KANTHAL
Precision Technology
Handbook

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KANTHAL

KANTHAL AB
P O Box 502
SE-734 27 Hallstahammar, Sweden
Telephone: +46 220 210 00
Telefax: +46 220 163 50
www.kanthal.com

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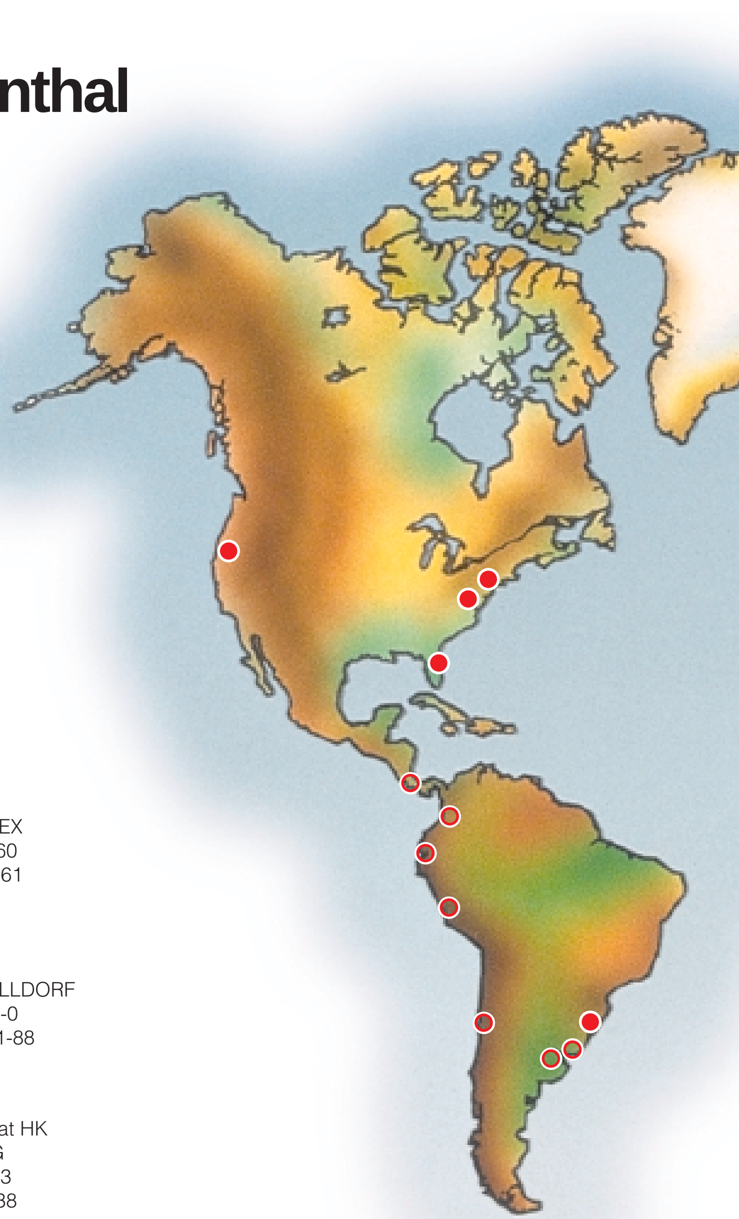

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Kanthal S.A.
COLOMBES-CEDEX
Tel. 33 1 4786 5660
Fax. 33 1 4786 5661

Australia
Kanthal Australia Pty, Ltd
EPPING
Tel. 61 (0)3 9401 1222
Fax. 61 (0)3 9401 3541

Germany
Kanthal GmbH
MÖRFELDEN-WALLDORF
Tel. 49 6105 4001-0
Fax. 49 6105 4001-88

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Kanthal Brasil Ltda
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Tel. 55 (0)11 5525 2611
Fax. 55 (0)11 5525 2670

Hong Kong
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Ltd, HONG KONG
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Fax. 852 2735 7238

Bulgaria
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Tel. 359 (0)2 2 958 1246
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Tel. 45 36 786 600
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Kanthal S.p.A.
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Tel. 39 (0)2 61245 1
Fax. 39 (0)2 61245 350

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Fax. 47 64 843 565

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Tel. 7 095 956 2080
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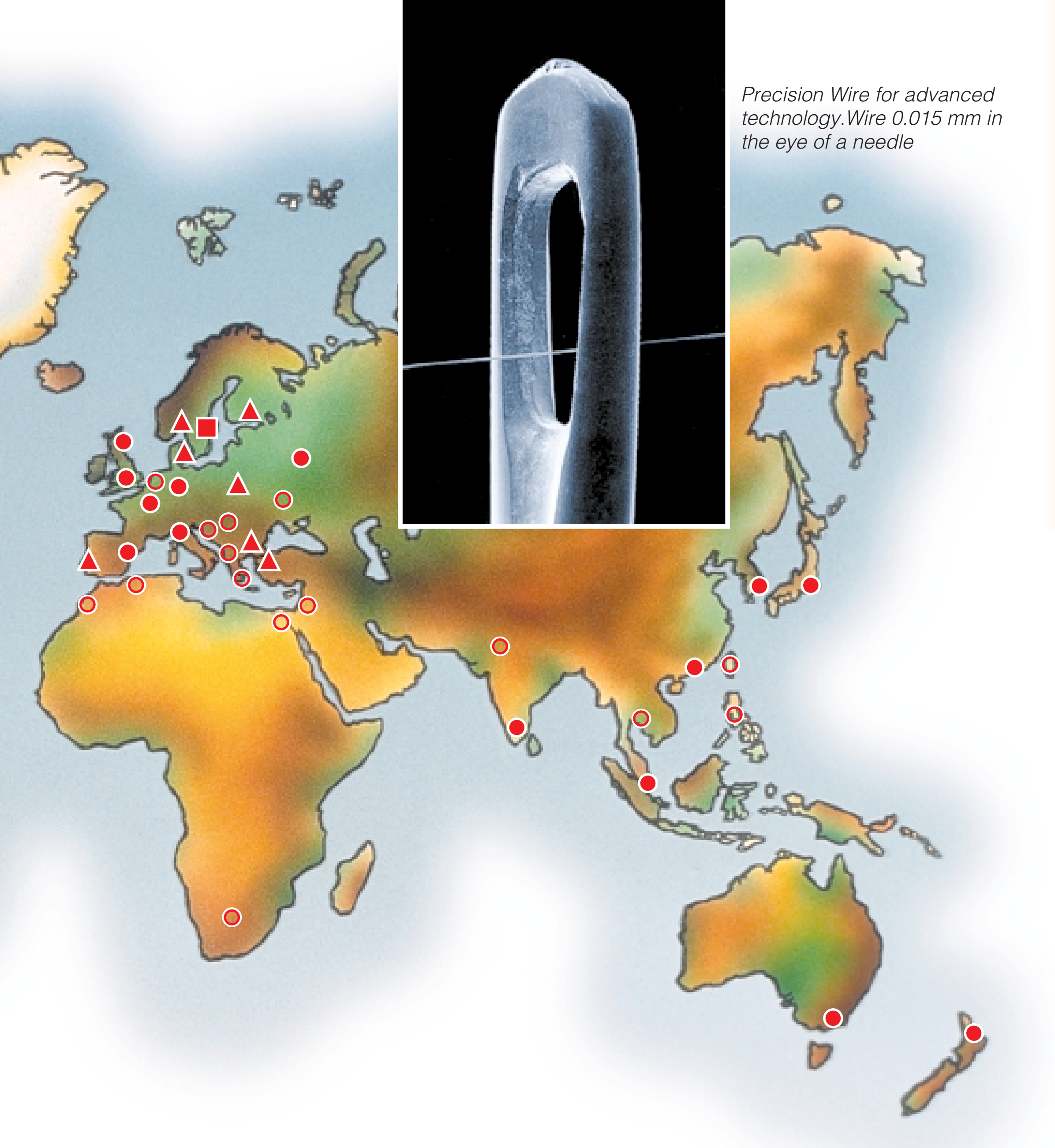

Precision Wire for advanced technology.Wire 0.015 mm in the eye of a needle

Turkey
Kanthal Turkey
ISTANBUL
Tel. 90 216 309 1515
Fax. 90 216 377 6957

South Korea
Kanthal Korea Ltd
SEOUL
Tel. 82 2 761 0432
Fax. 82 2 761 0435

Spain
Kanthal SP, S.A.
MOLINS DE REI
Tel. 34 93 680 2824
Fax. 34 93 680 2966

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Tel. 44 01782 22 48 00
Fax. 44 01782 22 48 20

Kanthal Ltd
PERTH
Tel. 44 01738 493 300
Fax. 44 01738 493 301

United States
Kanthal Bethel
BETHEL, CT
Tel. 1 203 744 1440
Fax. 1 203 743 2547

Kanthal Globar Inc
NIAGARA FALLS, NY
Tel. 1 716 286 7600
Fax. 1 716 286 7602

Kanthal Palm Coast
PALM COAST, FL
Tel. 1 904 445 2000
Fax. 1 904 446 2244

MRL Industries inc
SONORA, CA
Tel. 1 209 533 1990
Fax. 1 209 533 4079

Introduction

Welcome to the fascinating world of Kanthal Precision Technology!

The alloys we offer cover a broad range with different optimized properties on electrical resistivity, temperature coefficient, mechanical properties, corrosion resistance properties or surface treatment.

They can be drawn to any diameter in our manufacturing range down to 0.015 – 0.010 mm *0.0006 – 0.0004 in*. They can also be rolled into ribbon or square wire configurations.

We deliver with the surface treatment needed – Plated, Anodized, Enameled, Coated, Bond Coated or other special surface treatment.

Precision wire is used in a vast range of applications, which normally fall into these categories:

- Alloys for Electrical Resistance
- Conductive Alloys
- Alloys for Medical Applications
- Precious metals
- High Temperature Alloys for Mechanical Applications
- Alloys for Special Applications

However, new applications are added every day as customers find out the versatility of our Precision Technology, and Kanthal Palm Coast has the resources to help in designing and testing customized high quality wire that meet very specific customer needs.

This Handbook will give you information about our product range, technical data and application ideas. Apart from the alloys described here, Kanthal is manufacturing other alloys that also could be produced in the Precision Wire sizes upon request. For information about the complete Kanthal product range, see our home page www.kanthal.com or www.kanthalpalmcoast.com or just contact the nearest Kanthal office.

The cover photo indicates the high technical level of many precision wire applications but also the view from Kanthal Palm Coast, situated a bit north of Cape Kennedy in Florida.

KANTHAL AB

Contents

2 Services and Capabilities

Kanthal Precision Technology offers a broad range of wires in the dimensions between 0.51 – 0.010 mm *0.0201 – 0.0004 in.*

For those applications where commodity grade wire is inadequate in its properties, Kanthal Precision Technology has the capabilities to customize and optimize high quality wire with precision tolerances, specialty coatings or other unique qualities that meet the very specific customer needs.

Our service concept includes the design and development of a complete custom wire or to take advantage of a single step of the engineering process, for instance coating, stranding, plating or enameling of customer supplied wire.

Milling

- Custom rolling mills to manufacture aluminum, copper, copper clad aluminum, precious metals and stainless steel ribbon
- Thickness of 0.025 mm or less are possible
- Aspect ratios as high as 40:1

Electro Plating

- Pure gold (99.99%) may be applied with or without a nickel substrate on most alloys Specialty is ultra-fine gold plated copper (0.2 – 0.7 mm *0.008 - 0.027 in.*)
- Other plating materials are available such as nickel, copper and silver
- Ability to plate square and ribbon wire
- Ability to gold plate stainless steel, nickel and MP35N wire alloys

Anodizing

- Anodizing round or flat aluminum wire to create a very thin high temperature coating – the thinnest possible electrical insulation available for aluminum wire

Enameling

- Wide range of insulating coatings and bonds are available
- Ability to provide a wide range of colored insulations

Engineered Coil Prototyping

- Coil design and development
- Coil winding tooling design
- Winding of prototype coils
- Vacuum and conventional baking

Insulating Coatings

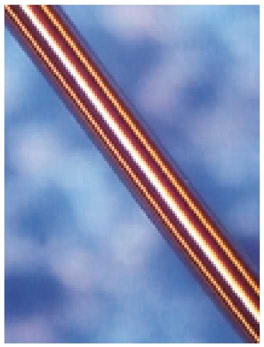
- 130 °C, 155 °C and 180 °C *266 °F, 311 °F and 356 °F* rated solderable Polyurethanes
- 180 °C *356 °F* solderable Polyester-imide
- 180 °C *356 °F* modified Polyester
- 240 °C *464 °F* Polyimide

Bond Coats

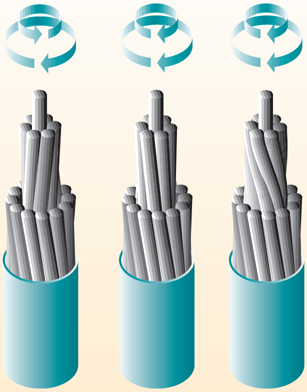
- Solvent and heat activated coatings
- High temperature/high strength coating
- Low out-gassing coatings developed for the Disk Drive Industry

Stranding

- Stranded standard resistance wires into 7, 19, 37 or other configurations
- Other alloy wire strands on request



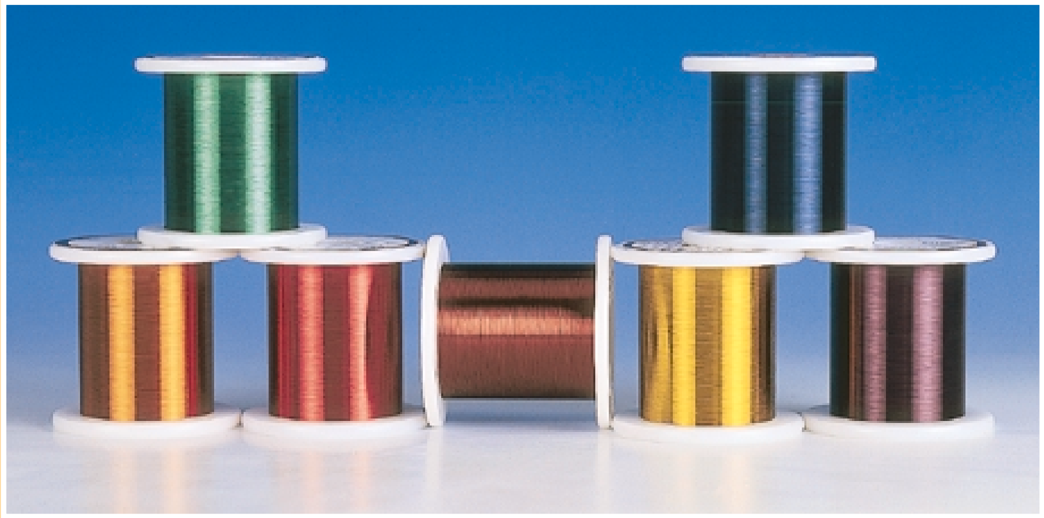
Electro Plating.

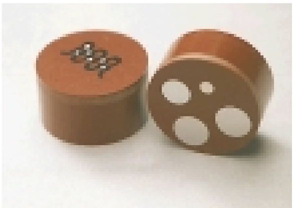


Stranding

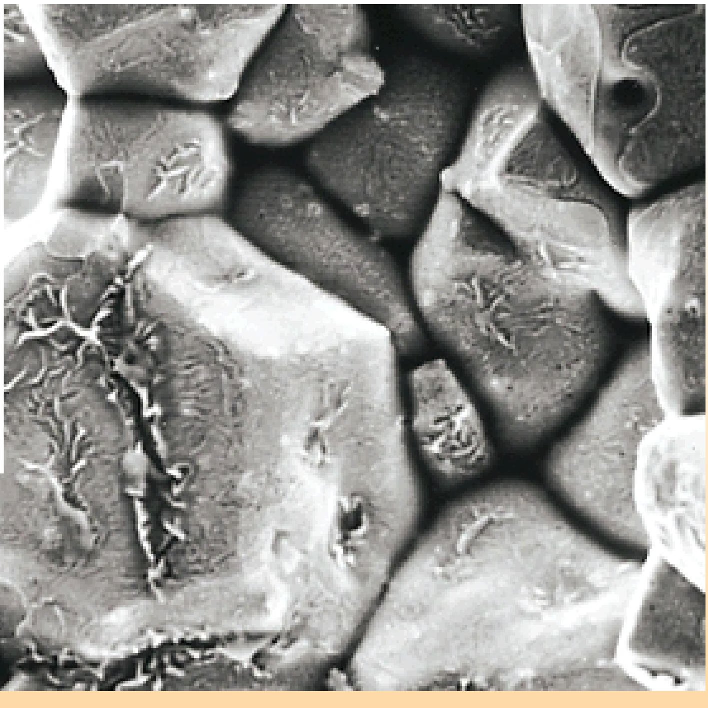
Engineered Coil Prototyping.

Insulating Coatings.





The Kanthal R&D laboratories.



