate these excessively hard areas.

ASME SA216 Grades WCB and WCC and SAME SA105 are the most commonly used body materials. It is Fisher's policy to stress relieve all welded carbon steels that are supplied to NACE MR0175/ISO 15156.

All carbon steel castings sold to NACE MR0175/ISO 15156 requirements are produced using one of the following processes:

1. In particular product lines where a large percentage of carbon steel assemblies are sold as NACE MR0175/ISO 15156 compliant, castings are ordered from the foundry with a requirement that the castings be either normalized or stress relieved following all weld repairs, major or minor. Any weld repairs performed, either major or minor, are subsequently stress relieved.
2. In product lines where only a small percentage of carbon steel products are ordered NACE MR0175/ISO 15156 compliant, stock castings are stress relieved whether they are weld repaired by Emerson Process Management or not. This eliminates the chance of a minor foundry weld repair going undetected and not being stress relieved.

ASME SA352 grades LCB and LCC have the same composition as WCB and WCC, respectively. They are heat treated differently and impact tested at -50°F (-46°C) to ensure good toughness in low temperature service. LCB and LCC are used in locations where temperatures commonly drop below the -20°F (-29°C) permitted for WCB and WCC. LCB and LCC castings are processed in the same manner as WCB and WCC when required to meet NACE MR0175/ISO 15156.

For carbon and low-alloy steels NACE MR0175/ISO 15156 imposes some changes in the requirements for the weld procedure qualification report (PQR). All new PQR's will meet these requirements; however, it will take several years for Emerson Process Management and our suppliers to complete this work. At this time, we will require user approval to use HRC.

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### Carbon and Low-Alloy Steel Welding Hardness Requirements

- HV-10, HV-5 or Rockwell 15N.
- HRC testing is acceptable if the design stresses are less than 67% of the minimum specified yield strength and the PQR includes PWHT.
- Other methods require user approval.
- 250 HV or 70.6 HR15N maximum.
- 22 HRC maximum if approved by user.

### Low-Alloy Steel Welding Hardness Requirements

- All of the above apply with the additional requirement of stress relieve at 1150°F (621°C) minimum after welding.

All new PQR's at Emerson Process Management and our foundries will require hardness testing with HV-10, HV-5 or Rockwell 15N and HRC. The acceptable maximum hardness values will be 250 HV or 70.6 HR15N and 22 HRC. Hardness traverse locations are specified in NACE MR0175/ISO 15156 part 2 as a function of thickness and weld configuration. The number and locations of production hardness tests are still outside the scope of the standard. The maximum allowable nickel content for carbon and low-alloy steels and their weld deposits is 1%.

Low alloy steels like WC6, WC9, and C5 are acceptable to NACE MR0175/ISO 15156 to a maximum hardness of 22 HRC. These castings must all be stress relieved to FMS 20B52.

The compositions of C12, C12a, F9 and F91 materials do not fall within the definition of "low alloy steel" in NACE MR0175/ISO 15156, therefore, these materials are not acceptable.

A few customers have specified a maximum carbon equivalent (CE) for carbon steel. The primary driver for this requirement is to improve the SSC resistance in the as-welded condition. Fisher's practice of stress relieving all carbon steel negates this need. Decreasing the CE reduces the hardenability of the steel and presumably improves resistance to sulfide stress cracking (SSC). Because reducing the CE decreases the strength of the steel, there is a limit to how far the CE can be reduced.

### Cast Iron

Gray, austenitic and white cast irons cannot be used for any pressure-retaining parts, due to low ductility. Ferritic ductile iron to ASTM A395 is acceptable when permitted by ANSI, API or other industry standards.

### Stainless Steel

#### 400 Series Stainless Steel

UNS 410 (410 SST), CA15 (cast 410), 420 (420 SST) and several other martensitic grades must be double tempered to a maximum hardness of 22 HRC. PWHT is also required. An environmental limit now applies to the martensitic grades; 1.5 psi (10 kPa) H<sub>2</sub>S partial pressure and pH greater than or equal to 3.5, 416 (416 SST) is similar to 410 (410) with the exception of a sulfur addition to produce free machining characteristics. Use of 416 and other free machining steels is not permitted by NACE MR0175/ISO 15156.

