Technical Information:
Common Tubing, Sheath, Protection Tube And Well Materials

Performance Characteristics

CONVECTRONICS provides a variety of common tubing, MgO sheath, protection tube, and drilled well materials to protect temperature sensing elements from the environmental conditions typically found in industrial process applications. The following tables are intended as guidelines to aid in the selection of the proper materials for sensors used in different environments. Consult the factory for the availability of other protective materials for specialty applications. **NOTE:** All chemical compositions and temperature ratings are nominal and are stated as received from suppliers.

Metals

Material/Composition	Typical Areas of Use				Application Guideline Information
	Tubing	MgO Sheath	Prot. Tubes	Drilled Wells	
Aluminum	X				Up to 1000°F (538°C) continuous. Good thermal conductivity and mechanical strength. Oxidation can arise when not anodized or protected.
Brass	X			X	Up to 1000°F (538°C) continuous. Good thermal conductivity and mechanical strength.
Carbon Steel-C1018 0.17% Carbon, 0.75% Manganese, 0.035 Phosphorous max., 0.045 Sulfur max., balance Iron	X	X Limited Avail.	X	X	Up to 1000°F (538°C) in non-oxidizing environments. Main areas of usage are galvanizing pots, tinning pots, molten Babbit metal, molten Magnesium, molten Zinc, Petroleum refinery applications such as dewaxing and thermal cracking.
Carpenter 20 34% Nickel, 20% Chromium, 3.5% Copper, 2.5% Molybdenum, 1.0% Silicon max., 2.0% Manganese max., .06% Carbon max., Columbian & Tantalum; 8 x C min/1 max		X Limited Avail.	X	X	Superior resistance to stress-corrosion cracking in boiling 20-40% Sulfuric Acid. Also used in high octane gas, solvents, explosives, heavy chemicals and agrichemicals.
Cast Iron			X		Up to 1300°F (704°C) in oxidizing conditions. Main area of usage is in molten non-ferrous metals. Daily whiting is recommended. Can be used to 1600°F (817°C) under reducing conditions.
Copper	X	X Limited Avail.		X	Up to 500°F (260°C) continuous. Excellent thermal conductivity. Poor mechanical strength.
HR - 160 37% Ni, 2% Fe, 29% Co, 28% Cr, 2.75% Si, 5% Mn, .05% C			X		A premier alloy that provides excellent resistance to Sulfur, Vanadium, Chlorines, Chlorides and other Salt deposits up to 2200°F (1204°C). A superior protection tube material for use in aggressive waste incineration process.
Alloy 214 76.5% Ni, 3% Fe, 16% Cr, 4.5% Al, .01% Y			X		Excellent oxidation, carburization and chlorination resistance up to 2200°F (1204°C). Finds use in carburizing furnaces, high Sulfur content environments and in waste incineration process.
Alloy 556 32% Fe, 18% Co, 22% Cr, 3% Mo, 2.5% W, 20% Ni, other trace materials.			X		Good high temperature resistance to sulfidizing, carburizing and Chlorine bearing environments up to 2100°F (1150°C). Main usage is in waste incineration, molten Chloride Salts and in molten Zinc and galvanizing.
Hastelloy B 67% Nickel, 1.0% Cobalt, 1.0% Chromium, 28% Moybdenum, 2.0% Iron, .01% Silicon, 1.0% Manganese, .02% Carbon	X	X Limited Avail.	X	X	Up to 1500°F (815°C) in inert or vacuum atmosphere. 1000°F (538°C) in air. Has excellent resistance to pitting, and stress-corrosion cracking. Suitable for most chemical processes. Application excellent in Hydrochloric Acid.
Hastelloy C 62.5% Nickel, 2.0% Cobalt, 16.0% Chromium, 15.5% Molybdenum, 3.0% Iron, 0.8% Silicon, 1.0% Manganese, .015% Carbon	X	X Limited Avail.	X	X	Up to 1900°F (1038°C) in oxidizing atmosphere. Exceptional resistance to a wide variety of chemical environments. Withstands wet Chlorine Gas, Hypochloride and Chlorine Dioxide.
Inconel 600 76% Nickel, 16% Chromium, 8% Iron	X	X	X	X	Up to 2100°F (1149°C) under oxidizing conditions. Reducing conditions reduce maximum temperature to 1900°F (1038°C). Must not be placed in Sulfurous atmospheres above 1000°F (538°C). Main areas of application for thermocouple protection are carburizing, annealing and hardening funaces, Cyanide salt baths, blast furnace downcomers, open hearth flue stacks, steel soaking pits, waste heat boilers, ore roasters, cement exit flues, incinerators and glass tank flues.