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Properties Summary

Nikrothal 80, 60, 40, Kanthal A-1, Kanthal AE

	N 80	N 60	N 40	Kanthal A-1	Kanthal AE
Max continuous operating temperature (element temperature in air), °C *°F*	1200 *2190*	1150 *2100*	1100 *2010*	1400 *2550*	1300 *2370*
Nominal composition, %					
Cr	20	16	20	22	22
Al	-	-	-	5.8	5.3
Fe	-	Bal	Bal	Bal	Bal
Ni	80	60	35	-	-
Cu	-	-	-	-	-
Other	-	-	-	-	-
	-	-	-	-	-
Density, g/cm^3 *lb/in^3*	8.30 *0.300*	8.20 *0.296*	7.90 *0.285*	7.10 *0.256*	*7.15 0.258*
Electrical resistivity at 20 °C, Ωmm^2 m^{-1}	1.09	1.11	1.04	1.45	1.39
at 68 °F, Ω/cmf	*655*	*668*	*626*	*872*	*836*
Temperature factor of the resistivity, Ct					
250 °C *480 °F*	1.03	1.05	1.08	1.00	1.01
500 °C *930 °F*	1.04	1.08	1.15	1.01	1.03
800 °C *1470 °F*	1.04	1.10	1.21	1.03	1.05
1000 °C *1830 °F*	1.05	1.11	1.23	1.04	1.06
1200 °C *2190 °F*	1.07	-	-	1.04	1.06
Coefficient of thermal expansion, K^{-1}					
-100-0 °C	-	-	-	-	-
20-100 °C *68-210 °F*	-	-	-	-	-
20-250 °C *68-480 °F*	$15*10^{-6}$	$14*10^{-6}$	$16*10^{-6}$	-	-
20-500 °C *68-930 °F*	$16*10^{-6}$	$15*10^{-6}$	$17*10^{-6}$	-	-
20-750 °C *68-1380 °F*	$17*10^{-6}$	$16*10^{-6}$	$18*10^{-6}$	-	-
20-1000 °C *68-1830 °F*	$18*10^{-6}$	$17*10^{-6}$	$19*10^{-6}$	-	-
Thermal conductivity at 50 °C, W m^{-1} K^{-1}	15	13	13	11	11
122 °F, Btu in ft^{-2} h^{-1} °F^{-1}	*104*	*90*	*90*	*76*	*76*
Specific heat capacity, kJ kg^{-1} K^{-1}, 20 °C	0.46	0.46	0.50	-	-
Btu lb^{-1} °F^{-1}, 68 °F	*0.110*	*0.110*	*0.119*	-	-
Melting point (approx.), °C *°F*	1400 *2550*	1390 *2335*	1390 *2335*	-	-
Temperature coefficient of resistance, PPM/°C	-	-	-	-	-
with reference temperature 25 °C	-	-	-	-	-
and temperature range, °C	-	-	-	-	-
Mechanical properties *(approx.)					
Tensile strength, N mm^{-2}	810	730	675	760	720
psi	*117500*	*105900*	*97900*	*110200*	*104400*
Yield point, N mm^{-2}	420	370	340	545	520
psi	*60900*	*53700*	*49300*	*79000*	*75400*
Hardness, Hv	180	180	170	240	230
Elongation at rupture, %	30	35	30	20	20
Tensile strength at 900 °C, N mm^{-2}	100	100	120	34	34
at 1650 °F, psi	*14500*	*14500*	*17400*	*4900*	*4900*
Creep strength**					
at 800 °C, N mm^{-2} *at 1470 °F, psi*	15 *2160*	15 *2160*	20 *2900*	1.2 *170*	1.2 *170*
at 1000 °C, N mm^{-2} *at 1830 °F, psi*	4 *580*	4 *580*	-	0.5 *70*	-
at 1100 °C, N mm^{-2} *at 2010 °F, psi*	-	-	-	-	-
at 1200 °C, N mm^{-2} *at 2190 °F, psi*	-	-	-	-	-
Magnetic properties	Non-magnetic	Slightly	Non-magnetic	Magnetic***	Magnetic***
Emissivity, fully oxidized condition	0.88	0.88	0.88	-	-

* The values given apply for sizes of approx. 1.0 mm diameter *0.04 in.*

** Calculated from observed elongation in a Kanthal standard furnace test. 1% elongation after 1000 hours.

*** Curie point approx. 600 °C *1100 °F*

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Kanthal AF, Kanthal D, Alkrothal, Nikrothal LX, Cuprothal 49

	Kanthal AF	Kanthal D	Alkrothal	Nikrothal LX	Cuprothal 49
Max continuous operating temperature (element temperature in air), °C *°F*	1300 *2370*	1300 *2370*	1100 *2010*	300 *570*	600 *1110*
Nominal composition, %					
Cr	22	22	15	20	-
Al	5.3	4.8	4.3	-	-
Fe	Bal	Bal	Bal	-	+
Ni	-	-	-	75	44
Cu	-	-	-	-	Bal
Other	-	-	-	-	1 Mn+
	-	-	-	-	-
Density, g/cm³ *lb/in³*	7.15 *0.258*	7.25 *0.262*	7.28 *0.263*	8.1 *0.293*	8.9 *0.321*
Electrical resistivity at 20 °C, Ωmm² m⁻¹	1.39	1.35	1.25	1.33	0.49
at 68 °F, Ω/cmf	*836*	*812*	*755*	*812*	*295*
Temperature factor of the resistivity, Ct					
250 °C *480 °F*	1.01	1.01	1.03	-	1.0
500 °C *930 °F*	1.03	1.03	1.05	-	1.02
800 °C *1470 °F*	1.05	1.06	1.10	-	-
1000 °C *1830 °F*	1.06	1.07	1.11	-	-
1200 °C *2190 °F*	1.06	1.08	-	-	-
Coefficient of thermal expansion, K^{-1}					
-100-0 °C	-	-	-	-	-
20-100 °C *68-210 °F*	-	-	-	-	$14*10^{-6}$
20-250 °C *68-480 °F*	$11*10^{-6}$	$11*10^{-6}$	$11*10^{-6}$	$13.6*10^{-6}$	-
20-500 °C *68-930 °F*	$12*10^{-6}$	$12*10^{-6}$	$12*10^{-6}$	-	-
20-750 °C *68-1380 °F*	$14*10^{-6}$	$14*10^{-6}$	$14*10^{-6}$	-	-
20-1000 °C *68-1830 °F*	$15*10^{-6}$	$15*10^{-6}$	$15*10^{-6}$	-	-
Thermal conductivity at 50 °C, W m^{-1} K^{-1}	11	11	16	-	21.2
122 °F, Btu in ft^{-2} h^{-1} $°F^{-1}$	*76*	*76*	*110*	-	*145*
Specific heat capacity, kJ kg^{-1} K^{-1}, 20 °C	0.46	0.46	0.46	0.46	0.40
Btu lb^{-1} $°F^{-1}$, 68 °F	*0.110*	*0.110*	*0.110*	*0.110*	*0.096*
Melting point (approx.), °C *°F*	1500 *2730*	1500 *2730*	1500 *2730*	1400 *2550*	1210 *2210*
Temperature coefficient of resistance, PPM/°C	-	-	0+/-10	0+/-20	
with reference temperature 25 °C	-	-	0+/-5	-	
and temperature range, °C	-	-	-55/+150	20/100	
Mechanical properties *(approx.)					
Tensile strength, N mm^{-2}	700	670	630	950-1400	450-550
psi	*101500*	*97200*	*91400*	*137750-203000*	*65250-79700*
Yield point, N mm^{-2}	500	485	455	800-1200	250
psi	*72500*	*70300*	*66000*	*11600-174000*	*36000*
Hardness, Hv	230	230	220	-	130
Elongation at rupture, %	23	23	22	25	30
Tensile strength at 900 °C, N mm^{-2}	37	34	30	-	-
at 1650 °F, psi	*5400*	*4900*	*4300*	-	-
Creep strength**					
at 800 °C, N mm^{-2} *at 1470 °F, psi*		1.2 *170*	1.2 *170*	-	-
at 1000 °C, N mm^{-2} *at 1830 °F, psi*		0.5 *70*	1 *140*	-	-
at 1100 °C, N mm^{-2} *at 2010 °F, psi*	0.7 *100*	-	-	-	-
at 1200 °C, N mm^{-2} *at 2190 °F, psi*	0.3 *40*	-	-	-	-
Magnetic properties	Magnetic***	Magnetic***	Magnetic***	Non-magnetic	Non-magnetic
Emissivity, fully oxidized condition	0.70	0.70		-	-

* The values given apply for sizes of approx. 1.0 mm diameter *0.04 in.*

** Calculated from observed elongation in a Kanthal standard furnace test. 1% elongation after 1000 hours.

*** Curie point approx. 600 °C *1100 °F*

3

Cuprothal 15, Cuprothal 10, Cuprothal 5, Cuprothal 30

	Cuprothal 15	Cuprothal 10	Cuprothal 5	Cuprothal 30
Max continuous operating temperature (element temperature in air), °C *°F*	400 *750*	300 *570*	300 *570*	400 *750*
Nominal composition, %				
Cr	-	-	-	-
Al	-	-	-	-
Fe	-	-	-	-
Ni	11	6	2.2	23
Cu	Bal	Bal	Bal	Bal
Other	-	-	-	-
	-	-	-	-
Density, g/cm³ *lb/in³*	8.9 *0.321*	8.90 *0.321*	8.90 *0.321*	8.9 *0.321*
Electrical resistivity at 20 °C, Ωmm² m⁻¹	0.15	0.10	0.05	0.30
at 68 °F, Ω/cmf	*90*	*60*	*30*	*180*
Temperature factor of the resistivity, Ct				
250 °C *480 °F*	1.09	1.15	1.32	1.03
500 °C *930 °F*	-	-	-	-
800 °C *1470 °F*	-	-	-	-
1000 °C *1830 °F*	-	-	-	-
1200 °C *2190 °F*	-	-	-	-
Coefficient of thermal expansion, K^{-1}				
-100-0 °C	-	-	-	-
20-100 °C *68-210 °F*	$16*10^{-6}$	$16,2*10^{-6}$	$16*10^{-6}$	$16*10^{-6}$
20-250 °C *68-480 °F*	-	-	-	-
20-500 °C *68-930 °F*	-	-	-	-
20-750 °C *68-1380 °F*	-	-	-	-
20-1000 °C *68-1830 °F*	-	-	-	-
Thermal conductivity at 50 °C, W m^{-1} K^{-1}	60	90	160	35
122 °F, Btu in ft^{-2} h^{-1} $°F^{-1}$	*416*	*624*	*1100*	*240*
Specific heat capacity, kJ kg^{-1} K^{-1}, 20 °C	0.39	0.39	0.39	0.39
Btu lb^{-1} $°F^{-1}$*, 68 °F*	*0.093*	*0.093*	*0.093*	*0.093*
Melting point (approx.), °C *°F*	1080 *1975*	1080 *1975*	1080 *1975*	1100 *2010*
Temperature coefficient of resistance, PPM/°C	-	-	-	-
with reference temperature 25 °C	-	-	-	-
and temperature range, °C	-	-	-	-
Mechanical properties (approx.)				
Tensile strength, N mm^{-2}	250-350	250-350	200-300	300-400
psi	*36250-50750*	*36250-50750*	*29000-43500*	*43500-58000*
Yield point, N mm^{-2}	130	110	100	170
psi	*19000*	*16000*	*14500*	*24600*
Hardness, Hv	100	-	-	110
Elongation at rupture, %	30	30	30	30
Tensile strength at 900 °C, N mm^{-2}	-	-	-	380
at 1650 °F, psi	-	-	-	*55100*
Creep strength**				
at 800 °C, N mm^{-2} *at 1470 °F, psi*	-	-	-	-
at 1000 °C, N mm^{-2} *at 1830 °F, psi*	-	-	-	-
at 1100 °C, N mm^{-2} *at 2010 °F, psi*	-	-	-	-
at 1200 °C, N mm^{-2} *at 2190 °F, psi*	-	-	-	-
Magnetic properties	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic
Emissivity, fully oxidized condition	-	-	-	-

3

Aluminum 1350 AL (EC), Aluminum EEE AL, Copper Clad (10%) Aluminum

	Aluminum 1350 AL (EC)	Aluminum EEE Al	Copper Clad (10%) Aluminum	
			Hard	Annealed
Purity or composition	99.5	99.3	-	-
Electrical resistivity at 20 °C, Ωmm² m⁻¹	0.028	0.028	0.026	-
at 68 °F, Ω/cmf	*16.782*	*16.84*	*15.9*	-
Temperature factor of the resistivity, Ct	0.00408	0.00408	-	-
(0-100 °C)	-	-	-	-
Tensile strength, N mm⁻²	186-207	200-234	193	110
psi	*27000-30000*	*29000-34000*	*28000*	*16000*
Yield strength, N mm⁻²	165-179	193-200	-	-
psi	*24000-26000*	*28000-29000*	-	-
Elongation at rupture, %	1.2-1.4	2-4	-	-
DC Conductivity	61.8% of Cu	65.2% of Cu	65% of Cu	-
Density, g/cm³ *lb/in³*	2.7 … *0.977*	2.7 … *0.977*	3.32 … *0.1203*	-

Copper Clad (15%) Aliminum, Copper Grade 2, Beryllium Copper

	Copper Clad (15%) Aluminum		Copper Grade 2		Beryllium Copper
	Hard	Annealed	Hard	Annealed	
Purity or composition	-	-	99.95% + Ag	-	1.2-2.0 Be
Electrical resistivity at 20 °C, Ωmm² m⁻¹	0.026	-	0.017	-	0.095-0.191
at 68 °F, Ω/cmf	*15.5*	-	*10.371*	-	*57-115*
Temperature factor of the resistivity, Ct	-	-	-	-	-
(0-100 °C)	-	-	-	-	-
Tensile strength, N mm⁻²	207	138	455	220	414-1585
psi	*30000*	*20000*	*66000*	*32000*	*60000-230000*
Yield strength, N mm⁻²	-	-	-	-	-
psi	-	-	-	-	-
Elongation at rupture, %	-	-	-	-	-
DC Conductivity	67% of Cu	-	100%	-	15-30% IACS
Density, g/cm³ *lb/in³*	3.36 … *0.1312*	-	8.94 … *0.323*	-	8.25 … *0.298*

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MP35N, AISI 302 V, AISI 304 V, AISI 316 LV

	MP35N	AISI 302 V	AISI 304 V	AISI 316 LV
Max continuous operating temperature (element temperature in air), °C *°F*	1315 *2400*		475 *885*	475 *885*
Nominal composition, %				
Cr	19/21	17-19	18-20	13-16.5
Al	-	-	-	-
Fe	-	Bal.	Bal.	Bal.
Ni	33/37	10	8.5-10	10.5-13
Cu	-	-	-	-
Other	Mo 9/10.50	C 0.15	C 0.08	C 0.03
	Cobalt Bal.	-	-	Mo 2.5
Density, g/cm^3 *lb/in^3*	8.43 *0.304*	7.9 *0.235*	7.9 *0.285*	7.9 *0.285*
Electrical resistivity at 20 °C, Ωmm^2 m^{-1}	1.03	0.73	0.73	0.73
at 68 °F, Ω/cmf	*621*	*440*	*440*	*440*
Temperature factor of the resistivity, Ct				
250 °C *480 °F*	1.06	-	1.24	1.2
500 °C *930 °F*	1.11	-	1.46	1.37
800 °C *1470 °F*	-	-	1.66	1.52
1000 °C *1830 °F*	-	-	-	-
1200 °C *2190 °F*	-	-	-	-
Coefficient of thermal expansion, K-1				
-100-0 °C	-	-	-	-
20-100 °C *68-210 °F*	12.8*10^{-6}	15*10^{-6}	17*10^{-6}	16*10^{-6}
20- 250 °C *68-480 °F*	14*10^{-6}	-	17*10^{-6}	17*10^{-6}
20- 500 °C *68-930 °F*	15.5*10^{-6}	-	18*10^{-6}	18*10^{-6}
20- 750 °C *68-1380 °F*	-	-	19*10^{-6}	19*10^{-6}
20-1000 °C *68-1830 °F*	-	-	20*10^{-6}	-
Thermal conductivity at 50 °C, W m^{-1} K^{-1}	12.0	16	13	12.7
122 °F, Btu in ft^{-2} h^{-1} °F^{-1}	*83*	*111*	*90*	*88*
Specific heat capacity, kJ kg-1K-1, 20 °C	-	-	0.49	0.48
Btu lb^{-1} °F^{-1}, 68 °F	-	-	*0.117*	*0.115*
Melting point (approx.), °C *°F*	1440 *2625*	1420 *2590*	1390 *2335*	1390 *2335*
Temperature coefficient of resistance, PPM/°C	-	-	-	-
with reference temperature 25 °C	-	-	-	-
and temperature range, °C	-	-	-	-
Mechanical properties *(approx.)				
Tensile strength, N mm^{-2}	-	-	620	600
psi	-	-	*90000*	*87000*
Yield point, N mm^{-2}	-	-	300	300
psi	-	-	*43500*	*43500*
Hardness, Hv	-	160	160	160
Elongation at rupture, %	70	60	30	30
Tensile strength at 900 °C, N mm^{-2}	-	-	100	100
at 1650 °F, psi	-	-	*14500*	*14500*
Creep strength**				
at 800 °C, N mm^{-2} *at 1470 °F psi*	-	-	20 *2900*	25 *3625*
at 1000 °C, N mm^{-2} *at 1830 °F psi*	-	-	-	-
at 1100 °C, N mm^{-2} *at 2010 °F psi*	-	-	-	-
at 1200 °C, N mm^{-2} *at 2190 °F psi*	-	-	-	-
Magnetic properties	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic
Emissivity, fully oxidized condition	-	-	-	-

3

Platinum (reference grade), Platinum (commercial grade), Platinum 10 Iridium, Platinum 20 Iridium

	Platinum (reference grade)		Platinum (commercial grade)		Platinum 10 Iridium		Platinum 20 Iridium	
	Hard	Annealed	Hard	Annealed	Hard	Annealed	Hard	Annealed
Purity or composition	99.999%	99.999%	99.96	99.96	Pt-10%Ir	Pt-10%Ir	Pt-20%Ir	Pt-20%Ir
Electrical resistivity at 20 °C, Ωmm² m⁻¹	0.098	0.096	0.105	0.101	0.256	0.249	0.320	0.309
at 68 °F, Ω/cmf	*59*	*57.6*	*63*	*61*	*154*	*150*	*193*	*186*
Temperature factor of the resistivity, Ct (0-100 °C)	0.0386	0.03926	0.00375	0.00386	0.0012	0.0013	0.007	0.008
Tensile strength, N mm⁻²	413	165	448	165	1330	690	413	165
psi	*60000*	*24000*	*65000*	*24000*	*193000*	*100000*	*60000*	*24000*
Elongation at rupture, %	2	38	2	38	2	20	2	38
Melting point (approx.), °C	1769	1769	1769	1769	1769	1769	1769	1769
°F	*3218*	*3218*	*3218*	*3218*	*3218*	*3218*	*3218*	*3218*
Density, g/cm³	21.45	21.45	21.45	21.45	21.61	21.61	21.45	21.45
lb/in³	*0.775*	*0.775*	*0.775*	*0.775*	*0.781*	*0.781*	*0.775*	*0.775*

Platinum -Tungsten, Gold (commercial), Silver

	Platinum - Tungsten		Gold (Commercial)		Silver	
	Hard	Annealed	Hard	Annealed	Hard	Annealed
Purity or composition	Pt-8%W		99.98		99.98	
Electrical resistivity at 20 °C, Ωmm² m⁻¹	0.598	0.664	0.021	0.021	0.016	0.015
at 68 °F, Ω/cmf	*360*	*400*	*12.8*	*12.6*	*9.3*	*8.83*
Temperature factor of the resistivity, Ct (0-100 °C)	0.0028	0.0024	0.0038	0.0039	0.0038	0.0041
Tensile strength, N mm⁻²	1380	895	317	138	360	165
psi	*200000*	*130000*	*46000*	*20000*	*52000*	*24000*
Elongation at rupture, %	2	24	1.5	36	1.5	46
Melting point (approx.), °C	1870	1870	1063	1063	961	961
°F	*3398*	*3398*	*1940*	*1940*	*1760*	*1760*
Density, g/cm³	21.34	21.34	19.3	19.3	10.5	10.5
lb/in³	*0.771*	*0.771*	*0.697*	*0.697*	*0.379*	*0.379*

