OPTIMASS

Corrosion & Abrasion Guidelines for Coriolis Meters

- 1000 Series Twin Straight Tube Coriolis Mass Flowmeter
- 3000 Series Single Z Tube Coriolis Mass Flowmeter
- 7000 Series Single Straight Tube Coriolis Mass Flowmeter
- 8000/9000 Series Twin U Tube Coriolis Mass Flowmeter

KROHNE

Contents:

1. Corrosion Of Wetted Parts

1.1 Introduction:

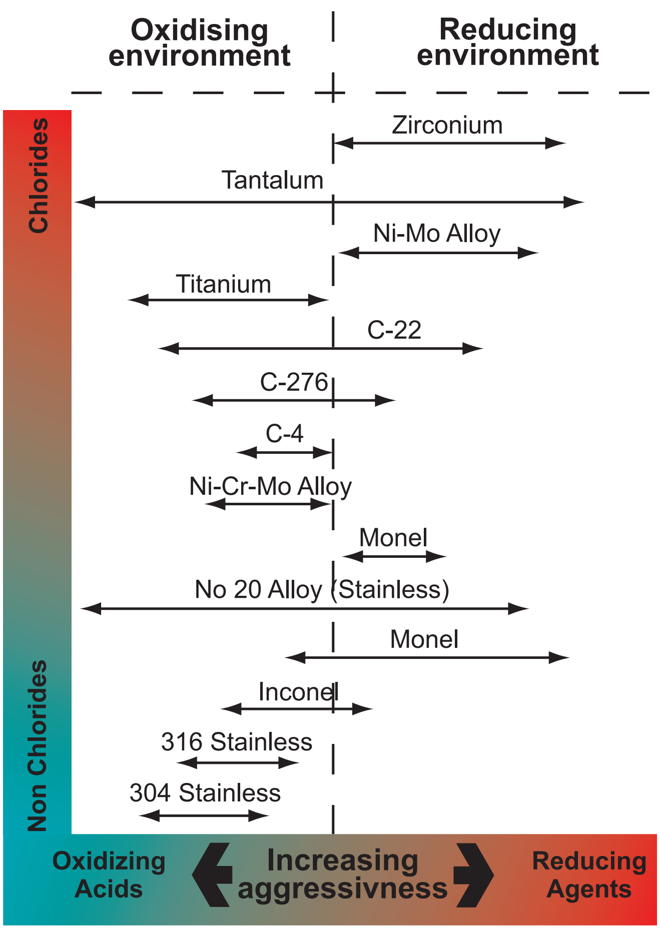
General corrosion guidelines for process vessels, pipework and parts (such as thermo-wells or MID flowmeter earthing rings) cannot be applied to Coriolis mass flowmeters, since they refer to the bulk removal of material from comparatively thick walled components, and they also tend not to address specific localised corrosion mechanisms.

Greater care must be taken in the case of mass flowmeters, since the tube wall thicknesses are in the region of 0.2 … 2mm (depending on meter size), so the removal of even a small amount of material can cause a measurement problem or a meter tube mechanical failure.

Additionally, localised corrosion effects such as pitting or stress corrosion cracking can occur even without corrosion of the overall tube. If severe enough, these effects may cause a meter tube mechanical failure.

For these reasons you will find that many fluids will be shown as unsuitable in this guide for use with mass flowmeters when compared to more general corrosion guidelines.

1.2 Material Compatibility



1.3 Material information

The Optimass meter range can be supplied with wetted parts (measuring tubes and connections) in the following materials:

Stainless Steel 318L 7000 series	All wetted parts: UNS S31803 to ASTM A789, A790, A479 and A240 (also known as DUPLEX Stainless Steel SAF2205). This 318L stainless steel is NACE approved. ALL hygienic and aseptic process connections: 316L UNS 31603 or equivalent (also NACE approved).
Hastelloy C22 7000 series	All wetted parts: UNS NO6022 to ASTM B619, B622, B626, B574 and B575 This HC-22 is NACE approved.
Titanium 7000 series	Measuring tube: UNS R56320 to ASTM B338 titanium grade 9 Flange raised faces: UNS R50400 to ASTM B348 and B265 titanium grade 2. Titanium grade 9 is not NACE approved.
Stainless Steel 316L 3000, 8000 / 9000 series	All wetted parts: 316L UNS 31603 or equivalent. 316L is NACE Approved.
Hastelloy C22 3000, 8000 / 9000 series	All wetted parts: UNS NO6022 to ASTM B622, B626, B564, B574 and B575. Hastelloy C22 is NACE approved.

Element	Typical	Specification
Al	3.0	2.5...3.5
V	2.5	2.0...3.0
Fe	0.13	0.25 Max
C	0.05	0.08 Max
Ti	Balance	Balance

Specifications for Titanium Gr9

Element	Typical	Specification
C	0.013	0.035 Max
Mn	1.6	2.0 Max
P	0.028	0.045 Max
S	0.009	0.030 Max
Si	0.38	1.0 Max
Cr	16.84	16.0...18.0
Ni	11.26	10.0...15.0
Mo	2.12	2.0...3.0
Fe	Balance	Balance

Specifications for SS316L

Element	Typical	Specification
C	0.02	0.030 Max
Mn	0.70	2.0 Max
P	0.025	0.030 Max
S	0.001	0.020 Max
Si	0.40	1.0 Max
Cr	22.4	21.0...23.0
Ni	5.8	4.5...6.5
Mo	3.3	2.5...3.5
N	0.16	0.08...0.2
Fe	Balance	Balance

Specifications for SS318L

Element	Typical	Specification
Cr	21.6	20.00...22.5
Mo	13.7	12.5...14.5
W	2.9	2.5...3.5
Fe	4.7	2.0...6.0
Co	1.1	2.5 Max
Mn	0.3	0.5 Max
V	0.13	0.35 Max
Ni	Balance	Balance

Specifications for Hasteloy C22

1.3.1 What is 318L Stainless steel?

Many customers have asked "what is the 318L stainless steel that you use in the Optimass 7000 single straight tube meter, and why do you use this material instead of 316L"? Measuring instruments are more normally manufactured with wetted parts from 316L stainless steel, which is a 100% austenic structure steel, with composition 18% .Chrome, 8% Nickel, 2.5% Molybdenum, with the balance Iron.

318L is a 50% austenitic / 50% ferritic structure steel (typically known as "duplex"), with (typical) composition 22% Chrome, 5% Nickel, 3% Molybdenum, with the balance Iron.

This material is defined under the following international codes:

- UNS S31803
- ASTM A789, A790, A479, A420
- DIN 1.4462

Please be aware that 318L is a "shorthand" expression KRONHE have adopted for the material to aid our customers' understanding that the material is a low carbon stainless steel of a speciifc composition, in the same way that 316L is used as "shorthand" for UNS S31603.

318L is more expensive to use than 316L, but we need to consider the technical benefits that it brings. 318L has a much higher tensile strength compared to 316L. We use this property in our meter to manage the stress caused by lengthening of the tube under thermal expansion. If we used 316L, the tube would deform well below the +100^{0}C maximum we specify for 318L.

