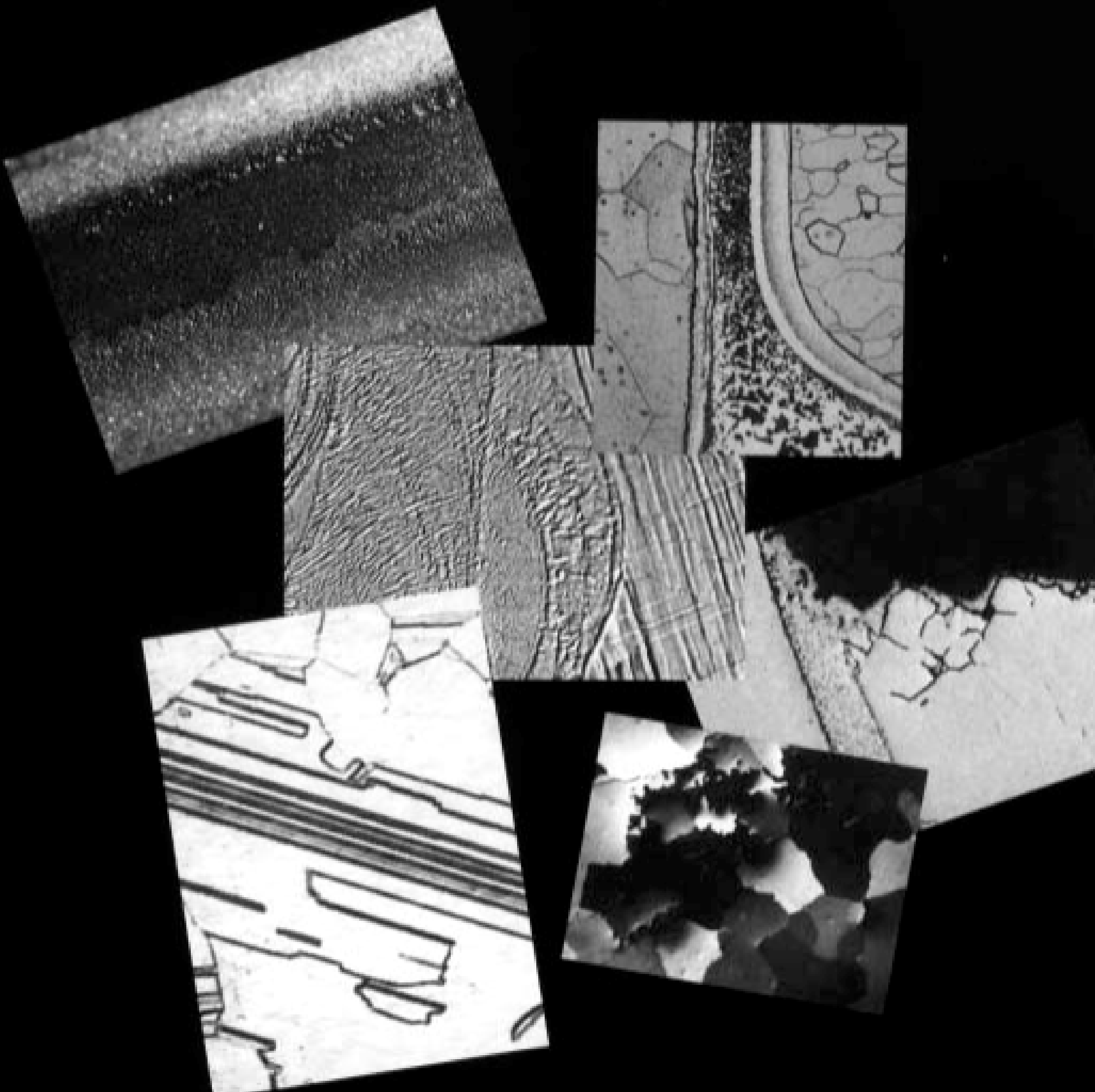
Micro Motion, Inc.
Coriolis Flowmeter
Corrosion Guide



Micro Motion

FISHER-ROSEMOUNT™ Managing The Process Better.™

Micro Motion Coriolis Flowmeter Corrosion Guide

Contents

Introduction

A major advance in the area of flow measurement was the introduction of the Coriolis mass flow and density sensor. This device has set a precedent for accuracy and repeatability under a wide variety of flow conditions. The inherent precision has established it as a standard for numerous industrial applications. The ability of these sensors to measure mass flow and density directly has led to their use in applications ranging from metering food products to corrosive chemicals. Coriolis sensors have proven extremely reliable when metering noncorrosive fluids. The same reliability can be achieved in corrosive services if consideration is given to the compatibility of the process fluid with the sensor materials of construction.

To satisfy the need of selecting the right material for a given application, Micro Motion manufactures sensors in 316L and 304L stainless steels, nickel-based alloys, tantalum, titanium, and 316L stainless steel lined with Tefzel® coating.

Material compatibility

Material compatibility must be considered in more detail for Coriolis sensors as compared to pressure-containing pipe. Compatibility in the latter case is usually addressed by consulting a general corrosion guide. General corrosion is a term that refers to the uniform loss of material. The rate of material removal is usually expressed in terms of inches or millimeters lost per year. These rates are determined experimentally by exposing a sample to the environment for a specific time period. Weight loss or dimensional changes are then used to determine the corrosion rate.

General corrosion tests are insensitive to detection of localized corrosion and are not always adequate for determining material compatibility for Coriolis sensors. Pitting, intergranular attack, stress corrosion cracking, and corrosion fatigue are all forms of localized corrosion that can lead to sensor failure.

Localized corrosion of the flow tube can initiate fatigue cracking. Sensor failure can then occur due to the rapid rate at which fatigue cracks propagate. The approach to preventing sensor failure is to avoid the onset of fatigue cracks. For this reason, the possibility of localized corrosive attack must be considered when selecting wetted materials.

Material compatibility cannot always be assessed by considering the alloy(s) selected for the remainder of the piping system. Material compatibility for most piping systems is based upon general corrosion rates alone and does not account for localized corrosion or cyclic loading. Coriolis sensors require vibration of one or two flow tubes to make a mass flow or density measurement. The cyclic loading condition is inherent to all Coriolis sensors and must be considered in the material selection process.

Material compatibility variables

The numerous environments in which the sensor can be used make it difficult to define process fluid compatibility for every possible material combination. The difference in chemical composition of most environments can be characterized by four variables. These are halogen concentration, pH, chemical potential, and temperature. If these variables can be defined for a particular environment, comparisons of alloy limitations can be made and a compatible material of construction chosen. Figures 1 through 3 show the domain of acceptable performance for 316L stainless steel, nickel-based alloys, titanium, and tantalum, as a function of the first three variables. The effect of temperature on sensor life can be characterized by considering its effect on the other three variables.

Halogens

The term halogen refers to a specific group of elements and includes chlorine, fluorine, bromine, and iodine. The most common halogen is chlorine. The presence of the ionic form, Cl^-, even as a contaminant, can be extremely detrimental to corrosion resistance. Stainless steels are particularly susceptible. Sensors constructed of 316L stainless steel have been extremely reliable in numerous applications where chloride concentrations can be maintained at sufficiently low levels or where free chlorides are absent (see Figure 1). Stainless steel can also be used in organic solutions that contain a chloride component, provided ion formation is avoided. Two factors that influence dissociation are temperature and moisture. Both need to be kept low to avoid failure. Figure 2 shows that the resistance of 316L to free chlorine-induced corrosion fatigue is temperature dependent. Low combinations of temperature and chloride concentration are compatible with 316L stainless steel. Pitting and corrosion fatigue are possible for higher combinations of temperature and chlorine concentrations. Nickel-based alloys should be used when these conditions exist. If the chloride content is increased further and pH lowered, nickel-based alloys may also succumb to localized attack and corrosion fatigue. Titanium is resistant to chloride solutions, but dry chlorine can cause rapid attack. Titanium should not be used with fluorine or fluoride solutions.

pH

The pH of a solution can also alter the corrosion behavior of any given alloy. In general, solutions that have a neutral pH (near 7) tend to be less aggressive than strongly acidic (pH<3) or strongly alkaline (pH>11) solutions (see Figure 3). Tantalum, for example, has superior corrosion resistance to 316L stainless steel and nickel-based alloys in neutral and acidic environments. High corrosion rates will occur if tantalum is used in caustic applications such as sodium hydroxide — even at room temperature. At higher temperatures, stress corrosion cracking and corrosion fatigue are possible. Under these conditions, nickel-based alloys are recommended. Nickel-based alloys should be used in all caustic applications in which there is a possibility of chloride contamination. Titanium can be used in some acidic and alkaline solutions. However, higher temperatures should be avoided in strongly alkaline solutions.

Chemical potential

The chemical potential is a measure of the oxidizing or reducing power of a process fluid. Chemical potential, sometimes referred to as *redox* potential, is defined relative to the $H_2 \varnothing 2H^+ + 2e^-$ half reaction, which is assigned a value of zero volts. Any environment that has a chemical potential greater than the reference is considered oxidizing. Chemical potentials that are equal to or less than the reference are considered reducing. Chemical potential is important because a minimum amount of oxidizing power is required to enable the formation of protective surface oxide layers. Optimal life will be realized as long as this layer is stable. Environments that are too oxidizing or reducing will prevent stable oxide formation. Under such conditions, failure due to corrosion fatigue or erosion/corrosion is possible.

The corrosion fatigue resistance of a material of construction is related to the range of chemical potentials over which oxide layer stability is maintained. The broader the range, the more environments in which the material will resist corrosion.

Tantalum pentoxide (Ta_2O_5) is stable on the surface of metallic tantalum at extremely low reducing potentials. This oxide also resists breakdown in all but the most oxidizing environments.

The wide range of chemical potentials over which passivity is maintained make tantalum resistant to most corrosive fluids. The second most stable oxide forms on the surface of nickel-based alloys. A high chromium and molybdenum content stabilizes the oxide layer, yielding improved performance over 316L stainless steel in chloride bearing applications. 316L stainless steel exhibits passivity over a narrow range, as compared to the other two materials. However, 316L stainless steel has proven to be suitable for a large number of chemical processing applications.

Titanium forms a stable oxide layer, which is protective in most oxidizing environments. The presence of moisture or oxygen promotes passivity. Titanium may also resist corrosion in reducing environments, when oxidizing agents, such as Fe^{+++} or Cr^{+++} are present in the solution.

