

# Material Selection and Compatibility Considerations for Rosemount™ Pressure Transmitters



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## 1.0 Introduction

The potential for damage due to corrosion is an important concern in the design of instrumentation for most process control systems. Rosemount™ pressure transmitters are available with several choices of materials of construction that can be expected to perform well in a wide range of applications. This technical data sheet briefly discusses some of the reasons why incompatibilities occur and the problems that can result. References are given to assist the user in making the appropriate material choices for an application.

The information presented here is intended only as a guide to the selection of material options. Any material will behave differently under the influence of such variables as temperature, pressure, flow rate, abrasives, and contaminants. All of the components of a process fluid should be considered when selecting materials. Fluids of a homogeneous chemical composition may react differently with a material than fluids of a heterogeneous composition. Additionally, even the presence of trace amounts of a chemical will impact material selection. It is the user's responsibility to make a careful analysis of all process parameters when specifying materials. Emerson™ cannot guarantee that a material is suited to a particular application under all possible process conditions.

If materials other than the standard materials discussed here are needed, contact your local Emerson sales office for assistance.

## 2.0 Corrosion basics

Corrosion is the gradual destruction of a metal by chemical or electrochemical means. The most generic form of corrosion is galvanic corrosion. A combination of a cathode, an anode, and an electrolyte must be present for this type of corrosion to occur. This combination of cathode, anode, and electrolyte is called a galvanic cell. Simply stated, a galvanic cell consists of two electrically connected, dissimilar metals and a medium, usually an aqueous solution, by which electron transfer can take place.

To fully understand the corrosion process, these terms must be better defined.

**Anode** — The electrode at which chemical oxidation occurs (or + current leaves the electrode and enters the electrolyte).

**Cathode** — The electrode at which chemical reduction occurs (or + current enters the electrode from the electrolyte).

A potential difference results when the electrically connected anode and cathode are separated by a physical distance in a conductive media. This potential difference causes the positively charged cations to flow from the anode to the cathode through the conductive medium. To complete the circuit, the negatively charged electrons flow from the anode to the cathode through the electrical connection. The resulting corrosion takes place at the anode. The cathode may also corrode, but not to the same extent.

The loss of electrons by the anode is called oxidation, and it causes the metal surface to become positively charged. These positively charged metal ions on the surface, called cations, attract the negative ions (anions) found in the electrolyte to form a new compound. This new compound no longer has its former metal characteristics, but rather it takes a new form such as rust or iron oxide.

The gain of electrons at the cathode is referred to as reduction. Reduction allows the metal at the cathode area to retain its metallic characteristics (see [Figure 1-1 on page 3](#)).

The tendency for corrosion to occur is governed by the magnitude of potential difference developed between the anode and the cathode. Generally, those metals with the highest potentials are at the anodic end of the galvanic series (see [Table 1-1 on page 4](#)).

Metals with the lowest potentials are at the cathodic end of the series. However, the level of potential can vary with different conditions and with different environments. In general, the farther apart the metals are positioned on the galvanic chart, the more likely they are to corrode when placed together in a solution.

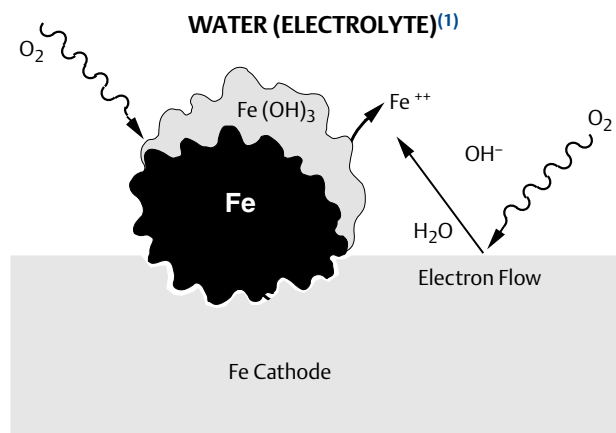
## 3.0 Types of corrosion

Generally, all corrosion is interrelated; however, it can take many forms. Corrosion can be uniform or localized. It may also combine with other forms of attack to produce even more undesirable effects. In the following discussion, some of the most common forms of corrosion are presented, including a separate section on sulfide stress cracking.

### 3.1 Uniform corrosion

This is characterized by an even distribution of corrosion that leaves the surface clean or coated with corrosion products. This even distribution is due to the movement of the anodic and cathodic sites on the metal's surface. With uniform attack, fouling of the metal is usually a bigger problem than failure.

Figure 1-1. Classic Corrosion Cell



As current flows through the electrolyte from the anode to the cathode, an anodic reaction ( $\text{Fe} = \text{Fe}^{++} + 2\text{e}^-$ ) results. Simultaneously, the iron ion,  $\text{Fe}^{++}$ , is liberated and combines with the  $\text{OH}^-$  to produce ferrous hydroxide,  $\text{Fe}(\text{OH})_2$ . Next, the ferrous hydroxide combines with oxygen and water to produce ferric hydroxide,  $\text{Fe}(\text{OH})_3$ , or common iron rust.

1. Electrolyte is seawater.

### 3.2 Pitting

One of the most destructive forms of corrosion is pitting. It is a form of localized attack that causes small holes to form in the metal. It is promoted by low-velocity, stagnant-type conditions where concentrated "bubbles" of corrosives could form. Pitting is often difficult to detect because the pits may be covered by corrosion by-products. Pitting may take months to years before its effects are visible.

However, once started, a pit penetrates the metal at an ever increasing rate. Pitting also has a tendency to undercut the surface. This makes detection even more difficult and subsurface damage more severe than the surface condition appears.

### 3.3 Galvanic corrosion

When two dissimilar metals come into contact and are immersed in a conductive medium, an electric potential develops. The corrosion rate of the more active (anodic) metal increases while the corrosion rate of the more noble (cathodic) metal decreases. The resulting corrosion can be uniformly distributed or localized.

### 3.4 Erosion-corrosion

Erosion-corrosion is the increase in rate of attack on a metal from abrasive effects. It can be characterized by grooves, holes, and waves, but usually exhibits a directional pattern. This form of corrosion is more common in the softer metals, and usually occurs after the protective film on the surface of the metal has been stripped away.