The corrosion resistance of 318L is equal to 316L. The standard surface roughness is similar and it can be polished to the same fine surface finish of <0.5 um Ra for hygienic and aseptic applications. 318L is extensively used worldwide, where customers utilise the higher tensile strength to reduce wall thickness (and so the cost and weight) of process plant and piping. This means that there should be no reluctance from our customers in accepting this material.

KROHNE is the only company to offer a stainless steel straight tube mass flowmeter.

1.4 NACE Information

National Association of Chemical Engineers (NACE standard MR0175-2000) is a material requirements standard relating to the general problems of Sulphide Stress Cracking (SSC) of metals directed towards sour environments.

1.5 Galvanic Corrosion with Titanium

This can occur when a titanium tube meter is placed in contact with other metals, for instance in a steel pipeline. As titanium is a "noble" metal, the other material will normally corrode in preference to the titanium.

In the case of stainless steel pipelines, titanium is very close in the galvanic table therefore galvanic corrosion is unlikely to be a problem and no precautions are necessary.

If carbon steel pipelines are used, galvanic corrosion of the carbon steel may occur with certain acids. This corrosion process causes small amounts of hydrogen gas to be liberated at the wetted metal-to-metal contact area. This hydrogen gas may then cause embrittlement in the titanium. This can be avoided by electrically insulating the Optimass from the pipeline using insulating gaskets, bolt sleeves and washers.

Of course the use of an alternative tube material e.g. Hastelloy C-22 will prevent the problem entirely.

1.6 Problem Applications

Hydrochloric acid (HCl):

This acid normally contains fluoride and chloride impurities that will promote stress corrosion cracking in all tube materials. This effect will always cause a meter failure even if there is no bulk removal of tube material. For this reason we do not recommend Optimass meters for any HCl application.

Instead look to alternative instrument technologies such as capacitive MID (Capaflux) or variable area flowmeters (H250 PTFE).

Methanol:

“Pure” methanol (> 98% purity) tends to cause the removal of the protective oxide layer on a titanium measuring tube thus promoting corrosion. Titanium therefore cannot be used. Stainless steel or Hastelloy C-22 are suitable alternatives for these applications.

Methanol with a minimum 2%, or greater, water content does not exhibit this tendency and can be freely used with all tube materials.

Oxygen gas:

There is a risk of ignition where an oxygen rich (> 35% O_2) gas mixture is used with a titanium measuring tube.Always offer stainless steel as an alternative.Remember also that the “degreasing” option for wetted parts should also be offered for use with oxygen gas applications.

Passivation of meters

A “passivation fluid” is normally composed of a mixture of nitric acid (HNO_3) and hydrofluoric acid (HF) and is used to ‘passivate’ (clean) stainless steel pipework in high purity systems, typically found in the pharmaceutical industry. The process removes weld discoloration, dirt, grease, metal particles, etc.

The nitric acid has negligible corrosive effect, but hydrofluoric acid is very aggressive even at levels less than 0.5% for all wetted tube materials. It is recommended that any meter is removed and replaced with spool pieces during the passivation process. This is due to the relatively thin wall of mass flow meter tubes; the customer’s pipework being relatively thick is tolerant to a small loss of material.

1.7 Using Material Compatibility Tables.

Identify the chemical to be used either by name or by the Formula.

Check that you know the concentration of the chemical and that it is within the concentrations listed in column 3.

Identify the best material for the application and then check that this is acceptable for the customer.

Remember in all cases KROHNE cannot accept responsibility for the final choice of material. The ultimate responsibility lies with the end user. We can only advise based on our experience!

Explanation of data tables

1. Key to symbols used

Symbol	Meaning
✓	Suitable, with a corrosion rate less than 0.05 mm (0.002”) per year
X	Unsuitable, due to higher corrosion rate
nd	No data is currently available

2. Where a temperature is given, this signifies suitability only up to this point (e.g. 212/100 denotes up to 212^{o}F or 100^{o}C). Where no temperature is given, this signifies suitability up to the lower of either the boiling point of the product, or the maximum operating temperature of the Optimass flowmeter concerned.

The first temperature given is always in Fahrenheit and the second in Centigrade/Celsius.

3. Always check the relevant technical data sheet for the maximum operating temperature of the meter series and wetted material.
4. For the purposes of corrosion resistance, stainless steel grades 316L and 318L can be considered as both being the same.

Fluid	Chem. Formula	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
Acetaldehyde	CH3CHO	100%	200/93	200/93	300/149
Acetate	CH3CO2CH3	100%	400/204	400/204	400/204
Acetic Acid	CH3COOH	20%	400/204	300/149	260/127
Acetic Acid	CH3COOH	50%	160/71	210/99	260/127
Acetic Acid	CH3COOH	80%	160/71	210/99	260/127
Acetic Acid	CH3COOH	95%	X	200/93	210/99
Acetic Acid	CH3COOH	100%	X	200/93	200/93
Acetone	CH3COCH3	100%	400/204	140/60	200/93
Acetyl Chloride	CH3COCl	100%	70/21	99/37	220/105
Acetylene	CH2	100%	400/204	220/105	79/26
Adipic Acid	(CH2)5(COOH)2	100%	50/10	200/93	428/220
Air			✓	✓	✓
Aluminium Chloride	AlCl3	10%	X	220/105	200/93
Aluminium Chloride	AlCl3	40%	X	220/105	X
Aluminium Chloride	AlCl3	100%	X	158/70	X
Aluminium Fluoride	AlCl3	20%	X	X	X
Aluminium Nitrate	AlNO3	100%	302/150	X	208/98
Aluminium Sulphate	Al2SO4	6.50%	X	285/140	220/105
Aluminium Sulphate	Al2SO4	40%	X	285/140	220/105
Aluminium Sulphate	Al2SO4	100%	X	nd	200/93
Ammonia (anhydrous)	dry NH3	always 100%	248/120	248/120	77/25
Ammonia (aqueous)	NH3 + water	30%	158/70	158/70	X
Ammonia (aqueous)	NH3 + water	50%	86/30	302/150	X
Ammonium Acetate	NH4CH3COO	15%	220/105	220/105	77/25
Ammonium Acetate	NH4CH3COO	55%	170/77	nd	nd
Ammonium Bicarbonate	NH4HCO3	50%	X	nd	212/100
Ammonium Carbonate	(NH4)2CO3	50%	X	X	✓
Ammonium Chlorate	(NH4)ClO3	30%	nd	nd	122/50
Ammonium Chloride	NH4Cl	40%	X	221/105	221/105
Ammonium Fluoride	NH4F	25%	X	170/77	nd
Ammonium Hydroxide	NH4OH	45%	X	X	170/77
Ammonium Nitrate	NH4NO3	28%	280/137	80/27	✓
Ammonium Oxalate	(NH4)C2O4	10%	X	75/24	75/24
Ammonium Perchlorate	NH4ClO4	20%	170/77	X	285/140
Ammonium Phosphate	(NH4)3PO4	10%	X	140/60	248/120
Ammonium Phosphate	(NH4)3PO4	100%	X	140/60	140/60
Ammonium Sulphate	(NH4)2SO4	10%	X	220/104	248/120
Ammonium Sulphate	(NH4)2SO4	100%	X	X	248/120
Aniline	C6H6NH2	100%	509/265	248/120	230/110
Aniline hydro chloride	C6H5NH2xHCl	25%	X	nd	212/100
Aqua Regia	HCl / H2SO4	100%	X	X	X
Argon	Ar	100%	✓	✓	✓
Barium Carbonate	BaCO3	100%	X	X	77/25
Barium Chloride	BaCl2	25%	X	158/70	122/50
Barium Hydroxide	Ba(OH)2	10%	225/107	225/107	77/25
Barium Nitrate	Ba(NO3)2	20%	150/65	X	77/25
Benzene	C6H6	100%	X	X	240/116
Benzoic Acid	C6H5COOH	10%	X	180/82	248/120
Benzoic Acid	C6H5COOH	100%	X	180/82	248/120
Benzyl Chloride	C7H7Cl	100%	X	X	140/60
Boric Acid	BH3	10%	X	320/160	320/160
Boric Acid	BH3	100%	nd	nd	77/25
Bromine Liquid	Br	100%	X	X	X
Butyric Acid	CH3(CH2)2COOH	100%	X	260/127	225/107
Calcium Carbonate	CaCO3	100%	✓	✓	✓
Calcium Chloride	CaCl2	75%	X	221/105	O 221/105
Calcium Chloride	CaCl2	100%	X	392/200	X

