

# Protection tubes and thermowells

## Thermowell Materials Selection Guide

Application	Protecting Tube Material
<b>Heat Treating</b>	
Annealing	
Up to 704°C	Black steel
Over 704°C	Inconel 600, Type 446 SS
Carburising hardening	
Up to 816°C	Black steel, Type 446 SS
816 to 1093°C)	Inconel 600, Type 446 SS
Over 1093°C	Ceramic*
Nitriding salt baths	Type 446 SS
Cyanide	Nickel (CP)
Neutral	Type 446 SS
High speed	Ceramic*
<b>Iron and steel</b>	
Blast furnaces	
Downcomer	Silicon carbide, LT-1
Stove dome	Inconel 600
Hot blast main	Inconel 600
Stove trunk	Black steel
Stove outlet flue	
Open hearth	
Flues and stack	Inconel 600, LT-1
Checkers	Inconel 600, Type 446 SS
Waste heat boiler	
Billet heating slab heating and butt welding	
Up to 1093°C	Silicon carbide, ceramic*
Over 1093°C	
Bright annealing batch	
Top work temperature	Type 446 SS
Bottom work temperature	Inconel 600, ceramic*
Continuous furnace section	Silicon carbide, ceramic*
Forging	
Soaking pits	
Up to 1093°C	Silicon carbide, ceramic*
Over 1093°C	
<b>Nonferrous metals</b>	
Aluminum – Melting	
– Heat Treating	Hexoloy®, Syalon®, 1100, Cast, Iron
Black steel	
Brass or bronze	Not required (use dip-type thermocouple)
Lead	Type 446 SS, black steel
Magnesium	Black steel, cast iron
Tin	Extra heavy carbon steel
Zinc	Extra heavy carbon steel
Pickling tanks	Chemical lead

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<b>Cement</b>	
Exit flues	Inconel 600, Type 446 SS
Kilns, heating zone	Inconel 600
<b>Ceramic</b>	
Kiln	Ceramic, and silicon carbide
Dryers	Silicon carbide, black steel
Vitreous enamelling	Inconel 600, Type 446 SS
<b>Paper</b>	
Digesters	Type 316 SS, Type 446S
<b>Glass</b>	
Fore hearths and feeders	Platinum thimble
Lehrs	Black steel
Tanks – Roof and wall	Ceramic
– Flues and checkers	Inconel 600, Type 446 SS
<b>Petroleum</b>	
De-waxing	Types 304, 310, 316, 321, 347 SS, carbon steel
Towers	Types 304, 310, 316, 321, 347 SS, carbon steel
Transfer lines	Types 304, 310, 316, 321, 347 SS, carbon steel
Factioning column	Types 304, 310, 316, 321, 347 SS, carbon steel
Bridgewall	Types 304, 310, 316, 321, 347 SS, carbon steel
<b>Power</b>	
Coal-air mixtures	304 SS
Flue gases	Black steel, Type 446 SS
Pre-heaters	Black steel, Type 446 SS
Steel lines	Types 347 or 316 SS
Water lines	Low carbon steels
Boiler tubes	Types 304, 309, or 310 SS
<b>Gas producers</b>	
Producer gas	Type 446 SS
<b>Water gas</b>	
Carburetor	Inconel 600, Type 446 SS
Superheater	Inconel 600, Type 446 SS
Tar stills	Low carbon steels
<b>Incinerators</b>	
Up to 1093°C	Inconel 600, Type 446 SS
Over 1093°C	Ceramic (primary) Hexoloy (secondary)*
Food	
Baking Ovens	Slack Steel
Charretort, Sugar	Slack Steel
Vegetables and fruit	Type 304 SS

