

KANTHAL®

THERMOCOUPLE, EXTENSION AND COMPENSATING ALLOYS

KANTHAL® ALLOYS



CONTENT

INTRODUCTION AND GENERAL COMMENTS	4
Standard grade	5
Special grade	5
Sheathing grade	5
Other special features	6
THERMOCOUPLES	7
Choice of thermocouple	7
Maximum operating temperature	7
NICROSIL/NISIL THERMOCOUPLE (TYPE N)	10
THERMOCOUPLE THERMOTHAL™ P/THERMOTHAL N (TYPE K)	12
THERMOCOUPLE THERMOTHAL P (EP)/CUPROTHAL® (EN) (TYPE E)	14
THERMOCOUPLE COPPER/CUPROTHAL (TN) (TYPE T)	15
THERMOCOUPLE IRON (JP)/CUPROTHAL (JN) (TYPE J)	16
CUPROTHAL CL	17
EMF TOLERANCES	18
FORMATION OF THE HOT JUNCTION	21
Oxyacetylene and gas welding	21
Arc welding	22
Discharge capacity welding	22
THERMOCOUPLE COMPENSATING AND EXTENSION GRADE ALLOYS	23
TABLES	26
Thermothal P wire	26
Thermothal N wire	27
Cuprothal (EN), Cuprothal (JN), Cuprothal (TN), Cuprothal WX wires	28
Iron wire	29
Cuprothal SX wire	30
Nicrosil wire	31
Nisil wire	32
DELIVERY FORMS	33
TOLERANCES	34
STANDARD REFRACTORY TUBES	35
KANTHAL® PROTECTION TUBES	37

INTRODUCTION AND GENERAL COMMENTS

For many industrial heating processes, particularly those carried out at high temperatures, a thermocouple is the most accurate, convenient and simple method of temperature measurement. In some instances, it is the only feasible method.

Kanthal has been a leader in the production of a wide range of thermocouple materials.

The principle on which the modern thermocouple operates is derived from Seebeck's discovery that if a circuit is formed using two dissimilar metal conductors with one junction at a higher temperature than the other, then a current will flow in the circuit. The resultant EMF is proportional to the temperature difference between the junctions.

Our Thermothal™ P and Thermothal N base metal alloys for use at temperatures up to 1260°C have long been specified for some of the most demanding applications – from nuclear reactors and nuclear submarines to jet engines and industrial furnaces. The inherent instability of NiCr/NiAl has been vastly improved by the introduction of Nicrosil/Nisil thermocouples. Other thermocouple combinations fulfill less exacting tasks with equal accuracy.

Full details of Kanthal® range of thermocouple alloys are given on the following pages. If you need technical advice or help, our accumulated knowledge and expertise in this highly specialised field is available.

Kanthal alloys are supplied according to the standards shown below.

Where older standards, which are not equivalent, are still in use, we can supply different EMF values at the customers' request. The equivalent Kanthal alloys and combinations are dealt under well-established trade-marks. These are itemized below, followed in each case by the relevant type code in brackets. 'P' and 'N' are used to indicate the positive and negative legs.

STANDARDS AND NORMS

ASTM	(American Society for Testing and Materials) E 230
ANSI	(American National Standard Institute) MC 96.1
IEC	(European Standard by the International Electrotechnical Commission) 584 -1/2/3
DIN	(Deutsche Industrie Normen) EN 60584 -1/2
BS	(British Standards) 4937-1041, EN 60584 -1/2
NF	(Norme Française) EN 60584 -1/2 - NFC 42323 - NFC 42324
JIS	(Japanese Industrial Standards) C 1602 - C 1610
GOST	(Unification of the Russian Specifications) 3044

STANDARD GRADE

This grade is calibrated throughout the entire operating temperature range and the EMF of the couples complies with the relevant standards or customer standards. Each individual arm is calibrated against platinum and EMF values are shown on the label of each coil or spool. The thermoelements of the thermocouple type J, Cuprothal® (JN) and iron (JP), are normally supplied in the bright annealed condition.

Thermothal P and Thermothal N wires (type K thermocouple) are available in the bright or oxidized condition.

SPECIAL GRADE

All thermocouple combinations are available by selection to closer tolerances than normal (1/2 and 1/4 tolerances) for applications where special accuracy is required. Tolerances for special grade material – which carries a surcharge – are listed on following pages.

For some applications, special tolerances of $\pm 0.25^{\circ}\text{C}$ or $\pm 0.002\text{ T}$ (whichever is greater – where 'T' is the temperature) can be manufactured.

Other special tolerance grades can be supplied on request.

SHEATHING GRADE

Where thermocouples are required for fabrication into mineral filled sheathed elements, it is necessary to select alloys to special EMF requirements. The wire conforms to the following international standards:

JIS C 1605 - ASTM E 608, E 585 and other main standards. During the production of thermocouples used in mineral filled sheathed elements, the EMF value changes because of:

- The preparation method and successive thermic treatments
- The type of material of the sheath: stainless steel or nickel-chromium alloys with high temperature resistance
- Insulation values

Sandvik produces special thermocouple wires to reduce these EMF variations and to ensure the finished cable has minimum deviation from standard values.

TYPES OF THERMOCOUPLE WIRES PRODUCED BY SANDVIK

CODE	WIRES COMPONENT THE THERMOCOUPLE	
	POSITIVE LEG	NEGATIVE LEG
N	Nicrosil (NP)	Nisil (NN)
K	Thermothal™ P (KP)	Thermothal N (KN)
E	Thermothal P (EP)	Cuprothal® (EN)
J	Iron (JP)	Cuprothal (JN)
T	Copper	Cuprothal (TN)

OTHER SPECIAL FEATURES

OXIDIZED SURFACE

Bright wires are easily attacked when an atmosphere of H₂S and CO₂ is present. Resistance to this corrosive attack is improved by the use of oxidized wires. In addition the wire can be protected by closed sheaths which are ventilated by pumping a small supply of clean air into a sheath which has a side vent at the cold junction end and is open at the hot junction end. Kanthal manufactures these oxidized wires to standard EMF requirements or to special customer needs.

The highest stability in EMF is obtained by special heat treatment for a particular application.

CALIBRATION

All thermocouple types are calibrated to ensure that the EMF is correct over the range of temperatures required by international standards. Thermocouples required for use at sub zero temperatures must be ordered as such. All thermoelectric alloys are individually calibrated against Pt 67 and the EMF values at the various temperatures are shown on the corresponding label.

HARD AND HALF HARD PROCESSING PRODUCTS (JOINTS)

It is frequently necessary to manufacture joints to connect thermocouples to compensation or extension cables. For this purpose, it is preferable to use the same alloy as the thermocouple (or cable) to avoid spurious EMF when the joint temperatures are different.

For machining purposes, it is often more satisfactory to use a harder temper of the alloy.

To improve workability, these materials have to be hard or half hard. Because the work hardening operation or other processing cause an EMF change, the finished product must be then annealed to obtain the correct EMF.

Bright annealing of Therموthal™ P/Therموthal N is carried out at 1100°C for 30 minutes in a reducing atmosphere or in a vacuum. The atmosphere must be free from sulphur gases and moisture.

THERMOCOUPLES

THE MOST USED THERMOCOUPLE COMBINATIONS

THERMOCOUPLE	THERMOELEMENT	ALLOY	WORKING ATMOSPHERE	TEMPERATURE RANGE, °C	
Type K	KP	Thermothal™ P	Oxidizing	-200	+1200
	KN	Thermothal N	Inert		
Type E	EP	Thermothal P (EP)	Oxidizing	-200	+900
	EN	Cuprothal® (EN)	Inert		
Type T	TP	Copper	Oxidizing, vacuum	-200	+350
	TN	Cuprothal (TN)	Reducing, inert		
Type J	JP	Iron (JP)	Oxidizing (limited use at high temp.)	-40	+750
	JN	Cuprothal (JN)	Reducing, inert, vacuum		
Type N	NP	Nicrosil	Oxidizing	-200	+1200
	NN	Nisil	Inert		

CHOICE OF THERMOCOUPLE

The thermocouple has to be chosen in relation to the temperature, working atmosphere and physical characteristics of the components.

A considerable advantage in using the thermocouple type J (iron (JP)/Cuprothal® (JN)) is its ability to work in oxidizing and reducing atmospheres.

Copper coated iron can be provided to prevent corrosion during shelf life.

Type K (Thermothal P/Thermothal N) is made with two alloys of high nickel content which allows their use in both oxidizing and reducing atmospheres.

Where type K is used in reducing atmospheres, it is necessary to take the precautions described in the following chapter.

Thermocouple type T (copper/Cuprothal (TN)) is mostly used at room and cryogenic temperatures.

For applications where a high thermoelectric value is required Thermocouple type E (Thermothal P (EP)/Cuprothal (EN)) is used.

MAXIMUM OPERATING TEMPERATURE

The conditions under which industrial thermocouples operate vary so widely that it is impossible to give exact values for thermocouple life.

PRINCIPAL FACTORS THAT AFFECT THE LIFE OF A THERMOCOUPLE

Temperature:

Thermocouple life decreases by about 50% when an increase of 50°C occurs.

Diameter:

By doubling the diameter of the wire, the life increases by 2–3 times.

Thermic cycling:

When thermocouples are exposed to thermic cycling from room temperature to above 500°C, their life decreases by about 50% compared to a couple used continuously at the same temperature.

Protection:

When thermocouples are covered by a protective sheath and placed into ceramic insulators, their life is considerably extended.

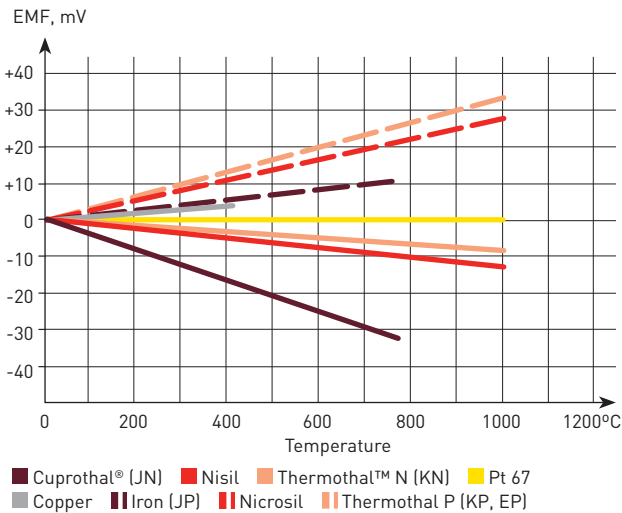
In the following table we give the maximum temperatures recommended for thermocouples used as bare and protected wires for different diameters, working in air without cycling.