CA6NM is a modified version of the cast 410 stainless steel. NACE MR0175/ISO 15156 allows its use, but specifies the exact heat treatment required. Generally, the carbon content must be restricted to 0.03% maximum to meet the 23 HRC maximum hardness. PWHT is required for CA6NM. The same environmental limit applies; 1.5 psi (10 kPa) H<sub>2</sub>S partial pressure and pH greater than or equal to 3.5.

#### 300 Series Stainless Steel

Several changes have been made with the requirements of the austenitic (300 Series) stainless steels. Individual alloys are no longer listed. All alloys with the following elemental ranges are acceptable: C 0.08% maximum, Cr 16% minimum, Ni 8% minimum, P 0.045% maximum, S 0.04% maximum, Mn 2.0% maximum, and Si 2.0% maximum. Other alloying elements are permitted. The other requirements remain; solution heat treated condition, 22 HRC maximum and free of cold work designed to improve mechanical properties. The cast and wrought equivalents of 302, 304 (CF8), S30403 (CF3), 310 (CK20), 316 (CF8M), S31603 (CF3M), 317 (CG8M), S31703 (CG3M), 321, 347 (CF8C) and N08020 (CN7M) are all acceptable per NACE MR0175/ISO 15156.

Environmental restrictions now apply to the 300 Series SST. The limits are 15 psia (100 kPa) H<sub>2</sub>S partial pressure, a maximum temperature of 140°F (60°C), and no elemental sulfur. If the chloride content is less than 50 mg/L (50 ppm), the H<sub>2</sub>S partial pressure must be less than 50 psia (350 kPa) but there is no temperature limit.

There is less of a restriction on 300 Series SST in oil and gas processing and injection facilities. If the chloride content in aqueous solutions is low (typically less than 50 mg/L or 50 ppm chloride) in operations after separation, there are no limits for austenitic stainless steels, highly alloyed austenitic stainless steels, duplex stainless steels, or nickel-based alloys.

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Post-weld heat treatment of the 300 Series SST is not required. Although the corrosion resistance may be affected by poorly controlled welding, this can be minimized by using the low carbon filler material grades, low heat input levels and low interpass temperatures. We impose all these controls as standard practice. NACE MR0175/ISO 15156 now requires the use of “L” grade consumables with 0.03% carbon maximum.

### S20910

S20910 (Nitronic® 50) is acceptable in both the annealed and high strength conditions with environmental restrictions; H<sub>2</sub>S partial pressure limit of 15 psia (100 kPa), a maximum temperature of 150°F (66°C), and no elemental sulfur. This would apply to components such as bolting, plugs, cages, seat rings and other internal parts. Strain hardened (cold-worked) S20910 is acceptable for shafts, stems, and pins without any environmental restrictions. Because of the environmental restrictions and poor availability on the high strength condition, use of S20910 will eventually be discontinued except for shafts, stems and pins where unrestricted application is acceptable for these components.

### CK3MCuN

The cast equivalent of S31254 (Avesta 254SMO®), CK3MCuN (UNS J93254), is included in this category. The same elemental limits apply. It is acceptable in the cast, solution heat-treated condition at a hardness level of 100 HRB maximum in the absence of elemental sulfur.

### S17400

The use of S17400 (17-4PH) is now prohibited for pressure-retaining components including bolting, shafts and stems. Prior to 2003, S17400 was listed as an acceptable material in the general section (Section 3) of NACE MR0175. Starting with the 2003 revision, however, it is no longer listed in the general section. Its use is restricted to internal, non-pressure containing components in valves, pressure regulators and level controllers. This includes cages and other trim parts. 17-4 bolting will no longer be supplied in any NACE MR0175/ISO 15156 construction. The 17-4 and 15-5 must be heat-treated to the H1150 DBL condition or the H1150M condition. The maximum hardness of 33 HRC is the same for both conditions.

CB7Cu-1 and CB7Cu-2 (cast 17-4PH and 15-5 respectively) in the H1150 DBL condition are also acceptable for internal valve and regulator components. The maximum hardness is 30 HRC or 310 HB for both alloys.

