



Protection Tube Materials

Material	Approximate Composition	Recommended Max. Temp.	NBS Code Number	Application	Remarks
Brass	55%-85% Cu Balance Zn Trace Others	570°F (300°C)	65	Marine Conditions	Good corrosion resistance.
Cast Iron	Fe	1600°F (870°C)	81	Molten Aluminum Die Castings	Needs daily application of white wash solution.
Wrought Iron	0.48% Mn 0.98% Cu Balance Fe	1250°F (675°C)	80	Food Ovens Asphalt Mixers Preheaters Glass Lehrs, Dryers	Non-corrosive atmospheres. Low temperature molten metals.
Carbon Steel	Sae 1018 or Sae 1020	1000°F (540°C)	85	Tinning Galvanizing Petroleum	Non-corrosive gases and liquids. Scales quickly at higher temperatures.
304 Stainless Steel	19% Cr 9% Ni 2% Mn 1% Si Balance Fe	1650°F (900°C)	84	Petroleum Products Mild Acids Steam Lines Food Processing	Good resistance to corrosion. Embrittles in the 900 to 1475°F range.
309 Stainless Steel	23% Cr 13% Ni 2% Mn 1% Si Balance Fe	2000°F (1090°C)	79	Sulfur-Dioxide Mild Acids	High resistance to scaling up to 1900°F. Strong, tough material.
310 Stainless Steel	25% Cr 20% Ni 2% Mn 1.5% Si Balance Fe	2100°F (1150°C)	76	Chemical Applications Petroleum Products Kiln	High mechanical and creep strength at elevated temperatures. Very good corrosion resistance.
316 Stainless Steel	17% Cr 12% Ni 2% Mn 1% Si 2% Mo, Balance Fe	1700°F (930°C)	83	Chemical Applications Food Products Steam Lines	Higher corrosion resistance than 304. Resists pitting in sulfuric and phosphoric acids.
321 Stainless Steel	18% Cr 10% Ni 2% Mn 1% Si Ti Stabilized, Balance Fe	1700°F (930°C)	72	Petroleum Products Steam Lines	Stability against carbide precipitation. Resists inter-granular corrosion.
330 Stainless Steel	18% Cr 35% Ni 2% Mn 1% Si Balance Fe	2100°F (1150°C)	88	Heat Treating Furnaces Kilns	Good in oxidizing or reducing atmospheres.
347 Stainless Steel	18% Cr 10% Ni 2% Mn 1% Si Cb + Ta Stabilized Balance Fe	1700°F (930°C)	77	Steam Lines Petroleum Products Boiler Tubes	Used for severe stress and corrosion resistance applications.
Alloy-20	34% Ni 20% Cr 2% Mo Cb + Ta Stabilized Balance Fe	2000°F (1090°C)	66	Chemical Applications	Corrosion resistant properties generally superior to 300 series stainless steels. Especially useful against hot sulfuric acid.
Deterheat® (446 Stainless Steel)	25% Cr 1.5% Mn 1% Si Balance Fe	2100°F (1150°C)	82	Neutral Salt Baths Some Molten Metals Furnaces	Highly resistant to sulfur attack. General-purpose alloy.
Inconel® 600	77% Ni 15% Cr 7% Fe	2200°F (1215°C)	86	Salt Baths Furnaces Kilns	Generally used for high temperature. Excellent resistance to oxidation. Should not be used where sulfur is present.
Inconel® 601	60% Ni 23% Cr 14% Fe	2100°F (1150°C)	71	Carburizing Nitriding Heat Treating	Resists scaling to 2100°F. Good resistance to corrosion at high temperature.