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	Tubing	MgO Sheath	Prot. Tubes	Drilled Wells	
Inconel 601 61% Nickel, 23% Chromium, 14% Iron, 1.35% Aluminum		X	X	X	Similar applications to Inconel 600 with superior resistance to Sulfur and has a high temperature oxidation resistance to 2300°F (1260°C).
Inconel 800 32.5% Nickel, .15% Carbon, .75% Manganese, 46% Iron, 25% Silicon, .13% Copper	X	X Limited Avail.	X	X	Strong resistance to oxidation and carburization at high temperatures. Resists Sulfur attack, internal oxidation, scaling in a wide variety of atmospheres.
Molybdenum 99.95% Molybdenum, .03% Tungsten	X	X			Up to 3500°F (1926°C) in inert atmospheres, to 3400°F (1871°C) in vacuum at 10-4 torr. Has poor mechanical shock resistance after heated to 1900°F (1038°C). Oxidizes in air above 800°F.
Monel 66.5% Nickel, .15% Carbon, 1.0% Manganese, 1.25% Iron, 25% Silicon, 31.5% Copper	X	X	X	X	Up to 1000°F (538°C) in Sulfur-free atmospheres. Excellent resistance to corrosion. Used in chemical processing equipment, food processing.
Nickel 200 99.5% Nickel, .08% Carbon, .18% Manganese, .2% Iron, .18% Silicon, .13% Copper		X Limited Avail.	X	X	Up to 1650°F (899°C) in Sulfur-free atmospheres. Good corrosion resistance. Used in contact with reducing acids, foods, chemicals, caustics, Rayon and plastics.
Nicrobell® 15% Chromium, 1.5% Silicon, .2% Magnesium, 80% Nickel, 3% Niobium, .04% Cerium		X	X		Up to 2300°F (1260°C). Superior oxidation resistance. Primary use is as a sheath material for mineral insulated type N and K thermocouples, in applications where thermal EMF instability occurs at high temperatures because of element contamination caused by the migration of contaminants from other metal sheath materials.
Platinum	X	X			Up to 2500°F (1374°C) continuous oxidizing atmospheres. Good thermal conductivity. Used in applications where high temperature but no vacuum or inert atmosphere is available.
304 Stainless Steel 10% Nickel, 19% Chromium, 0.08% Carbon max., 2% Manganese max., 1% Silicon max., traces of Sulfur & Phosphorous, balance Iron	X	X	X	X	Up to 1650°F (899°C) under oxidizing conditions. Has general good oxidation and corrosion resistance in a wide range of industrial environments. Subject to carbide precipitation, which can reduce corrosion resistance in the 800-1000°F (427-538°C) range. Good mechanical properties from -300 to 1450°F (-184 to 788°C). Main areas of usage for thermocouple protection is in chemicals, foods, plastics, Petroleum. Generally regarded as a standard protection tube material.
304 Stainless Steel Low Carbon 19% Chromium, 10% Nickel, .03% Carbon max.	X	X	X	X	Same characteristics as 304 except the Low Carbon allows corrosion resistant weld areas. Not recommended to be used above 800°F (427°C).
309 Stainless Steel 23% Chromium, 13.5% Nickel, .2% Carbon max., 2% Manganese max., 1% Silicon max., .04% Phosphorous max., .04% Sulfur max.			X	X	Maximum temperature 1900°F (1038°C). Resists destructive heat scaling at high temperatures. Retains strength at high temperatures.
310 Stainless Steel 25% Chromium, 21% Nickel, .2% Carbon max., 1.5% Silicon	X	X	X	X	Up to 2100°F (1149°C) continuous, 1900°F (1038°C) intermittent. Mechanical and corrosion resistance similar to and better than 304 Stainless Steel.
316 Stainless Steel 12% Nickel, 17% Chromium, 2½% Molybdenum, 2% Manganese max., 0.08% Carbon max., 1% Silicon max., traces of Sulfur and Phosphorous, balance Iron.	X	X	X	X	Up to 1700°F (927°C) under oxidizing conditions. Same areas of application as 304 Stainless Steel. Has improved resistance to mild acid and pitting corrosion.
316 Stainless Steel, Low Carbon 17% Chromium, 12% Nickel, .03% Carbon max., 2.5% Mo	X	X	X	X	Same as 304 Stainless Steel Low Carbon.