MAXIMUM TEMPERATURES RECOMMENDED FOR THERMOCOUPLES USED AS BARE AND PROTECTED WIRES

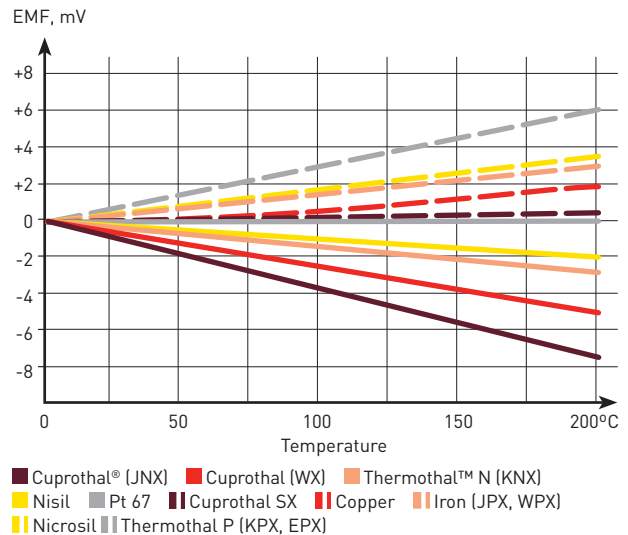
THERMOCOUPLE	TYPE	3.26 MM	1.63 MM	1.00 MM	0.80 MM	0.50 MM	0.30 MM	0.25 MM
Thermothal™ P/ Thermothal N (type K)	bare wire	1050°C	930°C	900°C	860°C	800°C	750°C	710°C
	protected wire	1150°C	1080°C	1050°C	970°C	910°C	860°C	820°C
Thermothal P (EP)/ Thermothal (EN) (type E)	bare wire	860°C	800°C	750°C	700°C	660°C	620°C	580°C
	protected wire	1000°C	910°C	860°C	810°C	770°C	730°C	690°C
Copper/ Cuprothal® (TN) (type T)	bare wire	–	400°C	360°C	320°C	280°C	250°C	220°C
	protected wire	–	450°C	410°C	370°C	370°C	330°C	270°C
Iron (JP)/ Cuprothal (JN) (type J)	bare wire	760°C	760°C	720°C	680°C	650°C	600°C	560°C
	protected wire	760°C	760°C	760°C	760°C	760°C	710°C	670°C
Nicrosil/Nisil (type N)	bare wire	1100°C	1010°C	960°C	930°C	890°C	840°C	800°C
	protected wire	1250°C	1180°C	1110°C	1040°C	1000°C	950°C	910°C

Temperatures are given as a guide to obtain a satisfactory life before burn out of the thermocouple occurs. Checks on stability should be carried out at regular intervals.

NOMINAL EMF FOR THERMOCOUPLE ALLOYS VS. PT 67



NOMINAL EMF FOR THERMOCOUPLE EXTENSION AND COMPENSATING CABLES VS. PT 67



PROPERTIES AND GRADES OF THERMOCOUPLE AND COMPENSATING ALLOYS

		THERMOTHAL™	THERMOTHAL	CUPROTHAL®	CUPROTHAL	CUPROTHAL
		P (+)	N (-)	(EN), (JN), TN (-)	WX (-)	SX (-)
Nominal composition, %	Ni	90	95	44	43	3
	Cr	10	-	-	-	-
	Fe	-	-	+	2	-
	Cu	-	-	balance	balance	balance
	Other	+	AlMn- Si+	Mn+	Mn+	2 Mn
Approx. melting point, °C		1430	1400	1210	1210	1080
Specific resistance at 20°C, micro-ohm cm		70.6	29.2	49	52	12
Density, g/cm ²		8.72	8.60	8.90	8.90	8.91
Temperature coefficient of resistance, ×10 ⁻⁶ /°C		300 20-100	1900 20-100	60 20-100	100 20-100	1500 20-100
Linear expansion coefficient, ×10 ⁻⁶ /°C		17 20-100	17 20-100	14 20-100	15 20-100	16 20-100
Thermal conductivity at 20°C Wm ⁻¹ °C ⁻¹		19.2	29.7	21.2	21.0	-

[cont.]

[cont.]

		PLATINUM	IRON (+)	NICROSIL (+)	NISIL (-)	COPPER (+)	CUPROTHAL® CL (-)
Nominal composition, %	Ni	-	-	balance	balance	-	45
	Cr	-	-	14.2	-	-	-
	Fe	-	100	-	-	-	-
	Cu	-	-	-	-	100	balance
	Other	-	+	Si+	4.3 Si	-	-
Approx. melting point, °C		1773	1535	1420	1420	1083	1210
Specific resistance at 20°C, micro-ohm cm		10.6	13	100	36.5	1.72	49
Density, g/cm ³		21.45	7.86	8.5	8.58	8.92	8.90
Temperature coefficient of resistance, ×10 ⁻⁶ /°C		3000 20-100	5000 20-100	390 20-100	678 20-100	3930 20-100	100 20-100
Linear expansion coefficient, ×10 ⁻⁶ /°C		89 20-100	11.7 20-100	17 20-100	17 20-100	16.6 20-100	14 20-100
Thermal conductivity at 20°C Wm ⁻¹ °C ⁻¹		69.5	66.2	13	27	388	21.2

NICROSIL/NISIL THERMOCOUPLE (TYPE N)

For many years, the type K base metal thermocouple has been the first choice for temperature measurements up to about 1000°C. Despite of its numerous advantages, this combination has nevertheless had certain drawbacks. A new and improved alloy combination, Nicrosil/Nisil, has therefore been developed.

Although the type K thermocouple combines calibration accuracy, stability, oxidation resistance and high thermal EMF at a reasonable price, certain operating conditions can impair its performance.

- Long exposure to high temperature may cause a gradual drift in EMF
- A short-term change in EMF may occur in the 250 – 550°C range

In terms of its liability to EMF drift and short-term EMF changes, type N is a significant improvement on the type K combination. It also has a much longer life, due to the improved oxidation resistance of the negative Nisil leg.

The thermal EMF output for Nicrosil/Nisil is lower than for type K, so direct substitution is not possible without modifying existing instrumentation. However, in the aerospace, nuclear and semiconductor industries, where temperature measurement and control are especially critical, the benefits of a longer life and improved thermal EMF stability cannot be ignored. In industry generally, there is also a considerable need for savings in the inspection, maintenance and calibration of thermocouple actuated pyrometric installations.

Extension wires for Nicrosil/Nisil thermocouples are available.

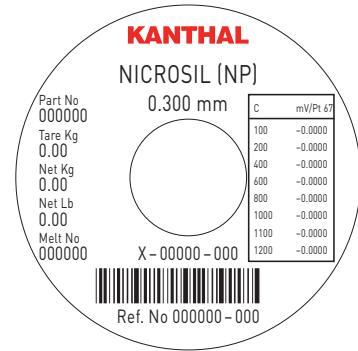
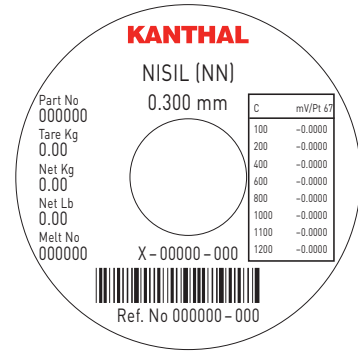
The following table lists the Nicrosil/Nisil EMF-temperature characteristics against Pt 67 (NIST Monograph 175) based on ITS 90.

NICROSIL/NISIL EMF REFERENCE TABLE (MV), REFERENCE JUNCTION 0°C

°C	0	10	20	30	40	50	60	70	80	90	100
0	0.000	0.261	0.525	0.793	1.065	1.340	1.619	1.902	2.189	2.479	2.774
100	2.774	3.072	3.374	3.680	3.989	4.302	4.618	4.937	5.260	5.585	5.913
200	5.913	6.245	6.579	6.916	7.255	7.597	7.941	8.288	8.637	8.988	9.341
300	9.341	9.696	10.054	10.413	10.774	11.136	11.501	11.867	12.234	12.603	12.974
400	12.974	13.346	13.719	14.094	14.469	14.846	15.225	15.604	15.984	16.362	16.748
500	16.748	17.131	17.515	17.900	18.286	18.672	19.059	19.447	19.835	20.224	20.613
600	20.613	21.003	21.393	21.784	22.175	22.566	22.958	23.350	23.742	24.134	24.527
700	24.527	24.919	25.312	25.705	26.098	26.491	26.883	27.276	27.669	28.062	28.455
800	28.455	28.847	29.240	29.632	30.024	30.416	30.807	31.199	31.590	31.981	32.371
900	32.371	32.769	33.151	33.541	33.930	34.319	34.707	35.095	35.482	35.869	36.256
1000	36.256	36.641	37.027	37.411	37.796	38.179	38.562	38.944	39.326	39.706	40.087
1100	40.087	40.466	40.845	41.223	41.600	41.976	42.352	42.727	43.101	43.474	43.846
1200	43.846	44.218	44.588	44.958	45.326	45.694	46.060	46.426	46.789	47.152	47.513
1300	47.513										

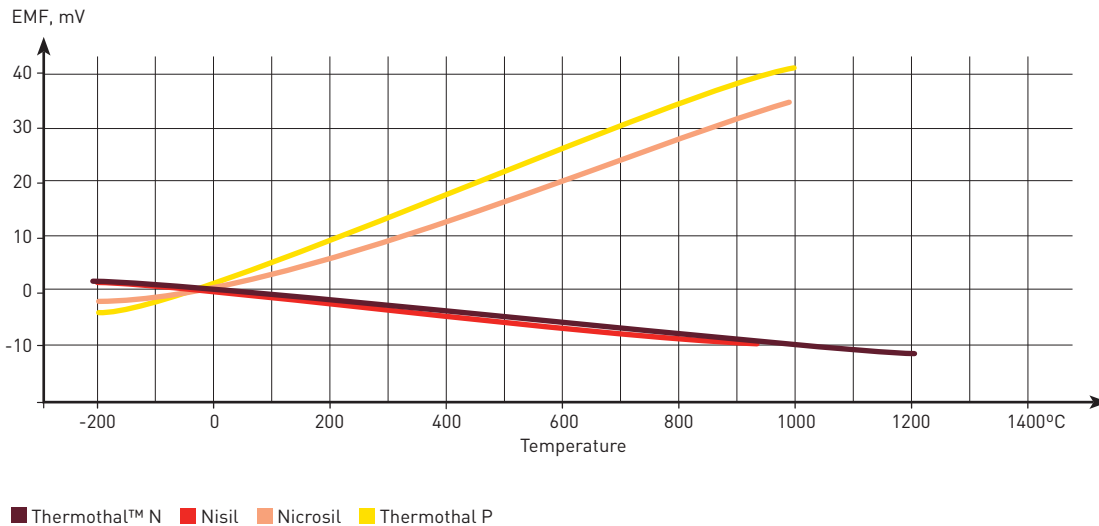
STANDARD EMF AGAINST PT 67, REFERENCE JUNCTION °C

TEMPERATURE °C	EMF, mV	
	NICROSIL LEG (POSITIVE)	NISIL LEG (NEGATIVE)
0	0.000	0.000
100	1.784	0.990
200	3.943	1.970
300	6.348	2.993
400	8.919	4.055
500	11.603	5.145
600	14.370	6.243
700	17.202	7.325
800	20.094	8.360
900	23.045	9.327
1000	26.046	10.210
1100	29.083	11.004
1200	32.144	11.702
1300	35.221	12.292



Labels used to identify Nicrosil and Nisil.