### Duplex Stainless Steel

Wrought and cast duplex SST alloys with 35-65% ferrite are acceptable based on the composition of the alloy, but there are environmental restrictions. There is no differentiation between cast and wrought, therefore, cast CD3MN is now acceptable. There are two categories of duplex SST. The “standard” alloys with a  $30 \leq \text{PREN} \leq 40$  and  $\geq 1.5\% \text{ Mo}$ , and the “super” duplex alloys with  $\text{PREN} > 40$ . The PREN is calculated from the composition of the material. The chromium, molybdenum, tungsten and nitrogen contents are used in the calculation. NACE MR0175/ISO 15156 uses this number for several classes of materials.

$$\text{PREN} = \text{Cr}\% + 3.3(\text{Mo}\% + 0.5\text{W}\%) + 16\text{N}\%$$

The “standard” duplex SST grades have environmental limits of 450°F (232°C) maximum and H<sub>2</sub>S partial pressure of 1.5 psia (10 kPa) maximum. The acceptable alloys include S31803, CD3MN, S32550 and CD7MCuN (Ferralium® 255). The alloys must be in the solution heat-treated and quenched condition. There are no hardness restrictions in NACE MR0175/ISO 15156, however, 28 HRC remains as the limit in the refinery document MR0103.

The “super” duplex SST with  $\text{PREN} > 40$  have environmental limits of 450°F (232°C) maximum and H<sub>2</sub>S partial pressure of 3 psia (20 kPa) maximum. The acceptable “super” duplex SST’s include S32760 and CD3MWCuN (Zeron® 100).

The cast duplex SST Z 6CNDU20.08M to the French National Standard NF A 320-55 is no longer acceptable for NACE MR0175/ISO 15156 applications. The composition fails to meet the requirements set for either the duplex SST or the austenitic SST.

### Highly Alloyed Austenitic Stainless Steels

There are two categories of highly alloyed austenitic SST’s that are acceptable in the solution heat-treated condition. There are different compositional and environmental requirements for the two categories. The first category includes alloys S31254 (Avesta 254SMO®) and N08904 (904L);  $\text{Ni}\% + 2\text{Mo}\% > 30$  and  $\text{Mo} = 2\%$  minimum.

Alloy S31254 and N08904 Environmental Limits			
MAXIMUM TEMPERATURE	MAXIMUM H <sub>2</sub> S PARTIAL PRESSURE	MAXIMUM CHLORIDES	ELEMENTAL SULFUR
140°F (60°C)	1.5 psia (10 kPa)	No restriction	No
140°F (60°C)	50 psia (345 kPa)	50 mg/L Chloride	No

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The second category of highly alloyed austenitic stainless steels are those having a PREN >40. This includes S31654 (Avesta 654SMO®), N08926 (Inco 25-6Mo), N08367 (AL-6XN), S31266 (UR B66) and S34565. The environmental restrictions for these alloys are as follows:

Alloy S31654, N08926, N08367, S31266, and S34565 Environmental Limits			
MAXIMUM TEMPERATURE	MAXIMUM H <sub>2</sub> S PARTIAL PRESSURE	MAXIMUM CHLORIDES	ELEMENTAL SULFUR
250°F (121°C)	100 psia (700 kPa)	5,000 mg/L chloride	No
300°F (149°C)	45 psia (310 kPa)	5,000 mg/L chloride	No
340°F (171°C)	15 psia (100 kPa)	5,000 mg/L chloride	No

### Nonferrous Alloys

#### Nickel-Base Alloys

Nickel base alloys have very good resistance to cracking in sour, chloride containing environments. There are 2 different categories of nickel base alloys in NACE MR0175/ISO 15156:

- Solid-solution nickel-based alloys
- Precipitation hardenable alloys

The solid solution alloys are the Hastelloy® C, Inconel® 625 and Incoloy® 825 type alloys. Both the wrought and cast alloys are acceptable in the solution heat-treated condition with no hardness limits or environmental restrictions. The chemical composition of these alloys is as follows:

- 19.0% Cr minimum, 29.5% Ni minimum, and 2.5% Mo minimum. Includes N06625, CW6MC, N08825, CU5MCuC.
- 14.5% Cr minimum, 52% Ni minimum, and 12% Mo minimum. Includes N10276, N06022, CW2M.