Typical performance in various chloride concentrations

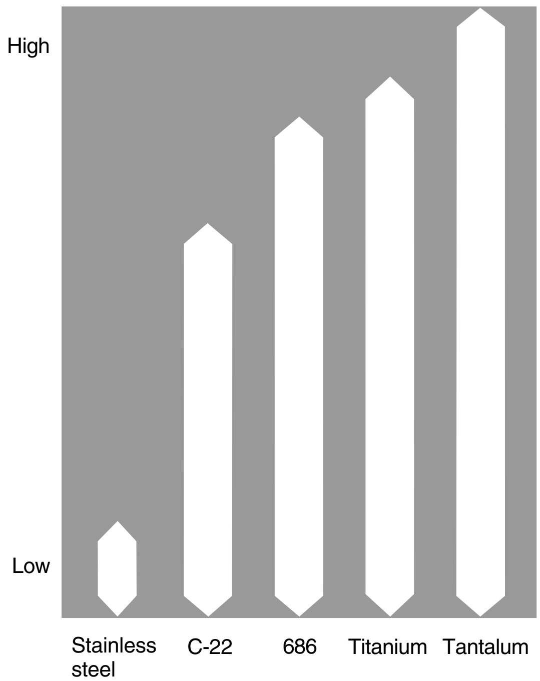


Figure 1

Chloride concentrations and temperature limits for 316L

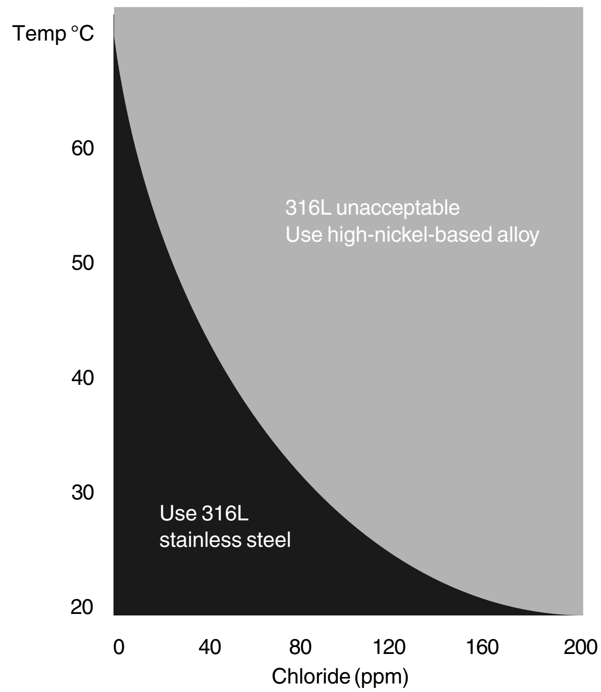


Figure 2

Typical performance in varying pH levels

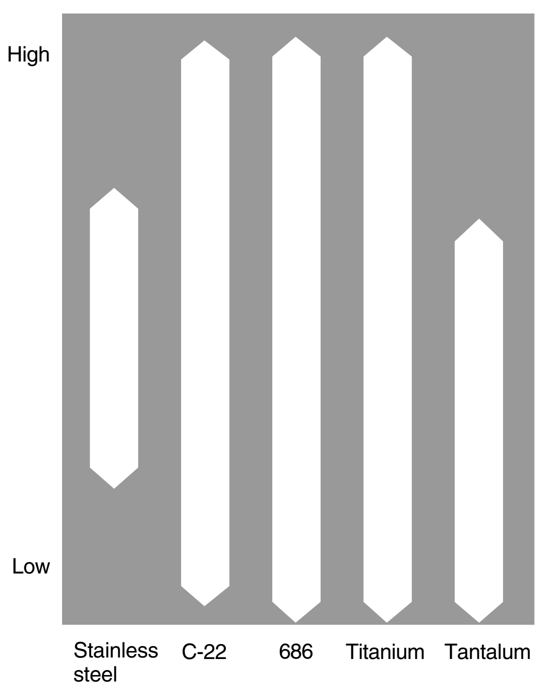


Figure 3

Performance in various chemical potentials

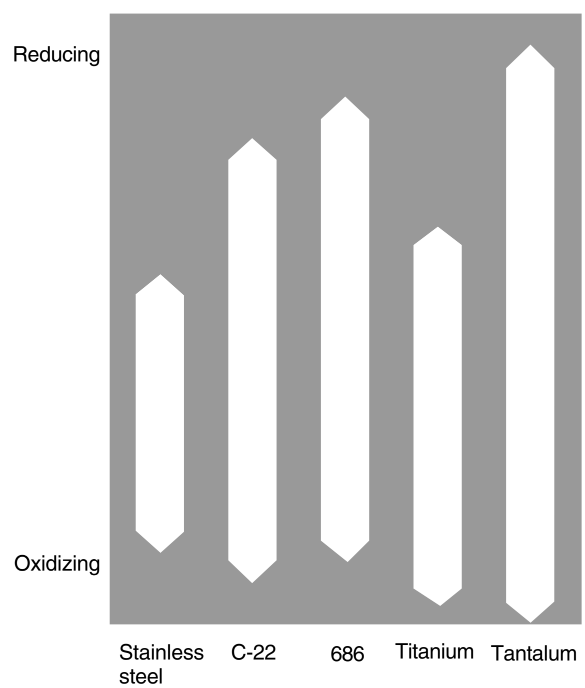


Figure 4

Tefzel®

Experience suggests that some applications are aggressive to all metallic components. Process fluids containing fluorine will rapidly corrode any metal. For example, hydrofluoric acid can be a contaminant in low quality grades of hydrochloric acid. Sensors employing metallic materials of construction, including 316L stainless steel, nickel-based alloys, titanium, and tantalum, will have short lives in aqueous fluorine applications. Premature sensor failure can often be avoided by checking the process stream for this component. If low concentrations are unavoidable, a Coriolis sensor lined with Tefzel can be used. Tefzel is very similar to Teflon® in both physical properties and corrosion resistance. The Tefzel lining acts as a barrier, which prevents the process fluid from coming in contact with the underlying metal and causing corrosion cracking. Tefzel is not, however, a universally corrosion-resistant material. Tefzel is embrittled by strong acids and strong bases. Certain organic solvents and temperatures can influence the mechanical strength of Tefzel. For this reason Tefzel-lined instruments are limited to applications where the temperature is less than 120°C. Because the Tefzel lining and the 316L stainless steel flow tubes have different coefficents of expansion, special temperature considerations apply. Tefzel-lined sensors have a maximum allowable rate of sensor temperature change equal to 30°F/hr (17°C/hr).

Summary

To help the customer select the right material for a given application, Micro Motion manufactures flow and density sensors in 316L and 304L stainless steels, nickel-based alloys, tantalum, titanium, and 316L lined with Tefzel. Experience indicates 316L is a good general purpose material suitable for many applications. In situations where more corrosive process fluids need to be measured, or when chlorine is present, a nickel alloy is often the material of choice. Tantalum is available for extreme conditions involving combinations of high temperature, low pH, or very high chloride concentrations. Titanium is suitable for a wide range of applications and is especially useful for chloride environments. These materials are not recommended for service in aqueous fluorine environments. A nonmetallic liner, such as Tefzel, is required under such conditions.

How to use the table

Fluids

Fluids are listed alphabetically and are generally listed under the appropriate chemical names, not trade names. The *Synonym* section at the end of this guide provides a means to reference trade names to chemical names. All fluids and flow conditions must be considered when making material selections. This includes the primary fluid, contaminants, cleaning, or other solutions.

Temperature and concentration

Each chemical may have one or more temperature and concentration combinations that define the environment to which the particular material was subjected. Temperature variation must be taken into account. In general, lower temperatures reduce the possibility of localized attack. This rule does not necessarily apply for variations in concentration. It is equally possible for a low or high concentration to cause corrosion. Evaporation of a fluid can result in elevated concentration of components, which can lead to corrosion. This situation can be avoided by keeping the sensor full at all times. If the sensor must be emptied, care must be taken to completely flush the sensor of any residual corrosive.

Materials

Compatibility of 316L stainless steel, Inconel® alloy 686, Hastelloy® C-22, tantalum, titanium, and Tefzel® are displayed in the *Materials* columns. To simplify interpretation, only four symbols have been used:

X The selected material is not compatible with the environment

O The selected material is compatible with the environment

– No data available

C Conflicting data

Note:

Corrosion data is not always available for the sensors' full temperature range. Materials will normally maintain corrosion resistance at temperatures below the lower limits in the table. Contact Micro Motion if your process might exceed the maximum temperature limits listed in the table for a particular application. Where temperature ranges have been omitted from the table, corrosion resistance is believed to be maintained throughout the sensors' temperature range. For applications that do not appear in this corrosion guide, please contact Micro Motion.

	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	**Low**	**High**	**Low**	**High**	**SS**	**HY**	**IN**	**TZ**	**TA**	**TI**	**Notes**
Acetaldehyde	-18	93	0	100	O	O	O	O	X	O	
Acetaldehyde	93	149	0	100	-	-	-	-	-	O	
Acetate	-18	52	0	100	O	O	O	O	-	O	
Acetate	52	77	0	100	O	O	O	-	-	O	
Acetate	77	204	0	100	O	O	O	X	-	O	
Acetic Acid	-18	10	0	50	O	O	O	C	O	O	
Acetic Acid	-18	10	50	80	O	O	O	X	O	O	
Acetic Acid	-18	10	80	95	-	O	O	X	O	O	
Acetic Acid	-18	66	95	100	O	O	O	O	O	O	
Acetic Acid	10	71	0	50	O	O	O	C	O	O	
Acetic Acid	10	71	50	80	O	O	O	X	O	O	
Acetic Acid	10	71	80	95	X	O	O	X	O	O	
Acetic Acid	66	93	95	100	O	O	O	-	O	O	
Acetic Acid	71	79	0	45	O	O	O	X	O	O	
Acetic Acid	71	79	45	50	C	O	O	X	O	O	
Acetic Acid	71	79	50	80	-	O	O	X	O	O	
Acetic Acid	79	93	0	45	O	O	O	X	O	O	
Acetic Acid	79	93	45	50	C	O	O	X	O	O	
Acetic Acid	79	93	50	55	-	O	O	X	O	O	
Acetic Acid	79	93	55	95	X	O	O	X	O	O	
Acetic Acid	93	99	0	20	O	O	O	X	O	O	
Acetic Acid	93	99	20	50	C	O	O	X	O	O	
Acetic Acid	93	99	50	55	-	O	O	X	O	O	
Acetic Acid	93	99	55	80	X	O	O	X	O	O	
Acetic Acid	93	99	80	95	X	X	-	X	O	O	
Acetic Acid	93	118	95	100	X	O	O	-	O	X	
Acetic Acid	99	104	0	20	O	O	O	X	O	O	
Acetic Acid	99	104	20	50	C	X	-	X	O	O	
Acetic Acid	99	104	50	55	-	X	-	X	O	O	
Acetic Acid	99	104	55	80	X	X	-	X	O	O	
Acetic Acid	99	104	80	95	X	X	-	X	O	-	
Acetic Acid	104	127	0	20	O	O	O	X	O	O	
Acetic Acid	104	127	20	50	C	X	-	X	O	O	
Acetic Acid	104	127	50	55	-	X	-	X	O	O	
Acetic Acid	104	127	50	80	X	X	-	X	O	O	
Acetic Acid	104	127	80	85	X	X	-	X	O	-	
Acetic Acid	104	127	85	95	X	X	-	X	O	X	
Acetic Acid	118	204	95	100	X	O	O	X	O	X	
Acetic Acid	127	135	0	20	O	O	O	X	O	-	
Acetic Acid	127	135	20	50	C	X	-	X	O	-	
Acetic Acid	127	135	50	95	X	X	-	X	O	X	
Acetic Acid	127	135	50	55	-	X	-	X	O	-	
Acetic Acid	135	149	0	20	O	O	O	X	O	X	
Acetic Acid	135	149	20	50	C	X	-	X	O	X	
Acetic Acid	135	149	50	55	-	X	-	X	O	X	
Acetic Acid	135	149	55	95	X	X	-	X	O	X	
Acetic Acid	149	204	0	20	O	-	-	X	O	X	
Acetic Acid	149	204	20	50	C	X	-	X	O	X	
Acetic Acid	149	204	50	55	-	X	-	X	O	X	
Acetic Acid	149	204	55	95	X	X	-	X	O	X	
Acetic Anhydride	-18	38	0	100	X	O	O	O	O	O	
Acetic Anhydride	38	93	0	100	X	O	O	O	X	O	
Acetic Anhydride	93	121	0	100	X	O	O	O	X	O	
Acetic Anhydride	121	143	0	100	X	O	O	X	X	O	
Acetone	-18	60	0	100	O	O	O	O	O	O	
Acetone	60	93	0	100	O	X	X	X	O	O	
Acetone	93	104	0	100	O	X	X	X	O	-	

SS = 316L Stainless Steel
HY = Hastelloy C-22
IN = Inconel 686
TZ = Tefzel Lined 316L
TA = Tantalum
TI = Titanium
X = Not Compatible
O = Compatible
– = No Data
C = Conflicting Data