EMF COMPARISON OF NICROSIL, NISIL, THERMOTHAL™ P AND THERMOTHAL N VS. PT



THERMOCOUPLE THERMOTHAL™ P/ THERMOTHAL N (TYPE K)

Type K thermocouples find widest use at temperatures above 500°C due to their strong resistance to oxidation better than other base metal thermocouples.

Thermothal P/Thermothal N thermocouples cover all the standards required by international standards.

Each thermocouple element is manufactured so as to meet special tolerances when matched to platinum; this enables any coil of Thermothal P to be matched with any coil of Thermothal N to form the standard tolerance. Each coil is tested at 200°C / 400°C / 600°C / 800°C / 1000°C against Platinum 67 and each one is provided with a tag which gives the EMF values against Pt 67.

The following table lists KP/KN EMF characteristics against Pt 67 (NIST Monograph 175).

PRECAUTIONS IN THE USE OF TYPE K

Indications are given below regarding the precautions to be taken when using type K couples. These are listed in ASTM STP 470A.

Type K thermocouples have a better resistance to oxidation than other combinations, except type N, and are recommended for oxidizing or inert atmospheres.

Thermocouple type K cannot be used directly or without protection in the following cases:

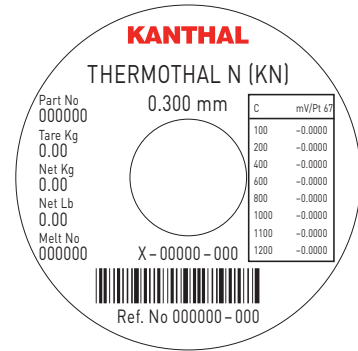
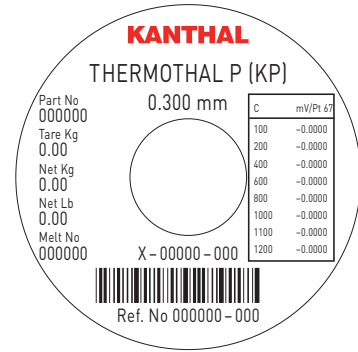
- Alternatively oxidizing and reducing atmospheres.
- Atmospheres with sulphur containing gases. The alloys are attacked causing intergranular corrosion, embrittlement and cracking of the negative leg (Thermothal N).
- Any protection sheaths should be cleaned to remove oils, fats, carbon containing substances, dirt.
- In a vacuum, except for a short time, chromium evaporates mostly from the positive leg Thermothal P, causing the EMF of the couple to alter.
- Reducing atmospheres such as hydrogen, dissociated ammonia or carbon monoxide which has low oxygen content.

THERMOTHAL P (KP)/THERMOTHAL N (KN) EMF REFERENCE TABLE (MV), REFERENCE JUNCTION 0°C

°C	0	10	20	30	40	50	60	70	80	90	100
0	0.000	0.397	0.798	1.203	1.612	2.023	2.437	2.851	3.267	3.682	4.096
100	4.096	4.509	4.920	5.328	5.735	6.138	6.540	6.941	7.340	7.739	8.139
200	8.139	8.539	8.940	9.343	9.747	10.153	10.561	10.971	11.382	11.795	12.209
300	12.209	12.624	13.040	13.457	13.875	14.293	14.713	15.133	15.554	15.975	16.397
400	16.397	16.820	17.243	17.667	18.091	18.516	18.941	19.366	19.792	20.218	20.644
500	20.644	21.071	21.497	21.924	22.350	22.776	23.203	23.629	24.055	24.480	24.906
600	24.906	25.330	25.755	26.179	26.602	27.025	27.447	27.869	28.290	28.710	29.129
700	29.129	29.548	29.965	30.382	30.798	31.214	31.628	32.041	32.453	32.865	33.275
800	33.275	33.685	34.093	34.501	34.908	35.313	35.718	36.121	36.524	36.925	37.326
900	37.326	37.726	38.124	38.522	38.918	39.314	39.708	40.102	40.494	40.885	41.276
1000	41.276	41.665	42.053	42.440	42.826	43.211	43.595	43.978	44.359	44.740	45.119
1100	45.119	45.497	45.873	46.249	46.623	46.996	47.367	47.737	48.105	48.473	48.839

STANDARD EMF AGAINST PT 67, REFERENCE JUNCTION °C

TEMPERATURE °C	EMF, mV	
	THERMOTHAL™ P (KP) LEG (POSITIVE)	THERMOTHAL N (KN) LEG (NEGATIVE)
0	0.000	0.000
100	2.814	1.283
200	5.970	2.168
300	9.323	2.886
400	12.764	3.633
500	16.214	4.431
600	19.618	5.287
700	22.951	6.178
800	26.205	7.070
900	29.386	7.940
1000	32.499	8.777
1100	35.544	9.575
1200	38.508	10.330



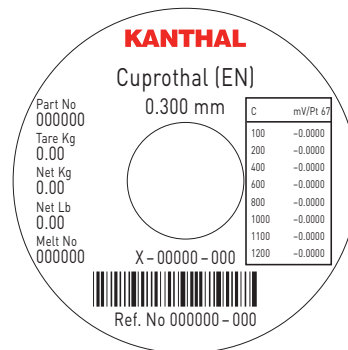
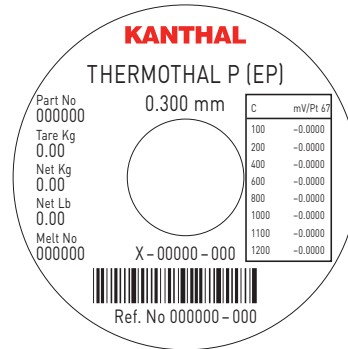
Labels used to identify Thermothal P and Thermothal N.

In reducing atmospheres, the positive leg (90% nickel 10% chromium) develops green oxide called “Green rot” (Cr_2O_3) instead of the nickel-chromium oxide ($\text{NiO-Cr}_2\text{O}_3$). The development of the green oxide decreases the chromium content in Thermothal P. This causes a reduction of its EMF, resulting in reduction in EMF output by up to 55% particularly in the range 816°C to 1038°C. This condition is accompanied by the KP arm becoming magnetic due to loss of chromium.

By use of suitable sheath material, the corrosive gases can be prevented from attacking the thermocouple. Sheaths with too small a diameter should be avoided.

THERMOCOUPLE THERMOTHAL™ P (EP)/ CUPROTHAL® (EN) (TYPE E)

Type E has the largest EMF output of any common thermocouple and is sometimes used in thermal-generators (thermopiles). It is used up to 900°C and has good stability from the cryogenic range up to 300°C. The positive arm of the couple is Thermothal P, the same as type K thermocouple, the negative arm is Cuprothal (EN).



STANDARD EMF AGAINST PT 67, REFERENCE JUNCTION °C

TEMPERATURE °C	EMF, mV	
	THERMOTHAL™ P (EP) LEG (POSITIVE),	CUPROTHAL® (EN) LEG (NEGATIVE)
0	0.000	0.000
100	2.814	3.505
200	5.970	7.457
300	9.323	11.713
400	12.764	16.182
500	16.214	20.792
600	19.618	25.475
700	22.951	30.161
800	26.205	34.812
900	29.386	39.401

Labels used to identify Thermothal P (EP) and Cuprothal (EN).

THERMOTHAL P (EP)/CUPROTHAL (EN) EMF REFERENCE TABLE (MV), REFERENCE JUNCTION 0°C

°C	0	10	20	30	40	50	60	70	80	90	100
0	0.000	0.591	1.192	1.801	2.420	3.048	3.685	4.330	4.985	5.648	6.319
100	6.319	6.998	7.685	8.379	9.081	9.789	10.504	11.224	11.951	12.684	13.421
200	13.421	14.164	14.912	15.664	16.420	17.181	17.945	18.713	19.484	20.257	21.036
300	21.036	21.817	22.600	23.386	24.174	24.964	25.757	26.552	27.348	28.146	28.946
400	28.946	29.747	30.550	31.354	32.159	32.965	33.772	34.579	35.388	36.196	37.005
500	37.005	37.815	38.624	39.434	40.244	41.053	41.862	42.671	43.479	44.286	45.093
600	45.093	45.900	46.705	47.510	48.313	49.116	49.917	50.718	51.517	52.315	53.112
700	53.112	53.908	54.703	55.497	56.289	57.080	57.870	58.659	59.446	60.232	61.017
800	61.017	61.801	62.583	63.364	64.144	64.922	65.698	66.473	67.246	68.017	68.787
900	68.787	69.554	70.319	71.083	71.844	72.603	73.360	74.115	74.869	75.621	76.373

THERMOCOUPLE COPPER/CUPROTHAL (TN) (TYPE T)

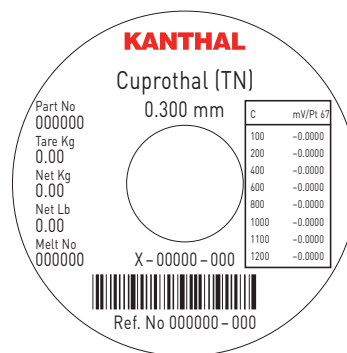
The combination of copper (as a positive element) and Cuprothal (TN) (as a negative element) gives rise to a thermocouple that finds use both in the laboratory and in industry over the temperature range -185°C to +370°C. It is advisable not to go beyond this temperature because of the limited resistance of copper to oxidation. Normally we only supply the negative element (Cuprothal (TN)) since any good, pure electrolytic copper (e.g. conforming to ASTM Standard B3) is sufficiently uniform and constant in EMF from one batch to another, especially at temperatures above -185°C.

It should be remembered that the negative element of the Thermothal P(EP)-Cuprothal (EN) and copper-Cuprothal (TN) do not give the same EMF output as Iron (JP)-Cuprothal (JN) and for this reason Cuprothal (EN) and Cuprothal (TN) are not interchangeable with Cuprothal (JN).

The EMF-temperature characteristics of copper/Cuprothal (TN) thermocouples are listed below. If material is required for use at sub zero temperatures it is essential to state this at the time of ordering as a special quality of Cuprothal has to be selected.