N08020 and CN7M (alloy 20 Cb3) are not included in this category. They must follow the restrictions placed on the austenitic SST's like 304, 316 and 317.

Although originally excluded from NACE MR0175/ISO 15156, N04400 (Monel® 400) in the wrought and cast forms are now included in this category.

The precipitation hardenable alloys are Incoloy® 925, Inconel® 718 and X750 type alloys. They are listed in the specification as individual alloys. Each has specific hardness and environmental restrictions.

N07718 is acceptable in the solution heat-treated and precipitation hardened condition to 40 HRC maximum. N09925 is acceptable in the cold-worked condition to 35 HRC maximum, solution-annealed and aged to 38 HRC maximum and cold-worked and aged to 40 HRC maximum.

The restrictions are as follows:

Cast N07718 Environmental Limits		
MAXIMUM TEMPERATURE	MAXIMUM H <sub>2</sub> S PARTIAL PRESSURE	ELEMENTAL SULFUR
450°F (232°C)	30 psia (0,2 MPa)	No
400°F (204°C)	200 psia (1,4 MPa)	No
300°F (149°C)	400 psia (2,8 MPa)	No
275°F (135°C)	No limit	Yes

Cast N07718 is acceptable in the solution heat-treated and precipitation hardened condition to 35 HRC maximum. The restrictions are as follows:

Alloy N07718 and N09925 Environmental Limits		
MAXIMUM TEMPERATURE	MAXIMUM H <sub>2</sub> S PARTIAL PRESSURE	ELEMENTAL SULFUR
450°F (232°C)	30 psia (0,2 MPa)	No
400°F (204°C)	200 psia (1,4 MPa)	No
390°F (199°C)	330 psia (2,3 MPa)	No
375°F (191°C)	360 psia (2,5 MPa)	No
300°F (149°C)	400 psia (2,8 MPa)	No
275°F (135°C)	No limit	Yes

#### Monel® K500 and Inconel® X750

N05500 and N07750 are now prohibited for use in pressure-retaining components including bolting, shafts and stems. They can still be used for internal parts such as cages, other trim parts and torque tubes. There are no environmental restrictions, however, for either alloy. They must be in the solution heat-treated condition with a maximum hardness of 35 HRC. N07750 is still acceptable for springs to 50 HRC maximum.

#### Cobalt-Base Alloys

Alloy 6 castings and hardfacing are still acceptable. There are no environmental limits with respect to partial pressures of H<sub>2</sub>S or elemental sulfur. All other cobalt-chromium-tungsten, nickel-chromium-boron (Colmonoy) and tungsten-carbide castings are also acceptable without restrictions.

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All cobalt based, nickel based and tungsten-carbide weld overlays are acceptable without environmental restrictions. This includes CoCr-A, NiCr-A (Colmonoy® 4), NiCr-C (Colmonoy® 6) and Haynes Ultimet® hardfacing.

Wrought UNS R31233 (Haynes Ultimet®) is acceptable in the solution heat-treated condition to 22 HRC maximum, however, all production barstock exceeds this hardness limit. Therefore, Ultimet® barstock cannot be used for NACE MR0175/ISO 15156 applications. Cast Ultimet is not listed in NACE MR0175/ISO 15156.

R30003 (Elgiloy®) springs are acceptable to 60 HRC in the cold worked and aged condition. There are no environmental restrictions.

### Aluminum and Copper Alloys

Per NACE MR0175/ISO 15156, environmental limits have not been established for aluminum base and copper alloys. This means that they could be used in sour applications per the requirements of NACE MR0175/ISO 15156, however, they should not be used because severe corrosion attack will likely occur. They are seldom used in direct contact with H<sub>2</sub>S.

### Titanium

Environmental limits have not been established for the wrought titanium grades. Fisher® has no experience in using titanium in sour applications. The only common industrial alloy is wrought R50400 (grade 2). Cast titanium is not included in NACE MR0175/ISO 15156.

### Zirconium

Zirconium is not listed in NACE MR0175/ISO 15156.

