Common Protection Tube Materials

(All Chemical compositions are nominal, as obtained from suppliers)

304 Stainless Steel 10% Nickel, 19% Chromium, 0.08% Carbon max., 2% Manganese max., 1% Silicon max., traces of Phosphorous and Sulfur, balance Iron	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 caribide 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.
316 Stainless Steel 12% Nickel, 17% Chromium, 2-1/2% Molybdenum, 2% Manganese max., 0.08% Carbon max., 1% Silicon max., traces of Phosphorous and Sulfur, balance Iron	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.
446 Stainless Steel 27% Chromium max., 0.25% Nitrogen max., 0.20% Carbon max., 1.50% Manganese max., 1.00% Silicon max., traces of Phosphorous and Sulfur, balance Iron	Up to 2000°F (1093°C) under oxidizing conditions. Excellent high temperature corrosion and oxidation 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), asphalt mixing incinerators to 2000°F (1093°C), glass tank flues.
Inconel 600 76% Nickel 16% Chromium, 8% Iron	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 furnaces, cyanide salt baths, blast furnace down-comers, open hearth flue-stacks, steel soaking pits, waste heat boilers, ore roasters, cement exit flues, incinerators, glass tank flues.
Inconel 601 61% Nickel, 23% Chromium, 14% Iron, 1.35% Aluminum	Similar applications to Inconel 600 but with superior resistance to Sulfur, and has high temperature oxidation resistance to 2300°F.
Carbon Steel - C1018 0.17% Carbon, 0.75% Manganese, 0.035 Phosphorous, max., 0.045 Sulfur, max., balance Iron	Up to 1000°F (538°C) in non-oxidizing environments. Main areas of usage are galvanizing pots, tinning pots, molten babbitt metal, molten magnesium, molten zinc, petroleum refinery applications such as dewaxing and thermal cracking.
Silicon Nitride	Up to 1700°F (927°C) For use in Aluminum and other non-ferrous metal foundries. Not wetted by molten aluminum and other non-ferrous metals. No contamination. Resists thermal and mechanical shock. Handle carefully.
Cast Iron	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 (871°C) under reducing conditions.
Metal Ceramic LT-1 (slip cast composite of Chromium and Aluminum Oxide,) 77% Chromium, 23% Aluminum Oxide	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.
Mullite (53% alumina)	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 temperatures.
Alumina (Recrystallized 99.7% $AL^2 0^3$)	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.
Silicon Carbide, Carbofrax 90% Silicon Carbide, 9% Silicon Dioxide, balance Aluminum Oxide	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 name impingement. Fair thermal-shock resistance. Approximately 14% porosity.
Refractory Coated, Series 1100	**Up to 1400°F (745°C).** Refractory laminated coating resists erosion from molten aluminum, zinc or galvanizing baths. Special protective bulb at tip for fast response and thermal expansion.