STANDARD EMF AGAINST PT 67, REFERENCE JUNCTION °C

TEMPERATURE °C	EMF, mV	
	COPPER LEG (POSITIVE),	CUPROTHAL® (TN) LEG (NEGATIVE)
-200	-0.195	-5.408
-100	-0.369	-3.010
0	0	0
100	0.773	3.505
200	1.837	7.451
300	3.149	11.713
400	4.690	16.182



Label used to identify Cuprothal (TN).

COPPER - CUPROTHAL (TN) EMF REFERENCE TABLE (MV), REFERENCE JUNCTION 0°C

°C	0	10	20	30	40	50	60	70	80	90	100
-200	-5.603	-5.439	-5.261	-5.070	-4.865	-4.648	-4.419	-4.177	-3.923	-3.657	-3.379
-100	-3.379	-3.089	-2.788	-2.476	-2.153	-1.819	-1.475	-1.121	-0.757	-0.383	0.000
0	0.000	0.391	0.789	1.196	1.612	2.036	2.468	2.909	3.358	3.814	4.279
100	4.279	4.750	5.228	5.714	6.206	6.704	7.209	7.720	8.235	8.760	9.288
200	9.288	9.822	10.362	10.908	11.458	12.013	12.574	13.139	13.709	14.283	14.862
300	14.862	15.445	16.032	16.624	17.219	17.819	18.422	19.030	19.641	20.255	20.872

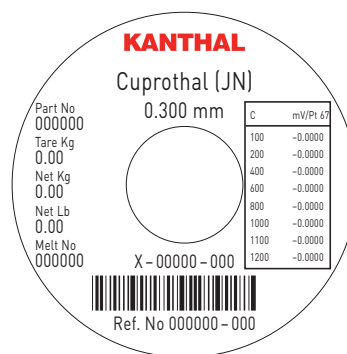
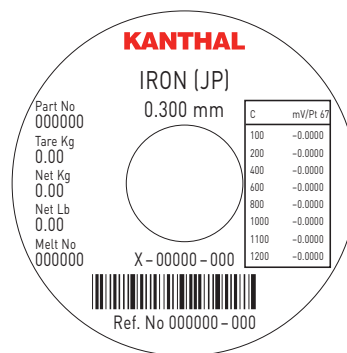
THERMOCOUPLE IRON (JP)/ CUPROTHAL® (JN) (TYPE J)

This thermocouple is frequently used because of its high EMF and its low cost. It can be used in oxidizing conditions up to 760°C or reducing conditions up to 900°C approx. We recommend the use of larger wire diameters with higher temperatures. It has also to be taken into consideration that a magnetic transformation occurs in the Iron at 770°C and a crystallographic change at 900°C. This affects the thermoelectric characteristics of Iron quite markedly.

Type J thermocouples must not be used in sulphurous atmospheres above 500°C and, due to embrittlement, they are not recommended at temperatures below zero.

Only a small amount of the world production of iron wire is allocated for use in thermocouples and the producers of iron are therefore not interested in controlling melts to an EMF value.

Therefore, on the basis of the iron available, it is necessary to select suitable melts of Cuprothal that, coupled to the iron, follow the standardization curves with the respective tolerances. Sandvik supplies the special iron for J thermocouples. It should be remembered that Cuprothal (JN) is not interchangeable with Cuprothal (TN) and with Cuprothal (EN), nor can it be used with other kinds of iron.



Labels used to identify Iron (JP) and Cuprothal (JN).

IRON (JP)/CUPROTHAL (JN) EMF REFERENCE TABLE (MV), REFERENCE JUNCTION 0°C

°C	0	10	20	30	40	50	60	70	80	90	100
0	0.000	0.507	1.019	1.537	2.059	2.585	3.116	3.650	4.187	4.727	5.269
100	5.269	5.814	6.360	6.909	7.459	8.010	8.562	9.115	9.669	10.224	10.779
200	10.779	11.334	11.889	12.445	13.000	13.555	14.110	14.665	15.219	15.773	16.327
300	16.327	16.881	17.434	17.986	18.539	19.091	19.642	20.194	20.745	21.297	21.848
400	21.848	22.400	22.952	23.504	24.057	24.610	25.164	25.720	26.276	26.834	27.393
500	27.393	27.953	28.516	29.080	29.647	30.216	30.788	31.362	31.939	32.519	33.102
600	33.102	33.689	34.279	34.873	35.470	36.071	36.675	37.284	37.896	38.512	39.132
700	39.132	39.755	40.382	41.012	41.645	42.281	42.919	43.559	44.203	44.848	45.494
800	45.494	46.141	46.786	47.431	48.074	48.715	49.353	49.989	50.622	51.251	51.877

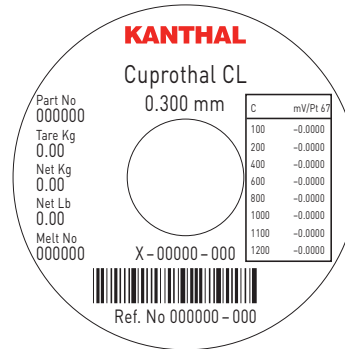
On request, Sandvik can supply Cuprothal (LN) that, combined with Iron (LP), meets the old German standard DIN 43710 for type L thermocouples.

CUPROTHAL CL

Cuprothal CL has a very high EMF value against Pt 67, the highest among the different types of Cuprothal. This property comes from the low content of additional elements in its chemical composition. On the contrary, in the other types of Cuprothal, some additions are necessary to meet the EMF values requested by the standards. Due to this characteristic of having a high thermoelectric output, Cuprothal CL is used mostly in the manufacture of thermocouples to detect the presence of the flame in gas burners, connected to safety devices.

DELIVERY FORM

The wire is normally supplied in coils, in the half-hard condition, with a tensile strength ranging between 600 and 800 MPa.



Labels used to identify Cuprothal CL.

CUPROTHAL CL – EMF MINIMUM VALUES (MV) AGAINST PT 67, REFERENCE JUNCTION AT 0°C

TEMPERATURE, °C	EMF MIN., MV
0	0
100	-4.00
200	-8.62
800	-38.68

EMF testing must be carried out on annealed material

EMF TOLERANCES

Unless otherwise specified thermocouples, compensating and extension materials are supplied to “standard” tolerances.

On request, material can be supplied with special tolerances. Each spool and coil has been calibrated in a temperature range between 0°C and the maximum

temperature value indicated for each alloy combination (max. temperature 1000°C, 1100°C and 1200°C on request).

Standard and special tolerances are detailed in the tables below.

AMERICAN STANDARDS ASTM E 230- ANSI MC 96.1

TYPE OF THERMOCOUPLE	TEMPERATURE RANGE, °C	TOLERANCE		
		STANDARD	SPECIAL	STANDARD
Thermothal™ P (KP)/Thermothal N (KN) (Type K)	from 0 to 1250	±2.2°C or ±0.75%	–	–
Thermothal P (EP)/Cuprothal® (EN) (Type E)	from 0 to 900	±1.7°C or ±0.5%	–	–
Copper/Cuprothal (TN) (Type T)	from 0 to 350	±1°C or ±0.75%	–	–
Iron (JP)/Cuprothal (JN) (Type J)	from 0 to 750	±2.2°C or ±0.75%	–	–
Nicrosil (NP)/Nisil (NN) (Type N)	from 0 to 1300	±2.2°C or ±0.75%	–	–
Thermothal P (KP)/Thermothal N (KN) (Type K)	from 0 to 1250	–	±1.1°C or ±0.40%	–
Thermothal P (EP)/Cuprothal (EN) (Type E)	from 0 to 900	–	±1°C or ±0.40%	–
Copper/Cuprothal (TN) (Type T)	from 0 to 350	–	±0.5°C or ±0.40%	–
Iron (JP)/Cuprothal (JN) (Type J)	from 0 to 750	–	±1.1°C or ±0.40%	–
Nicrosil (NP)/Nisil (NN) (Type N)	from 0 to 1300	–	±1.1°C or ±0.40%	–
Thermothal P (KP)/Thermothal N (KN) (Type K)	from -200 to 0	–	–	±2.2°C or ±2%
Thermothal P (EP)/Cuprothal (EN) (Type E)	from -200 to 0	–	–	±1.7°C or ±1%
Copper/Cuprothal (TN) (Type T)	from -200 to 0	–	–	±1°C or ±1.5%

Tolerance is whichever is the greater value

As can be seen, different tolerances are applied in the temperature range below 0°C. If the material has to be used below 0°C, this must be requested at the time of ordering, as special material has to be selected.

EUROPEAN STANDARDS IEC 584-2 (DIN EN 60584-2; BS EN 60584-2; JIS C 1602)

TYPE OF THERMOCOUPLE	TEMPERATURE RANGE, °C	TOLERANCE		
		CLASS 1	CLASS 2	CLASS 3
Thermothal P™ (KP)/Thermothal N (KN) (Type K)	from - 40 to 1000	± 1.5°C or ± 0.40%	-	-
Thermothal P (EP)/Cuprothal® (EN) (Type E)	from - 40 to 800	± 1.5°C or ± 0.40%	-	-
Copper/Cuprothal (TN) (Type T)	from - 40 to 350	± 0.5°C or ± 0.40%	-	-
Iron (JP)/Cuprothal (JN) (Type J)	from - 40 to 750	± 1.5°C or ± 0.40%	-	-
Nicrosil (NP)/Nisil (NN) (Type N)	from - 40 to 1000	± 1.5°C or ± 0.40%	-	-
Thermothal P (KP)/Thermothal N (KN) (Type K)	from - 40 to 1200	-	± 2.5°C or ± 0.75%	-
Thermothal P (EP)/Cuprothal (EN) (Type E)	from - 40 to 900	-	± 2.5°C or ± 0.75%	-
Copper/Cuprothal (TN) (Type T)	from - 40 to 350	-	± 1°C or ± 0.75%	-
Iron (JP)/Cuprothal (JN) (Type J)	from - 40 to 750	-	± 2.5°C or ± 0.75%	-
Nicrosil (NP)/Nisil (NN) (Type N)	from - 40 to 1200	-	± 2.5°C or ± 0.75%	-
Thermothal P (KP)/Thermothal N (KN) (Type K)	from - 40 to + 40	-	-	± 2.5°C or ± 1.5%
Thermothal P (EP)/Cuprothal (EN) (Type E)	from - 40 to + 40	-	-	± 2.5°C or ± 1.5%
Copper/Cuprothal (TN) (Type T)	from - 40 to + 40	-	-	± 1°C or ± 1.5%
Nicrosil (NP)/Nisil (NN) (Type N)	from - 200 to + 40	-	-	± 2.5°C or ± 1.5%