✓ = Compatible X = Not Compatible nd = No Data Available

Fluid	Chem. Formula	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
Calcium Hydroxide	Ca(OH)2	50%	X	212/100	171/77
Calcium Hypochlorite	Ca(Ocl)2	15%	X	122/50	221/105
Calcium Hypochlorite	Ca(Ocl)2	95%	X	X	221/105
Calcium Sulphate	CaSO4	10%	nd	X	nd
Calcium Sulphate	CaSO4	100%	X	nd	140/60
Calcium Hypochlorite	CaCl2+6H2O	15%	X	122/50	221/105
Calcium Hypochlorite	CaCl2+6H2O	95%	X	X	221/105
Carbon Tetrachloride (anhydrous)	dry CCl4	100%	140/60	140/60	248/120
Carbonic Acid		Saturated	X	✓	✓
Chlorine (anhydrous)	dry Cl2	any	X	X	X
Chlorine (aqueous)	Cl2 + water	any	X	X	X
Chloroacetic Acid	CH2ClCOOH	85%	X	X	221/105
Chloroform	CHCl3	100%	80/27	80/21	221/105
Chlorosulphonic Acid	HClSO3	100%	X	185/85	X
Chromic Acid	H8CrO5	25%	X	167/75	221/105
Chromic Acid	H8CrO5	50%	X	75/24	221/105
Chromic Acid	H8CrO5	100%	X	X	221/105
Citric Acid	C6H8O7	25%	X	221/105	212/100
Citric Acid	C6H8O7	60%	X	221/105	X
Copper Nitrate	Cu(NO3)2	100%	280/138	X	77/25
Copper Sulphate	CuSO4	100%	X	X	221/105
Cupric Chloride	CuCl2	any	X	X	X
Cupric Cyanide	CuCN	100%	X	X	77/25
Cuprous Chloride	CuCl	55%	nd	nd	194/90
Dichloroacetic Acid	CHCl2COOH	any	nd	nd	X
Diethyl Phthalate	C12H14O4	100%	221/105	nd	221/105
Ethyl Alcohol (Ethanol)	C2H5OH	100%	221/105	221/105	221/105
Ethylene gas	C2H4	100%	✓	✓	✓
Ethylene dichloride (anhydrous)	dry C2H2Cl2	100%	X	221/105	221/105
Ethyl Acetate	CH3 COOC2H5	100%	320/160	320/160	221/105
Ferric Chloride	FeCl3	100%	X	X	248/120
Ferric Hydroxide	Fe(OH)3	6%	70/21	80/27	68/20
Ferric Hydroxide	Fe(OH)3	100%	70/21	80/27	nd
Ferric Sulphate	Fe2(SO4)3	15%	221/105	104/40	221/105
Ferric Sulphate	Fe2(SO4)3	35%	X	104/40	221/105
Ferric Sulphate	Fe2(SO4)3	100%	X	X	221/105
Ferrous Sulphate	FeSO4	100%	X	X	248/120
Fluoboric Acid	HBF4	30%	80/27	200/93	X
Fluorine (anhydrous)	dry F	any	X	X	X
Fluosilicic Acid	H2SiF6	any	X	X	X
Formaldehyde	CH2O	100%	221/105	X	221/105
Formic Acid (aerated)	HCOO4	50%	X	221/105	221/105
Formic Acid (non-aerated)	HCOO4	85%	X	221/105	X
Heptane	C6H12	100%	221/105	221/105	221/105
Hydrazine	(NH2)2	100%	✓	✓	✓
Hydrobromic Acid	HBO3	100%	X	140/60	X
Hydrochloric Acid	HCL + water	any	X	X	X
Hydrofluoric Acid	HF + water	any	X	X	X
Hydrogen gas	H		✓	✓	✓
Hydrogen Chloride gas	HCL	any	X	X	X
Hydrogen Cyanide	NCN	100%	88/31	88/31	88/31
Hydrogen Fluoride gas	HF	any	X	X	X
Hydrogen Peroxide	H2O2	50%	194/90	194/90	X
Hydrogen Peroxide	H2O2	90%	118/48	118/48	X
Iodine Liquid	I2	100%	X	✓	77/25