Application	Protecting Tube Material
<b>Chemical</b>	
Acetic acid	
10 to 50%, 21°C	Type 304, Hastelloy C, Monel
50%, 100°C	Type 316, Hastelloy C, Monel
99% 21 to 100°C	Type 430, Hastelloy C, Monel
Alcohol, ethyl, methyl	
21 to 100°C	Type 304
Ammonia	Types 304, 316 SS
All concentration 21°C	
Ammonium chloride	
All concentration 100°C	Types 316 SS, Monel
Ammonium nitrate	
All concentration 21 to 100°C	Type 316 SS
Ammonium sulphate,	
10% to saturated 100°C	Type 316 SS
Barium chloride, all concentration, 21°C	Monel®, Hastelloy C®
Barium hydroxide, all concentration, 21°C	Low carbon steels
Barium sulphite	Nichrome® Hastelloy C
Brines	Monel
Bromine	Tantalum, Monel
Butadiene	Type 304 SS
Butane	Type 304 SS
Butylacetate	Monel
Butyl alcohol	Type 304 SS
Calcium chlorate, dilute 21 to 66°C	Type 304 SS
Calcium hydroxide	
10 to 20%, 100°C	Type 304 SS, Hastelloy C
50%, 100°C	Type 316 SS, Hastelloy C
Carbolic acid, all, 100°C	Type 316 SS
Carbon dioxide, wet or dry	2017-T4 aluminum, Monel, nickel
Chlorine gas	
Dry, 21°C	Type 316 SS, Monel
Moist, -7 to 100°C	Hastelloy C
Chromic acid, 10 to 50% 100°C	Type 316 SS, Hastelloy C (all concentrations)
Citric acid	
15%, 21°C	Type 304 SS, Hastelloy C (all concentrations)
15%, 100°C	Type 316 SS, Hastelloy C (all concentrations)
Concentrated, 100°C	Type 316 SS, Hastelloy C (all concentrations)
Copper nitrate	Types 304 SS, 316 SS
Copper sulphate	Types 304 SS, 316 SS
Cresols	Type 304 SS
Cyanogen gas	Type 304 SS
Dow therm®	Low carbon steels
Ether	Type 304 SS
Ethyl acetate	Monel, Type 304 SS
Ethyl chloride, 21°C	Type 304 SS, low carbon steel
Ethyl sulphate, 21°C	Monel
Ferric chloride, 5%, 21°C to boiling	Tantalum, Hastelloy C
Ferric sulphate, 5%, 21°C	Type 304 SS
Ferrous sulphate, dilute, 21°C	Type 304 SS

Application	Protecting Tube Material
Formaldehyde	Types 304 SS, 316 SS
Formic acid, 5%, 21 to 66°C	Type 316 SS
Freon	Monel
Gallic acid, 5%, 21 to 66°C	Monel
Gasoline, 21°C	Type 304 SS, low carbon steel
Glucose, 21°C	Type 304 SS
Glycerine, 21°C	Type 304 SS
Glycerol	Type 304 SS
Hydrobromic acid, 98%, 100°C	Hastelloy B®
Hydrochloric acid	
1%, 5% 21°C	Hastelloy C
1%, 5% 100°C	Hastelloy B
25%, 21 to 100°C	Hastelloy B
Hydrofluoric acid, 60%, 100°C	Hastelloy C, Monel
Hydrogen peroxide, 21 to 100°C	Types 316 SS, 304 SS
Hydrogen sulphide, wet and dry	Type 316 SS
Iodine, 21°C	Tantalum
Lactic acid	
5%, 21°C	Type 304 SS, 316 SS
5%, 66°C	Type 316 SS
10%, 100°C	Tantalum
Magnesium chloride	
5%, 21°C	Nickel, Monel,
5%, 100°C	Nickel
Magnesium sulphate, hot and cold	Monel
Muriatic acid, 21°C	Tantalum
Naptha, 21°C	Type 304 SS
Natural gas, 21°C	Types 304 SS, 316 SS, 317 SS
Nickel chloride, 21°C	Type 304 SS
Nickel sulphate, hot and cold	Type 304 SS
Nitric acid	
5%, 21°C	Types 304 SS, 316 SS
20% 21°C	Types 304 SS, 316 SS
50% 21°C	Types 304 SS, 316 SS
50% 100°C	Types 304 SS, 316 SS
65% 100°C	Type 316 SS
Concentrated, 21°C	Types 304 SS, 316 SS
Concentrated, 100°C	Tantalum
Nitrobenzene, 21°C	Type 304 SS
Oleic acid, 21°C	Type 316 SS
Oleum, 21°C	Type 316 SS
Oxalic acid	
5% hot and cold	Type 304 SS
10%, 100°C	Monel
Oxygen 21°C	Steel
Palmitic acid	Type 316 SS
Pentane	Type 340 SS
Phenol	