AISI 314, AISI 314 M, AISI 316, AISI 316 LC

	AISI 314	AISI 314 M	AISI 316	AISI 316 LC
Max continuous operating temperature (element temperature in air), °C *°F*	1000 *1830*	1000 *1830*	475 *885*	-
Nominal composition, %				
Cr	25	25	18	18
Al	-	-	-	-
Fe	Bal	-	Bal	Bal
Ni	20	20	10	10
Cu	-	-	-	-
Other	+	Si+Ce+	Mo 2.5	C 0.03 max
	-	-	-	Max 2 Mo
Density, g/cm^3 *lb/in^3*	7.8 *0.282*	7.8 *0.282*	7.9 *0.285*	7.9 *0.285*
Electrical resistivity at 20 °C, $\Omega mm^2 m^{-1}$	0.95	0.95	0.75	0.75
at 68 °F, Ω/cmf	*572*	*572*	*457*	*457*
Temperature factor of the resistivity, Ct				
250 °C *480 °F*	1.14	1.14	1.2	1.2
500 °C *930 °F*	1.26	1.26	1.37	1.37
800 °C *1470 °F*	1.36	1.36	1.52	1.52
1000 °C *1830 °F*	1.39	1.39	-	-
1200 °C *2190 °F*	-	-	-	-
Coefficient of thermal expansion, K^{-1}				
-100-0 °C	-	-	-	-
20-100 °C *68-210 °F*	$16*10^{-6}$	$16*10^{-6}$	$16*10^{-6}$	$16*10^{-6}$
20-250 °C *68-480 °F*	$17*10^{-6}$	$17*10^{-6}$	$17*10^{-6}$	$17*10^{-6}$
20-500 °C *68-930 °F*	$18*10^{-6}$	$18*10^{-6}$	$18*10^{-6}$	$18*10^{-6}$
20-750 °C *68-1380 °F*	$19*10^{-6}$	$19*10^{-6}$	$19*10^{-6}$	$19*10^{-6}$
20-1000 °C *68-1830 °F*	$20*10^{-6}$	$20*10^{-6}$	-	-
Thermal conductivity at 50 °C, $W m^{-1} K^{-1}$	11.5	11.5	12.7	12.7
122 °F, Btu in $ft^{-2} h^{-1} °F^{-1}$	*80*	*80*	*88*	*88*
Specific heat capacity, $kJ kg^{-1} K^{-1}$, 20 °C	0.47	0.47	0.48	0.48
Btu $lb^{-1} °F^{-1}$, 68 °F	*0.112*	*0.112*	*0.115*	*0.115*
Melting point (approx.), °C *°F*	1390 *2535*	1390 *2535*	1390 *2335*	1390 *2335*
Temperature coefficient of resistance, PPM/°C	-	-	-	-
with reference temperature 25 °C	-	-	-	-
and temperature range, °C	-	-	-	-
Mechanical properties (approx.)				
Tensile strength, $N mm^{-2}$	630	650	600	590
psi	*91400*	*91400*	*87000*	*85500*
Yield point, $N mm^{-2}$	310	320	300	290
psi	*45000*	*46400*	*43500*	*42000*
Hardness, Hv	170	180	160	160
Elongation at rupture, %	30	30	30	30
Tensile strength at 900 °C, $N mm^{-2}$	120	120	100	100
at 1650 °F, psi	*17400*	*17400*	*14500*	*14500*
Creep strength				
at 800 °C, $N mm^{-2}$ *at 1470 °F, psi*	30 *4350*	30 *4350*	25** *3625*	25** *3625*
at 1000 °C, $N mm^{-2}$ *at 1830 °F, psi*	14 *2030*	14 *2030*	-	-
at 1100 °C, $N mm^{-2}$ *at 2010 °F, psi*	-	-	-	-
at 1200 °C, $N mm^{-2}$ *at 2190 °F, psi*	-	-	-	-
Magnetic properties	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic
Emissivity, fully oxidized condition	-	-	-	-

3

AISI 304, AISI 304 LC, AISI 347

	AISI 304	AISI 304 LC	AISI 347
Max continuous operating temperature (element temperature in air), °C *°F*	475 *885*	-	-
Nominal composition, %			
Cr	18	18	17-19
Al	-	-	-
Fe	Bal	Bal	-
Ni	8	8	9-13
Cu	-	-	-
Other	+	C 0.03 max	-
	-	-	-
Density, g/cm^3 *lb/in^3*	7.9 *0.285*	7.9 *0.285*	8.0 *0.290*
Electrical resistivity at 20 °C, $\Omega mm^2 m^{-1}$	0.73	0.73	1.21
at 68 °F, Ω/cmf	*440*	*440*	*728*
Temperature factor of the resistivity, Ct			
250 °C *480 °F*	1.24	1.24	-
500 °C *930 °F*	1.46	1.46	-
800 °C *1470 °F*	1.66	1.66	-
1000 °C *1830 °F*	-	-	-
1200 °C *2190 °F*	-	-	-
Coefficient of thermal expansion, K^{-1}			
-100-0 °C	-	-	-
20-100 °C *68-210 °F*	$17*10^{-6}$	$17*10^{-6}$	$16.6*10^{-6}$
20-250 °C *68-480 °F*	$17*10^{-6}$	$17*10^{-6}$	$17.1*10^{-6}$
20-500 °C *68-930 °F*	$18*10^{-6}$	$18*10^{-6}$	$18.4*10^{-6}$
20-750 °C *68-1380 °F*	$19*10^{-6}$	$19*10^{-6}$	-
20-1000 °C *68-1830 °F*	$20*10^{-6}$	$20*10^{-6}$	-
Thermal conductivity at 50 °C, $W m^{-1} K^{-1}$	13	13	16
122 °F, Btu in $ft^{-2} h^{-1} °F^{-1}$	*90*	*90*	*111*
Specific heat capacity, $kJ kg^{-1} K^{-1}$, 20 °C	0.49	0.49	0.50
Btu $lb^{-1} °F^{-1}$, 68 °F	*0.117*	*0.117*	*0.12*
Melting point (approx.), °C *°F*	1390 *2335*	1390 *2335*	1400 *2550*
Temperature coefficient of resistance, PPM/°C	-	-	-
with reference temperature 25 °C	-	-	-
and temperature range, °C	-	-	-
Mechanical properties (approx.)			
Tensile strength, $N mm^{-2}$	620	600	-
psi	*90000*	*87000*	-
Yield point, $N mm^{-2}$	300	290	-
psi	*43500*	*42000*	-
Hardness, Hv	160	160	-
Elongation at rupture, %	30	30	-
Tensile strength at 900 °C, $N mm^{-2}$	100	100	-
at 1650 °F, psi	*14500*	*14500*	-
Creep strength			
at 800 °C, $N mm^{-2}$ *at 1470 °F, psi*	20 *2900**	20 *2900**	-
at 1000 °C, $N mm^{-2}$ *at 1830 °F, psi*	-	-	-
at 1100 °C, $N mm^{-2}$ *at 2010 °F, psi*	-	-	-
at 1200 °C, $N mm^{-2}$ *at 2190 °F, psi*	-	-	-
Magnetic properties	Non-magnetic	Non-magnetic	Non-magnetic
Emissivity, fully oxidized condition	-	-	- -

3

Nifethal 70, Nifethal 36, Cuni 67

	Nifethal 70	Nifethal 36	Cuni 67
Max continuous operating temperature (element temperature in air), °C *°F*	600 *1110*	-	-
Nominal composition, %			
Cr	-	-	-
Al	-	-	-
Fe	30	Bal	1.5
Ni	Bal	36	67
Cu	-	-	Bal
Other	-	-	-
	-	-	-
Density, g/cm^3 *lb/in^3*	8.45 *0.305*	8.08 *0.292*	8.83 *0.318*
Electrical resistivity at 20 °C, $\Omega mm^2 m^{-1}$	0.21	0.82 (indication only)	0.48
at 68 °F, Ω/cmf	*126*	*495*	*289*
Temperature factor of the resistivity, Ct			
250 °C *480 °F*	2.05	1.35	-
500 °C *930 °F*	3.40	-	-
800 °C *1470 °F*	-	-	-
1000 °C *1830 °F*	-	-	-
1200 °C *2190 °F*	-	-	-
Coefficient of thermal expansion, K^{-1}			
-100-0 °C	-	$2.0*10^{-6}$	-
20-100 °C *68-210 °F*	$15*10^{-6}$	$1.5*10^{-6}$	$14*10^{-6}$
20-250 °C *68-480 °F*	-	$2.5*10^{-6}$	-
20-500 °C *68-930 °F*	-	-	-
20-750 °C *68-1380 °F*	-	-	-
20-1000 °C *68-1830 °F*	-	-	-
Thermal conductivity at 50 °C, $W m^{-1} K^{-1}$	16	11	24.5
122 °F, Btu in $ft^{-2} h^{-1} °F^{-1}$	*110*	*77*	*170*
Specific heat capacity, $kJ kg^{-1} K^{-1}$, 20 °C	0.52	0.52	0.53
Btu $lb^{-1} °F^{-1}$, 68 °F	*0.120*	*0.120*	*0.123*
Melting point (approx.), °C *°F*	1430 *2610*	1425 *2600*	1350 *2460*
Temperature coefficient of resistance, PPM/°C	-	-	-
with reference temperature 25 °C	-	-	-
and temperature range, °C	-	-	-
Mechanical properties (approx.)			
Tensile strength, $N mm^{-2}$	640	490* 600-1080**	500-600
psi	*92800*	*71000 37000-156600*	*72500-87000*
Yield point, $N mm^{-2}$	340	320* 500-900**	-
psi	*49300*	*46400 72500-130500*	-
Hardness, Hv	-	130* (Brinell) 160-200**	-
Elongation at rupture, %	30	35* 20-2**	-
Tensile strength at 900 °C, $N mm^{-2}$	-	-	-
at 1650 °F, psi	-	-	-
Creep strength* **			
at 800 °C, $N mm^{-2}$ *at 1470 °F, psi*	-	-	-
at 1000 °C, $N mm^{-2}$ *at 1830 °F, psi*	-	-	-
at 1100 °C, $N mm^{-2}$ *at 2010 °F, psi*	-	-	-
at 1200 °C, $N mm^{-2}$ *at 2190 °F, psi*	-	-	-
Magnetic properties	Magnetic****	Magnetic***	Slightly
	-	-	-
Emissivity, fully oxidized condition	-	-	-

* Annealed

** Drawn

*** Up to (Curie point) 277 °C *535 °F*

**** Up to (Curie point) 610 °C *1130* <

4 Precision Wire Alloys and Applications

Alloys for Electrical Resistance

Austenitic Alloys (NiCr, NiCrFe)

Nikrothal 80

Nikrothal 80 is an 80% Ni, 20% Cr alloy which is marketed in heavier sizes as resistance heating wires. N80 has a relatively high resistivity, 1.09 ohm mm^2 m^{-1} and a moderate temperature coefficient value.

Applications

Where low temperature coefficient of resistance is not required.

- Wire wound resistors.
- Lead wires.
- Potentiometers.
- Pressure transducers.
- Detonators.
- Strings in musical instruments.
- Ceramic resistors where gas free oxidation is required.

Nikrothal 60

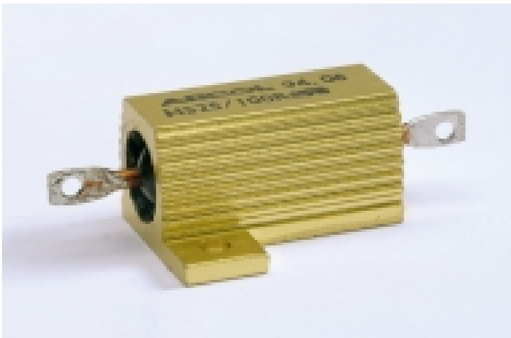
Having a nominal composition of 60% nickel, 16% chromium, balance iron, this alloy has won universal acceptance among users of metallic resistance materials. The resistance of Nikrothal 60 to corrosion makes it a very useful material for a variety of non-electrical applications.

Nikrothal 40

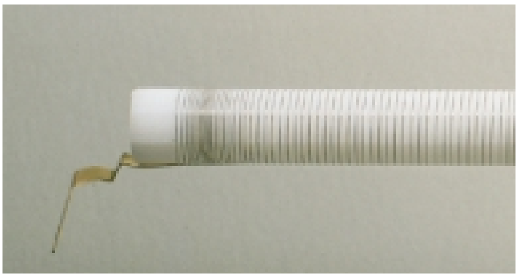
35% nickel, 20% chromium, 2% silicone, balance iron.

Potentiometer - Nikrothal 80.

Resistor - Nikrothal 80.



Resistor - Nikrothal 80.



Resistor - Nikrothal 80.

Nikrothal

$$cm^2\ in^2/\Omega = \frac{I^2 C_t}{P}$$

1 = Current
C_t = Temperature factor
P = Surface load W/cm²*in²*

	Resistivity Ωmm² m⁻¹	*Ω/cir.mil ft*	Density g cm⁻³	*lb/cu.in*	Dimensions, mm.	*Dimensions, In.*
NIKROTHAL 80	1.09	*655*	8.30	*0.300*	8.0-0.015	*0.312-0.000585*
NIKROTHAL 60	1.11	*668*	8.20	*0.296*	6.0-0.015	*0.234-0.000585*
NIKROTHAL 40	1.04	*626*	7.90	*0.285*	6.0-0.015	*0.234-0.000585*

To obtain resistance at working temperature multiply by the factor C_t in the following table

°C	**20**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**
°F	***68***	***212***	***392***	***572***	***752***	***932***	***1112***	***1292***	***1472***	***1652***	***1832***	***2012***	***2192***
NIKROTHAL 80	1.0	1.01	1.02	1.03	1.04	1.05	1.04	1.04	1.04	1.04	1.05	1.06	1.07
NIKROTHAL 60	1.0	1.02	1.04	1.05	1.06	1.08	1.09	1.09	1.10	1.10	1.11	1.12	1.13
NIKROTHAL 40	1.0	1.03	1.06	1.10	1.12	1.15	1.17	1.19	1.21	1.22	1.23	1.24	

Multiply the figures in the table to get:

NIKROTHAL 80	1.0	1.0	1.0
NIKROTHAL 60	1.02	0.98	0.99
NIKROTHAL 40	0.95	1.05	0.95

Diameter mm	**Resistance at 20 °C Ω/m**	**cm²/Ω at 20 °C**	**Weight g/m**	**Surface area cm²/m**	**Cross sectional area mm²**
0.12	96.4	0.0391	0.0939	3.77	0.0113
0.11	115	0.0301	0.0789	3.46	0.00950
0.10	139	0.0226	0.0652	3.14	0.00785
0.090	171	0.0165	0.0528	2.83	0.00636
0.080	217	0.0116	0.0417	2.51	0.00503
0.070	283	0.00776	0.0319	2.20	0.00385
0.060	386	0.00489	0.0235	1.88	0.00283
0.050	555	0.00283	0.0163	1.57	0.00196
0.045	685	0.00206	0.0132	1.41	0.00159
0.040	867	0.00145	0.0104	1.26	0.00126
0.035	1133	0.00097	0.0080	1.10	0.00096
0.030	1542	0.000611	0.00587	0.942	0.000707
0.028	1770	0.000497	0.00511	0.880	0.000616
0.025	2221	0.000354	0.00407	0.785	0.000491
0.022	2867	0.000241	0.00316	0.691	0.000380
0.020	3470	0.000181	0.00261	0.628	0.000314
0.019	3844	0.000155	0.00235	0.597	0.000284
0.018	4283	0.000132	0.00211	0.565	0.000254
0.017	4802	0.000111	0.00188	0.534	0.000227
0.016	5421	0.0000927	0.00167	0.503	0.000201
0.015	6168	0.0000764	0.00147	0.471	0.000177

Diameter SWG	***B & S***	***inch***	***Resistance at 68°F Ω/ft***	***in²/Ω at 68°F***	***Weight lb/1000 ft***	***Surface area in²/ft***	***Cross sectional area in² x 1000***
33	*30*	*0.0100*	*6.55*	*0.0576*	*0.283*	*0.377*	*0.0785*
34		*0.00920*	*7.74*	*0.0448*	*0.239*	*0.347*	*0.0665*
	31	*0.00890*	*8.27*	*0.0406*	*0.224*	*0.336*	*0.0622*
35		*0.00840*	*9.28*	*0.0341*	*0.200*	*0.317*	*0.0554*
	32	*0.00800*	*10.2*	*0.0295*	*0.181*	*0.302*	*0.0503*
36		*0.00760*	*11.3*	*0.0253*	*0.163*	*0.287*	*0.0454*
	33	*0.00710*	*13.0*	*0.0206*	*0.143*	*0.268*	*0.0396*
37		*0.00680*	*14.2*	*0.0181*	*0.131*	*0.256*	*0.0363*
	34	*0.00630*	*16.5*	*0.0144*	*0.112*	*0.238*	*0.0312*
38		*0.00600*	*18.2*	*0.0124*	*0.102*	*0.226*	*0.0283*
	35	*0.00560*	*20.9*	*0.0101*	*0.0887*	*0.211*	*0.0246*
39		*0.00520*	*24.2*	*0.00809*	*0.0765*	*0.196*	*0.0212*
	36	*0.00500*	*26.2*	*0.00719*	*0.0707*	*0.188*	*0.0196*
40		*0.00480*	*28.4*	*0.00637*	*0.0651*	*0.181*	*0.0181*
	37	*0.00450*	*32.3*	*0.00524*	*0.0573*	*0.170*	*0.0159*
41		*0.00440*	*33.8*	*0.00490*	*0.0547*	*0.166*	*0.0152*
42	*38*	*0.00400*	*40.9*	*0.00368*	*0.0452*	*0.151*	*0.0126*
43		*0.00360*	*50.5*	*0.00269*	*0.0366*	*0.136*	*0.0102*
	39	*0.00350*	*53.5*	*0.00247*	*0.0346*	*0.132*	*0.00962*
44		*0.00320*	*64.0*	*0.00189*	*0.0290*	*0.121*	*0.00804*
	40	*0.00310*	*68.2*	*0.00171*	*0.0272*	*0.117*	*0.00755*
45		*0.00280*	*83.5*	*0.00126*	*0.0222*	*0.106*	*0.00616*
		0.00275	*86.6*	*0.00120*	*0.0214*	*0.104*	*0.00594*
		0.00250	*105*	*0.000899*	*0.0177*	*0.0942*	*0.00491*
46		*0.00240*	*114*	*0.000796*	*0.0163*	*0.0905*	*0.00452*
47		*0.00200*	*164*	*0.000460*	*0.0113*	*0.0754*	*0.00314*
		0.00175	*214*	*0.000308*	*0.00866*	*0.0660*	*0.00241*
48		*0.00160*	*256*	*0.000236*	*0.00724*	*0.0603*	*0.00201*
		0.00150	*291*	*0.000194*	*0.00636*	*0.0565*	*0.00177*
		0.00125	*419*	*0.000112*	*0.00442*	*0.0471*	*0.00123*
49		*0.00120*	*455*	*0.0000995*	*0.00407*	*0.0452*	*0.00113*
50		*0.00100*	*655*	*0.0000576*	*0.00283*	*0.0377*	*0.000785*

Ferritic alloys (FeCrAl)

Kanthal A-1

Kanthal A-1 is a resistance heating alloy, which is drawn down to fine sizes. As heating element it can be used up to 1300 °C *2370 °F*. The resistivity is high, 1.35 ohm mm^2 m^{-1} and the temperature coefficient value is moderate.

Kanthal AF

An alloy that is especially recommended where good form stability properties are required. For maximum life above 1300 °C *2370 °F* wire temperature, Kanthal A-1 is recommended since it provides superior oxidation resistance.

Kanthal AE

Developed to meet the extreme demands in fast response elements, this alloy has exceptional form stability and life in spirals with large coil to wire diameter ratio.

Kanthal D

Employed chiefly in appliances, its high resistivity and low density, combined with better heat resistance than austenitic alloys, make it suitable for most applications.

Alkrothal

The chromium content is lower and the operating temperature is limited to 1100 °C *2110 °F*.

Applications

- Wire wound power resistors.
- Lead wires.
- Heating applications.
- Catalyst material.
- Mosquito killers

Wire Mesh Filter - Kanthal D.

Soldering Iron – Kanthal D.