Fluid Name	Temp., °C Low	High	Conc., %Wt Low	High	Material Compatibility SS	HY	IN	TZ	TA	TI	Notes
Acetone	104	149	0	100	O	-	-	X	O	-	
Acetone	149	204	0	100	O	-	-	X	-	-	
Acetone Cyanhydrin					O	-	-	-	O	-	
Acetone, 50% Water	-18	60	0	100	O	O	O	O	O	O	
Acetone, 50% Water	60	104	0	100	O	O	O	-	O	O	
Acetonitrile	0	60	0	100	O	-	O	O	O	-	
Acetyl Chloride	-18	21	0	100	O	O	-	O	O	-	
Acetyl Chloride	21	37	0	100	X	O	-	O	-	-	
Acetyl Chloride	37	60	0	100	X	-	-	O	-	-	
Acetylene	0	26	0	100	O	O	O	O	O	O	
Acetylene	26	37	0	100	O	O	O	O	-	-	
Acetylene	37	116	0	100	O	-	-	O	-	-	
Acetylene	116	204	0	100	O	-	-	-	-	-	
Acetylene Tetrabromide					X	-	-	O	O	-	
Acetylene Trichloride	0	106	0	90	X	O	O	O	O	-	
Acid Pulping	0	80	0	100	X	O	O	O	O	-	
Acrylic Acid	0	53			O	X	O	-	-	-	
Acrylic Emulsion					O	O	O	O	O	-	
Acrylonitrile	0	60	0	100	O	O	O	O	O	O	
Acrylonitrile	60	87	0	100	O	O	O	-	O	O	
Acrylonitrile	87	104	0	100	X	O	O	-	O	X	
Acrylonitrile	104	130	0	100	-	-	-	-	O	X	
Adipic Acid	0	10	0	100	O	O	O	O	O	O	
Adipic Acid	10	93	0	100	X	O	-	O	X	O	
Adipic Acid	93	120	0	100	X	-	-	O	X	O	
Adipic Acid	120	220	0	100	X	-	-	-	-	O	
Air					O	O	O	O	O	O	
Alachlor Technical					-	O	-	-	O	-	
Alcohols	0	100	0	100	O	O	O	O	O	O	X-Ti Anhydrous Methanol
Alkaline Liquor					O	O	O	O	X	-	
Alkylbenzene Sulfonic Acid					-	O	-	-	O	-	
Alkyldimethyl Ammonium Chloride					X	O	-	O	O	-	
Allyl Alcohol	0	93	0	100	O	X	-	O	X	X	
Allyl Alcohol	93	209	0	100	O	X	-	-	-	-	
Allyl Chloride	0	26	0	100	O	O	O	O	-	O	
Allyl Chloride	26	82	0	100	X	X	-	O	-	O	
Allyl Chloride Phenol					X	O	-	O	O	O	
Allyl Chloroformate					X	O	-	-	O	-	
Allyl Phenol	0	130	0	100	O	-	-	X	-	-	
Allylbenzene	20	60	0	100	O	-	-	-	-	-	
Alphamethylstyrene					O	O	O	O	O	-	
Alum	0	65	0	100	O	O	-	O	X	O	
Alum	65	98	0	100	-	X	-	O	-	O	
Alum	98	120	0	100	-	-	-	O	-	-	
Alumina					O	O	O	O	O	O	
Aluminum Chloride Aqueous	0	93	0	10	X	O	O	O	O	O	
Aluminum Chloride Aqueous	0	93	10	100	X	O	O	O	O	X	
Aluminum Chloride Aqueous	93	120	0	100	X	-	O	O	-	X	
Aluminum Chloride Dry	0	93	0	100	X	O	O	O	O	X	
Aluminum Chloride Dry	93	120	0	100	X	-	-	O	O	-	
Aluminum Chlorohydroxide					X	O	-	O	O	-	
Aluminum Fluorosulfate	0	200	0	15	-	O	O	-	O	-	
Aluminum Nitrate	0	98	0	100	O	-	-	O	O	O	
Aluminum Nitrate	98	120	0	100	O	-	-	O	O	-	
Aluminum Nitrate	120	150	0	100	O	-	-	X	-	-	
Aluminum Oxide					O	O	O	O	-	-	
Aluminum Sulfate	0	38	0	100	X	O	O	O	O	O	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	Low	High	Low	High	SS	HY	IN	TZ	TA	TI	Notes
Aluminum Sulfate	38	93	0	100	X	-	-	X	O	O	
Amine	0	100	0	100	O	O	O	-	O	O	
Amine	100	120	0	100	X	X	-	O	O	-	
Amine	120	148	0	100	-	-	-	X	O	X	
Ammonia	0	30	0	50	O	O	O	O	O	X	
Ammonia	30	70	0	30	O	O	O	O	X	X	
Ammonia	30	70	30	50	X	O	O	O	X	X	
Ammonia	70	150	0	50	X	O	O	X	X	X	
Ammonia Anhydrous	0	25			O	O	-	O	O	O	
Ammonia Anhydrous	25	120			O	O	-	O	O	X	
Ammonium Carbonate	0	20	0	30	O	O	-	O	O	O	
Ammonium Carbonate	20	93	0	30	X	X	-	O	O	O	
Ammonium Carbonate	93	120	0	30	X	-	-	O	-	-	
Ammonium Chloride	0	82	0	50	X	O	-	O	O	O	
Ammonium Chloride	0	93	0	10	O	O	-	O	O	O	
Ammonium Chloride	82	104	0	50	X	-	-	O	O	O	
Ammonium Chloride	104	120	0	50	X	-	-	O	-	-	
Ammonium Dihydrozene Phosphate					-	O	-	-	O	-	
Ammonium Hydroxide	0	75	0	100	O	O	-	-	X	O	
Ammonium Laurate					O	-	-	-	-	-	
Ammonium Laureth Sulfate					-	O	-	-	O	-	
Ammonium Nitrate	0	93	0	100	X	O	O	O	O	O	
Ammonium Nitrate	93	120	0	100	X	C	O	O	-	-	
Ammonium Oxalate	0	24	0	10	X	O	O	-	O	O	
Ammonium Persulfate	0	25	0	5	O	O	O	O	O	O	
Ammonium Persulfate	0	25	5	10	O	O	O	O	-	O	
Ammonium Persulfate	0	60	10	100	O	-	O	O	-	O	
Ammonium Persulfate	60	120	10	100	-	-	O	O	-	-	
Ammonium Phosphate	0	60	0	10	X	O	O	O	O	O	
Ammonium Phosphate	0	60	10	100	X	O	-	O	O	O	
Ammonium Phosphate	60	104	0	10	X	X	-	O	O	O	
Ammonium Phosphate	60	120	10	100	-	-	-	O	O	-	
Ammonium Phosphate	104	120	0	10	-	-	-	O	O	O	
Ammonium Phosphate	120	148	10	100	-	-	-	-	O	-	
Ammonium Saltwater	20	80	0	15	X	O	O	O	X	-	
Ammonium Sulfate	0	104	0	10	X	O	O	O	O	O	
Ammonium Sulfate	0	120	10	100	X	X	-	O	O	O	
Ammonium Sulfate	104	120	0	10	X	X	-	O	O	-	
Ammonium Sulfate	120	149	10	100	-	-	-	X	O	-	
Ammonium Sulfate	120	160	0	10	-	-	-	X	O	-	
Ammonium Sulfide	0	70	0	100	-	O	O	O	O	-	
Ammonium Thioglycolate					O	O	-	-	-	-	
Ammonium Thiosulfate					-	O	-	-	-	O	
Amyl Chloride	0	60	0	100	O	O	O	O	O	X	
Amyl Chloride	60	120	0	100	-	-	O	O	O	-	
Amyl Chloride	120	148	0	100	-	-	O	X	O	-	
Amyl Mercaptan	0	160	0	100	-	O	O	X	O	-	
Amylphenol	0	200	0	100	-	O	O	X	O	-	
Aniline	0	110	0	100	O	O	O	O	O	O	
Aniline	110	120	0	100	O	O	O	O	-	-	
Aniline	120	265	0	100	O	-	-	-	-	-	
Animal Fat					-	O	O	O	-	O	
Anodizing Solution Aluminum					-	O	-	-	O	-	
Anthracene Oil	80	90	0	100	O	-	-	-	-	-	
Anthraquinone					-	-	-	O	-	-	
Antibiotic Fermentation Media					-	O	-	-	O	-	
Antimony Pentachloride	0	71	0	50	X	O	O	O	O	-	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	**Low**	**High**	**Low**	**High**	**SS**	**HY**	**IN**	**TZ**	**TA**	**TI**	**Notes**
Apple Juice					O	O	-	O	O	O	
Aqua Quinine					O	O	-	-	-	-	
Aqua Regia	0	20	0	75	X	X	X	X	O	O	
Aqua Regia	20	82	0	75	X	X	X	X	O	-	
Argon					O	O	O	O	O	O	
Arsenic Acid	0	52	0	100	O	X	X	O	-	-	
Arsenic Acid	52	120	0	100	X	-	-	O	-	-	
Asphalt	0	200	0	100	O	-	O	X	O	O	
Atropine	0	60	0	100	-	O	-	-	-	-	
Barium Sulfate	0	93	0	100	X	O	-	O	X	O	
Barium Sulfate	93	120	0	100	-	-	-	O	-	-	
Beef Tallow					O	O	-	-	X	O	
Beer	0	37	0	100	O	O	O	O	O	O	
Beer	37	150	0	100	O	-	O	-	-	O	
Beeswax Bleach Solution	0	104	0	100	-	O	O	-	O	-	
Benzene	0	116	0	100	X	X	-	O	O	O	
Benzene Hexachloride	0	200	0	100	X	O	O	-	-	-	
Benzoic Acid	0	82	0	10	X	O	O	O	O	O	
Benzoic Acid	0	104	10	100	-	-	-	O	O	O	
Benzoic Acid	104	120	10	100	-	-	-	O	-	O	
Benzophenone					-	O	-	-	-	-	
Benzoquinine					O	O	-	-	O	-	
Benzoyl Chloride					-	O	-	O	O	-	
Benzoyl Peroxide					-	O	-	O	O	-	
Benzyl Chloride	0	120	0	100	X	X	-	O	C	-	
Black Acid	0	210	0	100	X	X	-	X	O	-	
Black Liquor	20	90	0	100	O	O	O	O	X	-	
Bleach					X	O	-	O	O	O	
Boric Acid	0	120	0	10	X	O	O	O	O	O	
Boric Acid	120	150	0	10	-	O	O	X	O	-	
Boron Sulfate					-	O	-	-	O	-	
Boron Trifluoride					-	O	-	-	-	-	
Boron Trifluoride Etherate	0	57	0	100	-	O	O	-	-	-	
Brine					X	O	-	O	O	O	
Bromethylbenzene					X	-	-	O	O	-	
Bromine			0	100	-	-	-	-	-	X	Mixed with Methanol
Bromine	0	20	0	100	X	O	O	O	O	O	Moist Gas
Bromine	0	30	0	100	-	-	-	-	-	X	Liquid
Bromine	0	66	0	100	X	O	O	O	O	X	Anydrous Gas
Bromine	20	150	0	100	X	-	-	-	O	-	Moist Gas
Butadiene	0	60	0	100	O	X	O	O	-	-	
Butadiene	60	120	0	100	-	-	-	O	-	-	
Butane					O	O	O	O	O	O	
Butanol					O	-	O	-	O	O	
Butyl Acetate	0	120	0	100	O	O	O	O	O	O	
Butyl Aldehyde					O	-	-	-	O	-	
Butylamine					O	O	-	-	-	-	
Calcium Carbonate					O	O	O	O	O	O	
Calcium Chloride	0	93	0	40	X	O	O	O	O	O	
Calcium Chloride	0	93	40	100	X	O	-	O	-	O	
Calcium Chloride	93	120	0	40	X	-	-	O	O	O	
Calcium Chloride	93	120	40	100	X	O	-	O	-	X	
Calcium Chloride	120	200	4	100	X	O	-	-	-	-	
Calcium Hydroxide	0	77	0	50	X	O	O	O	X	O	
Calcium Hydroxide	0	100	0	50	X	O	O	O	X	X	
Calcium Lignosulphonate					-	O	-	-	-	-	
Calcium Pyridine Sulfonate	0	66	0	100	-	O	-	X	-	-	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	**Low**	**High**	**Low**	**High**	**SS**	**HY**	**IN**	**TZ**	**TA**	**TI**	**Notes**
Calcium Sulfide	0	47	0	100	X	O	O	O	O	-	
Canola Oil					O	O	O	-	-	-	
Carbolite					O	O	-	O	O	-	
Carbon Dioxide	0	120	0	100	O	O	O	O	O	O	Dry
Carbon Dioxide	0	120	0	100	X	X	-	O	O	O	
Carbon Disulfide	0	43	0	100	O	-	-	O	O	O	
Carbon Disulfide	43	65	0	100	-	-	-	O	X	O	
Carbon Disulfide	65	93	0	100	-	-	-	-	-	O	
Carbon Tetrachloride					X	O	O	O	O	O	Moist
Carbon Tetrachloride	0	60	0	100	O	O	O	O	O	O	Anhydrous
Carbon Tetrachloride	60	120	0	100	-	-	-	O	O	O	Anhydrous
Carbon Tetrafluoride					X	-	-	-	-	-	
Carbonic Acid					X	O	O	O	O	O	Wet
Carbonochloric Acid					X	O	-	-	O	-	
Carboxylic Acid Salts					-	O	-	-	-	-	
Ceda Clean					-	O	-	-	-	-	
Cement					O	O	O	O	-	-	
Cerium Acetate					-	O	-	-	O	-	
Cetylpyridinium					O	O	-	-	-	-	
Cetylpyridinium Chloride					X	O	-	O	O	-	
Chloric Acid	0	31	0	20	X	O	-	O	O	-	
Chloric Acid	0	70	0	50	X	X	-	O	O	-	
Chlorinated Hydrocarbons					X	O	-	O	O	-	
Chlorinated Phenol					X	O	-	O	O	-	
Chlorinated Pyridine					X	O	O	O	O	-	
Chlorinated, Fluorinated Pyradines					X	O	-	X	O	-	
Chlorine	0	104	0	100	X	O	O	O	O	X	Anhydrous gas or liquid
Chlorine	0	120	0	100	X	O	-	O	O	-	Gas
Chlorine Dioxide					X	C	O	O	O	O	
Chlorine Triflouride					-	-	-	-	-	X	
Chloro Nitro Ethane					X	O	-	-	O	-	
Chloro Trifluoroethylene	0	49	0	100	-	O	-	-	O	-	
Chloroacetic Acid					X	O	-	O	O	O	
Chloroacetyl Chloride					X	O	-	-	O	-	
Chlorobenzene	0	38	0	60	X	O	O	O	O	O	
Chlorodifluoroethane					X	O	-	O	-	-	
Chlorodifluoromethane					X	-	-	O	-	-	
Chloroform	0	21	0	100	O	O	-	O	O	O	
Chloroform	21	104	0	100	X	X	-	O	O	O	
Chlorophenol	0	60	0	5	X	O	O	O	-	-	
Chloropicrin	0	95	0	100	X	O	O	-	O	O	
Chlorosilane					-	O	-	O	O	-	
Chlorosulfonic Acid	0	85	0	100	X	O	O	X	O	X	
Chlorotetrahydrophthalic Anhydride					X	O		-	O	-	
Chocolate					O	-	-	O	-	O	
Choline Chloride					X	O	-	-	O	-	
Chromic Acid	0	24	0	50	X	O	-	-	O	O	
Chromic Oxide					-	O	-	-	O	-	Based on 50% Chromic Acid.
Chromium Sulfate					O	O	-	-	O	-	
Citric Acid	0	60	10	50	X	O	O	O	O	O	
Citric Acid	0	100	10	25	X	O	O	O	O	O	
Citric Acid	100	150	50	62	X	-	-	-	-	X	
Coal Tar Fuel					O	O	O	X	O	-	
Coal Tar Pitch					O	O	O	X	O	-	
Cobalt Hydroxide	0	200	0	100	X	-	-	O	X	-	
Cobalt Octoate					O	O	-	-	-	-	
Cocoa Butter					O	-	O	O	O	O	