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Fluid	Chem. Formula	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
Lactic Acid	CH3CHOHCOOH	25%	122/50	122/50	122/50
Lithium Chloride	LiCl	50%	X	212/100	212/100
Magnesium Chloride	MgCl2	50%	X	280/138	248/120
Magnesium Hydroxide	Mg(OH)2	100%	212/100	212/100	167/75
Magnesium Sulphate	MgSO4	50%	nd	200/93	200/93
Maleic Acid	CH2(COOH)2	100%	X	176/80	248/120
Manganese Chloride	MnCl2	45%	X	212/100	212/100
Mercuric Chloride	HgCl2	10%	X	X	266/130
Mercuric Cyanide	Hg(CN)2	10%	95/35	X	95/35
Methanol + > 2% H2O	C2H4OH	98%	✓	✓	✓
Methanol + > 50ppm H20	C2H40H	99.99%	✓	✓	X
Methanol pure	C2H40H	100%	✓	✓	X
Methyl Ethyl Ketone	CH3CH2COCH3	100%	200/93	200/93	200/93
Methyl Methacrylate	C5H8O2	100%	✓	✓	✓
Methylene Chloride	CH2Cl2	100%	X	X	239/115
Mono Sodium Orthophosphate in water	NaPO3	200 millimoles	nd	nd	86/30
Monochloacetic Acid	CH2ClCOOH	100%	nd	nd	✓
N-Butyric Acid	CH3(CH2)2COOH	100%	X	212/100	212/100
Nickel Chloride	NiCl2	100%	X	194/90	194/90
Nickel Nitrate	Ni(NO3)2	50%	X	✓	77/25
Nickel Sulphamate		50%			✓
Nitric Acid	HNO3	100% “red fuming”	75/24	75/24	140/60
Nitric Acid	HNO3	70%	75/24	75/24	140/ 60
Nitric Acid	HNO3	50%	100/38	75/24	140/ 60
Nitric Acid	HNO3	40%	125/52	75/24	140/ 60
Nitric Acid	HNO3	30%	130/66	75/24	140/ 60
Nitric Acid	HNO3	20%	176/80	130/66	140/ 60
Oxalic Acid	(COOH)2	100%	X	212/100	X
Oxygen rich gas mixture	O2	> 35%	✓	✓	X
“Passivation” fluid	Mixture HNO3 + HF		X	X	X
Pentane	C5H10	100%	X	✓	✓
Perchloric Acid	HClO4	any	X	212/100	nd
Phenol	C6H5OH	95%	131/55	✓	X
Phosphoric Acid	H3PO4	100%	X	X	X
Phosphoric Acid	H3PO4	98%	X	77/25	X
Phosphoric Acid	H3PO4	20%	X	77/25	77/25
Phosphoric Acid	H3PO4	5%	77/25	77/25	77/25
Potassium Bromide	KBr	100%	X	X	✓
Potassium Bromide	KBr	30%	X	95/35	✓
Potassium Chloride	KCl	99%	X	✓	✓
Potassium Hydroxide	KOH	40%	170/77	170/77	170/77
Potassium Iodide	KI	75%	212/100	212/100	212/100
Potassium Nitrate	KNO3	100%	X	212/100	240/115
Potassium Permanganate	KMnO4	100%	X	✓	✓
Potassium Sulphate	K2SO4	25%	212/100	X	240/115
Propanol (Propyl Alcohol)	C3H6OH	100%	✓	✓	✓
Seawater (Brine)	C3H6OH	100%	X	✓	✓
Silver Nitrate	AgNO3	70%	85/30	85/30	212/70
Sodium Bisulphate	NaHSO4	20%	X	X	85/30
Sodium Carbonate	Na2CO3	100%	212/100	212/100	212/100
Sodium Chlorate	NaClO3	100%	X	302/150	302/150
Sodium Chloride	NaCl	100%	X	212/100	212/100
Sodium Cyanide	NaCN	50%	77/25	nd	266/130
Sodium Dichromate	Na2Cr	100%	X	80/27	77/25
Sodium Formate	HCOONa	50%	131/55	131/55	nd

✓ = Compatible   X = Not Compatible   nd = No Data Available

Fluid	Chem. Formula	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
Sodium Hydroxide	NaOH	45%	X	104/40	131/55
Sodium Hydroxide	NaOH	75%	X	104/40	X
Sodium Hypochlorite	NaOCl	any	X	X	X
Sodium Iodide	NaI	65%	X	nd	212/100
Sodium Nitrate	NaNO3	60%	233/112	233/112	248/120
Sodium Nitrate	NaNO3	100%	X	X	248/120
Sodium Nitrite	NaNO2	50%	212/100	212/100	266/130
Sodium Peroxide	(Na)2O2	15%	212/100	X	X
Sodium Phosphate	NaPO4	15%	X	212/100	212/100
Sodium Silicate	Na2SiO3	100%	212/100	212/100	212/100
Sodium Sulphate	Na2SO4	20%	212/100	212/100	X
Sodium Sulphide	Na2S	50%	X	212/100	X
Sodium Sulphite	NaSO3	25%	212/100	212/100	212/100
Sodium Sulphite	NaSO3	50%	nd	nd	212/100
Stannic Chloride	SnCl2	any	X	X	X
Stearic Acid	CH2(CH2)16COOH	100%	✓	212/100	X
Succinic Acid	(CH2 COOH)2	50%	X	X	✓
Sulphamic Acid	NH2 SO2 OH	any	X	nd	X
Sulphur (molten)	S	100%	✓	✓	✓
Sulphuric Acid	H2SO4	10%velocity < 3 m/s	100/38	100/38	X
Sulphuric Acid	H2SO4	25%velocity < 3 m/s	75/24	100/38	X
Sulphuric Acid	H2SO4	40%velocity < 3 m/s	X	100/38	X
Sulphuric Acid	H2SO4	55%velocity < 3 m/s	X	86/30	X
Sulphurous Acid	H2SO3	10%	X	X	175/80
Tannic Acid	C76H52O46	95%	212/100	X	212/100
Tartaric Acid	(CHOHCOOH) 2	50%	212/100	X	122/50
Terephthalic Acid	C8H6O4	77%	✓	✓	✓
Tetrachlorethane	C2H2Cl4	100%	X	160/71	160/71
Tetrachlorethylene (Perchloroethylene)	Cl2C:CCl2	100%	X	285/140	X
Thionyl Chloride	SO2Cl2	100%	X	nd	104/40
Toluene	C6H5CH3	100%		✓	✓
Trichlorethane	C2H3Cl3	100%	X	X	77/25
Tricloroacetic Acid	CCl3COOH	50%	X	212/100	nd
Trisodium Phosphate	(Na)3PO4	90%	X	✓	nd
Urea	(NH2)2CO	100%	194/90	194/90	194/90
Zinc Chloride	ZnCL2	75%	X	✓	212/100
Zinc Chloride	ZnCL2	100%	X	✓	X
Zinc Sulphate	ZnSO4	35%	X	212/100	212/100