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Phosphoric acid	
1%, 5%, 21°C	Type 304 SS,
10%, 21°C	Type 316 SS
10%, 100°C	Hastelloy C
30%, 21 to 100°C	Hastelloy B
85%, 21 to 100°C	Hastelloy B
Picric acid, 21°C	Type 304 SS
Potassium bromide, 21°C	Type 316 SS
Potassium carbonate, 1%, 21°C	Types 304 SS, 316 SS
Potassium chlorate, 21°C	Type 304 SS
Potassium hydroxide	
5% 21°C	Type 304 SS
25% 100°C	Type 304 SS
60% 100°C	Type 316 SS
Potassium nitrate	
5%, 21°C	Type 304 SS
5%, 100°C	Type 304 SS
Potassium permanganate, 5%, 21°C	Type 304 SS
Potassium sulphate, 5%, 21°C	Types 304 SS, 316 SS
Potassium sulphide, 21°C	Types 304 SS, 316 SS
Propane	Type 304 SS, low carbon steel
Pyrogallic acid	Type 304 SS
Quinine bisulphate, dry	Type 316 SS
Quinine sulphate, dry	Type 304 SS
Seawater	Monel, Hastelloy C
Salicylic acid	Nickel
Sodium bicarbonate	
All concentration, 21°C	Type 304 SS
5%, 66°C	Types 304 SS, 316 SS
Sodium carbonate, 5%, 21 to 66°C	Types 304 SS, 316 SS
Sodium chloride	
5%, 21 to 66°C	Type 316 SS
Saturated, 21 to 100°C	Type 316 SS, Monel
Sodium fluoride, 5%, 21°C	Monel
Sodium hydroxide	Types 304 S, 316 SS, Hastelloy C
Sodium hypochlorite, 5% still	Type 316 SS, Hastelloy C
Sodium nitrate, fused	Type 316 SS
Sodium peroxide	Type 304 SS
Sodium sulphate, 21°C	Types 304 SS, 316 SS
Sodium sulphide, 21°C	Type 316 SS

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Sodium sulphite, 30%, 66°C	Type 304 SS
Sulphur dioxide	
Moist gas, 21°C	Type 316 SS
Gas, 302°C	Types 304 SS, 316 SS
Sulphur	
Dry molten	Type 304 SS
Wet	Type 316 SS
Sulphuric acid	
5%, 21 to 100°C)	Hastelloy B, 316 SS
10%, 21 to 100°C	Hastelloy B
50%, 21 to 100°C	Hastelloy B
90%, 21°C	Hastelloy B
90% 100°C	Hastelloy D
Tannic acid 21°C	Type 304 SS, Hastelloy B
Tartaric acid	
21°C	Type 304 SS
150°C	Type 316 SS
Toluene	2017-T4 aluminium, low carbon steel
Turpentine	Types 304 SS 316 SS
Whiskey and wine	Type 304 SS, nickel
Xylene	Copper
Zinc chloride	Monel
Zinc sulphate	
5% 21°C	Types 304 SS, 316 SS
Saturated 21°C	Types 304 SS, 316 SS
25% 100°C	Types 304 SS, 316 SS

\* Due to the susceptibility to cracking, sudden thermal shocks should be avoided. Inconel ® is a registered trademark of the International Nickel Co. Hexoloy ® is a registered trademark of Carborundum Company. Syalon ® is a registered trademark of Cookson. Monel ® is a registered trademark of the International Nickel Co. Hastelloy C ® is a registered trademark of the Cabot Corp. Nicrome ® is a registered trademark of Driver-Harris Co. Dow therm ® is a registered trademark of Dow Chemical Corp. Pressure - Temperature rating - lbs. per square inch