Kanthal, Alkrothal

$$\text{cm}^2\,in^2/\Omega = \frac{I^2 C_t}{P}$$

I = Current
C_t = Temperature factor
P = Surface load W/cm² *in²*

	Resistivity Ωmm² m⁻¹	*Ω/cir.mil ft*	Density, g cm⁻³	*lb/cu.in*	Dimensions, mm	*Dimensions, in*
KANTHAL A-1	1.45	*872*	7.1	*0.256*	-	-
KANTHAL AE	1.39	*836*	7.15	*0.258*	-	-
KANTHAL AF	1.39	*836*	7.15	*0.258*	-	-
KANTHAL D	1.35	*812*	7.25	*0.262*	8.0-0.015	*0.312-0.000585*
ALKROTHAL	1.25	*755.00*	7.28	*0.263*	-	-

To obtain resistance at working temperature multiply by the factor C_t in the following table

°C	20.0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
°F	*68*	*212*	*392*	*572*	*752*	*932*	*1112*	*1292*	*1472*	*1652*	*1832*	*2012*	*2192*	*2372*	*2552*
KANTHAL A-1	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.02	1.03	1.04	1.04	1.04	1.04	1.05	1.05
KANTHAL AE	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.06	
KANTHAL AF	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.06	
KANTHAL D	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.07	1.07	1.08	1.08	
ALKROTHAL	1.00	1.00	1.02	1.03	1.04	1.05	1.08	1.09	1.10	1.11	1.11	1.12			

Multiply the figures in the table to get:

KANTHAL A-1	1.00	1.00	1.00
KANTHAL AE, AF	0.958	1.043	1.007
KANTHAL D	0.931	1.074	1.021
ALKROTHAL	0.862	1.160	1.025

Diameter mm	Resistance at 20 °C Ω/m	cm²/Ω at 20 °C	Weight g/m	Surface area cm²/m	Cross sectional area mm²
0.12	128	0.0294	0.0803	3.77	0.0113
0.11	153	0.0226	0.0675	3.46	0.00950
0.10	185	0.0170	0.0588	3.14	0.00785
0.090	228	0.0124	0.0452	2.83	0.00636
0.080	288	0.00871	0.0357	2.51	0.00503
0.070	377	0.00584	0.0273	2.20	0.00385
0.060	513	0.00368	0.0201	1.88	0.00283
0.050	738	0.00213	0.0139	1.57	0.00196
0.045	912	0.00155	0.0113	1.41	0.00159
0.040	1154	0.00109	0.0089	1.26	0.00126
0.035	1507	0.000730	0.0068	1.10	0.000962
0.030	2051	0.000459	0.0050	0.942	0.000707
0.028	2355	0.000374	0.0044	0.880	0.000616
0.025	2954	0.000266	0.0035	0.785	0.000491
0.022	3814	0.000181	0.0027	0.691	0.000380
0.020	4615	0.000136	0.0022	0.628	0.000314
0.019	5114	0.000117	0.0020	0.597	0.000284
0.018	5698	0.000099	0.0018	0.565	0.000254
0.017	6388	0.0000836	0.0016	0.534	0.000227
0.016	7212	0.0000697	0.0014	0.503	0.000201
0.015	8205	0.0000574	0.0013	0.471	0.000177

Diameter SWG	*B & S*	*inch*	*Resistance at 68°F Ω/ft*	*in²/Ω at 68°F*	*Weight lb/1000 ft*	*Surface area in²/ft*	*Cross sectional area in² x 1000*
33	30	0.0100	8.72	0.0432	0.241	0.377	0.0785
34		0.00920	10.30	0.0337	0.204	0.347	0.0665
	31	0.00890	11.01	0.0305	0.191	0.336	0.0622
35		0.00840	12.36	0.0256	0.170	0.317	0.0554
	32	0.00800	13.63	0.0221	0.154	0.302	0.0503
36		0.00760	15.10	0.0190	0.139	0.287	0.0454
	33	0.00710	17.30	0.0155	0.122	0.268	0.0396
37		0.00680	18.86	0.0136	0.112	0.256	0.0363
	34	0.00630	21.97	0.0108	0.096	0.238	0.0312
38		0.00600	24.22	0.0093	0.087	0.226	0.0283
	35	0.00560	27.81	0.00759	0.076	0.211	0.0246
39		0.00520	32.25	0.00608	0.065	0.196	0.0212
	36	0.00500	34.88	0.00540	0.060	0.188	0.0196
40		0.00480	37.85	0.00478	0.056	0.181	0.0181
	37	0.00450	43.06	0.00394	0.049	0.170	0.0159
41		0.00440	45.04	0.00368	0.047	0.166	0.0152
42	38	0.00400	54.50	0.00277	0.039	0.151	0.0126
43		0.00360	67.28	0.00202	0.031	0.136	0.0102
	39	0.00350	71.18	0.00185	0.030	0.132	0.00962
44		0.00320	85.16	0.00142	0.025	0.121	0.00804
	40	0.00310	90.74	0.00129	0.023	0.117	0.00755
45		0.00280	111.22	0.00095	0.019	0.106	0.00616
		0.00275	115.31	0.000899	0.018	0.104	0.00594
		0.00250	139.52	0.000676	0.015	0.0942	0.00491
46		0.00240	151.39	0.000598	0.014	0.0905	0.00452
		0.00225	172.25	0.000492	0.012	0.0848	0.00398
47		0.00200	218.00	0.000346	0.010	0.0754	0.00314
		0.00175	284.73	0.000232	0.007	0.0660	0.00241
48		0.00160	340.63	0.000177	0.006	0.0603	0.00201
		0.00150	387.56	0.000146	0.005	0.0565	0.00177
		0.00125	558.08	0.0000844	0.004	0.0471	0.00123
49		0.00120	605.56	0.0000747	0.003	0.0452	0.00113
50		0.00100	872.00	0.0000432	0.002	0.0377	0.000785

4

Nikrothal LX

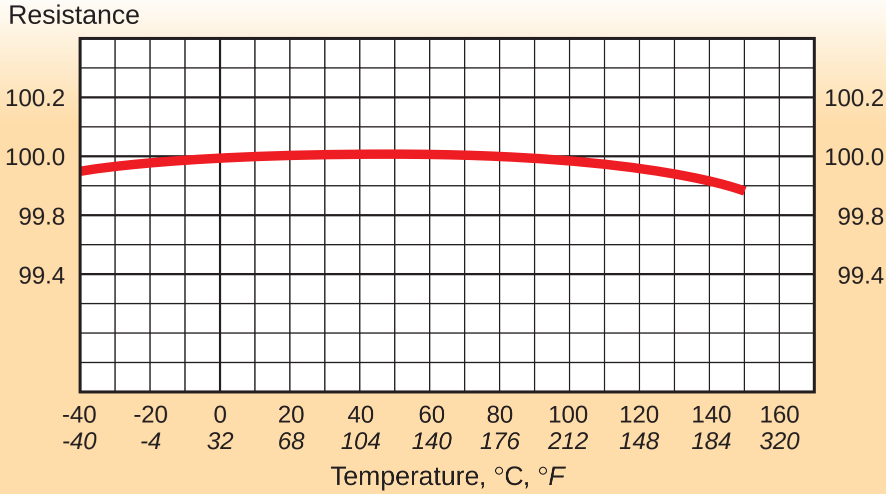
Nikrothal LX is essentially an 80/20 nickel-chromium alloy, modified by additions of aluminium and iron. It was specially developed for electronic applications to give increased resistivity. It has the exceptional specific resistance of 1.33 $\Omega mm^2 m^{-1}$ at 20 °C coupled with a low temperature coefficient of +/-0.00001 per degree C. These properties are essential in wire for the manufacture of precision resistors where a high ohm value and constancy of resistance are necessary. The recommended maximum operating temperature of Nikrothal LX is 300 °C *570 °F*.

One of the important features of this alloy is that it maintains its temperature resistance characteristic over a wide temperature range. This quality has a particular significance in the aircraft, computer and guided missile fields. Because of its composition, Nikrothal LX offers advantages over copper based alloys due to its extremely good oxidation and corrosion resisting qualities. These features enable the electrical properties to be maintained over a long period. It also has the advantage of a low thermal electromotive force against copper, and is non magnetic. Among its physical characteristics is very high tensile strength, which allows rapid winding speed even in very fine sizes and low thermal expansion, which minimises distortion and movements in windings. It can be soldered, brazed or welded.

Applications

- Precision potentiometers.
- Coil resistance.
- Strain gauges.
- Defrosting cables.

Resistance Temperature Characteristics - Nikrothal



Nikrothal LX

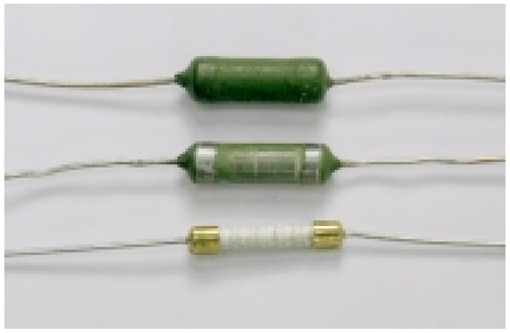
$$cm^2\ in^2/\Omega = \frac{I^2 C_t}{P}$$

I = Current
C_t = Temperature factor
P = Surface load W/cm² *in²*

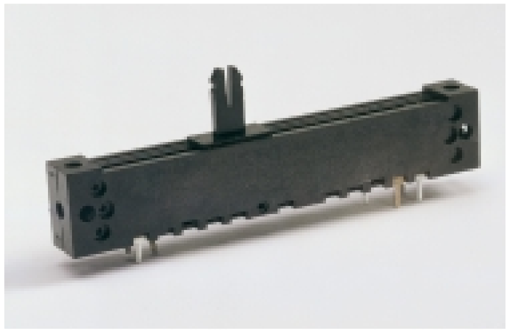
Resistivity Ωmm² m⁻¹	*Ω/cir.mil ft*	Density gm⁻³	*lb/cu.in*	Dimensions, mm	*Dimensions, in*
1.33	*812*	8.10	*0.293*	0.5-0.015	*0.0195-0.000585*

Diameter mm	Resistance at 20 °C Ω/m	cm²/Ω at 20 °C	Weight g/m	Surface area cm²/m	Cross sectional area mm²
0.50	6.77	2.32	1.59	15.71	0.1964
0.475	7.51	1.99	1.44	14.92	0.1772
0.45	8.36	1.69	1.29	14.14	0.1590
0.425	9.38	1.42	1.15	13.35	0.1419
0.40	10.6	1.19	1.02	12.57	0.1257
0.375	12.0	0.978	0.895	11.78	0.1104
0.35	13.8	0.795	0.779	11.00	0.0962
0.32	16.5	0.608	0.651	10.05	0.0804
0.30	18.8	0.501	0.573	9.42	0.0707
0.28	21.6	0.407	0.499	8.80	0.0616
0.26	25.1	0.326	0.430	8.17	0.0531
0.25	27.1	0.290	0.398	7.85	0.0491
0.24	29.4	0.256	0.366	7.54	0.0452
0.23	32.0	0.226	0.337	7.23	0.0415
0.22	35.0	0.198	0.308	6.91	0.0380
0.21	38.4	0.172	0.281	6.60	0.0346
0.20	42.3	0.148	0.254	6.28	0.0314
0.19	46.9	0.127	0.230	5.97	0.0284
0.18	52.3	0.108	0.206	5.65	0.0254
0.17	58.6	0.0911	0.184	5.34	0.0227
0.16	66.1	0.0760	0.163	5.03	0.0201
0.15	75.3	0.0626	0.143	4.71	0.0177
0.14	86.4	0.0509	0.125	4.40	0.0154
0.13	100	0.0408	0.108	4.08	0.0133
0.12	118	0.0321	0.0916	3.77	0.0113
0.11	140	0.0247	0.0770	3.46	0.00950
0.10	169	0.0186	0.0636	3.14	0.00785
0.090	209	0.0135	0.0515	2.83	0.00636
0.080	265	0.00950	0.0407	2.51	0.00503
0.070	346	0.00636	0.0312	2.20	0.00385
0.060	470	0.00401	0.0229	1.88	0.00283
0.050	677	0.00232	0.0159	1.57	0.00196
0.045	836	0.00169	0.0129	1.41	0.00159
0.040	1058	0.00119	0.0102	1.26	0.00126
0.035	1382	0.000795	0.00779	1.10	0.000962
0.030	1882	0.000501	0.00573	0.942	0.000707
0.028	2160	0.000407	0.00499	0.880	0.000616
0.025	2709	0.000290	0.00398	0.785	0.000491
0.022	3499	0.000198	0.00308	0.691	0.000380
0.020	4234	0.000148	0.00254	0.628	0.000314
0.019	4691	0.000127	0.00230	0.597	0.000284
0.018	5227	0.000108	0.00206	0.565	0.000254
0.017	5860	0.0000911	0.00184	0.534	0.000227
0.016	6615	0.0000760	0.00163	0.503	0.000201
0.015	7526	0.0000626	0.00143	0.471	0.000177

Resistors - Nikrothal LX



Variable Resistor - Nikrothal LX



4

Nikrothal LX

$$cm^2\ in^2/\Omega = \frac{I^2 C_t}{P}$$

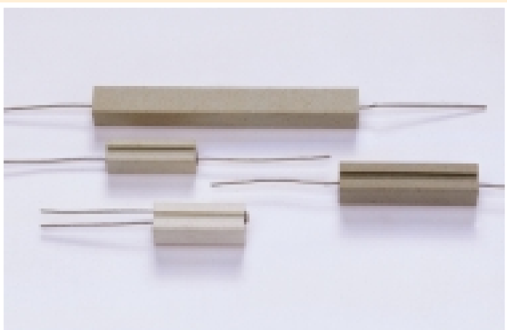
I = Current
C_t = Temperature factor
P = Surface load W/cm² *in²*

Resistivity Ωmm² m⁻¹	*Ω/cir.mil ft*	Density gm⁻³	*lb/cu.in*	Dimensions, mm	*Dimensions, in*
1.33	*812*	8.10	*0.293*	0.5-0.015	*0.0195-0.000585*

Diameter SWG	*B & S*	*inch*	*Resistance at 68°F Ω/ft*	*in²/Ω at 68°F*	*Weight lb/1000 ft*	*Surface area in²/ft*	*Cross sectional area in² x 1000*
	24	*0.0201*	*2.01*	*0.377*	*1.12*	*0.758*	*0.317*
25		*0.0200*	*2.03*	*0.371*	*1.10*	*0.754*	*0.314*
26		*0.0180*	*2.51*	*0.271*	*0.895*	*0.679*	*0.254*
	25	*0.0179*	*2.53*	*0.266*	*0.885*	*0.675*	*0.252*
27		*0.0164*	*3.02*	*0.205*	*0.743*	*0.618*	*0.211*
	26	*0.0159*	*3.21*	*0.187*	*0.698*	*0.599*	*0.199*
28		*0.0148*	*3.71*	*0.151*	*0.605*	*0.558*	*0.172*
	27	*0.0142*	*4.03*	*0.133*	*0.557*	*0.535*	*0.158*
29		*0.0136*	*4.39*	*0.117*	*0.511*	*0.513*	*0.145*
	28	*0.0126*	*5.11*	*0.0929*	*0.438*	*0.475*	*0.125*
30		*0.0124*	*5.28*	*0.0885*	*0.425*	*0.467*	*0.121*
31		*0.0116*	*6.03*	*0.0725*	*0.372*	*0.437*	*0.106*
	29	*0.0113*	*6.36*	*0.0670*	*0.353*	*0.426*	*0.100*
32		*0.0108*	*6.96*	*0.0585*	*0.322*	*0.407*	*0.0916*
33	*30*	*0.0100*	*8.12*	*0.0464*	*0.276*	*0.377*	*0.0785*
34		*0.00920*	*9.59*	*0.0362*	*0.234*	*0.347*	*0.0665*
	31	*0.00890*	*10.3*	*0.0327*	*0.219*	*0.336*	*0.0622*
35		*0.00840*	*11.5*	*0.0275*	*0.195*	*0.317*	*0.0554*
	32	*0.00800*	*12.7*	*0.0238*	*0.177*	*0.302*	*0.0503*
36		*0.00760*	*14.1*	*0.0204*	*0.160*	*0.287*	*0.0454*
	33	*0.00710*	*16.1*	*0.0166*	*0.139*	*0.268*	*0.0396*
37		*0.00680*	*17.6*	*0.0146*	*0.128*	*0.256*	*0.0363*
	34	*0.00630*	*20.5*	*0.0116*	*0.110*	*0.238*	*0.0312*
38		*0.00600*	*22.6*	*0.0100*	*0.0994*	*0.226*	*0.0283*
	35	*0.00560*	*25.9*	*0.00815*	*0.0866*	*0.211*	*0.0246*
39		*0.00520*	*30.0*	*0.00653*	*0.0747*	*0.196*	*0.0212*
	36	*0.00500*	*32.5*	*0.00580*	*0.0690*	*0.188*	*0.0196*
40		*0.00480*	*35.2*	*0.00513*	*0.0636*	*0.181*	*0.0181*
	37	*0.00450*	*40.1*	*0.00423*	*0.0559*	*0.170*	*0.0159*
41		*0.00440*	*41.9*	*0.00395*	*0.0535*	*0.166*	*0.0152*
42	*38*	*0.00400*	*50.8*	*0.00297*	*0.0442*	*0.151*	*0.0126*
43		*0.00360*	*62.7*	*0.00217*	*0.0358*	*0.136*	*0.0102*
	39	*0.00350*	*66.3*	*0.00199*	*0.0338*	*0.132*	*0.00962*
44		*0.00320*	*79.3*	*0.00152*	*0.0283*	*0.121*	*0.00804*
	40	*0.00310*	*84.5*	*0.00138*	*0.0265*	*0.117*	*0.00755*
45		*0.00280*	*104*	*0.00102*	*0.0216*	*0.106*	*0.00616*
		0.00275	*107*	*0.00097*	*0.0209*	*0.104*	*0.00594*
		0.00250	*130*	*0.000725*	*0.0173*	*0.0942*	*0.00491*
46		*0.00240*	*141*	*0.000642*	*0.0159*	*0.0905*	*0.00452*
		0.00225	*160*	*0.000529*	*0.0140*	*0.0848*	*0.00398*
47		*0.00200*	*203*	*0.000371*	*0.0110*	*0.0754*	*0.00314*
		0.00175	*265*	*0.000249*	*0.00846*	*0.0660*	*0.00241*
48		*0.00160*	*317*	*0.000190*	*0.00707*	*0.0603*	*0.00201*
		0.00150	*361*	*0.000157*	*0.00621*	*0.0565*	*0.00177*
		0.00125	*520*	*0.000091*	*0.00431*	*0.0471*	*0.00123*
49		*0.00120*	*564*	*0.0000802*	*0.00398*	*0.0452*	*0.00113*
50		*0.00100*	*812*	*0.0000464*	*0.00276*	*0.0377*	*0.000785*

Potentiometer - Nikrothal LX

Resistors - Nikrothal LX



Cuprothal 49

Cuprothal 49 is a copper-nickel alloy containing approximately 56% copper and 44% nickel. It is manufactured under close control from electrolytic copper and pure nickel.

Cuprothal 49 has a number of special characteristics - some electrical, some mechanical - which make it a remarkably versatile alloy. For certain applications, its high specific resistance and negligible temperature coefficient of resistance are its most important attributes. For others, the fact that Cuprothal 49 offers good ductility, is easily soldered and welded and has good resistance to atmospheric corrosion is more significant.

