Thermocouple Application Data

Calibration Code	Conductor & Characteristics		Recommended Temp. Range	Limits of Error			Application Information
	Positive	Negative		Range °F	Standard	Special	
J	Iron (Magnetic)	Constantan® (Non-Magnetic)	32 to 1400°F (0 to 760°C)	32 to 1400°F (0 to 760°C)	±4.0°F (±2.2°C) or ±0.75%*	±2.0°F (±1.1°C) or ±0.4%*	Suitable for vacuum, reducing, or inert atmospheres. Reduced life in oxidizing atmosphere. Iron oxidizes rapidly above 1000°F so only heavy gauge wire is recommended for high temperature. Bare elements should not be exposed to sulphurous atmospheres above 1000°F.
Jx	White	Red	-	32 to 392°F (0 to 200°C)	±4.0°F (±2.2°C)	±2.0°F (±1.1°C)	Compensating extension wire for "J" calibration.
K	Chromel® (Non-Magnetic)	Alumel® (Magnetic)	32 to 2300°F (0 to 1260°C)	-328 to 32°F (-200 to 0°C) 32 to 2300°F (0 to 1260°C)	±4.0°F (±2.2°C) or ±2.0%* ±4.0°F (±2.2°C) or ±0.75%	 ±2.0°F (±1.1°C) or ±0.4%	Recommended for continuous oxidizing or neutral atmospheres. Mostly used above 1000°F. Subject to failure if exposed to sulphur. Preferential oxidation of chromium in positive leg at certain low oxygen concentrations causes "green rot" and large negative calibration drifts most serious in the 1500-1900°F temperature range.
Kx	Yellow	Red	-	32 to 392°F (0 to 200°C)	±4.0°F (±2.2°C)	±2.0°F (±1.1°C)	Compensating extension wire for "K" calibration.
T	Copper (Yellow Metal)	Constantan® (Silver Metal)	-328 to 700°F (-200 to 371°C)	-328 to 32°F (-200 to 0°C) 32 to 700°F (0 to 371°C)	±1.8°F (±1.0°C) or ±1.5%* ±1.8°F (±1.0°C) or ±0.75%*	- ±0.9°F (±0.5°C) or ±0.4%*	Usable in oxidizing, reducing, or inert atmospheres, as well as vacuum. Not subject to corrosion in moist atmospheres.
Tx	Blue	Red	-	-75 to 212°F (-60 to 100°C)	±1.8°F (±1.0°C)	±0.9°F (±0.5°C)	Compensating extension wire for "T" calibration.
E	Chromel®	Constantan®	32 to 1600°F (0 to 871°C)	-328 to 32°F (-200 to 0°C) 32 to 1600°F (0 to 871°C)	±3.06°F (±1.7°C) or ±1.0%* ±3.06°F (±1.7°C) or ±0.5%*	 ±1.8°F (±1.0°C) or ±0.4%*	Recommended for continuous oxidizing or inert atmospheres. Highest thermoelectric output of common calibrations.
Ex	Purple	Red	-	32 to 392°F (0 to 200°C)	±3.0°F (±1.7°C)	±1.8°F (±1.0°C)	Compensating extension wire for "E" calibration.
R	Platinum 13% Rhodium	Platinum	32 to 2700°F (0 to 1482°C)	32 to 2700°F (0 to 1482°C)	±2.7°F (±1.5°C) or ±0.25%*	±1.08°F (±0.6°C) or ±0.1%*	Recommended for high temperature. Requires non-metallic protection tube and ceramic insulators. Long-term high temperature use causes grain growth and mechanical failure. Negative calibration drift caused by rhodium diffusion to pure leg as well as from rhodium volatilization.
S	Platinum 10% Rhodium	Platinum	32 to 2700°F (0 to 1482°C)	32 to 2700°F (0 to 1482°C)	±2.7°F (±1.5°C) or ±0.25%*	±1.08°F (±0.6°C) or ±0.1%*	Same as "R" calibration but output is lower. Also susceptible to grain growth and drift.
RSx	Copper (Black)	Alloy 11 (Red)	-	32 to 392°F (0 to 200°C)	±9°F (±5°C)	-	Compensating extension wire for "R" and "S" calibration.
B	Platinum 30% Rhodium	Platinum 6% Rhodium	1600 to 3100°F (870 to 1705°C)	1600 to 3100°F (870 to 1705°C)	±0.5%*	±0.25%*	Same as "R" calibration but output is lower. Also susceptible to grain growth and drift.
Bx	Gray	Red	-	32 to 392°F (0 to 200°C)	±7.6°F (±4.2°C)	-	Compensating extension wire for "B" calibration.
C (W5)	Tungsten 5% Rhenium	Tungsten 26% Rhenium	32 to 4200°F (0 to 2315°C)	32 to 800°F (0 to 426°C) 800 to 4200°F (426 to 2316°C)	±8.0°F (±4.4°C) ±1%*	- -	For very high temperature applications in inert and vacuum atmospheres.
L	Platinel II® +	Platinel II® -	32 to 2543°F (0 to 1395°C)	392 to 2192°F (200 to 1200°C)	±0.150mv to ±0.315mv	±0.100mv to ±0.158mv	Noble metal combination that approximates the "K" calibration but has much improved oxidation resistance. Should be treated as any noble metal thermocouple.
N	Nicrosil®	Nisil®	32 to 2300°F (0 to 1260°C)	32 to 2300°F (0 to 1260°C)	±4.0°F (±2.2°C) or ±0.75%*	±2.0°F (±1.1°C) or ±0.4%*	Modern nickel based alloy similar to "K" calibration but offering lower drift and longer life at high temperatures.
Nx	Orange	Red	-	32 to 392°F (0 to 200°C)	±4.0°F (±2.2°C)	±2.0°F (±1.1°C)	Compensating extension wire for "N" calibration.
Nickel-Moly	NiMo (Nickel-18% Molybdenum)	Nickel (Nickel-0.8% Cobalt)	32 to 2250°F (0 to 1232°C)	-	-	-	Used in hydrogen applications. Cycling causes excessive grain growth.