Tolerance is whichever is the greater value

FRENCH STANDARD NF EN 60584-2

TYPE OF THERMOCOUPLE	TEMPERATURE RANGE, °C	TOLERANCE		
		CLASS 1	CLASS 2	CLASS 3
Thermothal™ P (KP)/Thermothal N (KN) (Type K)	from -40 to 1000	±1.5°C or ±0.40%	-	-
Thermothal P (EP)/Cuprothal® (EN) (Type E)	from -40 to 800	±1.5°C or ±0.40%	-	-
Copper/Cuprothal (TN) (Type T)	from -40 to 350	±1.5°C or ±0.40%	-	-
Iron (JP)/Cuprothal (JN) (Type J)	from -40 to 750	±0.5°C or ±0.40%	-	-
Nicrosil (NP)/Nisil (NN) (Type N)	from -40 to 1000	±1.5°C or ±0.40%	-	-
Thermothal P (KP)/Thermothal N (KN) (Type K)	from -40 to 1200	-	±2.5°C or ±0.75%	-
Thermothal P (EP)/Cuprothal (EN) (Type E)	from -40 to 900	-	±2.5°C or ±0.75%	-
Copper/Cuprothal (TN) (Type T)	from -40 to 750	-	±2.5°C or ±0.75%	-
Iron (JP)/Cuprothal (JN) (Type J)	from -40 to 350	-	±1°C or ±0.75%	-
Nicrosil (NP)/Nisil (NN) (Type N)	from -40 to 1200	-	±2.5°C or ±0.75%	-
Thermothal P (KP)/Thermothal N (KN) (Type K)	from -200 to +40	-	-	±2.5°C or ±1.5%
Thermothal P (EP)/Cuprothal (EN) (Type E)	from -200 to +40	-	-	±2.5°C or ±1.5%
Copper/Cuprothal (TN) (Type T)	from -200 to +40	-	-	±1°C or ±1.5%
Nicrosil (NP)/Nisil (NN) (Type N)	from -200 to +40	-	-	±2.5°C or ±1.5%

Tolerance is whichever is the greater value

Note:

Thermocouple materials are normally supplied to meet the tolerances specified in the table for temperatures above -40°C. These materials, however, may not fall within the tolerances given for low temperatures under class 3 for types T, E, K and N.

If thermocouples are required to meet the limits of class 3, as well as those of class 1 or 2, the purchaser needs to state this, as selection of materials is usually required.

FORMATION OF THE HOT JUNCTION

To form the hot junction, a suitable method has to be adopted to obtain a good electrical contact between the thermocouple wires.

At low temperatures, where generally copper/Cuprothal® (TN) couples are used, soft or silver soldering can be adopted.

For Thermothal™ P/Thermothal N and other combinations, for use in high temperature measurements, welding is the only method to obtain a suitable joint.

For this purpose oxyacetylene welding is mostly used, but arc welding also gives good results.

OXYACETYLENE AND GAS WELDING

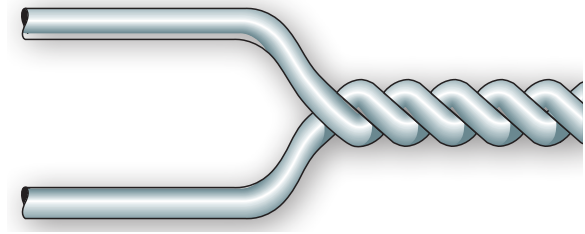
The wire ends have to be cleaned by filing or grinding and twisted together with two or three turns as shown in the picture below.

This procedure provides a good contact during welding and prevents any tension in the welded joint. The wires are held vertically in a vice and the flame positioned downwards on to the twisted wires for welding.

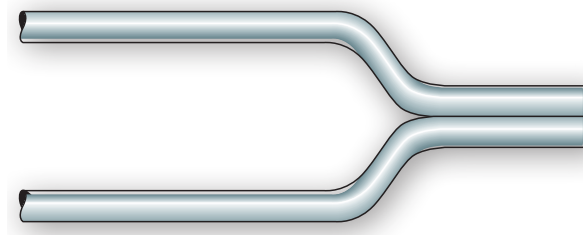
A good weld is formed by a small drop fusing the wires together at the twisted end. The size of the gas flame must be altered depending upon the wire diameter and it is necessary to use a neutral or reducing flame. Overheating should be avoided as this may cause embrittlement of the wires.

With experience, satisfactory welding can be achieved without the use of a flux but if difficulty occurs then borax can be used. Remember that it should be totally cleaned from the metal after the weld has cooled down.

Rewelding is difficult. If the weld is inadequate it is usually necessary to cut the wires and start a new weld.



Twisted wire ends.



Wire ends held in contact.

ARC WELDING

The wires are cleaned and twisted as in gas welding and are then held in a vice which is connected to a +VE arm of a d.c. supply. A carbon electrode as the -VE leg is then touched on the twisted wires just sufficiently to create an arc and weld the wires at the end. The required voltage depends upon the wire diameter but for 3.2 mm diameter a voltage of about 40 V is required. No flux is required in this type of welding.

When the carbon electrode is replaced by a Tungsten electrode, we have a TIG (Tungsten Inert Gas) weld which is also very common for welding thermocouple materials. In this case, a stream of inert gas is blown on to the welding joint to provide full protection against air contamination.

DISCHARGE CAPACITY WELDING

This method of welding is adopted for small diameter wires (up to 0.8 mm).

The ends of the thermoelement have to be cleaned with emery paper and the wires are held in contact as shown in picture below.

THERMOCOUPLE COMPENSATING AND EXTENSION GRADE ALLOYS

When connecting thermocouples to instruments, it is essential that a cable is used which has the same EMF output as the thermocouple, otherwise spurious EMF is generated at these junctions. The best solution is to use the same material as the thermocouple (extension cable). The tolerances for these are listed in the following tables.

A cheaper alternative is to use compensating cables, the alloys of which are different from those of the thermocouple but have the same output over a limited temperature range.

An example of this is in the use of copper/Cuprothal® (VNX) type KCB (VX) cable for use with Thermothal™ P/ Thermothal N (type K) thermocouples.

Our Cuprothal SX alloy (RCA-SCA, RCB-SCB, SNX-RNX) is used with copper for the compensation of Pt/PtRh thermocouples (S & R).

Compensating and extension grades of wire are supplied in the bright annealed condition.

The following is a list of the principal Kanthal® compensating and extension cables.

AMERICAN STANDARD ANSI MC 96-1

TYPE OF THERMOCOUPLE	COMPENSATING OR EXTENSION CABLES	NOMINAL COMPOSITION OF THE CABLES	AMERICAN STANDARD ANSI MC 96-1			
			MV	AT TEMP °C.	TOLERANCE	
					STANDARD	SPECIAL
Thermothal™ P (KP)/ Thermothal N (KN) (Type K)	Thermothal P (KPX)/ Thermothal N (KNX) (KX)	Thermothal P (KPX): 90% Ni - 10% Cr Thermothal N (KNX): 95% Ni + Al-Mn-Si	4.096 8.139	100 200	±2.2°C from 0°C to 200°C	
Thermothal P (KP)/ Thermothal N (KN) (Type K)	Copper/ Cuprothal® (VNX) (VX)*	Copper: 100% Cu Cuprothal (VNX): 44% Ni-balance Cu	4.096 -	100	±2.2° from 0°C to 100°C	
Thermothal P (EP)/ Cuprothal (EN) (Type E)	Thermothal P (EPX)/ Cuprothal (ENX) (EX)	Thermothal P (EPX): 90% Ni-10% Cr Thermothal N (KNX): 95% Ni M+Al-Mn-Si balance Cu	6.319 13.421	100 200	±1.7°C from 0°C to 200°C	
Copper/ Cuprothal (TN) (Type T)	Copper/ Cuprothal (TNX) (TX)	Copper: 100% Cu Cuprothal (TNX): 44% Ni-balance Cu	4.279	100	±1°C from 0°C to 100°C	±0.5°C from 0°C to 100°C
Iron (JP)/ Cuprothal (JN) (Type J)	Iron (JPX)/ Cuprothal (JNX) (JX)	Iron (JPX): 100% Fe Cuprothal (JNX): 44% Ni-balance Cu	5.269 10.779	100 200	±2.2°C from 0°C to 200°C	±1.1°C from 0°C to 200°C
Pt/Pt 10% Rh Pt/Pt 13% Rh (Type S, R)	Copper/ Cuprothal SX (SX) (RX)	Copper: 100% Cu Cuprothal SX: 3% Ni-Mn-balance Cu	0.646 1.441	100 200	±0.057 mV from 0°C to 200°C	
Nicrosil (NP)/ Nisil (NN) (Type N)	Nicrosil (NPX)/ Nisil (NNX) (NX)	Nicrosil (NPX): 84% Ni - 14.2% Cr - Si Nisil (NNX): 95% Ni - 4.3% Si	2.774 5.913	100 200	±2.2°C from 0°C to 200°C	

*Type VX is not included in the recent American standard but it is still used

EUROPEAN STANDARD IEC 584-3 (DIN EN 60584-3; BS 4937; NFC 42324)

TYPE OF THERMOCOUPLE	COMPENSATING OR EXTENSION CABLES	NOMINAL COMPOSITION OF THE CABLES	EUROPEAN STANDARD IEC 584-3			
			MV	AT TEMP °C.	TOLERANCE	
					STANDARD	SPECIAL
Thermothal™ P (KP)/ Thermothal N (KN) (Type K)	Thermothal P (KPX)/ Thermothal N (KNX) (KX)	Thermothal P (KPX): 90%Ni - 10%Cr Thermothal N (KNX): 95%Ni + Al-Mn-Si	4.096 8.139	100 200	±2.5°C from -25°C to 200°C	±1.5°C from -25°C to 200°C
Thermothal P (KP)/ Thermothal N (KN) (Type K)	Iron (WPX)/ Cuprothal® (WX) (WNX) (KCA)	Iron (WPX): 100% Fe Cuprothal WX (WNX): 43%Ni - 2% Mn 2%Fe - balance Cu	4.096 8.139	100 200	±2.5°C from 0°C to 150°C	
Thermothal P (KP)/ Thermothal N (KN) (Type K)	Copper/ Cuprothal (VNX) (KCB)	Copper: 100% Cu Cuprothal (VNX): 44% Ni-balance Cu	4.096 -	100	±2.2°C from 0°C to 100°C	
Thermothal P (EP)/ Cuprothal (EN) (Type E)	Thermothal P (EPX)/ Cuprothal (ENX) (EX)	Thermothal P (EPX): 90%Ni-10%Cr Cuprothal (ENX): 44%Ni-balance Cu	6.319 13.421	100 200	±2.5°C from -25°C to 200°C	±1.5°C from -25°C to 200°C
Copper/ Cuprothal (TN) (Type T)	Copper/ Cuprothal (TNX) (TX)	Copper: 100% Cu Cuprothal (TNX): 44% Ni-balance Cu	4.279 -	100	±1°C from -25°C to 100°C	±0.5°C from -25°C to 100°C
Iron (JP)/ Cuprothal (JN) (Type J)	Iron (JPX)/ Cuprothal (JNX) (JX)	Iron (JPX): 100% Fe Cuprothal (JNX): 44% Ni-balance Cu	5.269 10.779	100 200	±2.5°C from -25°C to 200°C	±1.5°C from -25°C to 200°C
Pt/Pt 10% Rh Pt/Pt 13% Rh (Type S, R)	Copper/ Cuprothal SX RCA- SCA RCB-SCB	Copper: 100% Cu Cuprothal SX: 3% Ni-Mn-balance Cu	- - 0.646 - - 0.646 1.441	- - 100 - - 100 200	±2.5°C from 0°C to 100°C ±5°C from 0°C to 200°C	
Nicosil (NP)/ Nisil (NN) (Type N)	Nicosil (NPX)/ Nisil (NNX) (NX)	Nicosil (NPX): 84%Ni - 14.2%Cr - Si Nisil (NNX): 95%Ni - 4.3%Si	2.774 5.913	100 200	±2.5°C from -25°C to 200°C	±1.5°C from -25°C to 200°C