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IN	=	Inconel 686	TI	=	Titanium						

	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	Low	High	Low	High	SS	HY	IN	TZ	TA	TI	Notes
Coconut Oil					O	-	-	O	O	O	
Coke Gas Oil					O	O	O	O	O	-	
Compressed Natural Gas					O	O	O	O	O	O	
Concrete					O	O	O	O	O	-	
Copper Bromide					X	-	-	O	O	-	
Copper Sulfate	0	104	0	100	X	O	O	O	O	O	
Corn Oil					O	O	-	O	O	O	
Corn Oil and Garlic					O	O	O	O	O	-	
Corn Steep Liquor					O	O	-	O	O	-	
Corn Syrup					O	O	O	O	O	O	
Creosote Oil					X	O	O	-	-	O	
Cresol					O	O	O	O	-	O	
Cresylic Acid	0	100	0	100	-	O	O	X	O	O	
Crude Geranyl Ester					O	O	-	O	O	-	
Cupric Bromide	0	30	0	100	X	X	-	-	O	-	
Cupric Chloride	0	21	5	50	X	O	O	-	O	O	
Cupric Chloride	0	104	0	5	X	O	O	O	O	O	
Cupric Chloride	21	120	5	50	X	X	-	-	O	O	
Cuprous Chloride	0	90	0	55	-	-	-	-	-	O	
Cyanogen Chloride	0	46	0	20	-	O	-	-	O	-	
Cyclohexane	0	93	0	100	O	X	-	O	X	O	
Cyclohexane	93	120	0	100	O	X	-	O	-	O	
Cyclopropylamine					O	O	-	-	-	-	
Decane Sulfonyl Fluoride					X	-	-	O	-	-	
Diacryl Phthalate	0	15	0	100	O	-	O	-	O	-	
Dibromobenzene	0	200	0	100	X	-	-	-	O	-	
Dichloroacetyl Chloride					X	-	-	O	-	-	
Dichlorobenzene					X	O	-	O	-	X	
Dichlorobutene					X	O	-	-	O	-	
Dichlorodifluoromethane	0	21	0	100	X	O	O	O	O	O	
Dichlorodifluoromethane	21	71	0	100	X	-	-	O	-	-	
Dichlorofluoroethane					-	O	-	-	O	O	
Dichlorophenol	0	120	0	100	X	O	O	O	O	-	
Dichlorotrifluoroethane					X	-	-	O	-	-	
Diesel Fuel	0	38	0	100	O	X	-	O	-	X	
Diesel Fuel	38	120	0	100	-	-	-	O	-	-	
Diethanolamine	0	100	0	100	O	O	-	-	O	O	
Diethyl Aluminum Chloride					X	-	-	-	O	-	
Diethyl Disulfide	0	90	0	100	-	O	-	-	O	-	
Diethyl Sulfate					-	O	-	O	O	-	
Diethyl Sulfide					-	O	-	O	O	-	
Diethylamine	0	120	0	100	O	-	O	O	-	X	
Diethylene Glycol	0	52	0	100	O	X	-	O	-	O	
Diethylene Glycol	52	76	0	100	O	-	-	-	-	O	
Difluorobenzonitrile					-	-	-	O	-	-	
Difluoromonochlorethane					-	O	-	-	-	-	
Dihydrogen Sulfide					-	O	-	O	O	-	
Diisononylphtalate					O	O	-	-	-	-	
Diisopropyl Peroxydicarbonate					O	O	-	-	-	-	
Dimethyl Aminoethyl Methacrylate					O	-	-	-	O	-	
Dimethyl Chloride					X	O	-	-	O	-	
Dimethyl Dichloride					X	O	-	O	O	-	
Dimethyl Formaldehyde					O	-	O	-	O	-	
Dimethyl Hydrazine					O	O	-	-	-	-	
Dimethyl Malonate	0	100	0	100	-	O	-	-	O	-	
Dimethyl Succinate			0	100	O	O	-	-	O	-	
Dimethyl Sulfate					O	O	-	O	O	-	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	Low	High	Low	High	SS	HY	IN	TZ	TA	TI	Notes
Dimethyl Sulfide					O	O	-	O	O	-	
Dimethyl Terephthalate					O	-	-	X	O	-	
Dimethylacetamide	0	200	0	100	X	-	-	-	-	-	
Dimethylamine	25	180	0	100	O	-	O	X	O	-	
Dimethylpolysiloxanes					O	O	-	O	O	-	
Dinitrotoluene					O	O	-	-	O	-	
Dipaoxyzolidone											
Diphenyl Methane Diiosocyanate					O	O	-	-	-	-	
Diphenylamine	0	100	0	100	-	O	-	X	O	-	
Diprophylene Glycol Monomethyl Ether					O	O	-	O	O	-	
Dipropyl Peroxydicarbonate					O	O	-	-	-	-	
Disobutylene					O	O	-	-	O	-	
Disodium Iminodiacetate					X	-	-	-	-	-	
Divinylbenzene					O	O	-	-	-	-	
Dodecyl Mercaptan					O	O	O	-	O	-	
Dodecylbenzene Sulfonic Acid					-	O	O	-	-	-	
Drilling Mud					O	O	O	-	-	O	
Egg Slurry					O	O	O	O	O	O	
Epichlorohydrine	0	60	0	100	O	O	O	O	O	-	Dry
Epoxy Resin					O	O	O	-	-	O	
Ercimide					-	O	-	-	O	-	
Ester Vinyl Ether					X	O	O	O	-	-	
Ether	20	100	0	100	O	X	O	O	O	O	
Ethyl Acetate	20	65	0	100	O	O	O	O	O	O	
Ethyl Alcohol					O	-	O	O	O	O	
Ethyl Benzene	0	60	0	100	X	O	O	O	-	-	
Ethyl Benzene	60	100	0	100	X	O	O	-	-	-	
Ethyl Monochloroacetate					X	O	-	X	O	-	
Ethylbenzene Sulfonyl Fluoride					-	O	-	O	-	-	
Ethylene					O	O	O	O	O	-	Gas
Ethylene Chlorohydrin	0	100	0	100	X	X	-	O	-	X	
Ethylene Diamine	0	37	0	100	O	X	-	O	X	O	
Ethylene Diamine	37	43	0	100	-	-	-	O	-	-	
Ethylene Dichloride	0	93	0	100	X	O	O	O	O	O	Anhydrous
Ethylene Glycol	0	120	0	100	O	O	O	O	O	O	
Ethylene Glycol	120	200	0	100	-	O	O	-	-	-	
Ethylene Glycol/Bromoform				97	X	-	-	X	O	-	
Ethylene Oxide	0	31	0	100	O	O	-	O	O	O	
Ethylene Oxide	31	120	0	100	O	-	-	O	-	-	
Ethylproplacrolein					O	O	-	-	-	-	
Evaposhine					X	O	-	X	O	-	
Fat/Garlic					O	O	-	O	-	O	
Fatty Acid	0	120	0	100	O	O	O	O	O	O	
Fatty Acid	120	200	0	100	O	O	O	X	O	-	
Ferric Chloride	0	120	0	50	X	X	X	O	O	O	
Ferric Chloride	0	120	50	100	X	X	X	O	O	O	
Ferric Nitrate	0	20	0	100	X	O	O	O	O	O	
Ferric Nitrate	20	120	0	100	X	-	-	O	-	O	
Ferric Nitrite					O	O	-	-	O	-	
Ferric Sulfate	0	60	0	10	O	O	O	O	O	O	
Ferric Sulfate	0	60	10	30	-	O	-	O	O	O	
Ferric Sulfate	0	98	30	100	-	-	-	O	O	O	
Ferrous Chloride	0	120	0	100	X	X	-	O	O	O	
Ferrous Sulfate	0	120	0	100	X	O	-	O	O	O	
Fluorine					X	-	-	O	X	X	Dry
Fluoroalcohol					X	-	-	O	-	-	
Fluorobenzene					X	-	-	O	-	-	