**Table 1-1. Galvanic Series of Metals and Alloys<sup>(1)(2)</sup>**

<b>Cathodic (most noble) or passive</b>	
Platinum	↑ ↑↑ ↑↑↑ ↑↑↑↑ ↑↑↑↑↑ ↑↑↑↑↑↑ ↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑ ↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑↑
Gold	
Graphite	
Silver	
Alloy C-276	
316 stainless steel (SST) (passive)	
304 SST (passive)	
Titanium	
Alloy 600 (passive)	
Nickel (passive)	
Bronzes	
Alloy 400	
Copper-Nickel Alloys	
Copper	
Brasses	
Alloy 600 (active)	
Nickel (active)	
Tin	
Lead	
316 SST (active)	
304 SST (active)	
410 SST (active)	
Cast Iron	
Steel or Iron	
2024 Aluminum	
Cadmium	
Commercially Pure Aluminum	
Zinc	
Magnesium Alloys	
Magnesium	
<b>Anodic (least noble) or active</b>	

1. Electrolyte is seawater.
2. A material in its passive state contains a protective oxide layer. In the active state, this protective layer does not exist.

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**Note**

Table 1-1 on page 4 was adapted from ASTM G82-98 (2014).

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## 3.5 Stress corrosion

By definition, Stress Corrosion Cracking (SCC) is a phenomenon that, by virtue of the simultaneous application of a tensile stress and corrosive environment, promotes a brittle-type failure at stress levels well below the yield strength of the metal. The higher the tensional stress, the shorter the time to failure. Although time to cracking at low stress levels may be long, there is no practical minimum stress below which the possibility of cracking is eliminated, given sufficient time in a critical environment.

For austenitic steels, such as type 316 SST, the two major damaging ions are hydroxide and chloride (OH<sup>-</sup> and Cl<sup>-</sup>).

## 3.6 Crevice corrosion

This localized corrosion occurs within crevices and other shielded areas on the metal surface. The solution within the crevice becomes highly concentrated and acidic. Crevice corrosion might occur inside holes, at metal-to-metal surfaces, and on sealing surfaces.

## 3.7 Intergranular corrosion

This form of corrosion is a selective attack on the grain boundaries (the surface of crystal mismatch between adjacent grains) of a metal without appreciable attack on the grains (individual crystal of a microstructure) themselves. The attack mechanism results from a difference in potential between the grain boundaries and the grain. Because welding often causes segregation of impurities at grain boundaries, or precipitation of intermetallics, welded areas are a common source of intergranular corrosion. The attack causes a loss of strength and ductility much greater than the loss due to the amount of metal destroyed.

## 3.8 Hydrogen embrittlement

Almost all metals lose ductility when they absorb hydrogen. This is especially noticeable at temperatures below 100 °C. The exact mechanism involved is still undetermined; however, the leading theories suggest that hydrogen causes a highly localized alteration of the metallic bonds at a flaw or crack tip under stress. This may either decrease the cohesive strength of the bonds or lower the shear stress required for slip. In either case, the metal fractures in a brittle manner at loads well below the macroscopic yield strength of the structure.

Hydrogen embrittlement is a common problem when tantalum is placed in hydrogen service.

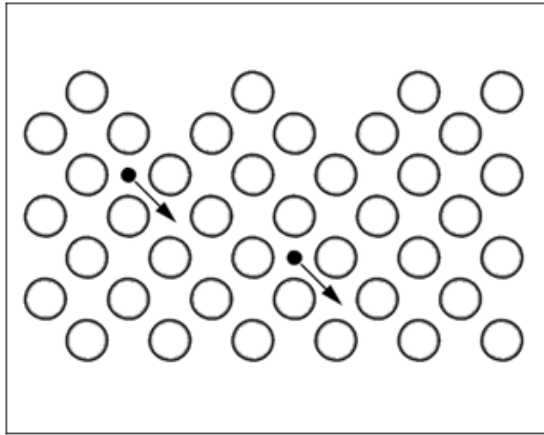
## 3.9 Hydrogen permeation

Hydrogen permeation is the process where hydrogen atoms diffuse through the metal isolating diaphragm into the sensor module fill fluid by either an interstitial mechanism or a vacancy mechanism. Although the mechanism is much more involved, for the sake of simplicity, this definition will be sufficient.

A hydrogen atom is said to diffuse by an interstitial mechanism when it passes from one interstitial site to one of its nearest-neighbor interstitial sites without permanently displacing any of the matrix atoms (see [Figure 1-2 on page 6](#)).

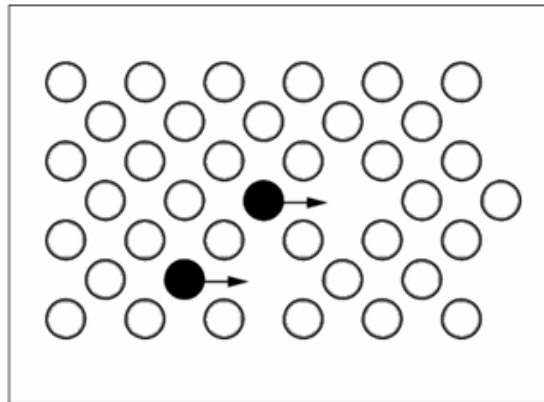


**Figure 1-2. Path of Atom Diffusion by Interstitial Mechanism**



A hydrogen atom is said to diffuse by the vacancy mechanism when it passes through an unoccupied lattice site that occurs within all crystals. It gets its name because these unoccupied sites are called vacancies. When one of the atoms on an adjacent site jumps into the vacancy, the atom is said to have diffused by a vacancy mechanism (see [Figure 1-3](#)).

**Figure 1-3. Movement of an Atom into Adjacent Vacancy**



Because transmitter diaphragms are thinner than other parts of the transmitter, hydrogen atoms can permeate through the diaphragm and unite to form molecular hydrogen. Because molecular hydrogen is too large to permeate back through the diaphragm, it gets trapped and forms hydrogen bubbles in the fill fluid. The presence of hydrogen gas bubbles can severely affect transmitter performance.

Care must be taken to prevent placing certain dissimilar metals that would cause molecular hydrogen to dissociate near transmitter isolating diaphragms. Positioning cadmium or cadmium-plated parts near nickel containing isolating diaphragm materials, such as SST or Alloy C-276, in the presence of an electrolyte such as water, can result in the creation of a Ni Cad battery effect where atomic hydrogen is released. This atomic hydrogen can then permeate through the isolating diaphragm.

In general, in applications where atomic hydrogen is present, materials that are not susceptible to permeation should be chosen. Because of the loose lattice structure, nickel based alloys are more susceptible to permeation. See [“Materials of construction” on page 7](#) for more information.

Increased hydrogen activity occurs when the gas pressure reaches above 1000 psi or the process temperatures rise above 350 °F (176 °C) increasing the risk of permeation.

When installing the pressure transmitters in hydrogen applications, some suggestions to consider are:

- In aqueous applications, avoid installation with dissimilar metals near the diaphragm
- Distance the diaphragm from elevated temperatures to reduce permeation risk

For gas applications, install the diaphragm above the vessel/pipe to avoid condensation from collecting against the diaphragm. If the installation is below the vessel/pipe, consider the application suggestion for Aqueous Solutions with Hydrogen (Table 1-2).