JAPANESE STANDARD JIS C 1610

TYPE OF THERMOCOUPLE	COMPENSATING OR EXTENSION CABLES	NOMINAL COMPOSITION OF THE CABLES	JAPANESE STANDARD JIS C 1610			
			MV	AT TEMP °C.	TOLERANCE	
					CLASS 2	CLASS 1
Thermothal P™ (KP)/ Thermothal N (KN) (Type K)	Thermothal P (KPX)/ Thermothal N (KNX) (KX)	Thermothal P (KPX): 90%Ni - 10%Cr Thermothal N (KNX): 95%Ni + Al-Mn-Si	4.096 8.139	100 200	± 100 mV from -25°C to 200°C	± 60 mV from -25°C to 200°C
Thermothal P (KP)/ Thermothal N (KN) (Type K)	Iron (WPX)/ Cuprothal® (WX) (WNX) (KCA)	Iron (WPX): 100% Fe Cuprothal WX (WNX): 43%Ni - 2% Mn 2%Fe - balance Cu	4.096 8.139	100 200	± 100 mV from 0°C to 150°C	
Thermothal P (KP)/ Thermothal N (KN) (Type K)	Copper/ Cuprothal (VNX) (KCB)	Copper: 100% Cu Cuprothal (VNX): 44% Ni-balance Cu	4.096 -	100	± 100 mV from 0°C to 100°C	
Thermothal P (EP)/ Cuprothal (EN) (Type E)	Thermothal P (EPX)/ Cuprothal (ENX) (EX)	Thermothal P (EPX): 90%Ni-10%Cr Cuprothal (ENX): 44%Ni-balance Cu	6.319 13.421	100 200	±200 mV from -25°C to 200°C	± 120 mV from -25°C to 200°C
Copper/ Cuprothal (TN) (Type T)	Copper/ Cuprothal (TNX) (TX)	Copper: 100% Cu Cuprothal (TNX): 44% Ni-balance Cu	4.279 -	100	± 160 mV from -25°C to 100°C	± 30 mV from -25°C to 100°C
Iron (JP)/ Cuprothal (JN) (Type J)	Iron (JPX)/ Cuprothal (JNX) (JX)	Iron (JPX): 100% Fe Cuprothal (JNX): 44%Ni-balance Cu	5.269 10.779	100 200	± 140 mV from -25°C to 200°C	± 185 mV from -25°C to 200°C
Pt/Pt 10%Rh Pt/Pt 13%Rh (Type S, R)	Copper/ Cuprothal SX RCA-SCA RCB-SCB	Copper: 100% Cu Cuprothal SX: 3% Ni-Mn-balance Cu	- - 0.646 - - 0.646 1.441	- - 100 - - 100 200	±30 mV from 0°C to 100°C ±60 mV from 0°C to 200°C	
Nicrosil (NP)/ Nisil (NN) (Type N)	Nicrosil (NPX)/ Nisil (NNX) (NX)	Nicrosil (NPX): 84%Ni - 14.2%Cr - Si Nisil (NNX): 95%Ni - 4.3%Si	2.774 5.913	100 200	± 200 mV from -25°C to 200°C	± 60 mV from -25°C to 200°C

TABLES

THERMOTHAL™ P WIRE

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	8.62	116.0	8	4.064	8.84	113.1
7	3.658	10.91	91.64	9	3.658	10.91	91.64
8	3.251	13.82	72.38	10	3.251	13.82	72.38
10	2.591	21.75	45.98	12	2.642	20.92	47.80
12	2.057	34.51	28.98	14	2.032	35.36	28.28
14	1.626	55.23	18.11	16	1.626	55.23	18.11
16	1.295	87.07	11.49	18	1.219	98.26	10.18
18	1.016	141	7.07	19	1.016	141	7.07
20	0.813	221	4.53	20	0.914	175	5.72
22	0.643	353	2.83	21	0.813	221	4.53
24	0.511	559	1.79	22	0.711	289	3.46
25	0.455	705	1.418	24	0.559	467	2.14
26	0.404	895	1.12	26	0.457	699	1.43
28	0.320	1426	0.70	30	0.315	1472	0.68
32	0.203	3543	0.28	34	0.234	2667	0.38
36	0.127	9053	0.11	36	0.193	3920	0.26

THERMOTHAL P WIRE

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.46	684.9	1.20	101	9.86
8.00	2.28	438.3	1.15	110	9.06
7.00	2.98	335.6	1.13	114	8.75
6.00	4.06	246.6	1.00	146	6.85
4.70	6.61	151.3	0.81	223	4.49
4.00	9.13	109.6	0.64	356	2.81
3.90	9.60	104.2	0.63	368	2.72
3.26	13.74	72.8	0.60	406	2.47
3.20	14.26	70.1	0.51	561	1.78
3.00	16.22	61.6	0.50	584	1.71
2.50	23.36	42.8	0.45	721	1.39
2.30	27.60	36.2	0.40	913	1.10
2.05	34.74	28.8	0.32	1426	0.70
2.00	36.50	27.4	0.30	1622	0.62
1.63	54.96	18.2	0.25	2336	0.43
1.50	64.89	15.4	0.20	3650	0.27
1.40	74.50	13.41	0.18	4507	0.22
1.29	87.74	11.41	0.10	14601	0.07

THERMOTHAL N WIRE

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	8.7	114.4	8	4.064	8.96	111.6
7	3.658	11.1	90.3	9	3.658	11.06	90.38
8	3.251	14.0	71.3	10	3.251	14.01	71.39
10	2.591	22.1	45.34	12	2.642	21.21	47.15
12	2.057	35.0	28.58	14	2.032	35.86	27.89
14	1.626	56.0	17.86	16	1.626	56.00	17.86
16	1.295	88.3	11.33	18	1.219	99.63	10.04
18	1.016	143	6.97	19	1.016	143	6.97
20	0.813	224	4.46	20	0.914	177	5.64
22	0.643	353	2.79	21	0.813	224	4.46
24	0.511	567	1.76	22	0.711	293	3.41
25	0.455	715	1.36	24	0.559	474	2.11
26	0.404	907	1.10	26	0.457	709	1.41
28	0.320	1446	0.69	30	0.315	1492	0.67
32	0.203	3593	0.28	34	0.234	2704	0.37
36	0.127	9179	0.11	36	0.193	3975	0.25

THERMOTHAL N WIRE

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.48	675.4	1.20	103	9.73
8.00	2.31	432.3	1.15	112	8.93
7.00	3.02	331.0	1.13	116	8.62
6.00	4.11	243.2	1.00	148	6.75
4.70	6.70	149.2	0.81	226	4.43
4.00	9.25	108.1	0.64	361	2.77
3.90	9.73	102.7	0.63	373	2.68
3.26	13.93	71.78	0.60	411	2.43
3.20	14.46	69.17	0.51	569	1.76
3.00	16.45	60.79	0.50	592	1.69
2.50	23.69	42.22	0.45	731	1.37
2.30	27.99	35.73	0.40	925	1.08
2.05	35.23	28.39	0.32	1446	0.69
2.00	37.01	27.02	0.30	1645	0.61
1.63	55.72	17.95	0.25	2369	0.42
1.50	65.80	15.20	0.20	3701	0.27
1.40	75.54	13.24	0.18	4569	0.22
1.29	88.97	11.24	0.10	14805	

CUPROTHAL® (EN), CUPROTHAL (JN), CUPROTHAL (TN), CUPROTHAL WX WIRES

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	8.4	118.4	8	4.064	8.66	115.4
7	3.658	10.7	93.53	9	3.658	10.69	93.53
8	3.251	13.5	73.88	10	3.251	13.54	73.88
10	2.591	21.3	46.93	12	2.642	20.50	48.79
12	2.057	33.8	29.58	14	2.032	34.65	28.86
14	1.626	54.1	18.48	16	1.626	54.11	18.48
16	1.295	85.3	11.72	18	1.219	96.27	10.39
18	1.016	139	7.22	19	1.016	138.6	7.22
20	0.813	216	4.62	20	0.914	171.2	5.84
22	0.643	346	2.89	21	0.813	216.4	4.62
24	0.511	548	1.83	22	0.711	283.0	3.53
25	0.455	691	1.45	24	0.559	457.8	2.18
26	0.404	877	1.14	26	0.457	685	1.46
28	0.320	1397	0.72	30	0.315	1442	0.69
32	0.203	3472	0.29	34	0.234	2613	0.38
36	0.127	8870	0.11	36	0.193	3841	0.26

CUPROTHAL® (EN), CUPROTHAL (JN), CUPROTHAL (TN), CUPROTHAL WX WIRES

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.43	699.0	1.20	99	10.07
8.00	2.24	447.4	1.15	108	9.24
7.00	2.92	342.5	1.13	112	8.93
6.00	3.97	251.6	1.00	143	6.99
4.70	6.48	154.4	0.81	218	4.59
4.00	8.94	111.8	0.64	349	2.86
3.90	9.41	106.3	0.63	360	2.77
3.26	13.46	74.29	0.60	397	2.52
3.20	13.97	71.58	0.51	550	1.82
3.00	15.90	62.91	0.50	572	1.75
2.50	22.89	43.69	0.45	707	1.42
2.30	27.04	36.98	0.40	894	1.12
2.05	34.04	29.38	0.32	1397	0.72
2.00	35.77	27.96	0.30	1590	0.63
1.63	53.84	18.57	0.25	2289	0.44
1.50	63.58	15.73	0.20	3577	0.28
1.40	72.99	13.70	0.18	4415	0.23
1.29	85.97	11.63	0.10	4306	0.07