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Fluid Name	Temp., °C Low	High	Conc., %Wt Low	High	Material Compatibility SS	HY	IN	TZ	TA	TI	Notes
Fluorosulfonic Acid					X	-	-	-	O	X	
Fluorotrichloromethane					X	-	-	O	-	-	
Formaldehyde					O	-	O	X	-	O	
Formic Acid	0	100	0	5	X	O	O	O	O	O	Aerated
Formic Acid	0	100	10	50	X	O	-	O	O	O	Aerated
Formic Acid	0	104	10	85	X	O	-	O	O	X	
Formic Acid	100	120	0	5	X	-	-	O	O	O	Aerated
Formic Acid	120	153	0	5	X	-	-	X	O	O	Aerated
Freon E-2					-	-	-	-	-	X	
Fruit Juice					O	O	O	O	O	O	
Gasoline	0	43	0	100	O	O	O	O	O	O	
Gasoline	43	120	0	100	-	O	O	O	-	-	
Gelatin					O	-	-	-	-	O	
Glycerine	0	104	0	100	O	O	O	O	O	O	
Glycolite					O	O	-	O	O	-	
Glyoxalic Acid					X	O	-	-	O	-	
Green Liquor					-	-	-	O	-	-	
Halogenated Alkyl Ether					X	O	-	O	O	-	
Halogenated Styrene					-	O	O	-	O	-	
Helium					O	O	O	O	O	O	
Heptane	0	60	0	100	O	O	O	O	O	O	
Heptane	60	98	0	100	-	O	-	O	-	O	
Hexachlorocyclopentadiene					X	X	-	-	O	-	
Hexafluoropropene					-	O	-	-	O	-	
Hexahydrophthalic Anhydride					O	O	-	-	-	-	
Hexamethylenediisocyanate					-	O	-	-	O	-	
Hexane					O	O	O	O	X	O	
Hydrazine					O	O	O	O	-	-	
Hydrobromic Acid	0	60	0	100	X	O	-	-	O	X	
Hydrochloric Acid	0	120	0	5	X	O	O	O	O	X	
Hydrochloric Acid	0	120	5	15	X	X	O	O	O	X	
Hydrochloric Acid	0	120	15	38	X	X	X	O	O	X	
Hydrochloric Acid	120	200	0	38	X	X	X	X	O	X	
Hydrochloric Acid Slurry			0	15	X	O	O	O	O	-	
Hydrofluoric Acid					O	O	O	O	O	X	Anhydrous
Hydrofluoric Acid			0	2	X	X	X	O	X	X	Aqueous
Hydrofluoric Acid	0	120	2	100	X	X	X	O	X	X	
Hydrofluosilicic Acid			10	50	X	-	-	O	X	X	
Hydrogen	0	75	0	100	O	O	O	O	X	O	
Hydrogen	75	120	0	100	O	O	O	O	X	X	
Hydrogen	120	200	0	100	O	O	O	X	X	X	
Hydrogen Bromide					X	X	-	-	O	X	
Hydrogen Chloride					X	-	-	O	O	X	Moist
Hydrogen Chloride					X	O	O	O	X	X	Anhydrous
Hydrogen Cyanide	0	31	0	100	O	O	O	O	-	O	
Hydrogen Cyanide	31	53	0	100	-	O	-	O	-	-	
Hydrogen Cyanide	53	120	0	100	-	-	-	O	-	-	
Hydrogen Fluoride	0	43	0	100	O	O	O	O	X	X	Anhydrous
Hydrogen Peroxide	0	48	50	90	O	O	O	O	X	X	
Hydrogen Peroxide	0	90	0	50	O	O	O	O	X	X	Acid Free
Hydrogen Sulfide					X	X	-	O	O	O	Aqueous Solution
Hydrogen Sulfide	0	31	0	100	O	O	O	O	O	O	Anhydrous
Hydrogen Sulfide	0	38	0	100	X	O	-	O	O	O	Moist gas
Hydrogen Sulfide	31	82	0	100	O	O	-	O	O	-	Anhydrous
Hydrogen Sulfide	38	120	0	100	X	-	-	O	O	-	Moist Gas
Hydrogen Sulfide	82	120	0	100	X	-	-	O	O	-	Anhydrous
Hydrogen Sulfide/Water/Oil					O	O	-	-	O	-	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	Low	High	Low	High	SS	HY	IN	TZ	TA	TI	Notes
Hydroquinone					O	O	O	O	O	X	
Hydroxymethyl Ester					O	O	-	-	-	-	
Hydroxyphenylethanone					O	O	-	-	-	-	
Hydroxypropylmethylcellulose					X	-	-	-	O	-	
Hypochlorous Acid					X	O	O	O	O	O	
Ice Cream					O	O	O	O	O	O	
Igepon Surfactant					O	O	-	-	-	-	
Ink					O	-	O	-	O	O	
Insulin Extract					-	O	O	-	O	-	
Iron Sulfate					X	O	-	O	O	-	
Isobutanol					O	-	-	-	O	O	
Isobutyl Acetate					O	-	O	-	O	-	
Isooctyl Alchohol					O	O	-	-	-	-	
Isopar E					-	O	-	-	-	-	
Isopentane					O	O	O	-	-	-	
Isopropyl Acetate					O	O	-	O	-	-	
Isopropyl Alcohol					O	O	O	O	O	O	
Isopropylamine					O	O	-	-	-	-	
Jet Fuel	0	30	0	100	O	O	O	O	O	O	
Kathon Lx 1.5% Biocide					X	O	-	O	O	-	
Kerosene					O	O	O	O	O	O	
Ketchup					O	O	-	O	O	O	
Lactic Acid	0	49	0	25	O	O	O	O	O	O	
Lactic Acid	49	120	0	100	X	X	O	O	O	O	
Lactose	0	100	0	100	O	-	-	-	-	-	
Laoquer Thinner/Lupranate					O	O	-	-	O	O	
Lard Oil					O	O	-	O	O	O	
Lasso Herbicide					X	-	-	-	O	-	
Latex	0	60	0	100	O	-	-	-	-	O	
Latex Emulsion					O	O	-	O	-	O	
Lauryl Bromide					X	O	-	O	O	-	
Lead Acetate	0	104	0	100	O	O	O	O	O	O	
Lime Slurry	0	55	0	100	X	O	O	-	-	O	
Limestone	0	49	0	8	O	O	O	O	O	O	Maintain velocity < 10ft/sec
Liquefied Petroleum Gas					O	O	O	-	O	O	
Lithium					-	-	-	-	-	X	Liquid
Lithium Bromide					X	O	-	O	O	-	
Lithium Chloride	0	100	0	60	X	O	-	O	O	O	
Magnesium Chloride	0	120	0	50	X	O	O	O	O	O	
Magnesium Chloride	0	120	50	100	X	O	O	O	O	X	
Magnesium Chloride	120	153	50	100	X	O	O	X	O	X	
Magnesium Hydroxide	0	75	0	100	O	O	O	O	O	O	
Magnesium Hydroxide	75	100	0	100	O	O	O	O	O	X	
Magnesium Hydroxide	100	120	0	100	-	-	-	O	-	-	
Magnesium Nitrate	0	93	0	100	O	O	-	O	O	O	
Magnesium Oxide					O	O	O	O	O	O	
Magnesium Silicate					O	O	-	O	-	-	
Magnesium Sulfate	0	93	0	50	-	O	O	O	O	O	
Magnetic Slurries					-	O	-	O	O	-	
Maleic Acid	0	80	0	100	C	O	O	O	O	O	
Maleic Acid	80	120	0	100	X	-	-	O	-	O	
Maleic Anhydride					O	O	O	O	O	-	
Malumar					O	O	-	-	-	-	
Manganese Cobalt Acetate					O	O	-	-	-	-	
Manganese Sulfate	0	63	0	100	-	O	O	-	O	O	
Mayonnaise					O	O	O	O	O	O	
Mercaptan					O	O	O	-	O	-	

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Fluid Name	Temp., °C Low	Temp., °C High	Conc., %Wt Low	Conc., %Wt High	SS	HY	IN	TZ	TA	TI	Notes
Mercapto Ethanol					O	O		-	-	-	
Mercury					-	-	-	-	-	X	Liquid
Methacrylic Acid					O	O	-	-	O	-	
Methane					O	O	O	O	O	O	
Methyl Acetate	0	60	0	60	O	O	O	-	-	-	
Methyl Acrylate					O	O	-	-	O	-	
Methyl Acrylic Acid					-	O	-	-	O	-	
Methyl Alcohol	0	100	0	100	O	O	O	O	O	*O	*Unless anhydrous
Methyl Benzimidazole Zinc Salt					-	O	-	-	O	-	
Methyl Bromide	0	20	0	100	O	-	-	O	O	O	
Methyl Bromide	20	120	0	100	-	-	-	O	-	-	
Methyl Chloride	0	104	0	100	X	O	O	O	O	O	
Methyl Chloride	0	120	0	100	O	O	O	O	O	O	Anhydrous
Methyl Ethyl Ketone	0	93	0	100	O	O	O	O	O	O	
Methyl Iodide					X	-	-	-	O	-	
Methyl Methacrylate					O	O	O	-	O	-	Will polymerize if subjected to shear. Use DL meter
Methylamine					O	-	O	X	O	X	
Methyldichlorosilane					X	O	-	-	O	-	
Methylene Chloride	0	30	0	100	X	X	O	O	O	O	
Methylene Chloride	0	120	0	100	X	X	-	O	O	O	
Methylpyrolidone					O	O	-	-	-	-	
Mineral Oil					O	O	O	O	O	O	
Mineral Spirts					O	O	-	-	O	-	
Molasses					O	O	O	O	O	O	
Monochlorobenzene					X	O	-	O	O	X	
Monochlorodifluoromethane					O	O	O	O	O	O	
Monoethanoamine Hydrochloride	0	65	0	100	-	O	-	X	O	-	
Monoethanol Amine					X	O	-	O	O	O	
Monoethanolamine	0	100	0	90	O	O	-	O	O	O	
Morpholine					O	O	-	-	X	-	
Musk Concentrate					O	O	-	-	-	-	
Mustard Gas					X	-	-	O	O	-	
Nadir Methyl Anhydride					O	O	-	-	-	-	
Nalco 625					-	O	-	-	-	-	
Naphtha					O	O	O	O	O	O	
Naphthalene	0	120	0	100	O	O	-	O	O	O	
Naphthalene Sulfonic Acid	0	200	0	100	-	O	-	X	O	-	
Neopentyl Glycol					-	O	-	-	-	-	
Nickel Chloride	0	90	0	100	X	O	O	O	O	O	
Nickel Slurry					O	O	-	O	-	-	
Nitric Acid	-18	10	0	75	O	O	O	O	O	O	304L O
Nitric Acid	-18	10	75	100	O	O	-	O	O	O	304L O
Nitric Acid	10	24	0	70	O	O	O	O	O	O	304L O
Nitric Acid	10	24	70	100	O	O	-	O	O	O	304L O
Nitric Acid	24	38	0	20	O	O	O	O	O	O	304L O
Nitric Acid	24	38	20	50	O	X	X	O	O	O	304L O
Nitric Acid	24	38	50	90	X	X	X	O	O	X	304L O
Nitric Acid	24	38	90	100	X	X	X	O	O	X	304L X
Nitric Acid	38	52	0	10	O	O	O	O	O	O	304L O
Nitric Acid	38	52	10	40	O	X	X	O	O	O	304L O
Nitric Acid	38	52	40	80	X	X	X	O	O	X	304L O
Nitric Acid	38	52	80	100	X	X	X	O	O	X	304L X
Nitric Acid	52	66	0	30	O	X	X	O	O	O	304L O
Nitric Acid	52	66	30	70	X	X	X	O	O	O	304L O
Nitric Acid	52	66	70	100	X	X	X	X	O	X	304L X
Nitric Acid	66	80	0	20	O	X	X	O	O	X	304L O