### Springs

Springs in compliance with NACE represent a difficult problem. To function properly, springs must have very high strength (hardness) levels. Normal steel and stainless steel springs would be very susceptible to SSC and fail to meet NACE MR0175/ISO 15156. In general, relatively soft, low strength materials must be used. Of course, these materials produce poor springs. The two exceptions allowed are the cobalt based alloys, such as R30003 (Elgiloy®), which may be cold worked and hardened to a maximum hardness of 60 HRC and alloy N07750 (alloy X750) which is permitted to 50 HRC. There are no environmental restrictions for these alloys.

### Coatings

Coatings, platings and overlays may be used provided the base metal is in a condition which is acceptable per NACE MR0175/ISO 15156. The coatings may not be used to protect a base material which is susceptible to SSC. Coatings commonly used in sour service are chromium plating, electroless nickel (ENC) and nitriding. Overlays and castings commonly used include CoCr-A (Stellite® or alloy 6), R30006 (alloy 6B), NiCr-A and NiCr-C (Colmonoy® 4 and 6) nickel-chromium-boron alloys. Tungsten carbide alloys are acceptable in the cast, cemented or thermally sprayed conditions. Ceramic coatings such as plasma sprayed chromium oxide are also acceptable. As is true with all materials in NACE MR0175/ISO 15156, the general corrosion resistance in the intended application must always be considered.

NACE MR0175/ISO 15156 permits the uses of weld overlay cladding to protect an unacceptable base material from cracking. Fisher does not recommend this practice, however, as hydrogen could diffuse through the cladding and produce cracking of a susceptible basemetal such as carbon or low alloy steel.

### Stress Relieving

Many people have the misunderstanding that stress relieving following machining is required by NACE MR0175/ISO 15156. Provided good machining practices are followed using sharp tools and proper lubrication, the amount of cold work produced is negligible. SSC and SCC resistance will not be affected. NACE MR0175/ISO 15156 actually permits the cold rolling of threads, provided the component will meet the heat treat conditions and hardness requirements specified for the given parent material. Cold deformation processes such as burnishing are also acceptable.

### Bolting

Bolting materials must meet the requirements of NACE MR0175/ISO 15156 when directly exposed to the process environment ("exposed" applications). Standard ASTM A193 and ASME SA193 grade B7 bolts or ASTM A194 and ASME SA194 grade 2H nuts can and should be used provided they are outside of the process environment ("non-exposed" applications). If the bolting will be deprived atmospheric contact by burial, insulation or flange protectors and the customer specifies that the bolting will be "exposed", then grades of bolting such as B7 and 2H are unacceptable. The most commonly used fasteners listed for "exposed" applications are grade B7M bolts (99 HRB maximum) and grade 2HM nuts (22 HRC maximum). If 300 Series SST fasteners are needed, the bolting grades B8A Class 1A and B8MA Class 1A are acceptable. The corresponding nut grades are 8A and 8MA.

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It must be remembered, however, that the use of lower strength bolting materials such as B7M may require pressure vessel derating. The special S17400 double H1150 bolting previously offered on E body valves to maintain the full B7 rating is no longer acceptable to NACE MR0175/ISO 15156. Prior to the 2003, S17400 was listed as an acceptable material in the general section (Section 3) of NACE MR0175. Following the 2003 revision, it is no longer listed in the general section. Its use is now restricted to internal, non-pressure containing components in valves, pressure regulators and level controllers. The use of S17400 for bolting is specifically prohibited. N07718 (alloy 718) bolting with 2HM nuts is one alternative.

Two different types of packing box studs and nuts are commonly used by Fisher®. The stainless steel type is B8M S31600 class 2 (strain hardened) and 316 nuts per FMS 20B86. The steel type is B7 studs with 2H nuts. If the customer specifies that the packing box studs and nuts are “exposed” then grade B7M studs and grade 2HM nuts or B8MA Class 1A studs and 8MA nuts are commonly used.