IRON WIRE

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	9.57	104.51	8	4.064	9.8	102.0
7	3.658	12.11	82.60	9	3.658	12.1	82.60
8	3.251	15.33	65.24	10	3.251	15.3	65.24
10	2.591	24.13	41.44	12	2.642	23.2	43.09
12	2.057	38.28	26.12	14	2.032	39.2	25.49
14	1.626	61.27	16.32	16	1.626	61.3	16.32
16	1.295	96.59	10.35	18	1.219	109	9.17
18	1.016	157	6.37	19	1.016	157	6.37
20	0.813	245	4.08	20	0.914	194	5.16
22	0.643	392	2.55	21	0.813	245	4.08
24	0.511	620	1.61	22	0.711	320	3.12
25	0.455	783	1.28	24	0.559	518	1.93
26	0.404	992	1.01	26	0.457	776	1.29
28	0.320	1582	0.63	30	0.315	1633	0.61
32	0.203	3931	0.25	34	0.234	2958	0.34
36	0.127	10043	0.10	36	0.193	4349	0.23

IRON WIRE

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.62	617.3	1.20	112	8.89
8.00	2.53	395.1	1.15	122	8.16
7.00	3.31	302.5	1.13	127	7.88
6.00	4.50	222.2	1.00	162	6.17
4.70	7.33	136.4	0.81	247	4.05
4.00	10.12	98.77	0.64	395	2.53
3.90	10.65	93.89	0.63	408	2.45
3.26	15.24	65.61	0.60	450	2.22
3.20	15.82	63.21	0.51	623	1.61
3.00	18.00	55.56	0.50	648	1.54
2.50	25.92	38.58	0.45	800	1.25
2.30	30.62	32.66	0.40	1012	0.99
2.05	38.55	25.94	0.32	1582	0.63
2.00	40.50	24.69	0.30	1800	0.56
1.63	60.97	16.40	0.25	2592	0.39
1.50	72.00	13.89	0.20	4050	0.25
1.40	82.65	12.10	0.18	5000	0.20
1.29	97.34	10.27	0.10	16199	0.06

CUPROTHAL® SX WIRE

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	8.4	118.5	8	4.064	8.7	115.6
7	3.658	10.7	93.64	9	3.658	10.7	93.64
8	3.251	13.5	73.96	10	3.251	13.5	73.96
10	2.591	21.3	46.98	12	2.642	20.5	48.85
12	2.057	33.8	29.61	14	2.032	34.6	28.89
14	1.626	54.0	18.50	16	1.626	54.0	18.50
16	1.295	85.2	11.74	18	1.219	96	10.40
18	1.016	138	7.22	19	1.016	138	7.22
20	0.813	216	4.63	20	0.914	171	5.85
22	0.643	346	2.89	21	0.813	216	4.63
24	0.511	547	1.83	22	0.711	283	3.54
25	0.455	690	1.45	24	0.559	457	2.19
26	0.404	876	1.14	26	0.457	684	1.46
28	0.320	1390	0.72	30	0.315	1440	0.69
32	0.203	3468	0.29	34	0.234	2610	0.38
36	0.127	8860	0.11	36	0.193	3836	0.26

CUPROTHAL® SX WIRE

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.43	699.8	1.20	99	10.08
8.00	2.23	447.9	1.15	108	9.25
7.00	2.92	342.9	1.13	112	8.94
6.00	3.97	251.9	1.00	143	7.00
4.70	6.47	154.6	0.81	218	4.59
4.00	8.93	112.0	0.64	349	2.87
3.90	9.40	106.4	0.63	360	2.78
3.26	13.45	74.37	0.60	397	2.52
3.20	13.96	71.66	0.51	549	1.82
3.00	15.88	62.98	0.50	572	1.75
2.50	22.86	43.74	0.45	706	1.42
2.30	27.01	37.02	0.40	893	1.12
2.05	34.00	29.41	0.32	1396	0.72
2.00	35.73	27.99	0.30	1588	0.63
1.63	53.78	18.59	0.25	2286	0.44
1.50	63.51	15.75	0.20	3573	0.28
1.40	72.91	13.72	0.18	4410	0.23
1.29	85.87	11.65	0.10	14290	0.07

NICROSIL WIRE

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	8.8	113.4	8	4.064	9.0	110.6
7	3.658	11.2	89.65	9	3.658	11.2	89.65
8	3.251	14.1	70.81	10	3.251	14.1	70.81
10	2.591	22.2	44.98	12	2.642	21.4	46.76
12	2.057	35.3	28.35	14	2.032	36.2	27.66
14	1.626	56.5	17.71	16	1.626	56.5	17.71
16	1.295	89.0	11.24	18	1.219	100	9.96
18	1.016	145	6.92	19	1.016	145	6.92
20	0.813	226	4.43	20	0.914	179	5.60
22	0.643	361	2.77	21	0.813	226	4.43
24	0.511	572	1.75	22	0.711	295	3.39
25	0.455	721	1.39	24	0.559	478	2.09
26	0.404	915	1.09	26	0.457	715	1.40
28	0.320	1458	0.69	30	0.315	1504	0.66
32	0.203	3622	0.28	34	0.234	2726	0.37
36	0.127	9255	0.11	36	0.193	4007	0.25

NICROSIL WIRE

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.49	669.9	1.20	104	9.65
8.00	2.33	428.8	1.15	113	8.86
7.00	3.05	328.3	1.13	117	8.55
6.00	4.15	241.2	1.00	149	6.70
4.70	6.76	148.0	0.81	228	4.40
4.00	9.33	107.2	0.64	364	2.74
3.90	9.81	101.9	0.63	376	2.66
3.26	14.05	71.20	0.60	415	2.41
3.20	14.58	68.60	0.51	574	1.74
3.00	16.59	60.30	0.50	597	1.67
2.50	23.88	41.87	0.45	737	1.36
2.30	28.22	35.44	0.40	933	1.07
2.05	35.52	28.15	0.32	1458	0.69
2.00	37.32	26.80	0.30	1659	0.60
1.63	56.18	17.80	0.25	2388	0.42
1.50	66.34	15.07	0.20	3732	0.27
1.40	76.16	13.13	0.18	4607	0.22
1.29	89.70	11.15	0.10	14927	0.07

NISIL WIRE

B&S OR AWG				SWG			
B&S OR AWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M	SWG	DIAM., MM	LENGTH, M/KG	WEIGHT, G/M
6	4.115	8.8	114.1	8	4.064	9.0	111.3
7	3.658	11.1	90.17	9	3.658	11.1	90.17
8	3.251	14.0	71.22	10	3.251	14.0	71.22
10	2.591	22.1	45.24	12	2.642	21.3	47.04
12	2.057	35.1	28.51	14	2.032	35.9	27.82
14	1.626	56.1	17.82	16	1.626	56.1	17.82
16	1.295	88.5	11.30	18	1.219	100	10.01
18	1.016	144	6.96	19	1.016	144	6.96
20	0.813	225	4.45	20	0.914	178	5.63
22	0.643	359	2.79	21	0.813	225	4.45
24	0.511	568	1.76	22	0.711	294	3.41
25	0.455	717	1.40	24	0.559	475	2.11
26	0.404	909	1.10	26	0.457	711	1.41
28	0.320	1449	0.69	30	0.315	1496	0.67
32	0.203	3601	0.28	34	0.234	2710	0.37
36	0.127	9201	0.11	36	0.193	3984	0.25

NISIL WIRE

METRIC					
DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M	DIAMETER, MM	LENGTH, M/KG	WEIGHT, G/M
10.00	1.48	673.9	1.20	103	9.70
8.00	2.32	431.3	1.15	112	8.91
7.00	3.03	330.2	1.13	116	8.60
6.00	4.12	242.6	1.00	148	6.74
4.70	6.72	148.9	0.81	226	4.42
4.00	9.27	107.8	0.64	362	2.76
3.90	9.76	102.5	0.63	374	2.67
3.26	13.96	71.62	0.60	412	2.43
3.20	14.49	69.00	0.51	571	1.75
3.00	16.49	60.65	0.50	594	1.68
2.50	23.74	42.12	0.45	733	1.37
2.30	28.05	35.65	0.40	927	1.08
2.05	35.31	28.32	0.32	1449	0.69
2.00	37.10	26.95	0.30	1649	0.61
1.63	55.85	17.90	0.25	2374	0.42
1.50	65.95	15.16	0.20	3710	0.27
1.40	75.71	13.21	0.18	4580	0.22
1.29	89.181	11.21	0.10	14840	0.07

DELIVERY FORMS

PACKAGING

Kanthal® branded materials are normally packed as described to the right. In case, wire can also be specially packed to individual requirements, if possible. If additional protection is required, spools are wrapped with plastic film.

WIRE

Up to approximately 1.40 mm diameter is available on spools as the table shows.

Wire of 1.50 mm and up to 6 mm diameter is supplied in coils with an inner diameter of approx. 500–600 mm. Wire of 2 mm and up to 6 mm can be straightened in half-hard condition, 3 m lengths, if requested. Wire larger than 6 mm and up to 10 mm can be supplied only in oxidized or straightened form. Straight lengths are supplied in bundles.

RIBBON

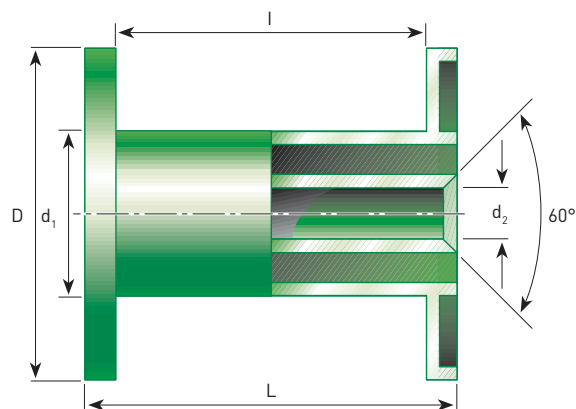
Ribbon is normally supplied on K 125 spools. Sizes of section $\geq 0.3 \text{ mm}^2$ are wound on K 100 spools. If requested, the smallest sizes can be supplied on K 80 spools.

STRIPS

Standard delivery is in coil form.

RODS

Available shaved or un-shaved depending on the alloy.



Spool dimensions.

DIMENSIONS FOR DIFFERENT TYPE OF SPOOLS

SPOOL DESIGNATION	DIAMETER, MM	NOMINAL WIRE WEIGHT, KG	D, MM	D ₁ , MM	D ₂ , MM	L, MM	I, MM	TARE, G
K 500	0.80–1.40	90	500	315	36	250	189	8000
K 355	0.50–1.40	40	355	224	36	200	160	1850
K 250	0.30–1.00	20	250	160	36	200	160	1050
K 200	0.25–0.80	10	200	125	36	200	160	600
K 160	0.20–0.80	6	160	100	22	160	128	350
K 125	0.15–0.80	3	125	80	16	125	100	200
K 100	0.10–0.50	1.5	100	63	16	100	80	125
K 80	0.04–0.15	0.5	80	50	16	80	64	70

TOLERANCES

Unless specified to the contrary, all wire, strip and ribbon are supplied fully annealed with either a bright, matt or oxidized finish. The type of finish should be stated when ordering.