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	Tubing	MgO Sheath	Prot. Tubes	Drilled Wells	
321 Stainless Steel 18% Chromium, 9.5% Nickel, .10% Carbon max., 2.0% Manganese max., 1.0% Silicon max., .04% Phosphorous max., .04% Sulfur max., 4% Titanium x Carbon min.	X	X	X	X	Same as 347 Stainless Steel.
347 Stainless Steel 18% Chromium, 11.5% Nickel, .10% Carbon max., 2.0% Manganese max., 1.0% Silicon max., .04% Phosphorous max., .04% Sulfur max., 8% Columbian x Carbon min.	X	X Limited Avail.		X	Good Corrosion resistance between 900°F (482°C) to 1600°F (871°C). Used where conditions are too severe for Low Carbon Stainless Steel.
446 Stainless Steel 27% Chromium, 0.25% Nitrogen max., 20% Carbon max., 1.5% Manganese max., 1.0% Silicon max., traces of Phosphorous and Sulfur, balance Iron		X	X	X	Up to 2000°F (1093°C) under oxidizing conditions. Excellent high temperature corrosion and oxidizing resistance. Main areas of application are hardening, nitriding, and annealing furnaces, salt baths, molten Lead, Tin and Babbit metal, Sulfurous atmospheres. Not for carburizing atmospheres. Other areas are steel soaking pits, tinning pots, waste heat boilers, ore roasters, cement exit flues, boiler tubes to 1800°F (982°C), incinerators to 2000°F (1093°C), glass flue tanks.
Tantalum	X	X		X	Up to 4350°F (2349°C). Good resistance to corrosion and quick heat conductivity. Good mechanical strength. Used in chemical processes and high temperatures in vacuum or inert atmosphere.
Titanium	X	X		X	Up to 2300°F (1260°C) in inert or vacuum atmosphere. Acid and chemical resistance. Oxidation resistance to 1000° (538°C).

Ceramics

Material/Composition	Typical Areas of Use				Application Guideline Information
	Tubing	MgO Sheath	Prot. Tubes	Drilled Wells	
Alumina (Recrystallized 99.7% AL_2O_3)			X		Up to 3400°F (1889°C) when supported. Has only fair resistance to thermal and mechanical shock. Essentially same areas as Mullite including induction melting, vacuum furnaces. Impervious to gases at high temperatures.
Boron Nitride			X		Can be used up to 5400°F (3000°C) in reducing atmosphere. Excellent thermal shock resistance and electrical resistance. It is not wet by most molten metals and slags; Iron, Aluminum, Steel, Copper, Sodium and most molten glasses.
Hexoloy®SA Sintered Alpha, Silicone Carbide			X		Up to 3000°F (1650°C) in air. High thermal conductivity, excellent wear and abrasion resistance, high thermal shock resistance, and good mechanical strength. Superior chemical resistance in both reducing and oxidizing environments. Attacked by Halides, fused caustics and ferrous metals.
Mullite 63% Alumina			X		Up to 2750°F (1510°C) when supported. Has poor mechanical shock resistance, good thermal shock resistance. For Barium Chloride salt baths to 2350°F (1288°C). Should be vertical mounted or supported if horizontal. For high temperature applications of ceramic industry, heat treating, glass manufacture. Impervious to gases at high temperature.
Silicon Carbide 90% Silicon Carbide, 9% Silicon Dioxide, balance Aluminum Oxide			X		Up to 3000°F (1649°C). For a secondary protection tube with Alumina or Mullite primary tube. For brick and ceramic kilns, steel soaking pits, molten non-ferrous metals. Can withstand direct flame impingement. Fair thermal shock resistance. Approximately 14% porosity.

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Composite Materials

Material/Composition	Typical Areas of Use				Application Guideline Information
	Tubing	MgO Sheath	Prot. Tubes	Drilled Wells	
Cerite-II (Cast oxide composites) 39.4% Alumina, 41.3% Silicon, 9.4% Calcium, 6.3% Iron, 3.8% other			X		Up to 2000°F (1093°C). For submerged use in Aluminum and other non-ferrous metals. Not wetted by molten Aluminum and other non-ferrous metals. No contamination. Good thermal and mechanical shock resistance.
Cerite-III (Cast oxide composites) 40% Aluminum Oxide, 10% Magnesium Oxide, 30% Refractory Aggregates, 20% Aqueousmono Aluminum Phosphate Solution.			X		Up to 2000°F (1093°C). For submerged use in Aluminum and other non-ferrous metals. Not wetted by molten Aluminum and other non-ferrous metals. No contamination. Good thermal and mechanical shock resistance.
Metal Ceramic LT-1 (Slip cast composite of Chromium and Aluminum Oxide). 77% Chromium, 23% Aluminum Oxide			X		Up to 2500°F (1374°C) in oxidizing conditions. Main areas of usage are molten Copper base alloys to 2100°F (1149°C), blast furnace and stack gases to 2400°F (1316°C), Sulfur burners to 2000°F (1093°C), cement kilns to 2200°F (1204°C), chemical process reactors to 2500°F (1371°C). A ceramic primary tube is required when a Noble metal thermocouple is used.
Vesuvius			X		Up to 1700°F (927°C). For use in Aluminum and other non-ferrous metals. Not wetted by molten Aluminum and other non-ferrous metals. No contamination. Resists thermal and mechanical shock. Brittle after heating. Handle carefully.