High specific resistance, together with good ductility and resistance to corrosion are all important requirements, and Cuprothal 49 satisfies the most demanding specifications.

Many of the components in the resistor field are subject to large variations of temperature and it is often vital that there should be a minimal change in resistance. Cuprothal 49 meets such a requirement admirably. Cuprothal 49 develops a high thermal electromotive force against certain other metals. It is therefore commonly used as a thermocouple alloy, in conjunction with copper, iron or T1 alloys.

Applications

- Rheostats.
- Resistors.
- Temperature-stable potentiometers.
- Volume control devices.
- Strain gauges.
- Heating cables.
- Strings in musical instruments.

Cuprothal 15, Cuprothal 10, Cuprothal 5, Cuprothal 30

Kanthal produces copper-nickel alloys with resistivities lower than Cuprothal 49, suitable for high current electrical resistances and many other applications: Heating cables, electric blankets, defrosting cables.

Cuprothal 15, resistivity 0.15 $\Omega mm^2 m^{-1}$.

Cuprothal 10, resistivity 0.10 $\Omega mm^2 m^{-1}$.

Maximum operating temperature of 250-300 °C *480-570 °F* is recommended.

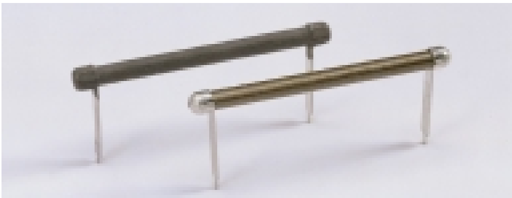
Cuprothal 5, is a low resistivity (0.05 $\Omega mm^2 m^{-1}$) Copper-Nickel alloy suitable for low temperature resistances.

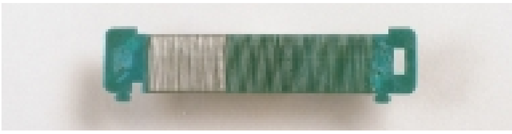
Applications
- Heating cables.
- Electric blankets.

Cuprothal 30, is a copper- nickel alloy with medium resistivity (0.3 $\Omega mm^2 m^{-1}$) suitable for medium-low temperature resistances.

Applications
- Heating cables.
- Fuses, shunts, resistors.
- Various types of controllers.

Resistors - Cuprothal 49





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Cuprothal 49, Cuprothal 15, Cuprothal 10, Cuprothal 5, Cuprothal 30

$cm^2\ in^2/\Omega = \frac{I^2 C_t}{P}$

I = Current
C_t = Temperature factor
P = Surface load W/cm² *in²*

	Resistivity Ωmm² m⁻¹	*Ω/cir.mil ft*	Density g cm⁻³	*lb/cu.in*	Dimensions, mm	*Dimensions, in*
CUPROTHAL 49	0.49	*295*	8.90	*0.322*	10-0.025	*0,390-0.000975*
CUPROTHAL 15	0.15	*90*	8.90	*0.322*	10-0.025	*0,390-0.000975*
CUPROTHAL 10	0.10	*60*	8.90	*0.322*	10-0.025	*0,390-0.000975*
CUPROTHAL 5	0.05	*30*	8.90	*0.322*	10-0.025	*0.390-0.000975*
CUPROTHAL 30	0.30	*181*	8,90	*0.322*	10-0.025	*0.390-0.000975*

To obtain resistance at working temperature multiply by the factor C_t in the following table

°C	**20**	**100**	**200**	**300**	**400**	**500**	**600**
°F	***68***	***212***	***392***	***572***	***752***	***932***	***1112***
CUPROTHAL 49	1.000	1.002	1.002	1.001	1.005	1.017	1.037
CUPROTHAL 15	1.000	1.03	1.07	1.11	1.15		
CUPROTHAL 10	1.000	1.05	1.11	1.19			
CUPROTHAL 5	1.000	1.11	1.25	1.40			
CUPROTHAL 30	1.000	1.02	1.03	1.40	1.06		

Multiply the figures in the table to get:

CUPROTHAL 49	1.0	1.0	1.0
CUPROTHAL 15	0.306	3.27	1.0
CUPROTHAL 10	0.204	4.90	1.0
CUPROTHAL 5	0.102	9.80	1.0
CUPROTHAL 30	0.612	1.63	1.0

Diameter mm	**Resistance at 20 °C Ω/m**	**cm²/Ω at 20 °C**	**Weight g/m**	**Surface area cm²/m**	**Cross sectional area mm²**
0.12	43	0.0870	0.101	3.77	0.0113
0.11	52	0.0670	0.0789	3.46	0.00950
0.10	62	0.0504	0.0652	3.14	0.00785
0.090	77	0.0367	0.0528	2.83	0.00636
0.080	97	0.0258	0.0417	2.51	0.00503
0.070	127	0.0173	0.0319	2.20	0.00385
0.060	173	0.0109	0.0235	1.88	0.00283
0.050	250	0.00629	0.0163	1.57	0.00196
0.045	308	0.00459	0.0132	1.41	0.00159
0.040	390	0.00322	0.0104	1.26	0.00126
0.035	509	0.00216	0.00799	1.10	0.000962
0.030	693	0.00136	0.00587	0.942	0.000707
0.028	796	0.00111	0.00511	0.880	0.000616
0.025	998	0.000787	0.00407	0.785	0.000491

Diameter SWG	***B & S***	***inch***	***Resistance at 68°F Ω/ft***	***in²/Ω at 68°F***	***Weight lb/1000 ft***	***Surface area in²/ft***	***Cross sectional area in² x 1000***
33	*30*	*0.0100*	*2.95*	*0.128*	*0.303*	*0.377*	*0.0785*
34		*0.00920*	*3.49*	*0.0995*	*0.257*	*0.347*	*0.0665*
	31	*0.00890*	*3.72*	*0.0901*	*0.240*	*0.336*	*0.0622*
35		*0.00840*	*4.18*	*0.0757*	*0.214*	*0.317*	*0.0554*
	32	*0.00800*	*4.61*	*0.0654*	*0.194*	*0.302*	*0.0503*
36		*0.00760*	*5.11*	*0.0561*	*0.175*	*0.287*	*0.0454*
	33	*0.00710*	*5.85*	*0.0457*	*0.153*	*0.268*	*0.0396*
37		*0.00680*	*6.38*	*0.0402*	*0.140*	*0.256*	*0.0363*
	34	*0.00630*	*7.43*	*0.0320*	*0.120*	*0.238*	*0.0312*
38		*0.00600*	*8.19*	*0.0276*	*0.109*	*0.226*	*0.0283*
	35	*0.00560*	*9.41*	*0.0224*	*0.0952*	*0.211*	*0.0246*
39		*0.00520*	*10.9*	*0.0180*	*0.0821*	*0.196*	*0.0212*
	36	*0.00500*	*11.8*	*0.0160*	*0.0759*	*0.188*	*0.0196*
40		*0.00480*	*12.8*	*0.0141*	*0.0699*	*0.181*	*0.0181*
	37	*0.00450*	*14.6*	*0.0116*	*0.0615*	*0.170*	*0.0159*
41		*0.00440*	*15.2*	*0.0109*	*0.0588*	*0.166*	*0.0152*
42	*38*	*0.00400*	*18.4*	*0.00818*	*0.0486*	*0.151*	*0.0126*
43		*0.00360*	*22.8*	*0.00596*	*0.0393*	*0.136*	*0.0102*
	39	*0.00350*	*24.1*	*0.00548*	*0.0372*	*0.132*	*0.00962*
44		*0.00320*	*28.8*	*0.00419*	*0.0311*	*0.121*	*0.00804*
	40	*0.00310*	*30.7*	*0.00381*	*0.0292*	*0.117*	*0.00755*
45		*0.00280*	*37.6*	*0.00281*	*0.0238*	*0.106*	*0.00616*
		0.00275	*39.0*	*0.00266*	*0.0230*	*0.104*	*0.00594*
		0.00250	*47.2*	*0.00200*	*0.0190*	*0.0942*	*0.00491*
46		*0.00240*	*51.2*	*0.00177*	*0.0175*	*0.0905*	*0.00452*
		0.00225	*58.3*	*0.00146*	*0.0154*	*0.0848*	*0.00398*
47		*0.00200*	*73.8*	*0.00102*	*0.0121*	*0.0754*	*0.00314*
		0.00175	*96.3*	*0.000685*	*0.00929*	*0.0660*	*0.00241*
48		*0.00160*	*115*	*0.000523*	*0.00777*	*0.0603*	*0.00201*
		0.00150	*131*	*0.000431*	*0.00683*	*0.0565*	*0.00177*
		0.00125	*189*	*0.000250*	*0.00474*	*0.0471*	*0.00123*
49		*0.00120*	*205*	*0.000221*	*0.00437*	*0.0452*	*0.00113*
50		*0.00100*	*295*	*0.000128*	*0.00303*	*0.0377*	*0.000785*

4

Conductive Alloys

Aluminum

Aluminum wire is used primarily as electrical conductors due to its inherent ability to rapidly dissipate heat, resist corrosion and its reduction in weight over other alloys.

• 1350 Aluminum has a purity of 99 to 99.5%. 1350 Al has been widely used for disk drive coils and development of tethers with heat resistant enamels and high strength bond coatings.

• EEE Aluminum, is a proprietary alloy with a purity of 99 to 99.3%. This alloy allows us to produce wire with narrow fields for resistance, elongation, and tensile strength.

Nominal Physical Properties

ASTM specification B230, B609, B544, B231, B400.

1350 AL (EC)

Resistivity: 0.028 $\Omega mm^2 m^{-1}$, *16.782 Ω/cmf*
Density: 2.703 g/cm^3, *0.097 lb/in³*
DC Conductivity: 61.8% of Copper
Tensile: 186-207 N mm^{-2}, *27-30 ksi*
Yield: 166-179 N mm^{-2}, *24-26 ksi*
Elongation: 1.2-1.4%
Thermal Coefficient of Resistance, 20 °C
Change in Unit Resistance at 20 °C/°C: .00408

EEE Al

Resistivity: 0.028 $\Omega mm^2 m^{-1}$, *16.84 Ω/cmf*
Density: 2.70 g/cm^3, *0.097 lb/in³*
DC Conductivity: 65.2% of Copper
Tensile: 200-235 N mm^{-2}, *29-34 ksi*
Yield: 193-200 N mm^{-2}, *28-29 ksi*
Elongation: 2-4%
Thermal Coefficient of Resistance, 20 °C
Change in Unit Resistance at 20 °C/°C: .00408

Copper Clad Aluminum Wire

Copper Clad Aluminum is available with 10% or 15% Copper Cladding over an Aluminum core. CCA is used for electrical contact material and conductors. CCA offers the inherent characteristics of aluminum while the copper cladding provides greater conduction of current and the ease of soldering of copper.

Nominal Physical Properties

IAW ASTM B 566, B 193, B 258, NBS Handbook 100-Copper Wire Tables.

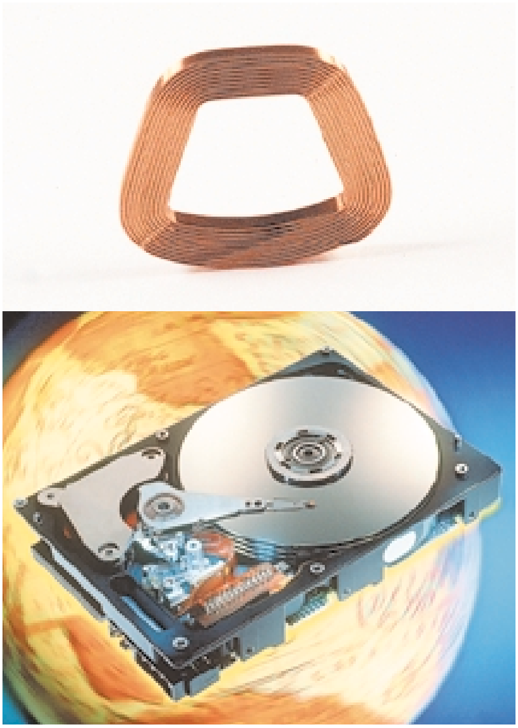
10% CCA (CDA 101)

Class 10A (annealed) &10H (hard)
Resistivity: 0.026 $\Omega mm^2 m^{-1}$, *15.90 Ω/cmf*
Density: 3.32 g/cm^3, *0.1203 lb/in³*
DC Conductivity: 65% of Copper
% Copper by Volume: 10%
% Copper by Weight: 26.8%
Tensile Strength - Hard: 193 N mm^{-2}, *28 ksi*
Tensile Strength – Annealed: 110 N mm^{-2}, *16 ksi*

15% CCA (CDA 102)

Class 15A (annealed) & 15H (hard)
Resistivity: 0.26 $\Omega mm^2 m^{-1}$, *15.50 Ω/cmf*
Density: 3.36 g/cm^3, *0.1312 lb/in³*
DC Conductivity: 67% of Copper
% Copper by Volume: 15%
% Copper by Weight: 36.6%
Tensile Strength – Hard: 207 N mm^{-2}, *30 ksi*
Tensile Strength – Annealed: 138 N mm^{-2}, *20 ksi*

Disk drive with conductive alloy coil.



4

Copper Wire

We offer OFHC copper in grades 1 & 2.

Copper has excellent physical, electrical conductivity and thermal resistance properties. Copper is easily soldered, welded, and plated for excellent corrosion resistance. Gold plated pure copper is used when electrical conductivity is crucial and its application is critical in maintaining a stable resistance with minimal variation from over the wire length.

Nominal Physical Properties

ASTM B 170, 1, 2, 3, F 68, 250, 272-grade1& 2

Grade 1 Copper C10100 99.99% Cu min.

Oxygen free electronic

Grade 2 Copper C10200 99.95% Cu+Ag min.

Oxygen free
Resistivity: 0.17 Ωmm^2 m^{-1}, *10.371 Ω/cmf*
Density: 8.94 g/cm^3, *0.323 lb/in^3*
DC Conductivity: 100%
Tensile strength – Hard: 455 N mm^{-2}, *66 ksi*
Tensile strength – Annealed: 220 N mm^{-2}, *32 ksi*

Beryllium Copper Wire

Within this group of alloys, Beryllium copper offers the highest tensile strength at approximately 1586 N mm^{-2}. It is used when high conductance and forming a rigid part is needed.

Nominal Physical Properties

Beryllium-copper C17200

Beryllium-copper C17200 Contains 1.8 to 2.0 Be
C17300 (alloy M25) ASTM B 197(C17200)
Resistivity: 0.095-0.191 Ωmm^2 m^{-1}, *57-115 Ω/cmf*
Density: 8.25 g/cm^3, *0.298 lb/in^3*
DC Conductivity: 15-30% IACS at 20C
Tensile strength: 415-1586 N mm^{-2}, *60-230 ksi*

Note: Various temper treatments determine tensile strength, elongation, yield, conductivity, and resistivity.

Applications

Conductive Alloys are used for coils in the Disk Drive, Audio Speaker and Microphone markets.

They are also used for small motors, solenoids, transformers, relays, and applications that require precision layer wound coils.

Beryllium copper can be used for the leads of Audio Voice Coils where extra strength and flexibility is needed.

Delivery forms

Conductive alloys can be drawn to any diameter in our manufacturing range. They can also be rolled into ribbon or square wire configurations. These can be delivered bare or coated with one of our wide range of Insulation's and/or Bond Coats.

Aluminum wire can also receive an anodized coating. This wire can also be delivered coated with an insulation and/or Bond.

Copper, Copper Clad and Beryllium Copper alloys can also be delivered bare or plated prior to any Insulation and/or Bond Coating.

Conductive alloys — coils for audiospeakers.