* Tolerance as stated value or percentage - whichever is greater. Where percentages are given, the tolerance (in °C) is calculated for a given temperature by multiplying the temperature (in °C) by the stated percentage.

Protection Tube Materials

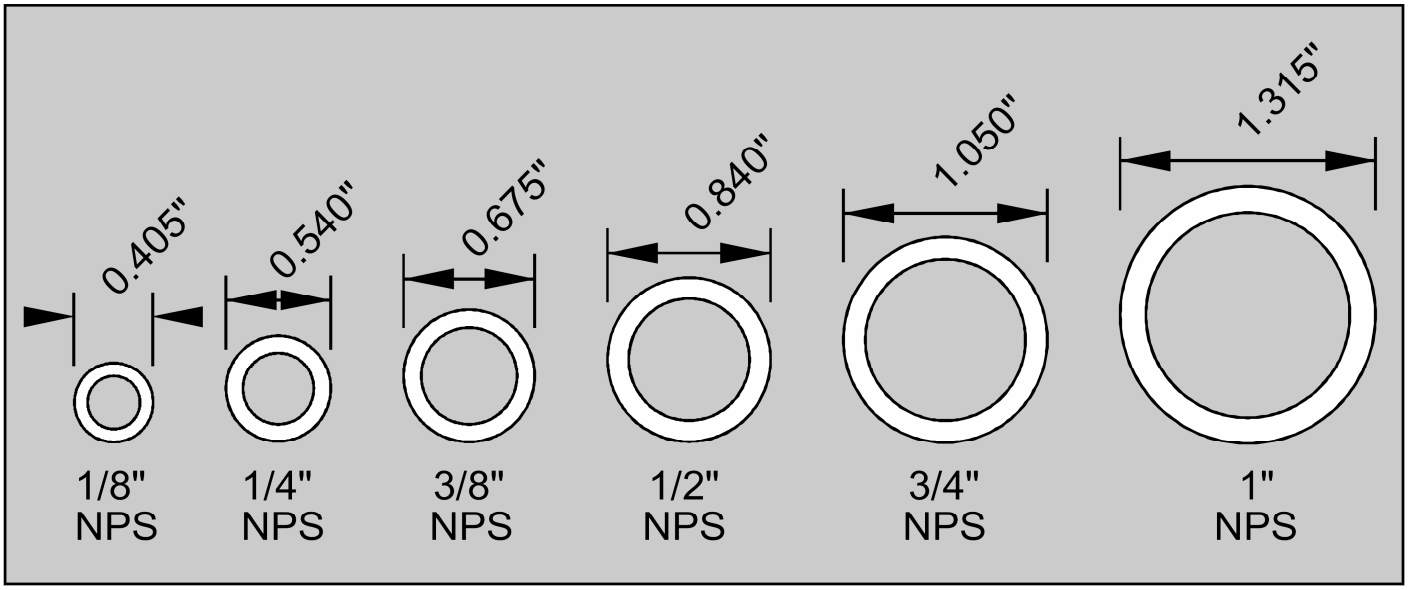
Material	Approximate Composition	Recommended Max. Temp.	NBS Code Number	Description	
				Application	Remarks
Inconel® 800	34% Ni 22% Cr Balance Fe	2000°F (1100°C)	89	Furnaces Cyanide Baths	Superior to 600 in resistance to green rot. Retains strength at elevated temperature.
Monel®	66% Ni 31% Cu 1% Fe	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 sulphur 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				**Comments**	
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_2O_3 34% 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_2O_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.	