### Bolting Coatings

NFC (Non-Corroding Finish) and ENC (Electroless Nickel Coating) coatings are acceptable on pressure-retaining and non-pressure-retaining fasteners. For some reason, there is often confusion regarding the acceptability of zinc plated fasteners per NACE MR0175/ISO 15156. NACE MR0175/ISO 15156 does not preclude the use of any coating, provided it is not used in an attempt to prevent SSC or SCC of an otherwise unacceptable base material. However, zinc plating of pressure-retaining bolting is not recommended due to liquid metal induced embrittlement concerns.

### Composition Materials

NACE MR0175/ISO 15156 does not address elastomer and polymer materials although ISO/TC 67, Work Group 7 is now working on a Part 4 to address these materials. The importance of these materials in critical sealing functions, however, cannot be overlooked. User experience has been successful with elastomers such as Nitrile (NBR), Neoprene and the Fluoroelastomers (FKM) and Perfluoroelastomers (FFKM). In general, fluoropolymers such as Polytetrafluoroethylene (PTFE), TCM Plus, TCM Ultra and TCM III can be applied without reservation within their normal temperature range.

Elastomer use is as follows:

1. If possible, use HNBR for sour natural gas, oil, or water at temperatures below 250°F (121°C). It covers the widest range of sour applications at a lower cost than PTFE or Fluoroelastomer (FKM). Unfortunately, the material is

relatively new, and only a handful of parts are currently set up. Check availability before specifying.

2. Use PTFE for sour natural gas, oil, or water applications at temperatures between 250°F (121°C) and 400°F (204°C).
3. Fluoroelastomer (FKM) can be used for sour natural gas, oil, or water applications with less than 10% H<sub>2</sub>S and temperatures below 250°F (121°C).
4. Conventional Nitrile (NBR) can be used for sour natural gas, oil, or water applications with less than 1% H<sub>2</sub>S and temperatures below 150°F (66°C).
5. CR can be used for sour natural gas or water applications involving temperatures below 150°F (66°C). Its resistance to oil is not as good.
6. IIR and Ethylenepropylene (EPDM) (or EPR) can be used for H<sub>2</sub>S applications that don't involve hydrocarbons (H<sub>2</sub>S gas, sour water, etc.).

### Tubulars

A separate section has been established for downhole tubulars and couplings. This section contains provisions for using materials in the cold-drawn condition to higher hardness levels (cold-worked to 35 HRC maximum). In some cases, the environmental limits are also different. This has no effect on Fisher as we do not make products for these applications. Nickel-based components used for downhole casing, tubing, and the related equipment (hangers and downhole component bodies; components that are internal to the downhole component bodies) are subject to the requirements.

### Expanded Limits and Materials

With documented laboratory testing and/or field experience, it is possible to expand the environmental limits of materials in NACE MR0175/ISO 15156 or use materials not listed in NACE MR0175/ISO 15156. This includes increasing the H<sub>2</sub>S partial pressure limit or temperature limitations. Supporting documentation must be submitted to NACE International Headquarters, which will make the data available to the public. NACE International will neither review nor approve this documentation. It is the user's responsibility to evaluate and determine the applicability of the documented data for the intended application.

It is the user's responsibility to ensure that the testing cited is relevant for the intended applications. Choice of appropriate temperatures and environments for evaluating susceptibility to both SCC and SSC is required. NACE Standard TM0177 and EFC Publication #1739 provide guidelines for laboratory testing.



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Field-based documentation for expanded alloy use requires exposure of a component for sufficient time to demonstrate its resistance to SCC/SSC. Sufficient information on factors that affect SCC/SSC (e.g., stress levels, fluid and gas composition, operating conditions, galvanic coupling, etc.) must be documented.

### Codes and Standards

Applicable ASTM, ANSI, ASME and API standards are used along with NACE MR0175/ISO 15156 as they would normally be used for other applications. The NACE MR0175/ISO 15156 requires that all weld procedures be qualified to these same standards. Welders must be familiar with the procedures and capable of making welds which comply.

### Certification

Fisher® Certification Form 7508 is worded as follows for NACE MR0175-2002 and MR0175/ISO 15156:

*“NACE MR0175/ISO 15156 OR NACE MR0175-2002: This unit meets the metallurgical requirements of NACE MR0175 or ISO 15156 (revision and materials of construction as specified by the customer). Environmental restrictions may apply to wetted parts and/or bolting.”*