✓ = Compatible X = Not Compatible nd = No Data Available

Chem. Formula	Fluid	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
	Air		✓	✓	✓
	Carbonic Acid	Saturated	X	✓	✓
	Nickel Sulphamate	50%			✓
(CH2 COOH)2	Succinic Acid	50%	X	X	✓
(CH2)5(COOH)2	Adipic Acid	100%	50/10	200/93	428/220
(CHOHCOOH) 2	Tartaric Acid	50%	212/100	X	122/50
(COOH)2	Oxalic Acid	100%	X	212/100	X
(Na)2O2	Sodium Peroxide	15%	212/100	X	X
(Na)3PO4	Trisodium Phosphate	90%	X	✓	nd
(NH2)2	Hydrazine	100%	✓	✓	✓
(NH2)2CO	Urea	100%	194/90	194/90	194/90
(NH4)2CO3	Ammonium Carbonate	50%	X	X	✓
(NH4)2SO4	Ammonium Sulphate	10%	X	220/104	248/120
(NH4)2SO4	Ammonium Sulphate	100%	X	X	248/120
(NH4)3PO4	Ammonium Phosphate	10%	X	140/60	248/120
(NH4)3PO4	Ammonium Phosphate	100%	X	140/60	140/60
(NH4)C2O4	Ammonium Oxalate	10%	X	75/24	75/24
(NH4)ClO3	Ammonium Chlorate	30%	nd	nd	122/50
AgNO3	Silver Nitrate	70%	85/30	85/30	212/70
Al2SO4	Aluminium Sulphate	6.50%	X	285/140	220/105
Al2SO4	Aluminium Sulphate	40%	X	285/140	220/105
Al2SO4	Aluminium Sulphate	100%	X	nd	200/93
AlCl3	Aluminium Chloride	10%	X	220 /105	200/93
AlCl3	Aluminium Chloride	40%	X	220 / 105	X
AlCl3	Aluminium Chloride	100%	X	158/70	X
AlCl3	Aluminium Fluoride	20%	X	X	X
AlNO3	Aluminium Nitrate	100%	302/150	X	208/98
Ar	Argon	100%	✓	✓	✓
Ba(NO3)2	Barium Nitrate	20%	150/65	X	77/25
Ba(OH)2	Barium Hydroxide	10%	225/107	225/107	77/25
BaCl2	Barium Chloride	25%	X	158/70	122/50
BaCO3	Barium Carbonate	100%	X	X	77/25
BH3	Boric Acid	10%	X	320/160	320/160
BH3	Boric Acid	100%	nd	nd	77/25
Br	Bromine Liquid	100%	X	X	X
C12H14O4	Diethyl Phthalate	100%	221/105	nd	221/105
C2H2Cl2 dry	Ethylene dichloride (anhydrous)	100%	X	221/105	221/105
C2H2Cl4	Tetrachlorethane	100%	X	160/71	160/71
C2H3Cl3	Trichlorethane	100%	X	X	77/25
C2H4	Ethylene gas	100%	✓	✓	✓
C2H40H	Methanol + > 50ppm H20	99.99%	✓	✓	X
C2H40H	Methanol pure	100%	✓	✓	X
2H4OH	Methanol + > 2% H2O	98%	✓	✓	✓
C2H5OH	Ethyl Alcohol (Ethanol)	100%	221/105	221/105	221/105
C3H6OH	Propanol (Propyl Alcohol)	100%	✓	✓	✓
C3H6OH	Seawater (Brine)	100%	X	✓	✓
C5H10	Pentane	100%	X	✓	✓
C5H8O2	Methyl Methacrylate	100%	✓	✓	✓
C6H12	Heptane	100%	221/105	221/105	221/105
C6H5CH3	Toluene	100%	✓	✓	✓
C6H5COOH	Benzoic Acid	10%	X	180/82	248/120
C6H5COOH	Benzoic Acid	100%	X	180/82	248/120
C6H5NH2xHCl	Aniline hydro chloride	25%	X	nd	212/100
C6H5OH	Phenol	95%	131/55	✓	X
C6H6	Benzene	100%	X	X	240/116
C6H6NH2	Aniline	100%	509/265	248/120	230/110

✓ = Compatible X = Not Compatible nd = No Data Available

Chem. Formula	Fluid	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
C6H8O7	Citric Acid	25%	X	221/105	212/100
C6H8O7	Citric Acid	60%	X	221/105	X
C76H52O46	Tannic Acid	95%	212/100	X	212/100
C7H7Cl	Benzyl Chloride	100%	X	X	140/60
C8H6O4	Terephthalic Acid	77%	✓	✓	✓
Ca(Ocl)2	Calcium Hypochlorite	15%	X	122/50	221/105
Ca(Ocl)2	Calcium Hypochlorite	95%	X	X	221/105
Ca(OH)2	Calcium Hydroxide	50%	X	212/100	171/77
CaCl2	Calcium Chloride	75%	X	221/105	221/105
CaCl2	Calcium Chloride	100%	X	392/200	X
CaCl2+6H2O	Calcium Hypochlorite	15%	X	122/50	221/105
CaCl2+6H2O	Calcium Hypochlorite	95%	X	X	221/105
CaCO3	Calcium Carbonate	100%	✓	✓	✓
CaSO4	Calcium Sulphate	10%	nd	X	nd
CaSO4	Calcium Sulphate	100%	X	nd	140/60
CCl3COOH	Tricloroacetic Acid	50%	X	212/100	nd
CCl4 dry	Carbon Tetrachloride (anhydrous)	100%	140/60	140/60	248/120
CH2	Acetylene	100%	400/204	220/105	79/26
CH2(CH2)16COOH	Stearic Acid	100%	✓	212/100	X
CH2(COOH)2	Maleic Acid	100%	X	176/80	248/120
CH2ClCOOH	Chloroacetic Acid	85%	X	X	221/105
CH2Cl2	Methylene Chloride	100%	X	X	239/115
CH2ClCOOH	Monochloacetic Acid	100%	nd	nd	✓
CH2O	Formaldehyde	100%	221/105	X	221/105
CH3 COOC2H5	Ethyl Acetate	100%	320/160	320/160	221/105
CH3(CH2)2COOH	Butyric Acid	100%	X	260/127	225/107
CH3(CH2)2COOH	N-Butyric Acid	100%	X	212/100	212/100
CH3CH2COCH3	Methyl Ethyl Ketone	100%	200/93	200/93	200/93
CH3CHO	Acetaldehyde	100%	200/93	200/93	300/149
CH3CHOHCOOH	Lactic Acid	25%	122/50	122/50	122/50
CH3CO2CH3	Acetate	100%	400/204	400/204	400/204
CH3COCH3	Acetone	100%	400/204	140/60	200/93
CH3COCl	Acetyl Chloride	100%	70/21	99/37	220/105
CH3COOH	Acetic Acid	20%	400/204	300/149	260/127
CH3COOH	Acetic Acid	50%	160/71	210/99	260/127
CH3COOH	Acetic Acid	80%	160/71	210/99	260/127
CH3COOH	Acetic Acid	95%	X	200/93	210/99
CH3COOH	Acetic Acid	100%	X	200/93	200/93
CHCl2COOH	Dichloroacetic Acid	any	nd	nd	X
CHCl3	Chloroform	100%	80/27	80/21	221/105
Cl2 + water	Chlorine (aqueous)	any	X	X	X
Cl2 dry	Chlorine (anhydrous)	any	X	X	X
Cl2C:CCl2	Tetrachlorethylene (Perchloroethylene)	100%	X	285/140	X
Cu(NO3)2	Copper Nitrate	100%	280/138	X	77/25
CuCl	Cuprous Chloride	55%	nd	nd	194/90
CuCl2	Cupric Chloride	any	X	X	X
CuCN	Cupric Cyanide	100%	X	X	77/25
CuSO4	Copper Sulphate	100%	X	X	221/105
F dry	Fluorine (anhydrous)	any	X	X	X
Fe(OH)3	Ferric Hydroxide	6%	70/21	80/27	68/20
Fe(OH)3	Ferric Hydroxide	100%	70/21	80/27	nd
Fe2(SO4)3	Ferric Sulphate	15%	221/105	104/40	221/105
Fe2(SO4)3	Ferric Sulphate	35%	X	104/40	221/105
Fe2(SO4)3	Ferric Sulphate	100%	X	X	221/105