COMPARISON OF PIPE SCHEDULES
(standard dimensions and weights)

NPS Pipe Size (DN)	Schedule	Outside Diameter in Inches	Wall Thickness in Inches	Inside Diameter in Inches	Weight Per Ft. in Lbs
1/8" (6mm)	10	.405	.049	.307	.186
	40	.405	.068	.269	.2447
	80	.405	.095	.215	3145
1/4" (8mm)	10	.540	.065	.410	.330
	40	.540	.088	.364	.4248
	80	.540	.119	.302	.5351
3/8" (10mm)	10	.675	.065	.545	.424
	40	.675	.091	.493	.5676
	80	.675	.126	.423	.7388
1/2" (15mm)	5	.840	.065	.710	.5380
	10	.840	.083	.674	.6710
	40	.840	.109	.622	.8510
	80	.840	.147	.546	1.088
	160	.840	.187	.466	1.304
3/4" (20mm)	5	1.050	.065	.920	.6838
	10	1.050	.083	.884	.8572
	40	1.050	.113	.824	1.131
	80	1.050	.154	.742	1.474
	160	1.050	.218	.614	1.937
1" (25mm)	5	1.315	.065	1.185	.8678
	10	1.315	.109	1.097	1.404
	40	1.315	.133	1.049	1.679
	80	1.315	.179	.957	2.172
	160	1.315	.250	.815	2.844
1-1/4" (32mm)	5	1.660	.065	1.530	1.107
	10	1.660	.109	1.422	1.806
	40	1.660	.140	1.380	2.273
	80	1.660	.191	1.278	2.997
	160	1.660	.250	1.160	3.765

NPS Pipe Size (DN)	Schedule	Outside Diameter in Inches	Wall Thickness in Inches	Inside Diameter in Inches	Weight Per Ft. in Lbs
1-1/2" (40mm)	5	1.900	.065	1.770	1.274
	10	1.900	.109	1.682	2.085
	40	1.900	.145	1.610	2.718
	80	1.900	.200	1.500	3.631
	160	1.900	.281	1.338	4.859
2" (50mm)	5	2.375	.065	2.245	1.604
	10	2.375	.109	2.157	2.638
	40	2.375	.154	2.067	3.653
	80	2.375	.218	1.939	5.022
	160	2.375	.343	1.689	7.444
2-1/2" (65mm)	5	2.875	.083	2.709	2.475
	10	2.875	.120	2.635	3.531
	40	2.875	.203	2.469	5.793
	80	2.875	.276	2.323	7.661
	160	2.875	.375	2.125	10.01
3" (80mm)	5	3.500	.083	3.334	3.029
	10	3.500	.120	3.260	4.332
	40	3.500	.216	3.068	7.576
	80	3.500	.300	2.900	10.25
	160	3.500	.437	2.626	14.32
3-1/2" (90mm)	5	4.000	.083	3.834	3.472
	10	4.000	.120	3.760	4.973
	40	4.000	.226	3.548	9.109
	80	4.000	.318	3.364	12.51