The presence of Hydrogen Sulfide (H<sub>2</sub>S) can reduce the recombination of monatomic hydrogen to diatomic hydrogen (H<sub>2</sub>) and increase the risk of permeation. Additionally, the presence of water can increase the risk of permeation. In aqueous applications, avoid dissimilar metals near the diaphragm to prevent galvanic corrosion.

In applications with chlorides combined with H<sub>2</sub>S and hydrogen, there is a high risk of permeation. Contact Rosemount to discuss the best solution.

**Table 1-2. Material Selection Guide for Pressure Transmitters in Hydrogen Applications**

Process fluid	Diaphragm material
Hydrogen gas below 1000 psi (68.9 bar) and below 350 °F (176 °C)	SST, Gold-plated SST
Hydrogen gas above 1000 psi (68.9 bar) and/or above 350 °F (176 °C)	Gold-plated SST
Hydrogen gas with H <sub>2</sub> S	
Aqueous solutions with hydrogen	
Aqueous solutions with hydrogen and H <sub>2</sub> S	
Aqueous solutions with hydrogen, H <sub>2</sub> S, and chlorides	Contact Rosemount

## 3.10 Sulfide stress cracking

Sulfide stress cracking is a common form of corrosion in oil field environments. When exposed to “sour” environments, sulfide stress cracking may occur in susceptible materials. Sour environments can be defined as a fluid containing liquid water and hydrogen sulfide such as sour gas and sour crude.

The rapidity with which hydrogen atoms absorbed on a metal surface combine to form molecular H<sub>2</sub> is affected by the catalytic properties of the electrode surface. If a catalyst poison like hydrogen sulfide is present, the rate of formation of molecular H<sub>2</sub> is decreased, while the accumulation of absorbed hydrogen on the electrode surface is increased. The increased concentration of surface hydrogen favors entrance of hydrogen atoms into the metal lattice, causing hydrogen embrittlement. In some stressed, high-strength ferrous alloys it may also induce spontaneous hydrogen cracking.

## 4.0 Materials of construction

Rosemount pressure transmitters include a wide variety of materials of construction to cover almost any application. The following discussion will aid in the understanding of various materials offered. It should be noted that for special applications, other materials of construction not listed in this paper may be offered. Only the most widely used materials are presented.

### 4.1 Type 316 SST

Alloys with a chromium content over 11 percent and an iron content well over 50 percent are known as stainless steels. The designation “stainless steels” can be attributed to their ability to withstand most corrosives under many conditions.

Type 316 SST (16-18Cr and 10-14Ni) belongs to the group of austenitic stainless steels. This group is essentially nonmagnetic and cannot be hardened by heat treatment. The nickel content contributes to the improved corrosion resistance, and it is also responsible for the retention of the austenitic structure.

Type 316 SST has a high resistance to corrosion. It is rust resistant in the atmosphere and is resistant to most concentrations of nitric acid. However, it is attacked by nonoxidizing acids such as sulfuric and hydrochloric acid in most concentrations.

Most salt solutions have little effect on type 316 SST, although the halide salts (fluorine, chlorine, bromine, iodine) can cause severe pitting and possibly stress-corrosion cracking.

Type 316 SST performs very well against hydrogen diffusion and is a good choice as a diaphragm material when the process is hydrogen gas.

Type 316 SST has good resistance to alkaline solutions, organic acids, and other organic compounds.

## 4.2 Nickel-based alloys

Nickel is the basis of an important group of materials used for corrosive applications. High-nickel alloys provide good resistance to a wide variety of corrosives. The nickel content helps provide good resistance as well as good physical and mechanical properties.

In general, nickel alloys have the basic corrosion resistance of nickel combined with the added resistance associated with the alloyed metal. This combination makes the alloy as good as, or even better than, nickel against corrosion.

### Alloy-400

Alloy-400 (67Ni-33Cu) has good resistance at ambient temperatures to most of the nonoxidizing acids, such as hydrofluoric, sulfuric, and phosphoric acids. It also resists nonoxidizing salts. The nickel in the alloy improves its resistance toward alkalies.

One challenge with Alloy-400 material is that it is more susceptible to hydrogen permeation. Therefore, Alloy-400 should not be used as a diaphragm material when the process is hydrogen gas or when hydrogen atoms are present unless other protection mechanisms, such as gold plating, are used (see [“Gold-plated materials” on page 9](#)). Gold-plated Alloy-400 may be a good choice for Hydrofluoric Acid service.

### Alloy C-276

In Alloy C-276 (54Ni-16Mo-16Cr), chromium and molybdenum are added to nickel to improve the alloy's resistance to oxidizing conditions. This alloy also retains a considerable degree of resistance to nonoxidizing conditions. For example, Alloy C-276 withstands oxidizing acids and also the acid salts such as ferric and cupric chlorides. Hydrochloric and sulfuric acids in most concentrations do not affect Alloy C-276 at moderate temperatures. Alloy C-276 is well suited to provide protection against alkalies, organic acids, and other organic compounds.

C-276 can be susceptible to hydrogen permeation and is thus not the best fit for hydrogen rich applications. If hydrogen permeation is a risk, gold-plated 316 SST or gold-plated Alloy-400 should be considered (see [“Gold-plated materials” on page 9](#)).

Both Alloy-400 and Alloy C-276 have excellent corrosion resistance against atmospheric conditions and fresh water. In addition, Alloy C-276 is resistant to stagnant seawater.



## 4.3 Tantalum

Tantalum has proven to be a useful material in corrosive applications involving hydrochloric acid and acidic ferric chloride solutions. This accounts for the wide acceptance of tantalum in the chemical industry. Tantalum has a high melting point and good strength even at elevated temperatures. Its high strength allows thin sections to be used. This is important because tantalum is very expensive.

Tantalum has superior corrosive resistance to most acids, chemical solutions, and organic compounds. In general, tantalum has good resistance to hydroiodic, hydrobromic, boiling hydrochloric, nitric, phosphoric, and sulfuric acids. Liquid metals generally do not affect tantalum. In addition, it has good resistance to most other acids. However, tantalum can be attacked severely by hydrofluoric acid, fluosilicic acid, hot fuming sulfuric acid, and fluorine. Also, it is attacked by strong alkaline solutions and by fused alkalis.

Tantalum can suffer severe embrittlement if in service with high-temperature oxygen or nitrogen, or with hydrogen at any temperature.

## 4.4 Nickel-plated carbon steel

Nickel plating is an effective means for giving metal surfaces a corrosion resistant coating. Nickel has good resistance against most of the common acids, except those of an oxidizing nature such as nitric acid. In general, neutral and alkaline solutions leave nickel relatively unattacked. It has good resistance to the milder forms of atmospheric conditions, to oxidation, to higher temperatures, and to halogen gases.