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Chem. Formula	Fluid	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
FeCl3	Ferric Chloride	100%	X	X	248/120
FeSO4	Ferrous Sulphate	100%	X	X	248/120
H	Hydrogen gas		✓	✓	✓
H2O2	Hydrogen Peroxide	50%	194/90	194/90	X
H2O2	Hydrogen Peroxide	90%	118/48	118/48	X
H2SiF6	Fluosilicic Acid	any	X	X	X
H2SO3	Sulphurous Acid	10%	X	X	175/80
H2SO4	Sulphuric Acid	10% velocity < 3 m/s	100/38	100/38	X
H2SO4	Sulphuric Acid	25% velocity < 3 m/s	75/24	100/38	X
H2SO4	Sulphuric Acid	40% velocity < 3 m/s	X	100/38	X
H2SO4	Sulphuric Acid	55% velocity < 3 m/s	X	86/30	X
H3PO4	Phosphoric Acid	100%	X	X	X
H3PO4	Phosphoric Acid	98%	X	77/25	X
H3PO4	Phosphoric Acid	20%	X	77/25	77/25
H3PO4	Phosphoric Acid	5%	77/25	77/25	77/25
H8CrO5	Chromic Acid	25%	X	167/75	221/105
H8CrO5	Chromic Acid	50%	X	75/24	221/105
H8CrO5	Chromic Acid	100%	X	X	221/105
HBF4	Fluoboric Acid	30%	80/27	200/93	X
HBO3	Hydrobromic Acid	100%	X	140/60	X
HClSO3	Chlorosulphonic Acid	100%	X	185/85	X
HCL	Hydrogen Chloride gas	any	X	X	X
HCl / H2SO4	Aqua Regia	100%	X	X	X
HCL + water	Hydrochloric Acid	any	X	X	X
HClO4	Perchloric Acid	any	X	212/100	nd
HCOO4	Formic Acid (aerated)	50%	X	221/105	221/105
HCOO4	Formic Acid (non-aerated)	85%	X	221/105	X
HCOONa	Sodium Formate	50%	131/55	131/55	nd
HF	Hydrogen Fluoride gas	any	X	X	X
HF + water	Hydrofluoric Acid	any	X	X	X
Hg(CN)2	Mercuric Cyanide	10%	95/35	X	95/35
HgCl2	Mercuric Chloride	10%	X	X	266/130
HNO3	Nitric Acid	100% "red fuming"	75/24	75/24	X
HNO3	Nitric Acid	75%	75/24	75/24	140/ 60
HNO3	Nitric Acid	70%	75/24	75/24	140/ 60
HNO3	Nitric Acid	50%	100/38	75/24	140/ 60
HNO3	Nitric Acid	40%	125/52	75/24	140/ 60
HNO3	Nitric Acid	30%	130/66	75/24	140/ 60
HNO3	Nitric Acid	20%	176/80	130/66	140/ 60
HNO3 + HF Mixture	"Passivation" fluid		X	X	X
I2	Iodine Liquid	100%	X	✓	77/25
K2SO4	Potassium Sulphate	25%	212/100	X	240/115
KBr	Potassium Bromide	100%	X	X	✓
KBr	Potassium Bromide	30%	X	95/35	✓
KCl	Potassium Chloride	99%	X	✓	✓
KI	Potassium Iodide	75%	212/100	212/100	212/100
KMnO4	Potassium Permanganate	100%	X	✓	✓
KNO3	Potassium Nitrate	100%	X	212/100	240/115
KOH	Potassium Hydroxide	40%	170/77	170/77	170/77
LiCl	Lithium Chloride	50%	X	212/100	212/100
Mg(OH)2	Magnesium Hydroxide	100%	212/100	212/100	67/75
MgCl2	Magnesium Chloride	50%	X	280/138	248/120
MgSO4	Magnesium Sulphate	50%	nd	200/93	200/93
MnCl2	Manganese Chloride	45%	X	212/100	212/100
Na2CO3	Sodium Carbonate	100%	212/100	212/100	212/100

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Chem. Formula	Fluid	Concentration	Stainless Steel Max °F/°C	Hastelloy C-22 Max °F/°C	Titanium Max °F/°C
	Sodium Dichromate	100%	X	80/27	77/25
Na2S	Sodium Sulphide	50%	X	212/100	X
Na2SiO3	Sodium Silicate	100%	212/100	212/100	212/100
Na2SO4	Sodium Sulphate	20%	212/100	212/100	X
NaCl	Sodium Chloride	100%	X	212/100	212/100
NaClO3	Sodium Chlorate	100%	X	302/150	302/150
NaCN	Sodium Cyanide	50%	77/25	nd	266/130
NaHSO4	Sodium Bisulphate	20%	X	X	85/30
NaI	Sodium Iodide	65%	X	nd	212/100
NaNO2	Sodium Nitrite	50%	212/100	212/100	266/130
NaNO3	Sodium Nitrate	60%	233/112	233/112	248/120
NaNO3	Sodium Nitrate	100%	X	X	248/120
NaOCl	Sodium Hypochlorite	any	X	X	X
NaOH	Sodium Hydroxide	45%	X	0/40	0/55
NaOH	Sodium Hydroxide	75%	X	0/40	X
NaPO3	Mono Sodium Orthophosphate in water	200 millimoles	nd	nd	O86/30
NaPO4	Sodium Phosphate	15%	X	212/100	212/100
NaSO3	Sodium Sulphite	25%	212/100	212/100	212/100
NaSO3	Sodium Sulphite	50%	nd	nd	212/100
NCN	Hydrogen Cyanide	100%	88/31	88/31	88/31
NH2 SO2 OH	Sulphamic Acid	any	X	nd	X
NH3 + water	Ammonia (aqueous)	30%	158/70	158/70	X
NH3 + water	Ammonia (aqueous)	50%	86/30	302/150	X
NH3 dry	Ammonia (anhydrous)	always 100%	248/120	248/120	77/25
NH4CH3COO	Ammonium Acetate	15%	220/105	220/105	77/25
NH4CH3COO	Ammonium Acetate	55%	170/77	nd	nd
NH4Cl	Ammonium Chloride	40%	X	221/105	221/105
NH4ClO4	Ammonium Perchlorate	20%	170/77	X	285/140
NH4F	Ammonium Fluoride	25%	X	170/77	nd
NH4HCO3	Ammonium Bicarbonate	50%	X	nd	212/100
NH4NO3	Ammonium Nitrate	28%	280/137	80/27	✓
NH4OH	Ammonium Hydroxide	45%	X	X	170/77
Ni(NO3)2	Nickel Nitrate	50%	X	✓	77/25
NiCl2	Nickel Chloride	100%	X	194/90	194/90
O2	Oxygen rich gas mixture	> 35%	✓	✓	X
S	Sulphur (molten)	100%	✓	✓	✓
SnCl2	Stannic Chloride	any	X	X	X
SO2Cl2	Thionyl Chloride	100%	X	nd	104/40
ZnCL2	Zinc Chloride	75%	X	✓	212/100
ZnCL2	Zinc Chloride	100%	X	✓	X
ZnSO4	Zinc Sulphate	35%	X	212/100	212/100

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If you do not find the required fluid in the table, please contact your nearest sales office.