GUIDE TO COMMON PIPE SIZES
(Depictions are to scale, OD & ID of schedule 40 pipe shown)



Thermocouple & Extension Wire

THERMOCOUPLE AND EXTENSION WIRE INSULATION PROPERTIES

Material	Temperature Range			Resistance To					
	Continuous	Maximum	Flexibility	Flame Retardance	Abrasion	Acid	Solvent	Base	Moisture
Polyvinyl Chloride	-58 to 212°F (-50 to 105°C)	302°F (150°C)	Excellent	Good	Good	Good	Fair	Good	Good
FEP-Teflon®	-90 to 400°F (-67 to 204°C)	482°F (250°C)	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
PFA-Teflon®	-90 to 500°F (-67 to 260°C)	550°F (288°C)	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
TFE-Teflon®	-90 to 500°F (-67 to 260°C)	550°F (288°C)	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Fiberglass	900°F (482°C)	1000°F (538°C)	Good	Excellent	Good	Good	Excellent	Excellent	Good
High Temp. Fiberglass	1400°F (760°C)	1600°F (871°C)	Good	Excellent	Good	Good	Excellent	Excellent	Good
Refrasil®	1600°F (871°C)	2000°F (1093°C)	Good	Excellent	Fair	Fair	Excellent	Good	Fair
Ceramic Fiber	2200°F (1204°C)	2600°F (1427°C)	Good	Excellent	Fair	Fair	Excellent	Excellent	Fair
Synthetic Fiber	500°F (260°C)	650°F (343°C)	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Good
Nylon®	-85 to 248°F (-65 to 120°C)	302°F (150°C)	Good	Poor	Excellent	Excellent	Good	Good	Fair
Kapton®	-450 to 500°F (-267 to 260°C)	800°F (427°C)	Good	Good	Excellent	Good	Good	Good	Good
Silicone Rubber	-100 to 392°F (-73 to 200°C)	500°F (260°C)	Excellent	Good	Fair	Poor	Fair	Good	Good

THERMOCOUPLE WIRE WEIGHTS AND RESISTANCES

Stated footages are in pound units, except noble metal calibrations, which are in troy ounce units. Resistances are nominal for 70°F.

Gauge (AWG)	8		14		16		20		24		28		30		38	
Diameter	.128"		.064"		.051"		.032"		.020"		.012"		.010"		.004"	
Conductor	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb	Res. Ω/Ft	Ft/ Lb
Copper	.0006	20	.003	80	.004	128	.010	322	.026	816	.065	2076	.103	3296	.659	20970
Iron	.004	23	.015	91	.003	145	.059	365	.149	926	.376	2356	.598	3741	3.83	23800
Constantan®	.018	20	.072	81	.114	128	.291	324	.725	821	1.85	2090	2.94	3318	18.70	21110
Chromel®	.026	20	.104	82	.165	130	.415	329	1.05	834	2.70	2121	4.03	3368	27.04	21430
Alumel®	.011	21	.043	83	.069	132	.113	334	.438	846	1.11	2153	1.76	3419	11.26	21750
Nicrosil®	.035	21	.142	84	.223	134	.566	337	1.44	854	3.65	2174	5.80	3452	36.25	21960
Nisil®	.013	20	.054	83	.085	131	.215	330	.545	837	1.39	2129	2.20	3380	13.75	21510
Alloy No. 11	.002	20	.007	80	.010	128	.027	322	.070	816	.175	2075	.275	3295	-	20960
	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT	Res. Ω/Ft	Ft/ OzT
Platinum	.004	.57	.016	2.29	.025	3.76	.066	9.17	.166	23.49	.240	65.2	.663	93.9	4.15	587
Plat. 6% Rhod.	-	.60	-	2.39	-	3.92	-	9.58	-	24.51	-	68.1	-	98.0	-	613
Plat. 10% Rhod.	.007	.61	.028	2.46	.044	4.03	.119	9.83	.298	25.16	.512	69.9	1.19	100.6	7.45	629
Plat. 13% Rhod.	.008	.63	.031	2.51	.049	4.11	.124	10.04	.312	25.71	.530	71.4	1.25	102.8	7.80	643
Plat. 30% Rhod.	-	.70	-	2.79	-	4.58	-	11.18	-	28.62	-	79.5	-	114.5	-	715