4

Conductive Alloy Comparison, metric

AWG	Diameter		RESISTANCE (Ω/m)				WEIGHT (g/m)			
	(Inches)	(mm)	OFHC Cu	15% CCAl	10% CCAl	1350 Al	OFHC Cu	15% CCAl	10% CCAl	1350 Al
25.00	0.01790	0.4547	0.1062	0.1587	0.1628	0.1718	1.4529	0.5915	0.5411	0.4408
25.25	0.01739	0.4417	0.1125	0.1681	0.1725	0.1820	1.3711	0.5582	0.5106	0.4160
25.50	0.01689	0.4291	0.1192	0.1782	0.1828	0.1929	1.2938	0.5267	0.4819	0.3926
25.75	0.01641	0.4168	0.1263	0.1888	0.1937	0.2044	1.2210	0.4971	0.4547	0.3704
26.00	0.01594	0.4049	0.1339	0.2001	0.2052	0.2166	1.1522	0.4691	0.4291	0.3496
26.25	0.01549	0.3933	0.1419	0.2120	0.2175	0.2296	1.0873	0.4427	0.4050	0.3299
26.50	0.01504	0.3821	0.1503	0.2247	0.2305	0.2433	1.0261	0.4177	0.3822	0.3113
26.75	0.01461	0.3712	0.1593	0.2381	0.2442	0.2578	0.9683	0.3942	0.3606	0.2938
27.00	0.01420	0.3606	0.1688	0.2523	0.2588	0.2732	0.9137	0.3720	0.3403	0.2772
27.25	0.01379	0.3503	0.1789	0.2673	0.2742	0.2895	0.8623	0.3510	0.3211	0.2616
27.50	0.01340	0.3403	0.1896	0.2833	0.2906	0.3067	0.8137	0.3313	0.3031	0.2469
27.75	0.01301	0.3305	0.2009	0.3002	0.3080	0.3250	0.7679	0.3126	0.2860	0.2330
28.00	0.01264	0.3211	0.2129	0.3181	0.3263	0.3444	0.7246	0.2950	0.2699	0.2199
28.25	0.01228	0.3119	0.2256	0.3371	0.3458	0.3650	0.6838	0.2784	0.2547	0.2075
28.50	0.01193	0.3030	0.2390	0.3572	0.3665	0.3868	0.6453	0.2627	0.2403	0.1958
28.75	0.01159	0.2944	0.2533	0.3786	0.3883	0.4099	0.6089	0.2479	0.2268	0.1848
29.00	0.01126	0.2859	0.2684	0.4012	0.4115	0.4343	0.5746	0.2340	0.2140	0.1744
29.25	0.01094	0.2778	0.2844	0.4251	0.4361	0.4603	0.5423	0.2208	0.2020	0.1645
29.50	0.01062	0.2698	0.3014	0.4505	0.4621	0.4877	0.5117	0.2083	0.1906	0.1553
29.75	0.01032	0.2621	0.3194	0.4774	0.4897	0.5168	0.4829	0.1966	0.1799	0.1465
30.00	0.01003	0.2546	0.3385	0.5059	0.5189	0.5477	0.4557	0.1855	0.1697	0.1383
30.25	0.00974	0.2474	0.3587	0.5360	0.5499	0.5804	0.4301	0.1751	0.1602	0.1305
30.50	0.00946	0.2403	0.3801	0.5680	0.5827	0.6150	0.4058	0.1652	0.1511	0.1231
30.75	0.00919	0.2334	0.4028	0.6019	0.6175	0.6517	0.3830	0.1559	0.1426	0.1162
31.00	0.00893	0.2268	0.4268	0.6379	0.6543	0.6906	0.3614	0.1471	0.1346	0.1097
31.25	0.00867	0.2203	0.4523	0.6759	0.6934	0.7318	0.3410	0.1388	0.1270	0.1035
31.50	0.00842	0.2140	0.4793	0.7163	0.7348	0.7755	0.3218	0.1310	0.1199	0.0976
31.75	0.00818	0.2079	0.5079	0.7590	0.7786	0.8218	0.3037	0.1236	0.1131	0.0921
32.00	0.00795	0.2019	0.5382	0.8043	0.8251	0.8709	0.2866	0.1167	0.1067	0.0870
32.25	0.00772	0.1962	0.5703	0.8523	0.8743	0.9228	0.2705	0.1101	0.1007	0.0821
32.50	0.00750	0.1906	0.6043	0.9032	0.9265	0.9779	0.2552	0.1039	0.0951	0.0774
32.75	0.00729	0.1851	0.6404	0.9571	0.9818	1.0363	0.2409	0.0981	0.0897	0.0731
33.00	0.00708	0.1798	0.6786	1.0142	1.0404	1.0981	0.2273	0.0925	0.0847	0.0690
33.25	0.00688	0.1747	0.7191	1.0748	1.1025	1.1637	0.2145	0.0873	0.0799	0.0651
33.50	0.00668	0.1697	0.7621	1.1389	1.1683	1.2331	0.2024	0.0824	0.0754	0.0614
33.75	0.00649	0.1649	0.8075	1.2069	1.2381	1.3067	0.1910	0.0778	0.0711	0.0580
34.00	0.00630	0.1601	0.8557	1.2789	1.3119	1.3847	0.1802	0.0734	0.0671	0.0547
34.25	0.00612	0.1556	0.9068	1.3553	1.3903	1.4674	0.1701	0.0692	0.0634	0.0516
34.50	0.00595	0.1511	0.9609	1.4362	1.4732	1.5550	0.1605	0.0653	0.0598	0.0487
34.75	0.00578	0.1468	1.0183	1.5219	1.5612	1.6478	0.1515	0.0617	0.0564	0.0460
35.00	0.00561	0.1426	1.0791	1.6127	1.6543	1.7461	0.1429	0.0582	0.0532	0.0434
35.25	0.00545	0.1385	1.1435	1.7090	1.7531	1.8503	0.1349	0.0549	0.0502	0.0409
35.50	0.00530	0.1346	1.2117	1.8110	1.8577	1.9608	0.1273	0.0518	0.0474	0.0386
35.75	0.00515	0.1307	1.2840	1.9191	1.9686	2.0778	0.1201	0.0489	0.0447	0.0364
36.00	0.00500	0.1270	1.3607	2.0336	2.0861	2.2018	0.1134	0.0462	0.0422	0.0344
36.50	0.00472	0.1198	1.5279	2.2836	2.3425	2.4725	0.1009	0.0411	0.0376	0.0306
37.00	0.00445	0.1131	1.7158	2.5643	2.6305	2.7764	0.0899	0.0366	0.0335	0.0273
37.50	0.00420	0.1067	1.9267	2.8796	2.9539	3.1177	0.0801	0.0326	0.0298	0.0243
38.00	0.00397	0.1007	2.1636	3.2336	3.3170	3.5010	0.0713	0.0290	0.0266	0.0216
38.50	0.00374	0.0950	2.4295	3.6311	3.7248	3.9314	0.0635	0.0258	0.0236	0.0193
39.00	0.00353	0.0897	2.7282	4.0774	4.1827	4.4147	0.0565	0.0230	0.0211	0.0172
39.50	0.00333	0.0846	3.0636	4.5787	4.6968	4.9574	0.0503	0.0205	0.0188	0.0153
40.00	0.00314	0.0799	3.4402	5.1415	5.2742	5.5668	0.0448	0.0183	0.0167	0.0136

Conductive Alloy Comparison, imperial

AWG	Diameter		RESISTANCE (Ω/ft)				WEIGHT (lbs/1000 ft)			
	(Inches)	(mm)	OFHC Cu	15% CCAl	10% CCAl	1350 Al	OFHC Cu	15% CCAl	10% CCAl	1350 Al
25.00	0.01790	0.4547	0.0324	0.0484	0.0496	0.0524	0.9754	0.3971	0.3633	0.2959
25.25	0.01739	0.4417	0.0343	0.0513	0.0526	0.0555	0.9205	0.3747	0.3428	0.2793
25.50	0.01689	0.4291	0.0363	0.0543	0.0557	0.0588	0.8686	0.3536	0.3235	0.2635
25.75	0.01641	0.4168	0.0385	0.0576	0.0590	0.0623	0.8197	0.3337	0.3053	0.2487
26.00	0.01594	0.4049	0.0408	0.0610	0.0626	0.0660	0.7735	0.3149	0.2881	0.2347
26.25	0.01549	0.3933	0.0433	0.0646	0.0663	0.0700	0.7300	0.2972	0.2719	0.2215
26.50	0.01504	0.3821	0.0458	0.0685	0.0703	0.0742	0.6889	0.2804	0.2566	0.2090
26.75	0.01461	0.3712	0.0486	0.0726	0.0745	0.0786	0.6501	0.2647	0.2421	0.1972
27.00	0.01420	0.3606	0.0515	0.0769	0.0789	0.0833	0.6134	0.2497	0.2285	0.1861
27.25	0.01379	0.3503	0.0545	0.0815	0.0836	0.0883	0.5789	0.2357	0.2156	0.1756
27.50	0.01340	0.3403	0.0578	0.0864	0.0886	0.0935	0.5463	0.2224	0.2035	0.1657
27.75	0.01301	0.3305	0.0612	0.0915	0.0939	0.0991	0.5155	0.2099	0.1920	0.1564
28.00	0.01264	0.3211	0.0649	0.0970	0.0995	0.1050	0.4865	0.1981	0.1812	0.1476
28.25	0.01228	0.3119	0.0688	0.1028	0.1054	0.1113	0.4591	0.1869	0.1710	0.1393
28.50	0.01193	0.3030	0.0729	0.1089	0.1117	0.1179	0.4332	0.1764	0.1614	0.1314
28.75	0.01159	0.2944	0.0772	0.1154	0.1184	0.1250	0.4088	0.1664	0.1523	0.1240
29.00	0.01126	0.2859	0.0818	0.1223	0.1255	0.1324	0.3858	0.1571	0.1437	0.1171
29.25	0.01094	0.2778	0.0867	0.1296	0.1329	0.1403	0.3641	0.1482	0.1356	0.1105
29.50	0.01062	0.2698	0.0919	0.1373	0.1409	0.1487	0.3436	0.1399	0.1280	0.1042
29.75	0.01032	0.2621	0.0974	0.1455	0.1493	0.1576	0.3242	0.1320	0.1208	0.0984
30.00	0.01003	0.2546	0.1032	0.1542	0.1582	0.1670	0.3060	0.1246	0.1140	0.0928
30.25	0.00974	0.2474	0.1093	0.1634	0.1676	0.1769	0.2887	0.1175	0.1075	0.0876
30.50	0.00946	0.2403	0.1159	0.1732	0.1777	0.1875	0.2725	0.1109	0.1015	0.0827
30.75	0.00919	0.2334	0.1228	0.1835	0.1883	0.1987	0.2571	0.1047	0.0958	0.0780
31.00	0.00893	0.2268	0.1301	0.1945	0.1995	0.2106	0.2426	0.0988	0.0904	0.0736
31.25	0.00867	0.2203	0.1379	0.2061	0.2114	0.2231	0.2290	0.0932	0.0853	0.0695
31.50	0.00842	0.2140	0.1461	0.2184	0.2240	0.2364	0.2161	0.0880	0.0805	0.0656
31.75	0.00818	0.2079	0.1548	0.2314	0.2374	0.2506	0.2039	0.0830	0.0759	0.0619
32.00	0.00795	0.2019	0.1641	0.2452	0.2516	0.2655	0.1924	0.0783	0.0717	0.0584
32.25	0.00772	0.1962	0.1739	0.2599	0.2666	0.2814	0.1816	0.0739	0.0676	0.0551
32.50	0.00750	0.1906	0.1842	0.2754	0.2825	0.2981	0.1714	0.0698	0.0638	0.0520
32.75	0.00729	0.1851	0.1952	0.2918	0.2993	0.3159	0.1617	0.0658	0.0602	0.0491
33.00	0.00708	0.1798	0.2069	0.3092	0.3172	0.3348	0.1526	0.0621	0.0568	0.0463
33.25	0.00688	0.1747	0.2192	0.3277	0.3361	0.3548	0.1440	0.0586	0.0536	0.0437
33.50	0.00668	0.1697	0.2323	0.3472	0.3562	0.3760	0.1359	0.0553	0.0506	0.0412
33.75	0.00649	0.1649	0.2462	0.3680	0.3775	0.3984	0.1282	0.0522	0.0478	0.0389
34.00	0.00630	0.1601	0.2609	0.3899	0.4000	0.4222	0.1210	0.0493	0.0451	0.0367
34.25	0.00612	0.1556	0.2765	0.4132	0.4239	0.4474	0.1142	0.0465	0.0425	0.0346
34.50	0.00595	0.1511	0.2930	0.4379	0.4492	0.4741	0.1078	0.0439	0.0401	0.0327
34.75	0.00578	0.1468	0.3105	0.4640	0.4760	0.5024	0.1017	0.0414	0.0379	0.0309
35.00	0.00561	0.1426	0.3290	0.4917	0.5044	0.5323	0.0960	0.0391	0.0357	0.0291
35.25	0.00545	0.1385	0.3486	0.5210	0.5345	0.5641	0.0906	0.0369	0.0337	0.0275
35.50	0.00530	0.1346	0.3694	0.5521	0.5664	0.5978	0.0855	0.0348	0.0318	0.0259
35.75	0.00515	0.1307	0.3915	0.5851	0.6002	0.6335	0.0806	0.0328	0.0300	0.0245
36.00	0.00500	0.1270	0.4148	0.6200	0.6360	0.6713	0.0761	0.0310	0.0283	0.0231
36.50	0.00472	0.1198	0.4658	0.6962	0.7142	0.7538	0.0678	0.0276	0.0252	0.0206
37.00	0.00445	0.1131	0.5231	0.7818	0.8020	0.8465	0.0604	0.0246	0.0225	0.0183
37.50	0.00420	0.1067	0.5874	0.8779	0.9006	0.9505	0.0537	0.0219	0.0200	0.0163
38.00	0.00397	0.1007	0.6596	0.9858	1.0113	1.0674	0.0479	0.0195	0.0178	0.0145
38.50	0.00374	0.0950	0.7407	1.1070	1.1356	1.1986	0.0426	0.0174	0.0159	0.0129
39.00	0.00353	0.0897	0.8318	1.2431	1.2752	1.3459	0.0380	0.0155	0.0141	0.0115
39.50	0.00333	0.0846	0.9340	1.3959	1.4320	1.5114	0.0338	0.0138	0.0126	0.0103
40.00	0.00314	0.0799	1.0488	1.5675	1.6080	1.6972	0.0301	0.0123	0.0112	0.0091

4

Alloys for Medical Applications

MP35N

MP35N is a nonmagnetic, nickel-cobalt-chromium-molybdenum alloy possessing a unique combination of ultrahigh tensile strength, good ductility and toughness, and excellent corrosion resistance. In addition, it displays exceptional resistance to sulfidation, high temperature oxidation and hydrogen embrittlement.

The MP35N is triple melted for extreme cleanliness, allowing its use as lead material for permanent implant.

For medical use, Kanthal delivers MP35N with the highest surface finish (Medical class), that makes it suitable for implants, like lead wires to pacemakers.

MP35N is a trademark of SPS Technologies, Inc.

AISI 302V, AISI 304V, AISI 316LV

These nickel-chromium stainless steel alloys are vacuum melted and drawn through new diamond dies to create a Medical class surface. The wire can also be coated to meet specific needs. The applications in the medical field include a broad range of devices for temporary use like needles, catheters etc.

Applications

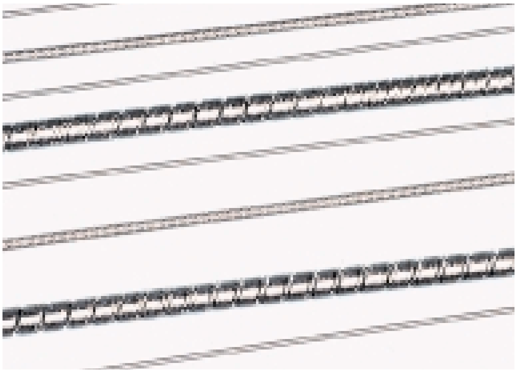
MP35N

Its main use is as permanent lead in pacemakers and other implants and in instrument parts in medical devices.

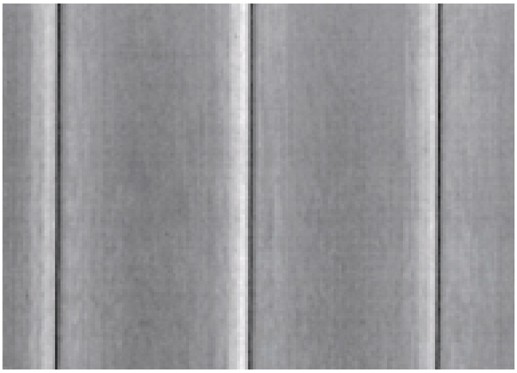
Stainless

Non-permanent use in needles, syringes, catheters, as guide wire etc.

Pacemaker leads.



Medical Grade Surface, MP35N at 2000 x.



4 Precious Metals

Platinum

Platinum is a noble metal used mainly in high temperature thermocouples but also in the medical industry due to its ability to resist corrosion under virtually any circumstances. Platinum and many of its alloys are unaffected to any degree by single acids or lengthy exposure to hostile environments.

It is available commercially in several different degrees of purity and the highest, 99.999% is not generally required for medical applications. Pure Platinum has a limited strength and it is therefore normally alloyed with Iridium or Tungsten, especially for fine wire in the medical field. In the Properties section, page 18, data for the commercial grade is shown only as reference.

All Platinum wire can be coated or even insulated and it can be supplied in the Medical Grade of surface finish.

Platinum Iridium

These alloys containing different proportions of Iridium and Platinum have been industry standards in wire form for a long time. Kanthal normally supplies wire with 10 or 20% Iridium for medical and other applications.

Platinum Tungsten

Apart from its exceptional corrosion resistance, this alloy features high resistance in combination with a low temperature coefficient of resistance. The very high tensile strength makes it widely used in different medical applications.

Gold

The unsurpassed resistance to oxidation and sulfidation of pure gold is a feature utilized in for instance electrical contacts. The low melting point, however, limits its use to a maximum of 0.5 A. The low hardness is often increased by alloying with copper, silver, palladium or platinum but even so, the use is restricted to low current applications.

A specialty of Kanthal Precision Technology is ultra-fine gold plating of copper, MP35N, stainless or other wire types to obtain exactly the properties needed for each specific application.

Silver

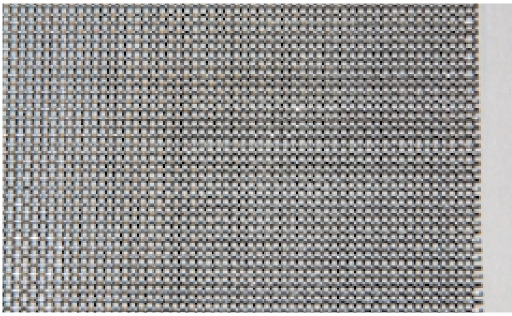
Silver has the highest electrical and thermal conductivity of all metals and is mainly used in high current contacts. For many other applications, silver is too soft and consequently alloyed with copper, cadmium, platinum, gold or other elements to increase the hardness.

Silver is also a plating material on different wire types.

Applications

Uses include coils for diagnostics, leads in pacemakers either as straight or string, and for woven cloth use for pharmaceutical filters or screening. The main feature of Platinum content alloys to remain unaffected in hostile environments, make them widely accepted in the medical field for instance as guide wires, pacing leads or contacts for interfacing of tissue. Gold plated wire is used in the electronics industry. Silver and silver alloys main application area is electrical contacts.

Wire cloth of precious metals.



High Temperature Alloys for Mechanical Applications

AISI 314/M, AISI 304/LC, AISI 316/LC, AISI 347

To resist high operating temperatures these alloys should have the following requirements:

- Should not crystallize or excessively anneal at working temperature, and not be susceptible to spalling by oxidation.
- Should keep a certain hardness at high temperature.
- Should not age at working temperature and cause unstable and brittle phases.
- Should have a good potential elongation, without either breaking or excessively creeping at those temperatures. Nickel, chromium and iron are the fundamental elements for corrosion resisting alloys, together with other alloying elements. As an indication a list of some effects of the elements is shown.

Chromium, sufficiently high in percentage, gives surface passivity in oxidising conditions and so forms a chromium oxide coating film resisting the attack of corrosion agents.

Nickel helps the effect of chromium in oxidising conditions and improves corrosion resistance in reducing conditions. In sufficiently high percentages nickel favours resistance to strong alkali and halogen compounds.

Molybdenum generally reduces pitting in sea water, improving resistance to sulphuric, phosphoric, hydrochloric acids.

Copper has similar effects to molybdenum.

Silicon improves resistance to dilute hydrochloric acid but reduces resistance to nitric acid.

Carbon has negative effects regarding corrosion resistance; if combined with chromium forms carbides; in order to reduce carbide formation, carbon percentage should be kept under 0.03 (low carbon series) or small quantities of columbium (niobium) or titanium added that form preferential Cb or Ti carbides instead of brittle chromium carbides. To reduce negative effects of carbon, solution treatment should finally be mentioned.

Applications

AISI 314 is used for operating temperatures between 870-1000 °C *1600-1830 °F.*

AISI 314 M has better resistance to oxidation; same temperature range.

AISI 304 and **AISI 316** are used in filters and screens in the chemical industry and as RF-shielding.

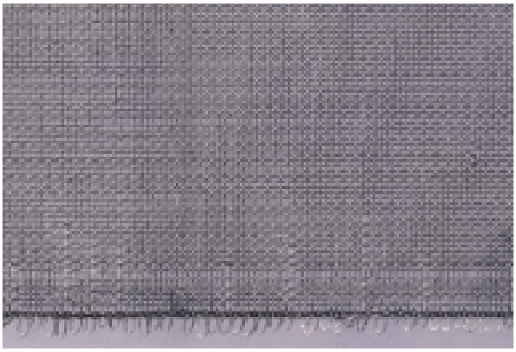
AISI 304 LC and **AISI 316 LC** have a better resistance to corrosion for lower chromium carbides formation

AISI 347 is a general purpose stainless steel with Niobium added to suppress gain boundary Chromium Carbide precipitation.