Standard tolerances for wire, straight lengths and strip are given below.

TOLERANCES ON DIMENSIONS OF COLD ROLLED RIBBON

Ribbon is normally specified with a resistance tolerance. If requested, dimension tolerance on width can be applied as in the table below.

TOLERANCES ON NOMINAL LENGTH FOR CUT AND STRAIGHTENED LENGTHS (RODS)

For all diameters, all lengths $-0/+1\%$ on the nominal length.

TOLERANCES ON DIAMETER OF WIRE

WIRE SIZE	MAX DEVIATION FROM NOMINAL VALUE, MM	MAX OVALITY, MM
d	Tol = $\pm 0.015 \cdot \sqrt{d}$	Tol = $\pm 0.015 \cdot \sqrt{d}$

TOLERANCES ON DIAMETER OF STRAIGHT LENGTHS

DIAMETER, MM	TOLERANCE, MM
1.7 to 3	+0/-0.060
3.01 to 6	+0/-0.075
6.01 to 10	+0/-0.09

TOLERANCES ON DIMENSIONS OF COLD ROLLED RIBBON

WIDTH, MM	THICKNESS, MM		
	0.07-0.2	0.2-0.5	0.5-0.8
0.5-1.5	+0.02-0.04	+0.01-0.03	
1.5-2.5	+0.04-0.07	+0.03-0.04	+0.02-0.04
2.5-4.0		± 0.08	+0.12

STANDARD REFRACTORY TUBES

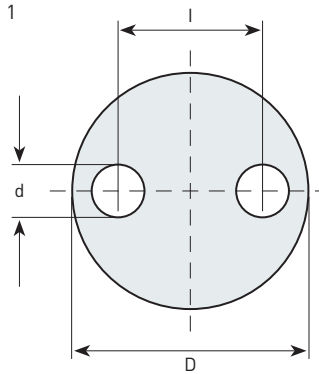
Al ₂ O ₃ %	MAX OPERATING TEMP., °C	ABSORPTION H ₂ O IN % VOLUME	BULK DENSITY KG/DM ³	THERMAL CONDUCTIVITY BETWEEN 20-100°C W/MK	COLD COMPRESSION STRENGTH	SPECIFIC HEAT BETWEEN 100-1000°C J/KGK	FE ₂ O ₃ % CONTENT	THERMAL SHOCK RESISTANCE	STANDARD
44	1250	12-18	1.9	1.28-1.74	300	837	< 1	good	KER 530 DIN 40685
63 plates 80 tubes	1350	12-18	2.2	1.74-2.32	400	837	0.8	good	KER 610 slightly porous
Cordierite	1200	10-15	1.9	1.28-1.63	500	837	< 1	excellent	KER 520

The choice between refractory with standard and high Al₂O₃ content is determined by the wire alloy and by the working temperature.

FIGURE 1 DIMENSIONS

NO.	D	D, MM	I, MM
028	3	0.8	1.3
028	3.5	1	1.6
028	3.8	1.15	1.8
028	4	1	1.8
028	4	1.2	1.8
028	4.5	1.3	2.35
028	5	1.5	2.35
028	5	1.8	2.35
028	6	2	2.8
028	6.5	2	3.2
028	7	2.5	3.2
028	7.5	2	3.6
028	7.5	2.5	3.6
028	8	2.2	3.6
028	8	3	3.6
028	8.5	3	4.1
028	9	3	4.1
028	10	3	4.5
028	12	4	5.4
028	12	4.5	5.4
028	14	4	6.4
028	14	5	6.4
028	16	5	7

Figure 1



Standard lengths: L = 25/50/100 mm, other lengths on request.

FIGURE 2 DIMENSIONS

NO.	D	D, MM	I, MM
029	3	2	1.6
029	4.3	3	1.8
029	12	7	5.5
029	12.7	7.21	5.5
029	15	9	7
029	15	9	7

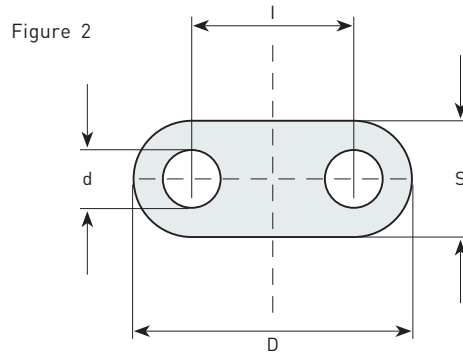


FIGURE 3 DIMENSIONS

NO.	D	D, MM	I, MM	NO. HOLES
030	4	0.8	2.2	4
030	4.5	1	2.5	4
030	6	1.5	3.0	4
030	8.5	2	4.5	4
030	8.5	2.5	4.7	4
030	8.5	1.5	4.25	4
030	9.5	3	5.3	4
030	12	3	6.5	4
030	12	3.5	6.7	4
030	13	4	7.3	4
030	14	4	7.7	4
030	16	5	9	4
030	16	4.5	9.5	4
030	17	5	10	4

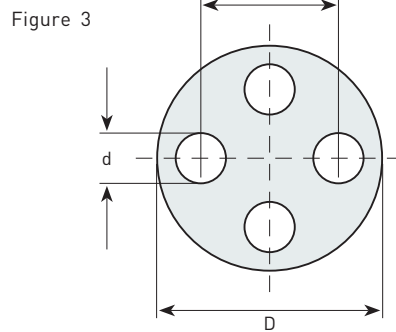


FIGURE 4 DIMENSIONS

NO.	D	D, MM	I, MM	NO. HOLES
030	5.5	1	3.4	6
030	8	1.6	5.1	6
030	10	2.2	6.5	6
030	14	3.5	9	6
030	15	3.5	9.5	6

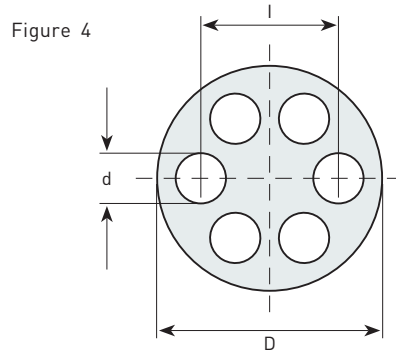
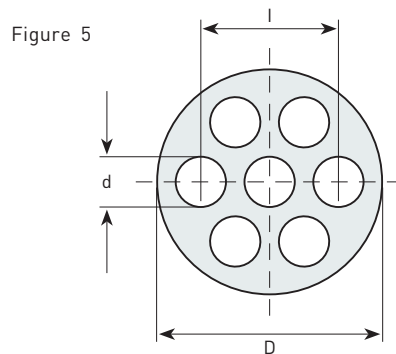


FIGURE 5 DIMENSIONS

NO.	D	D, MM	I, MM	NO. HOLES
030	11.5	2.7	8	7
030	12.4	2.7	8	7
030	13	3	8.5	7
030	14.5	2	9	7
030	16	4	10	7
030	18	4.5	11.5	7



Standard lengths: L = 25/50/100 mm, other lengths on request.

KANTHAL® PROTECTION TUBES

KANTHAL METALLIC PROTECTION TUBES UP TO 1400°C

These metallic protection tubes are manufactured from our high temperature resistance alloy Kanthal AF, 6.0–22.0 mm diameter and Kanthal APM™ 22.0–40.0 mm with maximum operating temperature in air of 1400°C.

The advantages offered by using Kanthal protection tubes for thermocouples are:

- Resistant to temperature which are 150 to 200°C higher than for other types of metallic protection tubes.
- High resistance to attack by sulphur or carbon compounds.
- The high temperature resistance of the material makes it possible to produce tubes with thin walls with a long service life. Thin walls give rapid heat transmission, which means higher sensitivity to temperature variations.
- The aluminum oxide layer on the protection tube has minimal tendency to flake which means that contamination is avoided.

KANTHAL METALLIC PROTECTION TUBES

DIMENSIONS OUTER DIAMETER, MM	WALL THICKNESS, MM	MAX ENPTH, MM
6.0	0.4	6000
15.0	1.3	6000
19.1	1.3	6000
22.0	1.3 or 2.0	6000
26.0	2.9	6000
33.7	3.0 or 6.0	6000
40.0	3.0	6000

Kanthal metallic tubes will be supplied closed in one end and provided threaded at the other end for the connection head. They can also be supplied in standard lengths up to 6 m with both ends open. OD 6–22 mm is welded, 26–40 mm extruded.

KANTHAL® SUPER PROTECTION TUBES UP TO 1700°C

These tubes are made of molybdenum disilicide, as our Kanthal® Super heating elements. Kanthal® Super protection tubes have the following advantages:

- The highest operating temperature is 1700°C.
- Porosity and brittleness are lower than for ceramic protection tubes. The tubes are thus particularly suitable for operating at high temperatures and in corrosive furnace atmospheres.
- Metallic protection tubes can under circumstances be influenced by electromagnetic oscillations which may disturb the function of the thermocouple. Kanthal® Super protection tube suppresses such oscillations.

KANTHAL® SUPER PROTECTION TUBES

DIMENSIONS OUTER DIAMETER, MM	WALL THICKNESS, MM	MAX LENGTH, MM
7.0	2.0	2000
10.0	2.0	2000
12.0	4.5	2000
12.0	3.0	2000
18.0	4.0	2000
22.0	4.5	2000
25.0	5.0	2000
32.0	7.0	1000
50.0	11.0	1000

Kanthal® Super tubes can be supplied with one end closed and also provided with a threaded tube fitting.

Sandvik Group

The Sandvik Group is a global high technology enterprise with 47,000 employees in 130 countries. Sandvik's operations are concentrated on five business areas in which the group holds leading global positions in selected niches: Sandvik Mining, Sandvik Machining Solutions, Sandvik Materials Technology, Sandvik Construction and Sandvik Venture.

Sandvik Materials Technology

Sandvik Materials Technology is a world-leading developer and manufacturer of products in advanced stainless steels and special alloys for the most demanding environments, as well as products and systems for industrial heating.

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Quality management

Sandvik Materials Technology has quality management systems approved by internationally recognized organizations. We hold, for example, the ASME Quality Systems Certificate as a materials organization, approval to ISO 9001, ISO/TS 16949, ISO 17025 and PED 97/23/EC. We also have product and/or shop approvals from bodies such as TÜV, JIS, DNV and Lloyd's Register.

Environment, health and safety

Environmental awareness, health and safety are integral parts of our business and are at the forefront of all activities within our operation. We hold ISO 14001 and OHSAS 18001 approvals.

Recommendations are for guidance only, and the suitability of a material for a specific application can be confirmed only when we know the actual service conditions. Continuous development may necessitate changes in technical data without notice.

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