2. Abrasion Guidelines & information.

2.1 Introduction

For almost 10 years, the Krohne Corimass G Class and Optimass 7000 series Coriolis mass flow meters have been successfully used on abrasive fluids such as slurries (mineral and metal mining) as wella as sand & water mixtures.

In these applications, a single straight measuring tube will always offer clear advantages over other designs with tube geometries that suffer erosion and premature failure of flow dividers and bends in the abrasive fluid stream. Notwithstanding this, even a meter with a single straight tube will suffer some erosion unless simple precautions are taken.

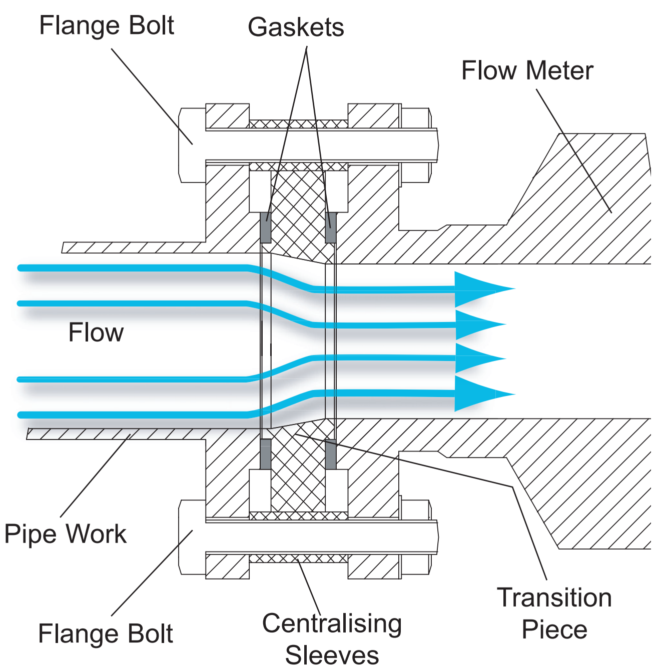
Other specific problems with abrasive fluids are typified by their tendency to separate out with the heavier particles falling to the bottom of the pipeline and the carrier fluid flowing above in a stratified flow.

The purpose of this application guidance is to highlight potential problems so that they can be mitigated against during the planning and installation of the meter.

2.2 Protecting Flanges with Transition Pieces

Since the meter measuring tube will typically have a different internal diameter than the process pipework, a “step change” will occur where the flanges are connected. This edge presents a very obvious erosion point and after a period, the weld between the flange raised face and measuring tube could fail causing a leak path.

Transition pieces are stainless steel (although Hastelloy can be used) discs that are sandwiched between the two flanges, secured by through bolts and centred by rubber sleeves around the bolts.



Typical Transition Piece Application

The taper on the internal diameter of the disc is manufactured to correct the difference between the meter and process pipe, thus providing a gradual transition for the abrasive fluid into the meter.

They must be considered as “sacrificial wear parts”, and should be removed periodically for inspection of the internal taper dimension and replacement if necessary.

Prices for these parts are available from Krohne.

2.3 Managing fluid velocity

There are two considerations here based on the fluid flow rate and density:

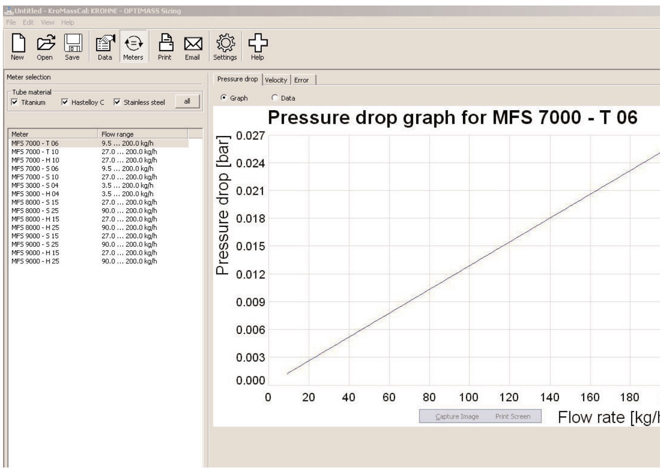
Maximum velocity

To prevent excessive erosion this should be never be more that 4 m/sec (12 ft/sec).

Minimum velocity

So the particles and carrier are homogeneous mixed this should be at least 1 m/s (3 ft/sec).

The Optimass sizing software will assist you in calculating these limits. For abrasive slurries always size according to these velocity limits, and not lowest measuring error which tends towards a smaller meter size and hence a higher velocity.



Optimass Sizing Software Screen Shot

2.4 Titanium as the standard material

Titanium should always be used as the standard material for measuring tubes. This is because size-for-size, a titanium measuring tube has a greater wall thickness than either stainless steel or Hastelloy. Simply put, this tube has more material to erode before failure, so extending the working lifetime of the meter.

Meter size	Material	Outside dia.	Wall Thickness	Internal dia.
40	T	38.10 ± 0.13	0.91 ± 0.09	36.28
	H	38.10 ± 0.1	0.71 ± 0.07	36.68
	S	38.10 ± 0.13	0.71 ± 0.07	36.68
50	T	50.80 ± 0.15	1.24 ± 0.01	48.32
	H	50.80 ± 0.15	1.00 ± 0.01	48.80
	S	48.26 ± 0.13	1.00 ± 0.01	46.26
80	T	73.00 ± 0.254	2.10 ± 0.02	68.80
	H	73.03 ± 0.254	1.04 ± 0.01	70.95
	S	73.00 ± 0.13	1.40 ± 0.01	70.20

All dimensions in mm

It should be noted that the exception to this is when stainless steel or Hastelloy are required for fluid compatibility (corrosion resistance).

2.5 Conditioning of the fluid flow profile (as it enters the meter)

Firstly remember that a Coriolis mass flow meter directly measures mass flow and density of the fluid. It does not measure velocity, so from a measuring principle standpoint there is no need for flow profile conditioning.

However with an abrasive fluid, there is the requirement to condition the flow so that the abrasive particles enter the meter parallel to the tube wall. This minimises the probability that any given abrasive particle will strike the tube wall and remove (erode) the tube material.

If the flow is “tumbling” or “swirling” as it enters the meter, there is a risk that erosion will occur at the specific point where the particles preferentially impact onto the tube wall, so causing premature failure. These problems are always associated with using a pipework bend or elbow very close to the meter inlet.

Therefore we recommend a straight length of inlet process pipe equal to at least 10, or preferably 20 x pipe internal diameters.