Sizes

0.51-0.040 mm, *0.0201-0.00156 in*

Chemical Filter - AISI 316 LC



4 Alloys for Special Applications

Nifethal 70

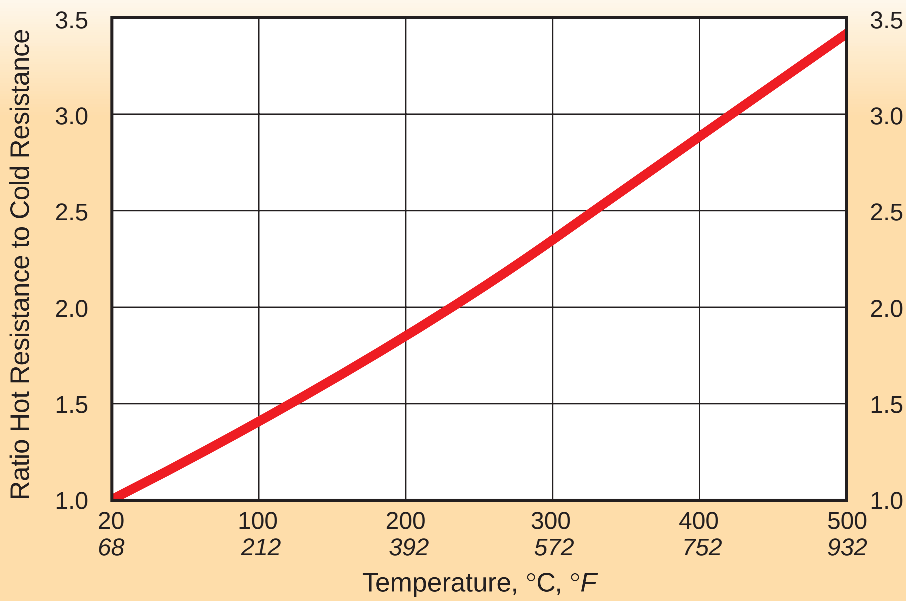
Nifethal 70 is an austenitic alloy based on nickel and iron, showing high temperature factor of resistivity (positive temperature coefficient). In addition to this property, it has a low thermal expansion coefficient and low resistivity.

An increase in resistance by a factor two, will result in a reduction in power output by the same factor, if the voltage remains constant. The result is a positive temperature coefficient effect, making the wire self-regulating, i.e. the power decreases as temperature, and thereby resistance, increases. The same property will also provide a sensing function, e.g. for temperature sensing devices.

Applications

- Self controlling heating elements with high start up power output.
- Voltage regulators.
- Timing devices.
- Temperature sensitive resistors and temperature compensating devices.
- Heating cables.
- Blankets.
- Strings for musical instruments.

Ratio of Resistance at a given Wire Temperature to Resistance at 20 °C, 68 °F, C_t vs Wire Temperature.



Nifethal 70

$$cm^2\ in^2/\Omega = \frac{I^2 C_t}{P}$$

I = Current
C_t = Temperature factor
P = Surface load W/cm² *in²*

	Resistivity Ωmm² m⁻¹	*Ω/cir.mil ft*	Density, g cm⁻³	*lb/cu.in*	Dimensions, mm	*Dimensions, in*
NIFETHAL 70	0.21	*126*	8.45	*0.305*	1.8-0.025	*0.070-0.00975*

To obtain resistance at working temperature multiply by the factor C_t in the following table

°C	**20.0**	**100**	**200**	**300**	**400**	**500**	**600**
°F	***68***	***212***	***392***	***572***	***752***	***932***	***1112***
NIFETHAL 70	1.0	1.35	1.80	2.30	2.82	3.40	4.08

Diameter mm	Resistance at 20 °C Ω/m	cm²/Ω at 20 °C	Weight g/m	Surface area cm²/m	Cross sectional area mm²
0.12	18.6	0.203	0.0956	3.77	0.0113
0.11	22.1	0.156	0.0803	3.46	0.00950
0.10	26.7	0.117	0.0664	3.14	0.00785
0.090	33.0	0.0857	0.0538	2.83	0.00636
0.080	41.8	0.0602	0.0425	2.51	0.00503
0.070	54.6	0.0403	0.0325	2.20	0.00385
0.060	74.3	0.0254	0.0239	1.88	0.00283
0.050	107	0.0147	0.0166	1.57	0.00196
0.045	132	0.0107	0.0134	1.41	0.00159
0.040	167	0.00752	0.0106	1.26	0.00126
0.035	218	0.00504	0.00813	1.10	0.000962
0.030	297	0.00317	0.00597	0.942	0.000707
0.028	341	0.00258	0.00520	0.880	0.000616
0.025	428	0.00184	0.00415	0.785	0.000491

Diameter SWG	*B & S*	*inch*	*Resistance at 68°F Ω/ft*	*in²/Ω at 68°F*	*Weight lb/1000 ft*	*Surface area in²/ft*	*Cross sectional area in² x 1000*
33	*30*	*0.0100*	*1.26*	*0.299*	*0.287*	*0.377*	*0.0785*
34		*0.00920*	*1.49*	*0.233*	*0.243*	*0.347*	*0.0665*
	31	*0.00890*	*1.59*	*0.211*	*0.228*	*0.336*	*0.0622*
35		*0.00840*	*1.79*	*0.177*	*0.203*	*0.317*	*0.0554*
	32	*0.00800*	*1.97*	*0.153*	*0.184*	*0.302*	*0.0503*
36		*0.00760*	*2.18*	*0.131*	*0.166*	*0.287*	*0.0454*
	33	*0.00710*	*2.50*	*0.107*	*0.145*	*0.268*	*0.0396*
37		*0.00680*	*2.72*	*0.0941*	*0.133*	*0.256*	*0.0363*
	34	*0.00630*	*3.17*	*0.0748*	*0.114*	*0.238*	*0.0312*
38		*0.00600*	*3.50*	*0.0646*	*0.103*	*0.226*	*0.0283*
	35	*0.00560*	*4.02*	*0.0525*	*0.0901*	*0.211*	*0.0246*
39		*0.00520*	*4.66*	*0.0421*	*0.0777*	*0.196*	*0.0212*
	36	*0.00500*	*5.04*	*0.0374*	*0.0719*	*0.188*	*0.0196*
40		*0.00480*	*5.47*	*0.0331*	*0.0662*	*0.181*	*0.0181*
	37	*0.00450*	*6.22*	*0.0273*	*0.0582*	*0.170*	*0.0159*
41		*0.00440*	*6.51*	*0.0255*	*0.0557*	*0.166*	*0.0152*
42	*38*	*0.00400*	*7.88*	*0.0191*	*0.0460*	*0.151*	*0.0126*
43		*0.00360*	*9.72*	*0.0140*	*0.0373*	*0.136*	*0.0102*
	39	*0.00350*	*10.3*	*0.0128*	*0.0352*	*0.132*	*0.0096*
44		*0.00320*	*12.3*	*0.00980*	*0.0294*	*0.121*	*0.00804*
	40	*0.00310*	*13.1*	*0.00891*	*0.0276*	*0.117*	*0.00755*
45		*0.00280*	*16.1*	*0.00657*	*0.0225*	*0.106*	*0.00616*
		0.00275	*16.7*	*0.00622*	*0.0217*	*0.104*	*0.00594*
		0.00250	*20.2*	*0.00468*	*0.0180*	*0.0942*	*0.00491*
46		*0.00240*	*21.9*	*0.00414*	*0.0166*	*0.0905*	*0.00452*
		0.00225	*24.9*	*0.00341*	*0.0146*	*0.0848*	*0.00398*
47		*0.00200*	*31.5*	*0.00239*	*0.0115*	*0.0754*	*0.00314*
		0.00175	*41.1*	*0.00160*	*0.00880*	*0.0660*	*0.00241*
48		*0.00160*	*49.2*	*0.00123*	*0.00736*	*0.0603*	*0.00201*
		0.00150	*56.0*	*0.00101*	*0.00647*	*0.0565*	*0.00177*
		0.00125	*80.6*	*0.000584*	*0.00449*	*0.0471*	*0.00123*
49		*0.00120*	*87.5*	*0.000517*	*0.00414*	*0.0452*	*0.00113*
50		*0.00100*	*126*	*0.000299*	*0.00287*	*0.0377*	*0.000785*

4

Nifethal 36

Nifethal 36 is an iron-nickel austenitic alloy, with very low thermal expansion below 180 °C *355 °F*. It combines a good mechanical resistance, ductility and malleability with a fair degree of corrosion resistance. It is magnetic over its normal range of use. Nifethal 36 is a standard alloy for applications where a low expansion is required up to a maximum of 180 °C *355 °F*, a temperature that is not advisable to exceed. The effect of heat treatment on the expansion of the alloy is correlated to the cooling treatment: a quick cooling reduces the expansion coefficient, a slow cooling produces the opposite effect. Cold working is even more effective in lowering the coefficient but possible subsequent annealing can remove the effects of this work in proportion to the temperature achieved. The alloy will assume the values corresponding to the annealed condition when annealing is carried out at 600 °C *1110 °F* (approx). In case Nifethal 36 is used for high precision applications, it is advisable to stabilise the material by stress relieving.

Nifethal 36 is also available in many forms than as Precision Wire.

Average coefficient of thermal expansion:

0-100 °C	$1.5x10^{-6}$
0-200 °C	$2.5x10^{-6}$
-100-0 °C	$2.0x10^{-6}$

Applications

All applications where an almost zero expansion rate in the range of the ambience temperature is needed, together with good resistance:

- Thermostat bars.
- Wires and ribbons for precision measures.
- Blades for adjustable condensers.
- Resonant radar cavities.
- Cryogenic applications.
- RF- shielding.

Thermal electromotive force against Cu, µV/°C, 20-100 °C	9.72
Inflexion point, °C *°F*	190 *375*
Young's modulus, N/mm^2	147000
Thermoelastic coefficient 0-100 °C	$+500x10^{-6}$/°C

RF-Shielding of cable - Nifethal 36.

Nifethal 36

$$cm^2\ in^2/\Omega = \frac{I^2 C_t}{P}$$

I = Current
C_t = Temperature factor
P = Surface load W/cm^2 *in^2*

4

	Resistivity $\Omega mm^2 m^{-1}$	*Ω/cir.mil ft*	Density, g cm^{-3}	*lb/cu.in*	Dimensions, mm	*Dimensions, in*
NIFETHAL 36	0.82 (indication only)	*495*	8.08	*0.292*	10.0-0.025	*0.39-0.00975*

Diameter mm	Resistance at 20 °C Ω/m	cm^2/Ω at 20 °C	Weight g/m	Surface area cm^2/m	Cross sectional area mm^2
0.12	72.5	0.0520	0.0914	3.77	0.0113
0.11	86.3	0.0401	0.0768	3.46	0.00950
0.10	104	0.0301	0.0635	3.14	0.00785
0.090	129	0.0219	0.0514	2.83	0.00636
0.080	163	0.0154	0.0406	2.51	0.00503
0.070	213	0.0103	0.0311	2.20	0.00385
0.060	290	0.00650	0.0228	1.88	0.00283
0.050	418	0.00376	0.0159	1.57	0.00196
0.045	516	0.00274	0.0129	1.41	0.00159
0.040	653	0.00193	0.0102	1.26	0.00126
0.035	852	0.00129	0.00777	1.10	0.000962
0.030	1160	0.000812	0.00571	0.942	0.000707
0.028	1332	0.000661	0.00498	0.880	0.000616
0.025	1670	0.000470	0.00397	0.785	0.000491

Diameter SWG	*B & S*	*inch*	*Resistance at 68 °F Ω/ft*	*in^2/Ω at 68 °F*	*Weight lb/1000 ft*	*Surface area in^2/ft*	*Cross sectional area in^2 x 1000*
33	*30*	*0.0100*	*4.95*	*0.0762*	*0.275*	*0.377*	*0.0785*
34		*0.00920*	*5.85*	*0.0593*	*0.233*	*0.347*	*0.0665*
	31	*0.00890*	*6.25*	*0.0537*	*0.218*	*0.336*	*0.0622*
35		*0.00840*	*7.02*	*0.0451*	*0.194*	*0.317*	*0.0554*
	32	*0.00800*	*7.73*	*0.0390*	*0.176*	*0.302*	*0.0503*
36		*0.00760*	*8.57*	*0.0334*	*0.159*	*0.287*	*0.0454*
	33	*0.00710*	*9.82*	*0.0273*	*0.139*	*0.268*	*0.0396*
37		*0.00680*	*10.7*	*0.0239*	*0.127*	*0.256*	*0.0363*
	34	*0.00630*	*12.5*	*0.0190*	*0.109*	*0.238*	*0.0312*
38		*0.00600*	*13.8*	*0.0165*	*0.0991*	*0.226*	*0.0283*
	35	*0.00560*	*15.8*	*0.0134*	*0.0863*	*0.211*	*0.0246*
39		*0.00520*	*18.3*	*0.01071*	*0.0744*	*0.196*	*0.0212*
	36	*0.00500*	*19.8*	*0.00952*	*0.0688*	*0.188*	*0.0196*
40		*0.00480*	*21.5*	*0.00842*	*0.0634*	*0.181*	*0.0181*
	37	*0.00450*	*24.4*	*0.00694*	*0.0557*	*0.170*	*0.0159*
41		*0.00440*	*25.6*	*0.00649*	*0.0533*	*0.166*	*0.0152*
42	*38*	*0.00400*	*30.9*	*0.00487*	*0.0440*	*0.151*	*0.0126*
43		*0.00360*	*38.2*	*0.00355*	*0.0357*	*0.136*	*0.0102*
	39	*0.00350*	*40.4*	*0.00327*	*0.0337*	*0.132*	*0.00962*
44		*0.00320*	*48.3*	*0.00250*	*0.0282*	*0.121*	*0.00804*
	40	*0.00310*	*51.5*	*0.00227*	*0.0264*	*0.117*	*0.00755*
45		*0.00280*	*63.1*	*0.00167*	*0.0216*	*0.106*	*0.00616*
		0.00275	*65.5*	*0.00158*	*0.0208*	*0.104*	*0.00594*
		0.00250	*79.2*	*0.001190*	*0.0172*	*0.0942*	*0.00491*
46		*0.00240*	*85.9*	*0.001053*	*0.0159*	*0.0905*	*0.00452*
		0.00225	*97.8*	*0.000868*	*0.0139*	*0.0848*	*0.00398*
47		*0.00200*	*124*	*0.000609*	*0.0110*	*0.0754*	*0.00314*
		0.00175	*162*	*0.000408*	*0.00843*	*0.0660*	*0.00241*
48		*0.00160*	*193*	*0.000312*	*0.00705*	*0.0603*	*0.00201*
		0.00150	*220*	*0.000257*	*0.00619*	*0.0565*	*0.00177*
		0.00125	*317*	*0.000149*	*0.00430*	*0.0471*	*0.00123*
49		*0.00120*	*344*	*0.0001316*	*0.00396*	*0.0452*	*0.00113*
50		*0.00100*	*495*	*0.0000762*	*0.00275*	*0.0377*	*0.000785*

4

Cuni 67

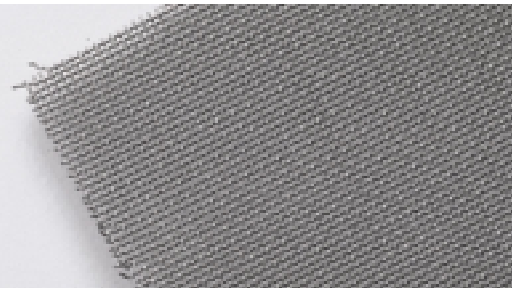
Cuni 67 is a copper-nickel alloy with good workability added to excellent resistance to oxidation and to many chemical agents. Because of its very good resistance to sea water it is frequently used for marine applications both in stagnant and under high velocity operating conditions. In the precision wire form, Cuni 67 can easily be interwoven. It complies with ASTM-B-164 and Werkstoff Nr. 2.436O.

Kanthal produces, besides Cuni 67, a wide series of copper-nickel alloys almost covering the whole range of relative percentages of Ni and Cu. These alloys are suitable in chemical applications for their high resistance to corrosion and for their excellent cold and hot forming.

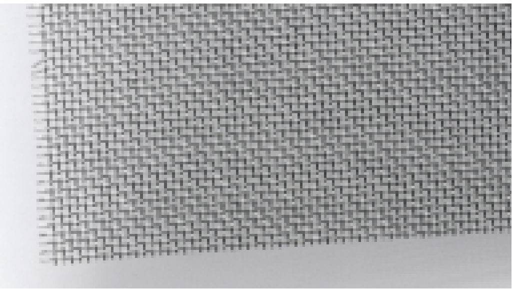
Applications

- Different marine applications.
- Filter bed material in the Petrochemical industry and for water purification purposes.
- In the bright finish condition it finds a wide field of employment in the small metallic parts industry and in the optical and glass industry.
- RF-shielding for special communication cables.

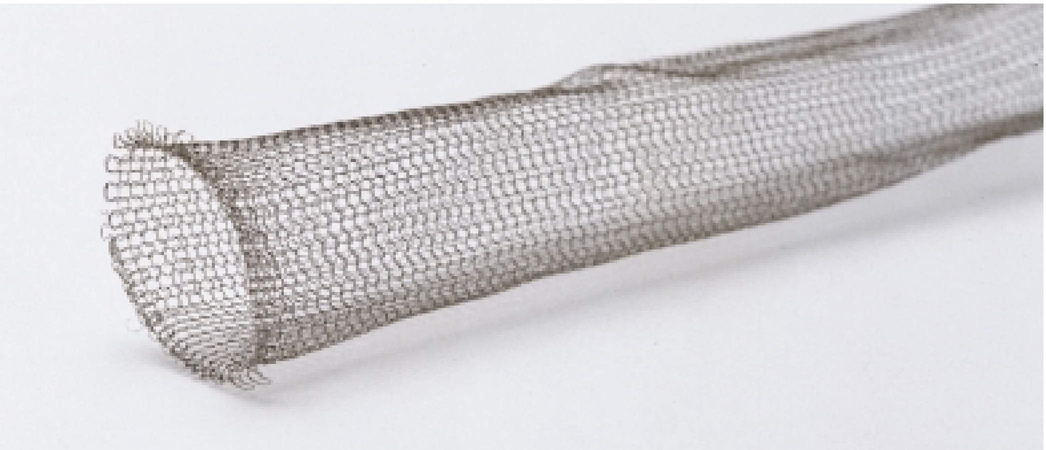
Industrial Chemical Filter - Cuni 67.



Wire Mesh - Cuni 67.



RF Shielding of transmission cable - Cuni 67.



Surface finish

5

Kanthal Precision Wire can be supplied with the following surface finishes.

Bright annealed

The material is annealed in reducing atmosphere.

Oxidized with annealing color

The material is annealed in air.

Anodizing

Anodizing round or ribbon wire creates a very thin, high temperature coating – the thinnest possible electrical insulation available for aluminum.

Electro-Plating

Using modern plating techniques we can achieve uniform thickness of a high polished gold surface. 99.99% pure gold may be applied with or without a nickel substrate on most alloys.
Other materials, such as nickel, copper and silver can also be plated onto round and ribbon wires.

Surface grades

The alloys are supplied in three different surface grades.

- **Standard.**

The wire shall be uniform and free from kinks, curls and surface defects such as seams, laminations, scale and other irregularities as the best commercial practice will permit.

- **Premium**

Minimal surface defects, such as die lines, scrapes, gouges. Used mainly for low noise applications (i.e. potentiometers)

- **Medical**

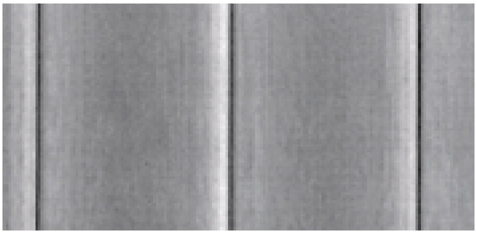
Defect free surface. No die lines, scrapes, inclusions or slivers permitted.