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Inconel® 800	34% Ni 22% Cr Balance Fe	2000°F (1100°C)	89	Furnaces Cyanide Baths	Superior to 600 in resistance to green rot. Retains strength at elevated temperature.
Monel®	66% Ni 31% Cu 1% Fe	1000°F (540°C)	75	Marine Conditions Chemical Applications Food Processing	Combines high strength and ductility. Withstands many corrosives.
Nickel	99%+ Ni	2000°F (1100°C)	74	Chemical Applications Food Products Autoclaves	Do not use in the presence of sulfur or reducing atmosphere.
Kanthal®	22% Cr 5% Al Balance Fe	2200°F (1200°C)	87	Molten Copper Furnace Tubes	Has good resistance to sulphides.
HR-160®	37% Ni 29% Co 28% Cr 2.5% Si, 2% Fe	2200°F (1200°C)	60	Boilers & furnaces. Municipal, industrial, and hazardous waste incinerators	Excellent resistance to sulfidation and chloride attack.
Hastelloy® B-2	69% Ni 28% Mo 2% Fe	1000°F (540°C)	78B	Chemical Applications	A nickel-molybdenum alloy with outstanding resistance to hydrochloric and sulfuric acids.
Hastelloy® C-276	57% Ni 16% Mo 16% Cr 5.5% Fe	1000°F (540°C)	78C	Marine Conditions Chemical Applications	Has excellent resistance to a wide variety of chemical process environments.
Hastelloy® X	48% Ni 22% Cr 18.5% Fe 9% Mo	2350°F (1290°C)	78X	Furnace Tubes Chemical Field Nuclear Reactors	Develops an oxide scale. Unusual resistance to oxidizing, reducing and neutral atmospheres.
Titanium	Ti	1000°F (540°C)	67	Power generation Chemical processing Desalination plants	Excellent corrosion resistance, especially in the presence oxidizing acids and chlorides.
Refractory Metals					
Molybdenum	99% Mo Desilicized	3100°F (1700°C)	95	Special Exotic Appl. Inert or Vacuum Atmosphere Only	Sensitive to oxidation above 925°F.
Tantalum	99% Ta Chromalized	4200°F (2300°C)	96	Same as Moly	Extremely sensitive to traces of oxygen above 500°F.
Metal-Ceramic LT-1 (Cermet)	77% Cr 23% Al Oxide	2500°F (1370°C)	97	High Temperature Applications	Good resistance to mechanical and thermal shock.
Ceramic Tube Materials				Remarks	
Quartz	Fused Silicon Dioxide	2200°F (1200°C)	94	Can be used in molten silver and gold. Excellent resistance to thermal shock.	
Silica	Silica	2900°F (1600°C)	91	Usually used for glass tank applications.	
Mullite (Porcelain)	63% Al ₂ O ₃ 4% SiO ₂ Other Trace	3100°F (1700°C)	90	Good thermal shock resistance due to low rate of thermal expansion. Some possible contamination of platinum above 2400°F due to silica.	
Alumina	99% + Al ₂ O ₃	3400°F (1870°C)	99	Impervious to gases at high temperature - Fair resistance to thermal and mechanical shock.	
Carbofrax	90% Silicon-Nitrate 9% Si-Dioxide	3000°F (1650°C)	92	Secondary protection for mullite or alumina tubes. Can take flame impingement. Fair thermal shock resistance.	
Re-crystallized Silicon Carbide	Re-crystallized SiC	3100°F (1700°C)	68	Secondary protection for mullite or alumina tubes.	
Refrax	Silicon-Nitrite bonded Si-Carbide	3150°F (1730°C)	93	Not wetted by molten aluminum. Better resistance to mechanical and thermal shock.	
Beryllium Oxide	99% BeO	4200°F (2300°C)	98	High thermal conductivity. Poor resistance to mechanical shock. Possible reaction with other oxides at high temperature. Should be used with caution as fumes and powders are toxic.	