Nickel-plated flanges and adapters can be used along with Alloy C-276 diaphragms. The large difference in potentials that is created between the use of cadmium-plated flanges and Alloy C-276 diaphragms is now eliminated.

## 4.5 Gold-plated materials

Adhering a thin layer of gold to a base metal will provide protection against hydrogen permeation. Gold plating is suggested in applications where atomic hydrogen is present. It is not necessary for all hydrogen service applications. The strength of the atomic bonding for hydrogen gas, for example, is strong enough that dissociation is unlikely. The base metal to which gold plating is applied should be chosen to provide suitable corrosion resistance, unless there is some other contributing factor. Alloy-400 is typically used as a base metal in hydrofluoric (HF) acid applications where the weaker bond between hydrogen and fluoride may result in the presence of hydrogen atoms. In other applications, 316L SST base metal may provide sufficient corrosion resistance and lower the cost of the isolating diaphragm material.

## 5.0 Components of a transmitter

Components that make up a transmitter can be separated into two groups, wetted and non-wetted, depending on whether or not they come into direct contact with the process. When selecting materials for wetted and non-wetted components one should consider the exposure environment.

### 5.1 Wetted components

Wetted components are those that come into direct contact with the process, which include process isolating diaphragms, drain/vent valves, process flange, and O-rings. Selecting the correct materials for a wetted component requires detailed knowledge of the process, such as the operating pressures, temperatures, and the process fluid. This section outlines how to use this information to select the correct material for all the wetted components.

## Process isolating diaphragms

The process isolating diaphragm separates the sensor fill fluid from the process it is measuring. It is important to select a material that is compatible to the process, otherwise the transmitter could experience failure. Rosemount pressure transmitters are available with process isolating diaphragms in the following materials, although not all materials are available with all transmitters.

- 316L SST (UNS S31603)
- Alloy C-276 (UNS N10276)
- Alloy 400 (UNS N04400)
- Tantalum (UNS R05440)
- Gold-Plated Alloy 400
- Gold-Plated 316L SST

### Implications

There are several items to consider when selecting a material for the process isolating diaphragm.

- The relative thickness of the process isolating diaphragm is considerably less than other wetted parts. It is critical to select a material that is compatible with the process.
- Gold plating options are available to help prevent hydrogen permeation through the sensor modules isolating diaphragm and into the fill fluid.
- Tantalum process isolating diaphragms are most commonly used in applications that are highly corrosive or acidic.

## Drain/vent valves

Drain/vent valves are located on the flange or manifold attached to the transmitter and are used to drain or vent the process from the transmitter. Rosemount pressure transmitters are available with drain/vent valves in the following materials, although not all materials are available with all transmitters:

- 316L SST (UNS S31603)
- Alloy C-276 (UNS N10276)
- Alloy 400/K-500 (Drain vent seat: Alloy 400; Drain vent stem: Alloy K-500)

### Implications

When selecting a drain/vent valve there are several implications to keep in mind.

- 316L SST drain/vent valves are not compliant with NACE® MR0175/ISO 15156 and MR0103.
- For NACE applications, 316 SST flanges with Alloy C-276 drain/vent valves are commonly used.
- Alloy 400/K-500 drain/vent valves are not compliant with NACE MR0175/ISO 15156 and MR0103.
- Alloy 400/K-500 drain/vent valves are only available with flange material Cast Alloy 400; they are not available with Level transmitter or direct-mount configurations.

## Process flanges and flange adapters

The process flange or flange adapter is used to connect the transmitter to the process. Rosemount pressure transmitters are available with process flanges and flange adapters in the following materials, although not all materials are available with all transmitters:

- Plated carbon steel
- CF-8M (Cast 316 SST) (UNS J92900)
- Cast C-276: CW-12MW-1 (UNS N10276)
- Cast Alloy 400: M-30C (UNS N04400)

## Implications

- Cast Alloy 400 flanges are only available with drain/vent material Alloy 400/K-500.

## Wetted O-rings

The wetted O-rings are used to seal the sensing diaphragms to the flange or manifold, as well as sealing flange adapters to flanges. Rosemount pressure transmitters are available with wetted O-rings in the following materials:

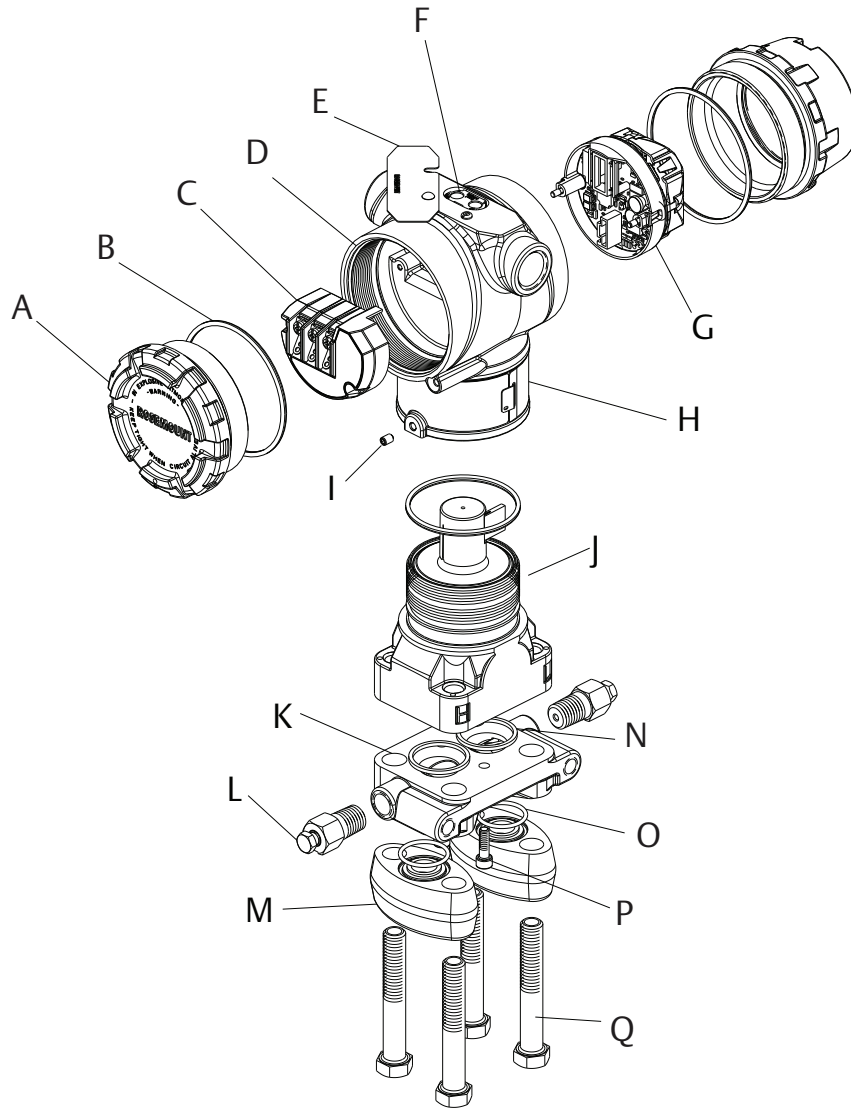
- Glass-filled PTFE
- Graphite-filled PTFE
- Graphite (available as a special option)

## Implications

There are some things to consider when choosing a material for the wetted O-rings.