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Fluid Name	**Low**	**High**	**Low**	**High**	**SS**	**HY**	**IN**	**TZ**	**TA**	**TI**	**Notes**
Nitric Acid	66	80	20	45	X	X	X	O	O	X	304L O
Nitric Acid	66	80	45	55	X	X	X	X	O	X	304L O
Nitric Acid	66	80	55	100	X	X	X	X	O	X	304L X
Nitric Acid	80	93	0	45	X	X	X	O	O	X	304L X
Nitric Acid	80	93	45	100	X	X	X	X	O	X	304L X
Nitric Acid	93	121	0	100	X	X	X	X	O	X	304L X
Nitric Acid	121	163	0	100	X	X	X	X	X	X	304L X
Nitroaniline					X	O	-	-	O	-	
Nitrobenzene					O	O	O	O	O	O	
Nitrochlorobenzene					X	O	-	-	O	-	
Nitrogen					O	O	O	O	O	O	
Nitrogen Tetroxide					-	-	-	-	-	X	
Nonanoic Acid Sludge					X	O	-	X	O	-	
Nonyl Phenol					O	O	-	-	O	-	
Octanol					O	O	O	-	-	-	
Oil Emulsion					O	O	O	O	O	O	
Oil, Crude					O	O	O	O	O	O	
Oil, Fuel					O	O	O	O	O	O	
Oil, Gas					O	O	O	O	O	O	
Oil, Hydraulic Cylinder					O	O	O	O	O	O	
Oil, Lube					O	O	O	O	O	O	
Oil, Soybean					O	O	-	O	O	O	
Oil, Spindle					O	O	O	O	O	O	
Oil, Transformer					O	O	O	-	O	O	
Oil, Turpentine					O	O	O	O	O	O	
Oil, Vegetable	0	43	0	100	O	O	O	O	O	O	
Oil, Vegetable	43	104	0	100	O	-	O	O	O	-	
Oil, Waste					X	O	O	-	-	-	
Oleum	20	50	0	100	-	O	O	O	O	-	
Orange Juice					O	O	-	O	O	O	
Oxalic Acid	0	104	0	10	X	O	O	O	O	X	
Oxygen					O	O	O	O	O	X	
Ozonated Water					O	-	-	O	-	O	
Ozone					O	O	O	O	-	O	
Paint					O	O	-	O	O	-	
Palmitic Acid					O	-	-	O	-	-	
Paper Pulp	0	74	0	15	X	O	-	-	-	-	Chlorine Bleached
Paraffine					O	O	O	-	O	O	
Paranitrochlorinebenzene					X	-	-	X	O	-	
Pentamethyl Indan					O	O	-	-	-	-	
Pentane					O	O	O	O	O	O	
Perchloroethylene					O	O	O	O	O	O	
Perfluorochemical Inert Liquid					X	-	-	O	-	-	
Peroxide Acid					-	O	-	-	O	-	
Phenol			0	95	O	O	O	X	O	X	
Phenol Formaldehyde	0	130	0	100	-	O	O	X	O	-	
Phenolsulfonic Acid					O	O	-	-	O	-	
Phenothiazine					O	O	-	-	O	-	
Phosgene	20	65	0	100	X	O	O	O	O	X	
Phosphoric Acid	0	25	0	5	O	O	O	O	O	O	
Phosphoric Acid	0	25	5	20	X	O	O	O	O	O	
Phosphoric Acid	0	25	20	98	X	O	O	O	O	X	
Phosphoric Acid	0	25	98	100	X	X	-	O	O	X	
Phosphoric Acid/Sodium Hydroxide					X	O	-	-	O	-	
Phosphoric Oxychloride	0	26			X	-	-	X	O	O	
Phosphorous					X	O	O	X	O	-	
Phosphorous Acid					X	O	-	X	O	-	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	**Low**	**High**	**Low**	**High**	**SS**	**HY**	**IN**	**TZ**	**TA**	**TI**	**Notes**
Phosphorous Trichloride	0	30			C	C	C	O	O	O	
Phthalic Acid	0	30			O	O	O	O	O	O	
Phthalic Anhydride	-18	99	98	100	O	O	O	C	C	-	
Phthalic Anhydride	99	149	98	100	O	O	O	X	C	-	
Phthalic Anhydride	149	204	98	100	O	O	O	X	-	-	
Phthalic Anhydride/Thermon					-	O	-	-	O	-	
Picric Acid					O	O	O	O	O	O	
Pitch	100	200	0	100	O	-	-	X	O	O	
Pivalic Acid					O	O	-	-	-	-	
Platinum Chloride					X	-	-	O	O	-	
Polyacrylamide					O	O	-	-	-	-	
Polyamine	0	182	0	100	-	O	-	X	O	-	
Polybutyl Chloride					X	O	-	-	O	-	
Polydimethylaminetetrachlorohydrate					-	O	-	-	O	-	
Polyester					O	O	O	-	O	-	
Polyethylene					O	O	O	-	O	-	
Polyethylene Glycol					O	O	O	O	O	O	
Polyethylene Wax					O	O	O	O	-	O	
Polyisobutylene					O	O	-	-	-	-	
Polyol					O	O	-	-	-	-	
Polyphosphorous					X	O	-	X	O	-	
Polyvinyl Alcohol					O	O	O	-	O	-	
Potassium Acetate					-	-	-	X	-	-	
Potassium Bisulfite	0	63	0	100	-	O	O	O	O	-	
Potassium Bromide	0	31	0	30	X	O	-	O	O	O	
Potassium Bromide	0	104	30	50	X	X	-	O	-	O	
Potassium Bromide	0	104	50	100	-	-	-	O	-	O	
Potassium Carbonate	0	80			O	O	O	O	O	O	
Potassium Chloride	0	160	0	99	X	O	O	X	O	O	
Potassium Chromate	0	24	0	10	X	O	O	O	O	-	
Potassium Hydroxide	0	77	0	40	O	O	O	O	X	O	
Potassium Hydroxide	0	100	40	50	X	O	O	O	X	X	
Potassium Iodide	0	30			O	-	-	O	O	O	
Potassium Nitrate	0	100			X	O	O	O	O	O	
Potassium Permanganate	0	100	0	50	X	O	O	O	O	O	
Potassium Persulfate	0	24	0	4	X	O	O	O	O	-	
Primary Stearyl Amine					O	O	-	-	-	-	
Propane					O	O	O	O	O	O	
Propionic Acid	0	140	0	97	-	O	O	X	O	X	
Propyl Alcohol	0	104	0	100	O	O	O	O	O	O	
Propylene					O	O	O	O	O	O	
Propylene Glycol					O	O	O	O	O	O	
Propylene Oxide					O	O	O	O	O	-	
Pyridine					X	X	O	O	O	X	
Rhodium					O	O	O	O	O	-	
Rosin	0	200	0	100	-	O	O	X	O	-	
Roundup Herbicide					X	O	-	-	O	-	
Rubber Cement					O	O	O	O	-	-	
Rubber Hydrocarbon					O	O	-	-	-	-	
Safety-kleen 105					O	O	-	O	O	-	
Salicylic Acid	0	120	0	100	X	O	O	O	O	O	
Scalp Oil					X	O	-	O	O	O	
Sebacic Acid	0	104	0	10	-	O	-	-	O	O	
Sentol (Liquid Acid Cleaner)					-	O	-	-	O	-	
Silica Slurry					O	O	-	O	O	-	
Silicon Dioxide					O	O	O	O	O	-	
Silicon Tetrafluoride					X	-	-	O	O	-	

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Fluid Name	Temp., °C Low	High	Conc., %Wt Low	High	Material Compatibility SS	HY	IN	TZ	TA	TI	Notes
Silicone					O	O	O	O	O	O	
Silicone Oil					O	O	O	O	O	O	
Silicontetrachloride Slurry					O	O	-	O	O	-	
Silver Nitrate	0	30	0	50	O	O	-	O	O	O	
Soap Fat	0	200	0	100	-	O	O	X	O	O	
Soap Solution					O	O	-	O	O	O	
Sodium Alkyl Glyceryl Sulfonate					-	O	-	O	-	-	
Sodium Aluminate	0	100	0	25	O	O	-	-	-	C	
Sodium Bicarbonate			0	20	O	O	O	O	O	O	
Sodium Bicarbonate			20	100	-	-	O	O	O	O	
Sodium Bisulfate	0	30	0	20	X	O	O	O	O	O	
Sodium Bisulfate	30	82	0	20	X	O	O	O	O	X	
Sodium Bisulfite	0	100	0	25	X	O	-	O	X	O	
Sodium Carbonate	0	100	0	25	O	O	O	O	O	O	
Sodium Carbonate	0	100	25	100	O	O	O	O	-	O	
Sodium Carbonate/Sulfuric Acid					O	O	-	X	O	-	
Sodium Chlorate	0	104	0	70	X	O	O	O	O	O	
Sodium Chlorate	60	150	70	100	X	O	O	O	O	O	
Sodium Chloride	0	60	0	100	X	O	O	O	O	O	
Sodium Cyanide	0	38	0	10	O	O	-	O	-	O	
Sodium Cyanide	0	120	0	100	X	X	-	O	-	-	
Sodium Formaldehyde					O	O	-	-	O	-	
Sodium Formaldehyde Bisulfate					O	O	-	-	O	-	
Sodium Formaldehyde sulfoxylate					-	O	-	-	O	-	
Sodium Gluconate					O	O	-	-	-	-	
Sodium Hydrosulfate					O	O	-	-	-	-	
Sodium Hydrosulfide	0	100	0	12	X	O	-	-	O	O	
Sodium Hydrosulfite					O	O	-	-	O	-	
Sodium Hydroxide	0	53	0	50	X	O	O	O	X	O	Observe chloride limits of Fig 4
Sodium Hydroxide	0	120	50	100	X	X	-	O	X	X	Observe chloride limits of Fig 4
Sodium Hydroxide	53	86	0	50	X	O	O	O	X	-	Observe chloride limits of Fig 4
Sodium Hypochlorite	0	30	0	1	O	O	O	O	O	O	
Sodium Hypochlorite	30	60	0	16	X	C	O	O	O	O	
Sodium Hypochlorite	60	120	0	16	X	X	X	O	O	-	
Sodium Hypophosphite					O	O	-	O	O	-	
Sodium Metabisulfite					-	O	-	O	-	-	
Sodium Metal					X	O	-	X	O	-	
Sodium Nitrate	0	112	0	60	O	O	O	O	O	O	
Sodium Nitrate	0	120	60	100	-	-	-	O	-	O	
Sodium Nitrite					X	O	O	O	O	O	
Sodium Perchlorlate	0	65	0	100	-	O	O	O	O	-	
Sodium Persulfate					-	O	-	-	O	-	
Sodium Phenolate	0	120	0	100	-	O	-	O	O	-	
Sodium Phosphate	0	100			X	O	O	O	O	O	
Sodium Polyphosphate					-	O	-	O	-	-	
Sodium Silicate					O	O	O	O	O	O	
Sodium Sulfate	0	100	0	20	O	O	O	O	O	O	
Sodium Sulfide	0	30	0	50	X	O	O	O	O	O	
Sodium Sulfide	30	120	0	50	X	O	O	O	O	X	
Sodium Sulfite	0	120	0	10	O	O	-	O	O	O	
Sodium Xylene Sulphonate					O	O	-	-	O	-	
Soy Oil					O	O	O	O	O	O	
Soy Protein			0	18	-	O	O	O	O	O	
Soy Sauce					X	O	O	O	O	O	
Spent Acid					X	X	-	O	O	-	
Stabilizer/Crosslinker					X	-	-	-	-	-	Amine compounds
Stannic Chloride	0	30			X	O	O	X	O	O	