Protection Tube Materials

Material Selection Guide

Industry Type	Process Application	Suggested Protection Tube Material
Heat Treating	Annealing to 1300°F	304SS Inconel® 601, 446SS
	Annealing over 1300°F	Inconel® 601, 446SS
	Carburizing	Inconel® 601
	Hardening to 1300°F	304SS
	Hardening to 2000°F	Inconel® 601, 446SS
	Hardening over 2000°F	Ceramic
	Lead Hardening	446SS
	Nitriding	Inconel® 601, 446SS
	Salt Bath (Cyanide)	Inconel® 601, 446SS
	Salt Bath (Neutral)	Inconel® 601, 446SS
	Salt Bath (High Speed)	Inc. 600, Infrared
	Quench Oil	Carbon Steel, 304SS
Iron & Steel	Billet & Slab heating to 2000°F	Inconel® 601, 446SS
	Billet & Slab heating over 2000°F	Ceramic, Silicon Carbide
	Blast Furnace	
	Downcomer	Inconel® 601, 446SS
	Stove Dome	Silicon Carbide
	Hot Blast - Main	Inconel® 601
	Stove Trunk	Inconel® 601
	Stove Outlet Flue	Carbon Steel, 304SS
	Bright Annealing (Batch)	Inconel® 601
	Bright Annealing (Cont.)	Inconel® 601, Ceramic
	Forging Furnaces	Ceramic, Silicon Carbide
	Galvanizing	Carbon Steel, Sil. Carbide
	Open Hearths (Flue-stack)	Inconel® 601, LT-1®
	Open Hearths (Checkers)	LT-1®
	Palm Oil	304 SS
	Pickling Tanks	Lead, Sil. Carbide, Teflon®
	Soaking Pits up to 2000°F	Inconel® 601, Sil. Carb.
	Soaking Pits over 2000°F	Ceramic, Silicon Carbide
	Tinning	Carbon Steel, 446SS
	Waste Heat Boilers	Inconel® 601, 446SS

The material recommendations for various service conditions listed are intended as a guide. No guarantee of material suitability can be made since other factors which effect material life may be present.

Industry Type	Process Application	Suggested Protection Tube Material
Non-Ferrous Metals	Aluminum (Molten Die-casting)	Cerite-II & III, Sil. Carbide Vesuvius®, Cast Iron (whitewashed)
	Aluminum (Heat Treating)	Carbon Steel, 304SS
	Aluminum (Annealing)	None or Carbon Steel
	Aluminum (Billet Heating)	Inconel® 601, 446SS
	Babbitt	446SS
	Brass, Bronze (Molten)	LT-1®, Sil. Carb., Hexoloy SA®
	Copper	LT-1®, Sil. Carb., Hexoloy SA®
	Lead	446 SS, Silicon Carbide
	Tin	CS, Silicon Carbide
	Smelting & Ore, Zinc	Inconel® 601, Sil. Carbide
	Exit Flues	Inconel® 601, 446SS
	Cement	Kilns
Ceramics	Kilns	Ceramic, Silicon Carbide
	Dryers	Ceramic, Silicon Carbide
	Enameling	Silicon Carbide
Chemical	General Applications	304SS, 316SS
	Incineration	LT-1®, Hexoloy SA®
	Reactors	LT-1®, Hexoloy SA®
Food/ Meat	Baking Ovens	304SS, 316SS
	Char. Kilns, Sugar	446SS
	Cooking-Fruits, Vegetables	304SS, 316SS
Gas	Meat, Smokehouses	304SS, 316SS
	Producer Gas	Inconel® 601, 446SS
	Water Gas (Carburetor)	Inconel® 601, 446SS
Glass	Water Gas (Superheater)	Inconel® 601, 446SS
	Tar Still	Carbon Steel, 304SS
	Forehearth and Feeders	Infrared, Platinum
Incineration	Tanks	Ceramic, Silicon Carbide
	Flues and Checkers	Inconel® 601, 446SS
	Lehrs	304 SS
Paper	up to 2000°F	Inconel® 601, 446SS
	over 2000°F	LT-1®, Sil. Carbide, Hexoloy SA®
	Digesters	304SS, 316SS
Petroleum	Bridgewall	Inconel® 601, 446SS
	Dewaxing	304SS, 316SS
	Fractionating Column	304SS, 316SS
	Towers	304SS, 316SS
	Transfer lines	304SS, 316SS
	Sulfur Burners	LT-1®
Power	Boiler Tubes	310SS, 446SS, Inconel® 601
	Flue Gas	446SS
	Preheaters	Carbon Steel, 446SS
	Steam Lines	347SS, 316SS
	Water Lines	304SS
Smelting & Refining	Roasting Sulfur Ovens	Silicon Carbide
	Zinc Retort Preheaters	Ceramic
	Zinc Smelter	Silicon Carbide