- Glass-filled PTFE wetted O-rings adds wear resistance and offers good compression strength. They should not be used in applications containing Fluorine or Hydrofluoric Acid.
- Graphite-filled PTFE wetted O-ring is supplied with gold-plated Alloy 400 isolating diaphragm.
- Temperature limits are identical for graphite-filled and glass-filled PTFE.

Figure 1-4. Rosemount 3051C Exploded View



- |                                |   |  |
|--------------------------------|---|--|
| A. Cover                       | G. Electronics board  | L. Drain/vent valve                                |
| B. Cover O-ring                | H. Name plate   | M. Flange adapters                                 |
| C. Terminal block              | I. Housing rotation set screw (180° maximum rotation without further disassembly) | N. Process O-ring                                  |
| D. Electronics housing         | J. Sensor module  | O. Flange Adapter O-ring                           |
| E. Configuration buttons cover | K. Coplanar flange  | P. Flange alignment screw (not pressure retaining) |
| F. Local configuration buttons |   | Q. Flange bolts                                    |

## 5.2 Non-wetted components

Non-wetted components are those that don't come into direct contact with the process, including bolts, electronics housings, cover O-rings, and mounting brackets. Selecting the correct materials for a non-wetted component requires knowledge of the environment, such as ambient temperatures, humidity and corrosive conditions.

### Bolts

Bolts are used to attach the transmitter to the flange or manifold. Although bolting is not process wetted, environmental conditions can impact material selection. Rosemount pressure transmitters are available with bolts in the following materials:

- ASTM A449, Type 1 (zinc-cobalt plated carbon steel)—standard material
- ASTM F593G, Condition CW1 (Austenitic 316 SST)
- ASTM A453, Grade 660, Class D, SST
- ASTM A193, Grade B7M alloy steel
- ASTM A193, Grade B8M, Class 2, SST
- Alloy K-500, ASTM F468

### Implications

In applications requiring compliance with NACE MR0175/ISO 15156 and NACE MR0103, bolting must meet requirements if they are directly exposed to the H<sub>2</sub>S environment either directly or because of insulation. Bolting compliant with NACE MR0175/ISO 15156 and NACE MR0103 are listed below.

- ASTM A453, Grade 660, Class D, SST
- ASTM A193, Grade B7M alloy steel

### Electronics housing

The electronics housing is the enclosure surrounding the electronics board and terminal block to ensure they are protected from the environment and can function reliably. Rosemount pressure transmitters are available with electronics housings in the following materials:

- Low-copper aluminum alloy
- CF-8M (Cast 316 SST)
- Engineered Polymer

### Implications

The standard painted aluminum housing is suitable for the majority of industrial environments. SST is typically used in marine environments.

- The aluminum housing uses polyurethane paint.
- Engineered Polymer is only available on wireless transmitters with internal antennas and has no conduit entries.



## Sensor module fill fluid

Sensor module fill fluid is contained behind the process isolating diaphragms and transmits the source pressure from the process to the sensor. Rosemount pressure transmitters are available with sensor module fill fluids in the following materials:

- Silicone
- Coplanar configurations use Halocarbon for the inert fill fluid option.
- In-Line configurations use Fluorinert™ FC-43 for the inert fill fluid option.

### Implications

It is important to select a fill fluid that is compatible with the process fluid should the sensor module isolating diaphragm become damaged. If this occurs, fill fluid can contact the process.

- Silicone fill fluid is standard. Inert fill fluids are typically used in applications where silicone fill fluid may be reactive with the process.
- Inert fill fluid has reduced operating limits compared to silicone fill fluid. Inert fill fluids are not available with coplanar absolute pressure measurement types.
- Inert fill fluids are not available with wireless transmitters.

## 6.0 Material related standards and certifications

When selecting the materials of construction for a pressure transmitter, compliance with certain standards is often a requirement. Emerson offers a wide range of material related standards and certifications, and understanding what each of them means can help identify those that are needed.

### 6.1 NACE MR0175/ISO 15156:2009 and NACE MR0103-2012

Sulfide stress cracking is a major concern in environments containing sour oil or gas. An environment is characterized as 'sour' by the presence of hydrogen sulfide ( $H_2S$ ), which is extremely corrosive and can exist as either a gas or a solution. Exposed components in sour environments that are not sufficiently resistant to hydrogen sulfide are likely to fail. Picking the right material is essential.

NACE MR0175/ISO 15156 (EN 2004), "Materials for Use in  $H_2S$ -Containing Environments in Oil and Gas Production", is a material standard for petroleum production, drilling, gathering and flow line equipment, and field processing facilities. NACE MR0175/ISO 15156 provides material requirements and application limits defined by environmental composition and pH, temperature range, and  $H_2S$  partial pressure in which these materials can be used.

NACE MR0103 is specifically for sour refinery process environments and was developed because refineries are outside the scope of NACE MR0175/ISO 15156. The NACE MR0103 standard establishes material requirements for resistance to sulfide stress cracking. Requirements are also established for metal fabrication such as weldments.

## Implications

When choosing the materials for each of the transmitter components with NACE MR0175/ISO 15156 or NACE MR0103 in mind, there are several things to consider.

- The standards only apply to the process wetted materials. NACE MR0175/ISO 15156 does not apply when the hydrogen sulfide content is less than 15 mol% and the partial pressure is less than 10 psia (0.07 MPa abs). Thus, components such as the transmitter housing do not need to comply.
- The standards only ensure an appropriate resistance to sulfide stress corrosion, not total immunity.
- NACE MR0175/ISO 15156 does not apply specifically to low-pressure environments. Refer to the standard for details.

## Certification - Q15, Q25

Rosemount transmitters are available with certification of compliance for both NACE MR0175/ISO 15156 and NACE MR0103 with product shipments at request.

ISO 15156/NACE MR0175 is available by selecting option code Q15.

NACE MR0103 is available by selecting option code Q25.