2.6 Installation of the flow meter

In order to keep the heavy abrasive particles evenly dispersed in the carrier fluid as a homogenous mixture that is required for correct meter operation, we would recommend a vertical meter installation. Otherwise there is the tendency, especially at lower flow velocities, for the fluid to separate out and become stratified.

Further, a flow direction vertically upwards is normally preferred to ensure that meter is always full of liquid, and does not “siphon” empty.

2.7 Inclusion of air or gas in the fluid

High density fluids such as mineral slurries typically require a high drive energy due to their tendency towards being inhomogeneously mixed.

Entrained air or gas will cause a further increase in the required energy to drive (vibrate) the tube system. If the inclusion is too great then the meter will not operate correctly. This problem is particularly pronounced on larger sized meters (T 50 & T 80), which typically are used for abrasive fluid applications in order to reduce the fluid velocity to acceptable levels.

So we would recommend that all efforts be made to prevent the inclusion of air or gas in the fluid as part of the process design, since from our experience once entrained in the fluid it is virtually impossible to remove prior to the metering point

2.8 Consider installing the meter in a by-pass

If the application is for density measurement only, then often a more cost-effective solution is to install a smaller sized meter (although size 25 is smallest recommended) in a by-pass line off the main pipeline.

2.9 Conclusions

We are confident that if the seven steps above are followed correctly, then the probability of application related problems are greatly reduced and the operating lifetime of the meter greatly increased.

3. Environmental Protection

The materials exposed to the environment as standard are:

<table>
<tr><td>MFM x050 Ex
MFM x051 Ex
MFM xo50 Ex
MFM x051 Ex
MFC 050 Ex
MFC 051 Ex</td><td>● 304L Stainless Steel for the sensor body with optional 316LStainless Steel for offshore applications.
● Electronics housing is die cast aluminium, powder coated.
● The aluminium has a low copper content (see specification table).</td></tr>
<tr><td colspan="2">All above housings will be powder coated in silver and All covers (screw-on type) will be painted in blue RAL 5005</td></tr>
<tr><td>MFC 300C
MFC 300F
MFC 300W</td><td>● 304L Stainless Steel for the sensor body with optional 316LStainless Steel for offshore applications.
● Electronics housing in Stainless Steel 316L.</td></tr>
</table>

Alloy type	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Pb
ADC 1 AlSi12Fe	11.0...13.0	1.3	1.0	0.3	0.3	-	0.5	0.5	-	-
ADC 3 AlSi9Mg0,5Fe	9.0...10.0	3	1.0	0.3	0.4...0.6	-	0.5	0.5	-	-
AlSi10Mg [Fe]	9.0...11.0	1.0	0.1	0.55	0.20...0.50	-	0.15	0.15	0.20	0.15
ALZn10Si8Mg	8.5...9.3	0.4	0.02	0.4	0.3...0.5	-	-	9.0...10.0	0.1	-

	ADC 1 AlSi12Fe	ADC 3 AlSi9Mg0,5Fe	AlSi10Mg [Fe]	ALZn10Si8Mg	SS 316L
MFC050			✓	✓	
MFC 051			✓	✓	
MFC050 Ex			✓	✓	
MFC051 Ex			✓	✓	
MFC 300	✓	✓			✓
MFC 300 Ex	✓	✓			✓

For aggressive coastal or off shore based environments, KROHNE can provide an optional salt water resistant coating. (see specifications below)

This is not in the standard price list. Please contact Product Management in Wellingborough, UK.

3.1 Housing Specifications

The MFC 050 and MFC 051 Range of Converters are available with KD(W) housings

KD Housing

This housing is prepared for long term applications in coastal and offshore environments.

KDW

The “W” suffix denotes the same specification as the standard KD housing but with the following additions:

- Ingress protection IP 67
- Special surface finish to:
  - Aluminium housing
  - Chromatized with (Henkel) Alodine 1200 S
  - Coated with Brillux 5910 Polyester powder
  - All outside threads have stainless steel inlays
- Blue (RAL 5005) housing colour
- 1000 h spray test with sodium chloride solutions to:
  - DIN 50021:1988
  - ISO 1456:1974
  - ASTM B 117:1973

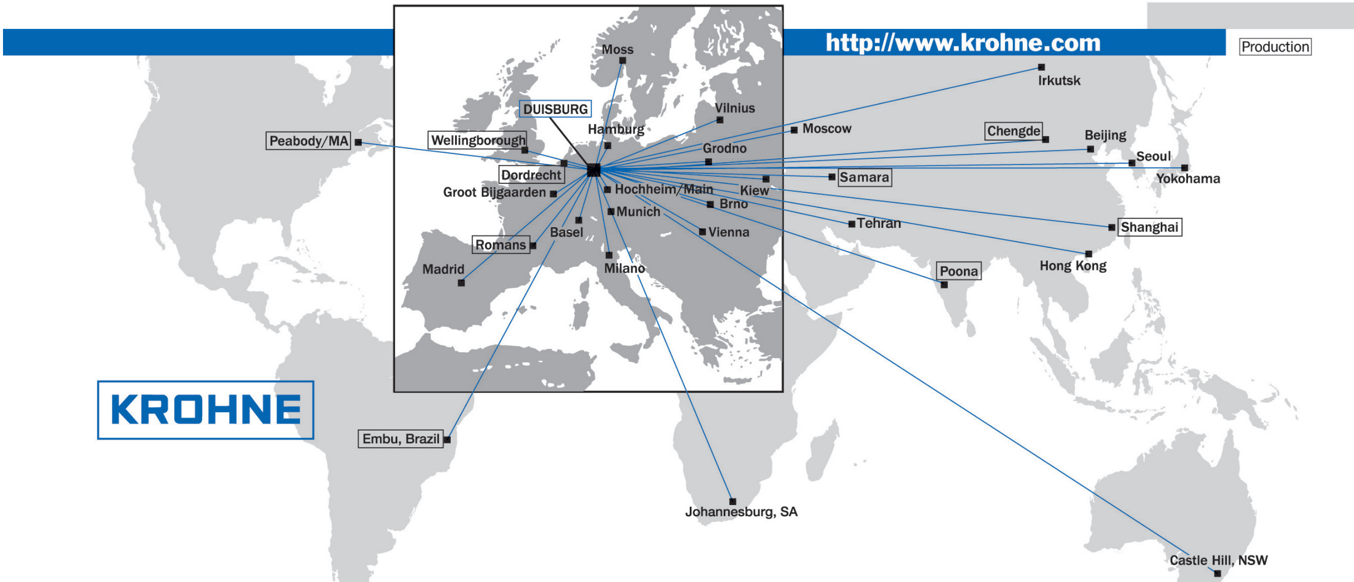
The MFC 300 Range of Converters are available with a SS 316L Housing

Sources of information:

ATI Wah Chung, Albany Oregon, *Technical Data Sheet: TitAly-052*

Haynes International, Kokomo, Indiana, USA

Sandvick AB, SE-811 81 Sandviken, Sweden



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