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Fluid Name	Low	High	Low	High	SS	HY	IN	TZ	TA	TI	Notes
Stannic Chloride	30	100			X	O	O	X	O	X	
Stannous Chloride	0	75	0	10	O	O	O	O	O	O	
Stannous Chloride	0	120	10	100	X	O	O	O	O	-	
Starch Syrup					O	O	O	O	O	-	
Stearic Acid					O	O	O	O	O	O	
Styrene					O	O	O	O	O	-	
Sucrose	0	93	0	62	O	O	O	O	O	-	
Sulfamic Acid	0	30			O	O	O	O	O	X	
Sulfite Liquor					X	O	-	O	X	O	
Sulfolane					O	O	-	O	O	-	
Sulfonic Acid					-	O	-	-	-	-	
Sulfonylchloride					X	O	-	-	O	-	
Sulfur	0	120	0	100	O	O	O	O	O	O	Molten
Sulfur Dichloride					X	O	-	O	O	-	
Sulfur Dioxide					O	O	O	X	O	O	Anhydrous
Sulfur Dioxide					X	O	-	X	O	X	Wet
Sulfur Monochloride		202			-	-	-	-	-	X	
Sulfur Monochloride/Isobutylene					X	-	-	-	O	-	
Sulfur Trioxide	0	25	0	100	-	O	O	O	X	X	
Sulfuric Acid	-18	24	0	20	O	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	-18	24	20	65	X	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	-18	24	65	75	X	X	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	-18	24	75	98	O	O	O	O	O	X	Maintain Velocity < 5 ft/sec
Sulfuric Acid	24	38	0	10	O	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	24	38	10	40	X	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	24	38	40	75	X	X	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	24	38	75	85	-	-	O	O	O	X	Maintain Velocity < 4 ft/sec
Sulfuric Acid	24	38	85	93	-	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	24	38	93	98	O	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	38	52	0	5	O	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	38	52	5	25	X	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	38	52	25	75	X	X	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	38	52	75	90	-	-	O	O	O	X	Maintain Velocity < 3 ft/sec
Sulfuric Acid	38	52	90	98	-	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	52	54	0	5	X	O	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	52	54	5	75	X	X	O	O	O	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	52	54	75	98	-	-	O	O	O	X	Maintain Velocity < 2 ft/sec
Sulfuric Acid	54	66	0	5	X	O	-	O	X	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	54	66	5	98	X	X	-	O	X	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	66	93	0	50	X	X	-	O	X	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	66	93	50	98	X	X	-	O	X	X	Maintain Velocity < 10 ft/sec
Sulfuric Acid	93	204	0	98	X	X	-	X	X	X	Maintain Velocity < 10 ft/sec
Sulfuric Flouride					X	-	-	O	-	-	
Sulfuryl Chloride					X	O	-	O	O	-	
Sulphenilic Acid					O	O	-	-	-	-	
Sulphurous Acid	0	25	0	6	X	O	O	O	O	O	
Tall Oil Fatty Acid					-	O	-	-	-	-	
Tall Oil Rosin					-	O	-	X	O	-	
Tall Oil Soap					X	O	-	O	X	-	
Tannic Acid	0	100	0	25	O	O	-	-	O	O	
Tar	150	200			O	O	O	X	O	O	
Tar Acid	0	200	0	100	X	O	-	X	O	-	
Tartaric Acid	60	100	10	50	-	-	-	-	-	O	
Tea					O	O	O	O	O	O	
Terephthalic Acid	0	160	0	77	O	O	O	X	O	O	
Terephthalic Acid	160	218	0	77	-	-	-	X	-	O	
Tetrachloroethane	0	70	0	100	X	O	O	O	O	O	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	Low	High	Low	High	SS	HY	IN	TZ	TA	TI	Notes
Tetrachloroethylene Sulfide					X	O	-	-	-	-	
Tetrachlorosilane					X	O	-	-	O	-	
Tetrafluoroethane					-	-	-	O	-	-	
Tetrahydrafluorine					-	-	-	O	-	-	
Tetrahydrofuran					O	O	-	X	-	X	
Tetrasodium EDTA					O	O	-	-	-	-	
Thinner					O	O	O	-	O	O	
Thiodichloric Acid					X	O	-	-	O	-	
Thionyl Chloride	0	26			X	-	-	-	O	X	
Tin Liquor					X	O	-	X	O	-	
Titanium Chloride	0	30			X	O	O	O	O	O	
Titanium Dioxide					O	O	O	O	O	O	
Titanium Iron Sulfate Solution					-	-	-	O	-	-	
Titanium Tetrachloride	0	30			X	O	O	O	O	O	
Toluene					O	O	O	O	O	O	
Toluene Diisocyanate					O	O	-	-	O	-	
Toluene Sulfonic Acid	0	125	0	94	-	O	-	X	O	-	
Toluene\ortho-nitrophenoxy Acetone					X	O	-	-	O	-	
Tomato Paste					O	O	O	O	-	-	
Triacetin					O	O	-	-	-	-	
Tribromomethane					X	-	-	O	O	-	
Trichloroacetic Acid	0	120	0	50	X	O	O	O	O	X	
Trichloroacetyl Chloride					X	O	-	-	O	-	
Trichlorobenzene					X	O	-	O	O	-	
Trichlorobromomethane					X	-	-	O	O	-	
Trichloroethane					X	X	-	X	O	O	
Trichloromethylpyridine					X	O	-	-	O	-	
Trichloromonofluoroethane					O	O	O	-	-	-	
Trichlorosilane					O	O	O	-	O	-	
Trichlorotrifluoroethane					O	O	O	O	-	X	
Triethanolamine	0	95	0	100	O	O	-	O	-	O	
Triethyl Aluminum					O	O	-	-	O	-	
Triethylamine					O	O	O	-	O	-	
Triethylene Glycol					O	O	O	X	O	O	
Trifluoroacetic Acid					X	O	-	X	-	-	
Trimethyl Sulfonium Bromide					X	-	-	-	O	-	
Trimethylchlorocyante					X	O	-	O	O	-	
Triphenyl Phosphite					O	O	-	X	O	O	
Trisodiumphosphate	0	200	0	90	X	O	O	X	O	-	
Tritylchloride					X	O	-	-	O	-	
Turpentine					O	O	-	O	O	X	
Urea	0	90	0	100	O	O	O	O	O	O	
Vanadium Benzene					O	O	-	-	-	-	
Vanadium Chloride					X	O	-	O	O	-	
Vanadium Oxychloride					X	O	-	-	O	-	
Vanadium Oxytrichloride					X	O	-	O	O	-	
Vanadium Tetrachloride					X	O	-	O	O	-	
Vanadium Triacetylacetonate					X	O	-	X	O	-	
Varnish					O	O	O	O	O	-	
Vazo					X	O	-	-	-	-	
Vegetable Tanning Liquor	0	79	0	100	-	O	-	O	O	-	
Vinegar					O	O	-	X	O	O	
Vinyl Acetate					O	O	O	O	-	-	
Vinyl Acetate Polymer Residues					O	O	-	-	-	-	
Vinyl Chloride	0	60	0	100	-	O	O	O	O	O	Latex
Vinyl Chloride	0	65	0	100	X	O	O	O	O	O	Monomer
Vinyl Fluoride					-	-	-	O	-	-	

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	Temp., °C		Conc., %Wt		Material Compatibility						
Fluid Name	**Low**	**High**	**Low**	**High**	**SS**	**HY**	**IN**	**TZ**	**TA**	**TI**	**Notes**
Vinylidene Chloride					X	O	-	O	O	-	
Vitamin E					O	O	-	-	-	-	
Water	0	200	0	100	O	O	O	O	O	O	Observe chloride limits of Fig 4
Water/Flour/Starch/Corn Syrup					-	O	-	O	O	O	
Wax Emulsion					O	O	-	O	-	O	
Whey/Milk					O	O	O	O	O	O	
Whiskey					O	O	O	O	O	O	
White Liquor	20	50	0	100	X	O	O	O	X	-	
Wine					O	O	O	O	O	O	
Xylene	20	120	0	100	O	O	O	O	O	O	
Yeast					O	O	O	-	-	-	
Yogurt					O	O	O	O	O	-	
Zeolite					-	O	-	O	-	-	
Zinc Carbonate Slurry	0	21	0	100	-	O	O	O	O	-	
Zinc Carbonate Slurry	21	82	0	100	-	O	-	O	O	-	
Zinc Chloride	0	107	0	71	X	O	O	O	O	O	
Zinc Dialkyl Dithiophosphate					X	O	-	-	O	-	
Zinc Hydrosulfite	0	120	0	10	X	O	O	O	O	-	
Zinc Sulfate	0	111	0	34	X	O	O	O	O	O	
Zirconium Chloride					X	O	-	X	O	-	Gas
Zirconium Chloride	0	85	0	25	X	O	-	O	O	-	

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Synonym	Listed under
1, 2 - Benzenedicarboxylic Acid Anhydride	Phthalic Anhydride
1, 3 - Phthalandione	Phthalic Anhydride
1,3 - Dioxophthalan	Phthalic Anhydride
2-Propenoic Acid	Acrylic Acid
Acetic Aldehyde	Acetaldehyde
Acetic Ether	Ethyl Acetate
Acetic Oxide	Acetic Anhydride
Acetyl Oxide	Acetic Anhydride
Acide Acetique (French)	Acetic Acid
Acide Sulfurique (French)	Sulfuric Acid
Acido Acetico (Italian)	Acetic Acid
Acido Solforico (Italian)	Sulfuric Acid
Actylene Tetrachloride	Tetrachloroethane
Albone	Hydrogen
Aldehyde Acetique (French)	Acetaldehyde
Aldeide Acetica (Italian)	Acetaldehyde
Amino Benzene	Aniline
Ammonium Hydroxide	Ammonia
Anhydride Phtalique (French)	Phthalic Anhydride
Anidride Ftalica (Italian)	Phthalic Anhydride
Ar	Argon
AsH3O4	Arsenic Acid
Azijnzuur (Dutch)	Acetic Acid
Azine	Pyridine
Aziotic Acid	Nitric Acid
Baking Soda	Sodium Bicarbonate
Battery Acid	Sulfuric Acid
Benzene Carboxylic Acid	Benzoic Acid
Benzol	Benzene
BH3O3	Boric Acid
Br	Bromine
Brine	Sodium Chloride
Brine	Brine
Bromoform	Tribromomethane
Bromomethane	Methyl Bromide
Butyl Alcohol	Butanol
Butylene	Butadiene
C13H10O	Benzophenone
C14H8O2	Anthraquinone
C23H17NO3	Atropine
C2H2	Acetylene
C2H3ClO	Acetyl Chloride
C2H3N	Acetonitrile
C3H3N	Acrylonitrile
C3H4O2	Acrylic Acid
C3H5Cl	Allyl Chloride
C3H6O	Acetone
C3H6O	Allyl Alcohol
C4H10	Butane
C4H6O3	Acetic Anhydride
C5Cl6	Hexachlorocyclopentadiene
C5H11CL	Amyl Chloride
C5H12S	Amyl Mercaptan
C6H10O4	Adipic Acid
C6H6	Benzene
C6H7N	Aniline
C7H16	Heptane
C7H5ClO	Benzoyl Chloride
C7H6O2	Benzoic Acid

Synonym	Listed under
C7H7Cl	Benzyl Chloride
C7H8O	Cresol
CaCl2	Calcium Chloride
CaH2O2	Calcium Hydroxide
Calcium Oxide	Limestone
Carbamide	Urea
Carbolic Acid	Phenol
Carbon Dichloride	Perchloroethylene
Carbon Oxychloride	Phosgene
Carbonyl Chloride	Phosgene
Carbonyl Diamide	Urea
Caustic Potash	Potassium Hydroxide
Caustic Soda	Sodium Hydroxide
Caustic Sulfite Liquor	Sulfite Liquor
CCl4	Carbon Tetrachloride
CFl4	Carbon Tetrafluoride
CH2O	Formaldehyde
CH3COCH3	Acetone
CH3COOH	Acetic Acid
Chlorallylene	Allyl Chloride
Chlorinated cyclic olefin	Hexachlorocyclopentadiene
Chlorine Gas	Chlorine
Chlorine Liquid	Chlorine
Chlorodiethylacetanilide	Alachlor Technical
Chloroethylen	Vinyl Chloride
Chloromethane	Methyl Chloride
Chloropentane	Amyl Chloride
Chlorotrichloromethyl	Pyridine
CL2	Chlorine
ClH4N	Ammonium Chloride
ClO2	Chlorine Dioxide
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
Crude Oil	Oil, Crude
CS2	Carbon Disulfide
CuCl2	Cupric Chloride
Cupric Sulfate	Copper Sulfate
Darammon	Ammonium Chloride
Deac	Diethyl Aluminum Chloride
Deionized Water	Water
Dichloroethane	Ethylene Dichloride
Dichloromethane	Methylene Chloride
Diethyl Ether	Ether
Diethylene Oxide, Tetramethylene Oxide	Tetrahydrofuran
Dihydroxyethane	Ethylene Glycol
Dimethyl Benzene	Xylene
Dimethyl Keytone	Acetone
Dipping Acid	Sulfuric Acid
Dipropyl	Hexane
Dodecyl Bromide	Lauryl Bromide
Dracylic Acid	Benzoic Acid
Epsom Salt	Magnesium Sulfate
Essigsaeure (German)	Acetic Acid
Ethanal	Acetaldehyde
Ethanoic Acid	Acetic Acid
Ethanoic Acid	Acetic Acid
Ethanol	Ethyl Alcohol
Ethanonitrile	Acetonitrile
Ethenyl Benzene	Styrene

Synonym	Listed under
Ethyl Aldehyde	Acetaldehyde
Ethyl Ethanoate	Ethyl Acetate
Ethylene Chloride	Ethylene Dichloride
Ethylic Acid	Acetic Acid
Ethyne	Acetylene
Ethyrene	Butadiene
Formalin	Formaldehyde
Freon 10	Carbon Tetrachloride
Freon 113	Trichlorotrifluoroethane
Freon 12	Dichlorodifluoromethane
Freon 17	Trichloromonofluoroethane
Freon 22 Monochlorodifluoromethane	
Ftaalzuuranhydride (Dutch)	Phthalic Anhydride
Ftalowy Bezwodnik (Polish)	Phthalic Anhydride
Fuel Oil	Oil, Fuel
Fuming Sulfuric Acid	Oleum
Glycol	Ethylene Glycol
H3N	Ammonia Anhydrous
H3N	Ammonia
H4N2O3	Ammonium Nitrate
H8N2O4S	Ammonium Sulfate
H8N2S	Ammonium Sulfide
Hartshorn	Ammonium Carbonate
HCl	Hydrochloric Acid
He	Helium
Herbicide	Alachlor Technical
Hexandioic Acid	Adipic Acid
HF	Hydrofluoric Acid
Hg	Mercury
HNO3	Nitric Acid
Hydoxy Benzoic Acid	Salicylic Acid
Hydraulic Cylinder Oil	Oil, Hydraulic Cylinder
Hydrochloric Acid/ Nitric Acid (3:1)	Aqua Regia
Hydrogen Peroxide Solution (DOT)	Hydrogen
Hypo Photographic Solution	Sodium Bisulfate
Inhibine	Hydrogen
Ispropanol	Isopropyl Alcohol
JP-4, JP-5	Jet Fuel
KOH	Potassium Hydroxide
Kyanol	Aniline
Li	Lithium
Lime	Limestone
Lime Sulfur	Calcium Sulfide
Liquid Chlorine	Chlorine
LPG	Liquefied Petroleum Gas
Lube Oil	Oil, Lube
Methanal	Formaldehyde
Methanecarboxylic Acid	Acetic Acid
Methanoic Acid	Formic Acid
Methanol	Methyl Alcohol
Methyl Benzene	Toluene
Methyl Cyanide	Acetonitrile
Methyltrichlorosilane	Methyldichlorosilane
Morkit	Anthraquinone
Mother Liquor	Potassium Carbonate
Muriatic Acid	Hydrochloric Acid
N	Nitrogen