## 6.2 Material traceability

No manufacturing process is perfectly repeatable. Variations in chemical proportions, environmental conditions and manufacturing procedures cause small differences in a material's properties. To show that each material is within the specified tolerances, manufacturers test samples from each material batch. Associating the test results with each material in a final product is referred to as material traceability.

### Implications

Regardless of which materials are selected, material traceability offers several benefits when ordering a transmitter.

- It provides proof that each component is constructed from the specified materials.
- It ensures the materials provided meet the specifications set for that material.

### Certification - Q8

Rosemount pressure transmitters are available with a Material Inspection Certificate, compliant with ISO 10474 3.1B/EN 10204 3.1, to document the material traceability. The included documentation is unique to each unit, and contains the follow items:

- Customer Information
- Manufacturer Information
- Rosemount Model Number
- Referenced Component and Corresponding Heat Number
- Certificate Issue Date
- Material Test Reports
- Material Compliance Statement

The Material Inspection Certificate is provided with the product shipment for all models containing the option code Q8. Documentation provided is retained for five years and can be re-created upon request.

## 6.3 Positive material identification

Positive Material Identification (PMI) uses an x-ray fluorescence spectrometer to identify the material composition by percentage of its base elements. This provides a non-destructive verification of the material and confirms the composition on the Q8 certification (see “Certification - Q8” on page 15).

### Implications

PMI has several implications for the selection of component materials.

- PMI confirms that the chemical composition of the material meets the applicable specifications.
- PMI only confirms chemical composition, it does not measure physical performance properties, such as hardness or strength.
- Emerson provides PMI on process wetted, pressure containing components upon request.
- Material Traceability Certification (Q8) must be ordered as an option if PMI testing is required.

### Certification - Q76

Rosemount transmitters are available with a PMI Certificate, compliant with ISO 10474 3.1B/EN 10204 3.1, to document the PMI testing that has been performed. This document can be ordered as a separate line on an order applicable to the entire order.

## 6.4 Special service cleaning

In specialty gas services, such as those containing oxygen, contamination can be a serious concern. Insufficient cleanliness of a component in contact with the process can result in combustion, or affect product purity. Special service cleaning ensures that the surfaces of all wetted components are cleaned using methods defined by ASTM G93, “Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments” so the process is not affected.

### Implications

When ordering special service cleaning there are several items to consider.

- After cleaning, components are visually inspected to look for moisture, debris, or organic materials.
- Once special service cleaning has been performed, all cleaned parts are sealed in a plastic bag and should remain sealed until installation.
- It is common practice to use inert sensor module fill fluids in applications requiring special service cleaning.
- When a transmitter and manifold assembly receives special service cleaning, both items must be purchased with this option. Graphite-packed manifolds are not available with special service cleaning.

### Certification - Q6

Rosemount pressure transmitters are available with a Certificate of Special Service Cleaning that states the compliance with ISO 10474 3.1B/EN 10204 3.1, and that the cleaning has been performed. The documentation is unique to each order and contains the following items:

- Customer information
- Manufacturer information
- Rosemount model number
- Issue date
- Compliance statement

special service cleaning can be ordered using option codes P2, P3, or PA in the product model code. Documentation provided is retained for five years and can be re-created upon request.

## 6.5 ISO 9001

To ensure maximum product quality and repeatability, Emerson has a robust quality management system for Rosemount pressure transmitters that complies with all the requirements of ISO 9001. This system is firmly established, implemented, maintained, and continually improved to meet the vary needs of Emerson customers and all applicable regulations.

### Implications

Emerson commitment to quality has several implications to consider when ordering the materials for a pressure transmitter.

- The quality management system applies to the entire organization, so all products and services offered by Emerson meet the high quality standards.
- ISO 9001 requires frequent audits by an independent organization, which ensures continuous compliance with all stated quality systems.

### Certification - Q1, Q2

Rosemount transmitters are available with a certification that confirms the products shipped meet all applicable standards and contracts, in accordance with ISO 9001. This certification is available with option code Q1. It is also available notarized with option code Q2.

Schweitzer, Philip A., P.E. *Corrosion Resistance Tables: Metals, Nonmetals, Coatings, Mortars, Plastics, Elastomers and Linings, and Fabrics*. Third Edition, Marcel Dekker, Inc., 1991.

National Association of Corrosion Engineers. *Corrosion Data Survey, Metals Section*, 6th Edition, 1985.

*ASM Metals Handbooks*, Volume 13 (Corrosion), 9th Edition, American Society of Metals, Sept. 1987.

*Cor-sur* and *Cor-sur2*, personal computer software versions of *Corrosion Data Survey for Metals and Non-metals*, National Association of Corrosion Engineers and National Bureau of Standards. PO Box 218340, Houston, TX 77218.

*Corrosion Data Survey for Metals and Non-metals*, National Association of Corrosion Engineers and National Bureau of Standards. PO Box 218340, Houston, TX 77218.

## 7.0 Materials selection guide<sup>(1)</sup>

- E = Excellent resistance. Corrosion rate <0.002-in. (0.05 mm) per year. Best choice for diaphragm material.
- G = Good resistance. Corrosion rate <0.020-in. (0.50 mm) per year.
- F = Fair resistance. Corrosion rate 0.020–0.050-in. (0.50–1.27 mm) per year.
- P = Poor resistance. Corrosion rate >0.050-in. (1.27 mm) per year.
- = Data not available.

(The numeric values for corrosion rate hold true only for selecting the isolating diaphragm, not for selecting the flange and adapter materials. When selecting the flange/adapter and O-ring materials, the “E, G, F, and P” ratings describe the performance of that material as excellent, good, fair, and poor.)

- <sup>1</sup> = May cause stress corrosion cracking
- <sup>2</sup> = May cause pitting, especially for low velocity or stagnant fluid conditions
- \* = Process fluid can be either aerated or non-aerated. If there is a significant difference in performance of the material, two letters may be separated by a slash (aerated/non-aerated data).

### Note

All data is based on a temperature of 70 °F (20 °C) unless noted otherwise.

Since a material’s resistance to corrosion can vary greatly due to many factors such as impurities, temperature, pressure, velocity, etc., this chart should be used only as a general guide.

Emerson makes no guarantee for the suitability of any transmitter material. The responsibility for material selection rests with the user.

Process fluid	Flange/adapter				Isolating diaphragm				Wetted O-rings		
	316 SST	Cast Alloy 400	Cast C-276	Ni. Pl. C.S.	316L SST	Alloy 400	Alloy C-276	Tantalum	Glass-filled PTFE	Graphite-filled PTFE	Graphite
Acetic acid (<50%)*	E	G/E	E	P/F	E	F/E	E	E	E	E	E
Acetic acid (>50%)*	E	G/E	E	P/F	E/G	F/E	E	E	E	E	E
Acetic acid (<50%, <200 °F)*	E	P/E	E	P	E	P/E	E	E	E	E	E
Acetic acid (>50%, <200 °F)*	E	P/E	E	P	G	P/E	E	E	E	E	E
Acetic acid (>50%, >200 °F)*	F/–	–/E	–/E	P	P/–	–/E	–/E	E	E	E	E
Acetylene (100%, <250 °F)*	E	E	E	E	E	E	E	E	E	E	E
Alcohols	E	E	E	G	E	E	E	E	E	E	E
Air	E	E	E	E	E	E	E	E	E	E	E
Aluminum sulfate (<50%, <200 °F)	E	G	E	P	E <sup>1</sup>	F	E	E	E	E	E
Aluminum sulfate (>50%, <200 °F)	F	F	E	P	P <sup>1</sup>	P	E	E	E	E	E
Ammonia (anhyd., <500 °F)	E	E	E	E	E	E	E	–	E	E	E
Ammonium acetate (<200 °F)	E	E	E	E	E	E	E	E	E	E	E
Ammonium bicarbonate (<175 °F)	E	P	E	P	E	P	G	E	E	E	E

1. Data for material selection guide compiled from NACE publication Corrosion Data Survey, metals section, sixth edition.



Process fluid	Flange/adapter				Isolating diaphragm				Wetted O-rings		
	316 SST	Cast Alloy 400	Cast C-276	Ni. Pl. C.S.	316L SST	Alloy 400	Alloy C-276	Tantalum	Glass-filled PTFE	Graphite-filled PTFE	Graphite
Ammonium bromide (<20%)	E	E	E	G	G <sup>2</sup>	G	G	E	E	E	E
Ammonium chloride (<10%, <200 °F)	E	E	E	G	E <sup>1,2</sup>	G	E	E	E	E	E
Ammonium chloride (10–20%, <200 °F)	E	E	E	G	G <sup>1,2</sup>	G	E	E	E	E	E
Ammonium hydroxide (<40%)	E	F	E	F	E	P	E	P	E	E	E
Ammonium nitrate (<200 °F)	E	F	E	F	E	P	G	E	E	E	E
Ammonium oxalate (<40%, <200 °F)	E	E	E	P	G	G	G	E	E	E	E
Ammonium phosphate (mono basic)	E	G	E	F	E	F	E	E	E	E	E
Ammonium phosphate (di basic)	E	G	E	–	E	F	E	–	E	E	E
Ammonium phosphate (tri basic)	E	E	E	–	E	G	E	–	E	E	E
Ammonium sulfate (<40%, <200 °F)	E	F	E	G	G	F	G	E	E	E	E
Aniline (100%, <200 °F)	E	E	E	G	E	G	G	E	E	E	E
Beer	E	E	E	E	E	E	E	E	E	E	E
Benzene	E	E	E	E	E	E	G	E	E	E	E
Black liquor (sulfate)	E	G	E	–	G <sup>1,2</sup>	G	E	E	E	E	E
Brines (calcium, dil.)	G	G	E	G	P <sup>2</sup>	F	E	E	E	E	E
Bromine (dry)	F	F	F	G	P	P	P	E	E	E	P
Bromine (wet)	F	F	F	F	P	P	P	E	E	E	E
Calcium carbonate (100%, <200 °F)	E	E	E	E	E	G	G	E	E	E	E
Calcium chloride (<50%)	E	E	E	E	G <sup>1,2</sup>	G	E	E	E	E	E
Calcium chloride (>50%)	E	–	E	G	G <sup>1,2</sup>	G <sup>1,2</sup>	E	E	E	E	E
Calcium sulfate (sat.)	E	E	E	E	G	G	G	E	E	E	E
Carbon dioxide (gas)	E	E	E	E	E	E	E	E	E	E	E
Carbonic acid (100%, <500 °F)	E	E	E	E	E	E	E	E	E	E	E
Carbon tetrachloride (dry–wet)	E	E	E	E	G	E	E	E	E	E	E
Cellulose acetate (100%, <100 °F)	E	E	E	G	E	G	E	E	E	E	E
Cellulose nitrate (100%, <200 °F)	E	E	E	G	G	G	sG	E	E	E	E
Chloric acid (<20%)	P	P	E	P	P	P	E	E	E	E	G
Chlorinated water (sat.)	P	G	E	F	p <sup>1,2</sup>	F	E	E	E	E	E
Chlorine gas (dry)	G	G	E	G	F	G	G	E	E	E	E
Chlorine gas (wet)	P	G	G	P	p <sup>1,2</sup>	G	F	E	E	E	E
Chlorine gas (liq. anhydrous)	F	G	E	–	P	G	G	E	E	E	E
Chloroform (80–100%, <200 °F)	E	E	E	E	G	E	G	E	E	E	E
Citric acid (<50%, <200 °F)	E	E	E	G	E	G	E	E	E	E	E

Process fluid	Flange/adapter				Isolating diaphragm				Wetted O-rings		
	316 SST	Cast Alloy 400	Cast C-276	Ni. Pl. C.S.	316L SST	Alloy 400	Alloy C-276	Tantalum	Glass-filled PTFE	Graphite-filled PTFE	Graphite
Citric acid (>50%, <200 °F)	P	E	E	G	P	G	E	E	E	E	E
Crude oil (sour)	E	E	E	-	G	E	E	-	E	E	E
Ethylene dichloride (100%, <200 °F)	E	E	E	G	G <sup>1,2</sup>	G	G	E	E	E	E
Ferric chloride (<10%)	P	F	E	P	P <sup>1,2</sup>	P	E	E	E	E	E
Ferric chloride (<40%, hot)	P	P	G	P	P <sup>1,2</sup>	P	F	E	E	E	E
Freon (gas, wet)	E	E	E	F	G	E	E	E	E	E	E
Fruit juices	E	E	-	-	E	G	-	-	E	E	E
Glycerol (0-100%, <200 °F)*	E	E	E	G	E	E	E	E	E	E	E
Green liquor (NaOH)	E	E	E	E	E <sup>1</sup>	E	E	E	E	E	E
Green liquor (sulfate, <200 °F)	E	E	E	E	G	G	G	-	E	E	E
Hydrochloric acid (<1%)	P	G	G	G	P	G	G	E	E	E	E
Hydrochloric acid (>2%, RT-Hot)*	P	P	F	P	P	P	P	E	P	E	E
Hydrofluoric acid (<50%)*	P	E	E	G	P	G	G	P	P	E	E
Hydrofluoric acid (>50%)*	P	E	G	F	P	G	G	P	P	E	E
Hydrogen chloride (anhydrous, <500 °F)	G	E	E	E	F	G	E	E	E	E	E
Hydrogen chloride (wet)	F	F	F	F	P	P	-	E	E	E	E
Hydrogen fluoride (dry, <500 °F)	G	E	E	E	F	G	G	P	E	E	E
Hydrogen gas (<500 °F)	E	E	E	E	E	E	E	E	E	E	E
Hydrogen peroxide	E	F	E	F	G	P	E	E <sup>1</sup>	E	E	G
Hydrogen sulfide (dry, <200 °F)	E	E	E	G	E <sup>1</sup>	G	G	E	E	E	G
Hydrogen sulfide (wet, <200 °F)	G	F	E	G	G <sup>1,2</sup>	P	E	E	E	E	G
Isopropanol (<200 °F)	E	E	E	E	E	E	E	E	-	-	-
Methanol	E	E	E	E	G	G	E	E	E	E	E
Natural gas (liq.)	E	E	E	E	E	E	E	E	E	E	E
Nitric acid (20%)	E	P	G	P	E	P	P	E	E	E	E
Nitric acid (20%, 200 °F)	E	P	P	P	G	P	P	E	E	E	E
Nitric acid (65%, boil.)	G	P	P	P	P	P	P	E	E	E	E
Nitric acid (conc., hot)	P	P	P	P	P	P	P	E	E	E	G
Nitric acid (fuming)	E	P	G	P	E	P	G	E	E	E	P
Nitrous oxide	G	P	G	P	G	P	G	E	E	E	E
Oxygen gas	E	E	E	E	E	E	E	E	E	E	E
Phosgene (RT to HOT)	G	E	E	E	G	E	G	-	E	E	E
Phosphoric acid (<50%)*	E	F/E	-/E	F/G	E	P/E	-/E	-/E	E	E	E