Synonym	Listed under
NaCl	Sodium Chloride
NaOH	Sodium Hydroxide
NCI-c56326	Acetaldehyde
Nitrobenzol	Nitrobenzene
Nordhausen Acid (DOT)	Sulfuric Acid
O2	Oxygen
Octowy Aldehyd (Polish)	Acetaldehyde
Octowy Kwas (Polish)	Acetic Acid
OH	Alcohols
Oil of Mirbane	Nitrobenzene
Oil of Vitriol	Sulfuric Acid
Opadry	Hydroxypropylmethyl-cellulose
Oxybisethanol	Diethylene Glycol
Pentanethiol	Amyl Mercaptan
Perchlorocyclopentadiene	Hexachlorocyclopentadiene
Perhydrol	Hydrogen
Perossido Di Idrogeno (Italian)	Hydrogen
Peroxan	Hydrogen
Peroxyde D'Hydrogene (French)	Hydrogen
Phenyl Amine	Aniline
Phenyl Chloride	Chlorobenzene
Phenyl Ethylene	Styrene
Phthalic Acid Anhydride	Phthalic Anhydride
Phthalsaeureanhydrid (German)	Phthalic Anhydride
Propanoic Acid	Propionic Acid
Propanol	Propyl Alcohol
Propanone	Acetone
Quartz	Silicon Dioxide
Red Wine	Wine
Saline Solution	Sodium Chloride
Salmiac	Ammonium Chloride
Salt	Sodium Chloride
Salt Brine	Sodium Chloride
Salt Water	Brine
Salt Water	Water
Schwefelsaeureloesungen (German)	Sulfuric Acid
Sea Water	Brine
Sib Adduct	Sulfur Monochloride/ Isobutylene
Soda Ash	Sodium Carbonate
Spindle Oil	Oil, Spindle
Sugar of Lead	Lead Acetate
Sulfurous Acid	Sulphurous Acid
Sulphuric Acid	Sulfuric Acid
Table Salt	Sodium Chloride
Tallow	Animal Fat
Tear Gas	Chloropicrin
Tectilon Blue	Anthraquinone
Tetrachloroethylene	Perchloroethylene
Tetrachloromethane	Carbon Tetrachloride
Tin Dichloride	Stannous Chloride
Tin Tetrachloride	Stannic Chloride
Toluol	Toluene
Transformer Oil	Oil, Transformer
Trichloromethane	Chloroform
Turpentine Oil	Oil, Turpentine
Vinegar Acid	Acetic Acid
Vinyl Benzene	Styrene

Synonym	Listed under
Vinyl Cyanide	Acrylonitrile
Vinylformic Acid	Acrylic Acid
Vinyltrichlorosilane	Methyldichlorosilane
Vitriol Brown Oil	Sulfuric Acid
Wasserstoffperoxid (German)	Hydrogen
Waste Oil	Oil, Waste
Water Glass	Sodium Silicate
Waterstofperoxyde (Dutch)	Hydrogen
White Wine	Wine
Zwavelauuroplossingen (Dutch)	Sulfuric Acid

Hydrochloric acid (HCl)

Hydrochloric acid is reducing in a 1% to 37% concentration range. The strong acidic character, combined with the presence of chlorine, make it a very severe corrosive. High nickel alloys and tantalum are two of the few materials having useful resistance in this environment. Nickel-based alloys are not resistant over about 18% at 85°F, however. At higher concentrations or higher temperatures, corrosion fatigue failure is expected due to loss of passivity and corrosion in the active field. Failure of nickel-based alloy sensors is definitely expected in the 19% to 37% concentration range under ambient temperature conditions. Tantalum is the recommended material for higher concentration.

Sodium hydroxide (NaOH)

Sodium hydroxide is a strong base that is used in many industries to control pH or as a cleaning compound. Sodium hydroxide is usually not a problem from a general corrosion perspective but has been known to cause stress corrosion cracking of stainless steels at elevated temperatures. A close relationship between stress corrosion cracking and corrosion fatigue is generally recognized. This implies that if stress corrosion cracking occurs, corrosion fatigue is also possible depending upon the stress state resulting from applied loads. It is also known through experience that sodium hydroxide is often mixed with water containing chlorine. The presence of chlorine may be a more dominant factor dictating sensor life.

Experimental work has been conducted in 50% NaOH and a 50% NaOH solution to which 2.5% Cl^- has been added. Electrochemical and corrosion fatigue data have been collected on 316L samples exposed to such environment. Failure of stainless steel sensors exposed to the pure 50% solution was not observed after 4 months of exposure. Metallographic analysis showed no indication of stress corrosion cracking or localized corrosion. A second group of sensors exposed to solutions containing the chloride ion failed via corrosion fatigue after 4 days of exposure. The temperature in all cases was 200°F. Electrochemical tests in these environments indicated the presence of an oxide layer on 316L surfaces. The passive current density, which is a measure of oxide layer thickness, was 25 times higher when the chloride ion was present. The higher current density indicates that the chloride ion will substantially thin the oxide layer, resulting in a higher susceptibility to mechanical damage. This, in turn, would explain the dramatically lower life shown in corrosion fatigue tests.

Stress corrosion cracking, or corrosion fatigue, is not expected in stainless steel sensors exposed to “pure” sodium hydroxide solutions where the concentration is less than 50% by weight and the temperature is 200°F or lower. Higher concentration, and especially higher temperature, could cause failure. A nickel-based alloy is recommended under these conditions. Nickel-based alloys should be resistant at all concentrations up to the boiling point. The presence of the chloride ion can be very detrimental to 316L sensor life. If the presence of chlorine is a possibility, a nickel-based alloy should be used over stainless steel.

Nitric Acid (HNO_3)

General corrosion in nitric acid, being a strong oxidizing acid, is best withstood by alloys which form stable adhering oxide films. In general high chromium-containing alloys and strongly passivating metals like titanium and tantalum are the most resistant.

Most used construction materials for storage of nitric acid is type 304L, the corrosion resistance of which is often slightly better than that of molybdenum containing 316L (Micro Motion standard flowmeter material).

Corrosion rates increase with higher temperatures and concentrations. Intergranular corrosion can occur when stainless steels or nickel alloys are sensitized, which means they contain precipitated carbides. Low carbon grades like 316L and 304L are normally not susceptible to intergranular corrosion.

However, intergranular can also occur, regardless of heat treatment or composition of the alloy, if hexavalent chromium ions are allowed to accumulate in the acid to some critical concentration.

Titanium is not compatible with red fuming nitric acid at any temperature.

Sulfuric Acid (H_2SO_4) Compatibility Technical Notes

The purpose of this technical note is to assist the customer in making the correct material decision for a Micro Motion Coriolis Sensor in sulfuric acid applications. As always, the final choice for sensor material is left to the customer.

Micro Motion's Tefzel lined sensor will provide excellent service in sulfuric acid applications over all concentration ranges up to 98% and at temperatures up to 200°F (93°C). However, if the process stream encounters changes in temperature at a rate greater than 30°F (17°C) per hour, a 316L stainless steel or nickel-based alloy sensor is a better choice. 316L stainless steel sensors are best suited for low temperatures at both low and high concentrations of sulfuric acid. Nickel-based alloy sensors can be used at slightly higher temperatures, and over a broader temperature range.

316L stainless steel and nickel-based alloys depend on electrochemical passivity for resistance to corrosion in sulfuric acid. Electrochemical passivity refers to the state of the material's protective oxide layer. The material's protective oxide layer can be considered to exist in one of three states. In the passive state, the oxide layer is highly stable and provides the material's excellent corrosion resistance. The active state refers to a condition where the oxide layer is less stable. In the active state, the removal of the oxide layer can expose the more susceptible base metal. The transpassive state is similar to the active state in that the oxide layer is again, less stable. To maximize sensor life it is important to maintain the oxide layer in the passive state. However, exposure to sulfuric acid under varying conditions can cause the passive or stable oxide layer to become active or less stable.

When making the decision to place a 316L stainless steel or nickel-based alloy sensor in a sulfuric acid application, all of the following variables need to be considered to make the correct material choice. Each of the following factors can have an affect on the stability of the protective oxide layer.

Concentration

Sulfuric acid is somewhat oxidizing and not very aggressive at dilute concentrations up to about 10-15%. As concentration increases into the intermediate range, it becomes reducing and considerably more aggressive. You should notice that we do not recommend 316L stainless steel in the intermediate concentration ranges of sulfuric acid. However, nickel-based alloys are more resilient in mildly reducing environments, and find some applicability in the intermediate concentration range. Further increases in the concentration range above 75% push sulfuric acid into the oxidizing region, and its ability to attack the protective oxide layer is reduced with increasing concentration. For concentrations over 98% 304L is recommended.

Temperature

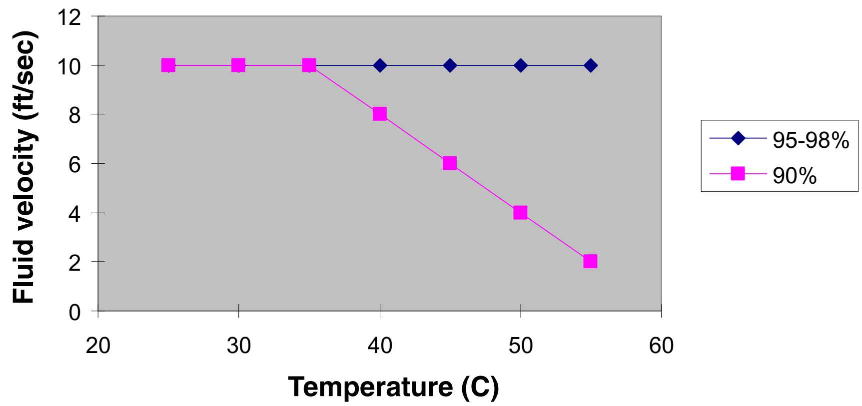
The temperature of the process stream has a great effect on the stability of the oxide layer. As temperature increases, the margin between an active and passive oxide layer becomes smaller and smaller. For any application in sulfuric acid, lowering the temperature will enhance the stability of the oxide layer.

Velocity

Many articles refer to apparent erosion by sulfuric acid. However, there are not any truly erosive constituents in most sulfuric acid process streams. So one might ask the question, "Why did my pipe erode away in the sulfuric acid application?" The answer lies with the oxide layer. Sulfuric acid in the higher concentration range can cause an unexpected oscillation in the oxide layer from passive to active to passive and so on. When the oxide layer is in the less stable, active state, the acid can pull the layer into the process stream before it can make the transition back to the more stable passive state. This results in a passive layer forming, becoming active and being stripped away, then another passive layer forms and the cycle repeats itself. This results in a gradual loss of material that would seem to be erosion.

It has been shown that reducing the fluid velocity can lessen the likelihood of the active oxide layer being removed from the material surface. The figure shown below provides a general guideline for maximum fluid velocity at different concentrations and temperatures.

The velocity recommendation was constructed primarily from the data for 316L stainless steel. However, it is felt that nickel-based alloy applications could benefit from adhering to this recommendation. Lastly, it should be noted that the 75%-90% concentration range is not covered in the velocity recommendation. This is due to a lack of data. Based on the relative aggressiveness of sulfuric acid in the 75-90% range, it is recommended that the fluid velocity be maintained as low as possible.



Other Factors

Aeration of the sulfuric acid solution can help enhance the stability of the passive oxide layer in both 316L stainless steel and nickel-based alloys.

The existence of oxidizing impurities such as Fe^{+++} (ferric), Cu^{++} (cupric), Sn^{++++} (stannic), or Ce4+ (cerric) ions in the process stream acts to stabilize the passive film. In higher concentrations of sulfuric acid (>97%), the presence of SO_3 (sulfite) can also add stability to the passive film. However, the presence of halides in sulfuric acid (such as chlorides) can have a detrimental effect on the stability of the oxide layer.

Summary

Material recommendations for sulfuric acid applications are at best difficult. Applications which appear to be very similar can have drastically different electrochemical properties. History is the best source of information to use when making material compatibility decisions. For newer applications, or applications where the risk of fluid release is to be minimized, Micro Motion Elite sensors are recommended. In addition to a built-in secondary containment, Elite sensors have excellent turn down characteristics, can be sized to reduce fluid velocity in the sensor, and are available in 304L.

Notes

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