Process fluid	Flange/adaptor				Isolating diaphragm				Wetted O-rings		
	316 SST	Cast Alloy 400	Cast C-276	Ni. Pl. C.S.	316L SST	Alloy 400	Alloy C-276	Tantalum	Glass-filled PTFE	Graphite-filled PTFE	Graphite
Phosphoric acid (>50%)*	G	P/E	-/E	P	G	P/E	-/E	-/E	E	E	E
Phosphoric acid (<10%, boil.)*	F	P/G	-/G	P	P/G	P/G	-/G	-/E	E	E	E
Phosphoric acid (85%, boil.)*	P/F	P/G	-/F	P	P/F	P/G	-/F	-/E	E	E	E
Polyethylene (100%, <200 °F)	E	E	E	E	E	E	E	E	-	-	-
Polyvinyl-chloride	E	E	-	G	E	G	-	-	E	E	E
Potassium chloride (<40%, <200 °F)	E	E	E	G	E	G	E	E	E	E	E
Potassium nitrate (<200 °F)	E	E	E	E	G	G	G	-	E	E	E
Propane (100%, <200 °F)	E	E	E	E	E	E	E	E	E	E	E
Propylene dichloride (100%)	E	E	E	E	G	G	G	-	-	-	-
Propylene oxide (<200 °F)	E	-	-	-	E	-	-	-	E	E	E
Sewage	E	E	E	E	E	E	G	E	E	E	E
Sodium chloride (<40%, <200 °F)	E	E	E	F	G	E	E	E	E	E	E
Sodium hydroxide (50%)	E	E	E	E	E <sup>1</sup>	E	E	P	E	E	E
Sodium hydrox. (<40%, <150 °F)	E	E	E	E	E <sup>1</sup>	E	G	P	E	E	E
Sodium hydrox. (40–75%, <150 °F)	E	E	E	E	G <sup>1</sup>	E	G	P	E	E	E
Sodium Hydroxide (molten)	F	F	P	G	P <sup>1</sup>	F	P	P	P	P	P
Steam (<500 °F)	E	E	E	E	E	E	E	E	E	E	E
Styrene	E	E	E	E	E	G	E	-	-	-	-
Sulfur (molten, dry, 230 °F)	E	E	E	G	G	G	E	E	E	E	G
Sulfur dioxide (dry)	E	P	G	P	G	P	F	E	E	E	G
Sulfur dioxide (wet)	E	P	E	P	G	P	F	E	E	E	E
Sulfuric acid (<2%)*	E/G	F/E	E	P	G	P/G	E	E	E	E	E
Sulfuric acid (2–40%)*	F/P	E/G	E	G/P	P	E/G	E	E	E	E	E
Sulfuric acid (conc.>95%)*	E	P	E	P	G	P	E	E	E	E	P
Sulfuric acid (10%–conc., boil.)*	P	P/F	P	P	P	P	P	E	E	E	-
Trichloroethylene (80–100%)	E	E	E	G	E	E	G	-	E	E	E
Vinyl chloride (100%)	E	E	E	E	G	E	E	-	E	E	E
Water (fresh and distilled)	E	E	E	E	E	E	E	E	E	E	E
Water (sea)	G <sup>2</sup>	E <sup>2</sup>	E	G	F <sup>1,2</sup>	G <sup>2</sup>	E	E	E	E	E
Water (brackish)	E	G	E	P	G <sup>2</sup>	F	E	E	E	E	E
White liquor	E	E	E	-	E	G	E	E	E	E	E
Xylene (100%, <200 °F)	E	E	E	E	E	E	E	E	E	E	E

## Global Headquarters

### Emerson Automation Solutions

6021 Innovation Blvd.

Shakopee, MN 55379, USA

+1 800 999 9307 or +1 952 906 8888

+1 952 949 7001

RFQ.RMD-RCC@Emerson.com

## North America Regional Office

### Emerson Automation Solutions

8200 Market Blvd.

Chanhassen, MN 55317, USA

+1 800 999 9307 or +1 952 906 8888

+1 952 949 7001

RMT-NA.RCCRFQ@Emerson.com

## Latin America Regional Office

### Emerson Automation Solutions

1300 Concord Terrace, Suite 400

Sunrise, FL 33323, USA

+1 954 846 5030

+1 954 846 5121

RFQ.RMD-RCC@Emerson.com

## Europe Regional Office

### Emerson Automation Solutions Europe GmbH

Neuhofstrasse 19a P.O. Box 1046

CH 6340 Baar

Switzerland

+41 (0) 41 768 6111

+41 (0) 41 768 6300

RFQ.RMD-RCC@Emerson.com

## Asia Pacific Regional Office

### Emerson Automation Solutions

1 Pandan Crescent

Singapore 128461

+65 6777 8211

+65 6777 0947

Enquiries@AP.Emerson.com

## Middle East and Africa Regional Office

### Emerson Automation Solutions

Emerson FZE P.O. Box 17033

Jebel Ali Free Zone - South 2

Dubai, United Arab Emirates

+971 4 8118100

+971 4 8865465

RFQ.RMTMEA@Emerson.com



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