Bright annealed.

Oxidized with annealing color.

Electro-Plating.

Medical surface finish.



Gold plated copper wire.

6 Insulation and Adhesive Coating

A broad range of wire insulations and adhesive bond coats is available. Each insulation differs in its temperature capability and end user properties. We can assist you in selecting coatings which are appropriate for your application. All coatings can be applied to meet standard industry specifications (NEMA, ASTM, JIS etc.), or they can be tailored to meet specific specifications. All insulations can be pigmented with a variety of colors.

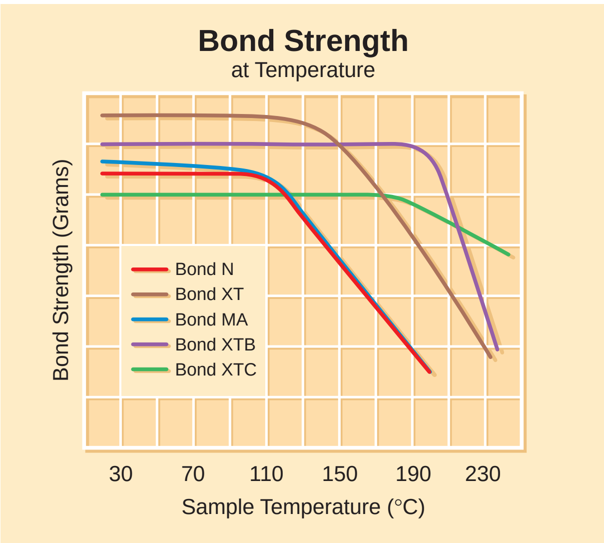
Insulating Coatings

Kanthal Designation	Description	Thermal Class (°C)	NEMA MW 1000 Specification	General Comments
Formvar	Polyvinyl Acetal Insulation	105	MW15-A,C	Excellent flexibility, abrasion resistance and chemical stability
4025 Polyurethane	Polyurethane Insulation	130	MW75-C	Long term cure stability. Easily solderable.
Poly	Polyurethane Insulation	155	MW2-C; MW75-C; MW79-C	Excellent dielectric properties and easily solderable.
Poly/Nylon	Polyurethane with Polyamide Topcoat	155	MW28-C; MW80-C	Easily solderable; abrasion resistant & easier winding.
Poly180B	Polyurethane Insulation	180	MW79-C	Highest Temperature Polyurethane - Easily Solderable
TRI-2-SOD	Solderable Polyester-imide Insulation	180	MW26-C; MW77-C	Highest Temperature capability solderable insulation.
TRI-2-SOD / Nylon	Solderable Polyester-imide with Polyamide Topcoat.	155	MW27-C	Solderable Polyester with the toughness/windability of Nylon.
Polyclad	THEIC Modified Polyester Insulation	200 for Copper 220 for Aluminum	MW72; MW74	Temperature stability of Polyester.
Polyclad / Nylon	THEIC Modified Polyester with Polyamide Topcoat.	180	MW76	Temperature stability of Polyester with toughness/ windability of Nylon.
Polyclad / Aminide	THEIC Modified . Polyester with Polyamide-imide Topcoat	200 for Copper 220 for Aluminum	MW35; MW73	Increased temperature capability over Polyclad N.
Estmide	Polyester-imide Insulation	180	MW30	Good temperature stability, solvent resistance & windability
Aminide	Polyamide-imide Insulation (also usable as Topcoat)	220	MW81-C	High Temperature Insulation with Lubricity & Chemical Resistance
PAC 240	Aromatic Polyimide Insulation	240	MW16; MW20; MW71	Highest temperature capability with good chemical resistance. Mechanically strip before soldering.

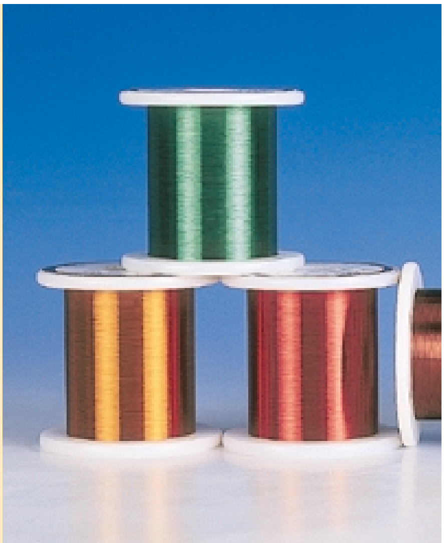
Bondcoats

Kanthal Designation	Description	Max. Usage Temperature* (°C)	Bonding Technique
Bond B	Thermoplastic Polyvinyl Butyral	100	Methanol, Acetone or Heat Activated
Bond E	Thermoplastic Epoxy	130	Acetone, MEK or Heat Activated
Bond P	Thermoplastic Polyester Phenolic	130	Acetone, MEK or Heat Activated
Bond N	Thermoplastic Polyamide	145	Heat Activated
Bond M-A	Thermoplastic Polyamide	155	Methyl Alcohol or Heat Activated
Bond SE	Thermosetting Structural Adhesive Epoxy	170	MEK or Heat Activated
Bond A-I	Thermoplastic Polyamide-imide	180	NMP or Heat Activated
Bond XT	Thermoplastic Polyamide-imide	195	Heat Activated
Bond XTC	Thermoplastic Polyamide-imide	220+	Heat Activated
Bond XTB	Thermoplastic Polyamide-imide	220+	Heat Activated, Isopropyl Alcohol, Methyl Alcohol

* Maximum usage temperature is based on the temperature at which the adhesive still retains 5 - 10% of its room temperature strength.



Insulating Coatings.



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Custom Insulation and Bond Builds

In addition to standard NEMA or JIS builds, Kanthal Palm Coast is capable of applying "Thin" and "Ultra Thin" builds of Insulations and Bonds. These builds are thinner than Nema Type 1 builds and still meet the Nema Dielectric, and other requirements. We can also apply custom builds to meet any special requirements.

Bare Wire		**Kanthal "Ultra Thin Builds"**					
Size Range		**Min. Increase of Insulating Film**		**Min. Increase of Bonding Film**		**Max. Diameter Increase**	
mm	***in***	**mm**	***in***	**mm**	***in***	**mm**	***in***
0.511	*0.02010*	0.0076	*0.0003*	0.0076	*0.0003*	0.0229	*0.0009*
thru							
0.287	*0.01130*	0.0051	*0.0002*	0.0051	*0.0002*	0.0178	*0.00070*
thru							
0.226	*0.00890*						
thru							
0.158	*0.00620*						
thru							
0.127	*0.00500*	0.0038	*0.00015*	0.0038	*0.00015*	0.0127	*0.00050*
thru							
0.071	*0.00280*						
thru							
0.056	*0.00220*	0.0031	*0.00012*	0.0031	*0.00012*	0.0114	*0.00045*
thru							
0.028	*0.00110*	0.0025	*0.0001*	0.0025	*0.0001*	0.0076	*0.0003*

Bare Wire		**Kanthal "Thin Builds"**					
Size Range		**Min. Increase of Insulating Film**		**Min. Increase of Bonding Film**		**Max. Diameter Increase**	
mm	***in***	**mm**	***in***	**mm**	***in***	**mm**	***in***
0.511	*0.02010*	0.0127	*0.0005*	0.0127	*0.0005*	0.0356	*0.0014*
thru							
0.287	*0.01130*	0.0102	*0.00040*	0.0102	*0.00040*	0.0305	*0.00120*
thru							
0.226	*0.00890*	0.0089	*0.00035*	0.0089	*0.00035*	0.0254	*0.00100*
thru							
0.158	*0.00620*	0.0081	*0.00032*	0.0081	*0.00032*	0.0226	*0.00089*
thru							
0.127	*0.00500*	0.0061	*0.00024*	0.0061	*0.00024*	0.0191	*0.00075*
thru							
0.071	*0.00280*	0.0051	*0.00020*	0.0051	*0.00020*	0.0152	*0.00060*
thru							
0.056	*0.00220*	0.0041	*0.00016*	0.0041	*0.00016*	0.0140	*0.00055*
thru							
0.028	*0.00110*	0.0031	*0.00012*	0.0031	*0.00012*	0.0940	*0.00037*

Tolerances

Resistance tolerances

Standard resistance tolerance for wire is as per the following table. Wire can be supplied to closer tolerance upon request.

Wire size **mm**	**Resistance tolerance** **%**	***Wire size*** ***in***
<0.05	±10	*<0.002*
0.05 - 0.127	±8	*0.002 - 0.00429*
>0.127	±5	*>0.00429*

Dimension tolerances

Wire can be supplied to specified dimension tolerance. However, dimension tolerance and resistance tolerance can not be specified simultaneously.

Wire size **mm**	**Max out of roundness** **mm**
- 0.05 - <0.10	0.0025
0.10 - < 0.20	0.005
≥ 0.20	0.010

in	***in***
0.001950 - <0.0039	*0.000098*
0.0039 - <0.0078	*0.000195*
≥ *0.0078*	*0.000390*

Manufacturing Tolerance Control

Wire Drawing to	±0.000635 mm	*0.000025 in*
Coating thickness	±0.00127 mm	*0.00005 in*
Ribbon wire, width	±0.0127 mm	*0.0005 in*
Ribbon wire, thickness	±0.00127 mm	*0.00005 in*

Ribbon wire aspect ratios to 40:1

8 Handling and Component Winding

Handling

1. Precision wires are supplied on precision spools enclosed in plastic containers to protect the wire against mechanical damage and contact with harmful substances in the air.

The spools normally contain more wire than the net weight stated on the labels. The wire which is marked with a special label, is the innermost part of the spool and should not be used.

2. Wire should be stored where possible with the axis of the spool in a horizontal position. If stood on end, any loose turns on a partially used spool may fall down the spool causing tangles when the wire is later unwound.

3. Never pick at the wire with a sharp pointed instrument since this will cause damage to the wire.

4. Where possible, in winding components, it is advisable to hold the spool in a horizontal position and also keep the tension on the wire as small as possible.

5. Wherever possible, avoid handling wire on a spool with bare hands, since body acids can cause breakage of bare wire due to corrosion. It is also advisable to clean components wound with bare wire in a suitable degreasing solvent before final assembly.

Soldering and Welding

Soft Soldering

The wires are readily soldered by using soft solder (60-40 Sn-Pb) in conjunction with a suitable flux that can be bought from specialised firms. It is not generally necessary to clean bright annealed precision wires before soldering. Where oxidised wires are used, these must be cleaned by abrasion with fine emery paper. Quick and reliable results are obtained by dipping the wires to be soldered into a bath of molten solder after application of the flux. Whilst the operation can be done with a soldering iron, it is not easy, and more reliable results have been reported by the use of an ultrasonic soldering iron. It is advisable to wash off any excess flux immediately after soldering.

Silver Soldering

This is not generally recommended for Nikrothal LX wire as the high temperature involved affects the electrical properties of this alloy. When silver soldering is carried out, the wire should first be cleaned, wrapped round the connecting lead and treated with flux. The silver solder is then applied on to the lead in close proximity to the wire, by means of a small torch and the molten solder allowed to flow down the lead on to the wire to effect a soldered joint. The flame of the torch should not be allowed to impinge upon the wire. There are several suitable fluxes on the market and the names of individual manufacturers will gladly be supplied.

Welding

All of the resistance alloys may be spot welded to terminal wires of similar composition to themselves if extreme care and control of time, pressure and current discharge conditions are practised. Increasing difficulty is experienced in welding these wires to copper or alloys of lower melting points.

Electric component winding

The manufacture of electronic components using precision wire requires extreme skill and engineering control in all phases of winding. To obtain optimum stability and retain the original electrical properties of the wire in the finished component, all stresses must be kept to a minimum. Stresses can be introduced by tension applied during winding, the bending of the wire round the former and differences in the expansion coefficients of the wire and the former.

It is normally recommended that tensions no greater than 30% of the yield load should be applied during winding resistors. The yield load is the load over which the physical characteristics of the wire are permanently changed.

Since bending stresses during the winding operation increase as the ratio of the wire diameter to that of the bobbin increases, larger wire diameters should be wound on larger diameter bobbins. It is recommended that the diameter of the bobbin should be at least 25 times that of the wire being wound.

Any stresses set up during winding a resistor can be substantially relieved, providing they are not excessive, by a suitable heat treatment of the resistor.

A commonly used practice is to heat treat for 12-24 hours at 120 °C *248 °F*, but it may be necessary to extend the time in cases where stresses are high and maximum stability is required.

Plastic Container

9 Spools and Packaging

Premium Potentiometer Wire

In the manufacture of wire-wound potentiometers it is essential that the resistance wire should be truly round and have a very clean surface to avoid "noise" at the contact point. It should also have a uniform resistance along its length to give a linear change in resistance with movement of the contact.

Premium Potentiometer Wire is a special grade of wire produced specifically with this application in mind. It is available in all alloys normally supplied as Precision Wire.

Premium wire is drawn to a particularly close resistance tolerance (± 3%) by using only the heart of the diamond die. This also allows us to maintain out-of-roundness to less than 5%.

By careful control and special techniques in the annealing and winding operations the highest possible degree of linearity of resistance is maintained and the physical properties are held at an optimum value for high speed winding on to mandrels. At the same time every precaution is taken to ensure that the surface is kept clean. This not only avoids excessive "noise" but also reduces contact wear in the potentiometer.

In all applications where the properties outlined above are desirable it is suggested that Premium Potentiometer Wire should be clearly specified. Our technical staff are readily available to discuss customers' individual requirements.

Surface Finish, Insulation and Coating

Please specify the surface finish according to the tables on page 43.

Metric Spool Types

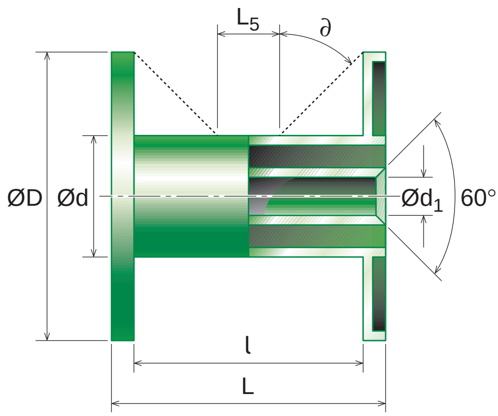
Biconical spools

Spool Type	D mm	d mm	d_1 mm	L mm	L_5 mm	∂ °	Tare gr
BS 63.5	63.5	44.4	16	86	60	45	73
BS 80	80	55	16	100	70	45	76
BS 100	100	56	16	100	49	45	130

Standard Spools

Spool Type	D mm	d mm	d_1 mm	L mm	ℓ mm	Wire size, mm ∅	Normal net weight, kg
Plastic box							
DIN 50	50	32	11	50	38	0.015-0.04	0.10
DIN 63	63	40	11	63	49	0.015-0.04	0.20
C 1/4	64	44	16	61	51	<0.030	0.05-0.25
C 1/2	64	44	16	86	76	0.030-0.099	0.5
DIN 80	80	50	16	80	64	0.05-0.099	0.75
Plastic film							
B 1	75	40	16	120	100	0.1-0.199	1.0
DIN 100	100	63	16	100	80	0.10-0.50	1.5
B 2	90	40	16	120	100	0.20-0.25	2.0
B 4	120	50	16	120	100	0.26-0.50	4.0
DIN 125	125	80	16	125	100	0.15-0.80	3.0

9



Imperial Spool Types

Spool Type	D in	d in	d1 in	L in	l in	Wire type
200	*2.125*	*1.375*	*5/8*	*1.375*	*1*	*Customer request only*
201	*2.24*	*1.98*	*1.93*	*1.1*	*1*	*Bonding wire*
205	*2.5*	*1.76*	*5/8*	*3.376*	*3*	*.007-.0031in Resistance wire*
210	*3.15*	*1.97*	*5/8*	*3.15*	*2.52*	*.002-.0063 in Resistance wire*
225	*5*	*3*	*5/8*	*4.11*	*3.5*	*.0035-.113 in Resistance wire & Al/Cu ribbon wires*
230	*6*	*3.5*	*5/8*	*4.11*	*3.5*	*.005-.0253 in Resistance wire*
255	*5*	*3.75*	*5/8*	*4*	*3*	*Wire requiring straightness*
260	63 mm	43.6 mm	16 mm	60 mm	51.2 mm	*.0004-.0006 in Resistance wire & Au plated Cu wire*
275	*3.5*	*2.125*	*2.125*	*2.438*	*2.125*	*Oiled resistance wire*
280	*5.5&4.875*	*4.375&3.875*	*1*	*7.875*	*6.688*	*Tapered spool for Disk Drive & Audio round wires*
285	*11.75*	*8*	*2*	*3.938*	*3.62*	*JBL & Bare Al wir*

10 Appendix

List of Symbols

The symbols used in this handbook comply as far as possible with the internationally approved standard (IEC-27-1).

The following symbols are used:

Symbol	Meaning	Unit for Calculation Metric	*Imperial*
A_c	Surface area of heating conductor	mm²	*in²*
C_t	Temperature factor (ratio of resistivity at operating temperature to resistivity at room temperature)		
D	Outercoil diameter	mm	*in*
d	Wire diameter	mm	*in*
I	Current	A	*A*
K	Kelvin		
L_e	Coil length	mm	*in*
L	Length of heating conductor	m	*ft*
P	Power	W	*W*
p	Surface load of heating element	W/cm²	*W/in²*
q	Cross-sectional area of heating conductor	mm²	*in²*
R_T	Resistance at working temperature	Ω	Ω
R_{20}	Resistance at room temperature (20 °C, *68 °F*)	Ω	Ω
s	Pitch	mm	*in*
T, θ	Temperature	K	*K*
U	Voltage, V	V	*V*
α	Temperature coefficient of resistivity	K^{-1}	*F^{-1}*
ρ	Resistivity	Ωmm² m^{-1}	*Ω/smf** *Ω/cmf*

**smf=square mil-foot*
cmf=circular mil-foot

10

Definitions

Resistivity

The resistance of a conductor, R_{20}, is directly proportional to its length, L, and inversely proportional to its cross-sectional area, q:

$$R_{20} = \rho \frac{l}{q}$$

The proportional constant, ρ, is defined as the resistivity of the material and is temperature dependent.

The standard unit for resistivity in the metric system is $\Omega mm^2\ m^{-1}$. In the imperial system two different units are used:

Ohms per circular mil-foot (Ω/cmf)
Ohms per square mil-foot (Ω/smf)

The relationship between metric and imperial units are:

$1\ \Omega mm^2\ m^{-1} = 601.54\ \Omega$ /cmf
$1\ \Omega mm^2\ m^{-1} = 472.44$ W /smf
1 mil = *0.001 inch* = 0.0254 mm

The unit Ω/cmf is used for round conductors. In the equation above, wire length is given in feet and diameter in mils, omitting Ω/4.

Example:

Calculate the resistance of a 3-foot-long Kanthal D wire 22 B&S *(0.02535 inch diameter).*

Metric units:

$$R_{20} = \frac{1.35 \times 3 \times 0.305 \times 4}{0.644^2\ \pi} = 3.79\ \Omega$$

Imperial unit (cmf):

$$R_{20} = \frac{812 \times 3}{25.35^2} = 3.79\ \Omega$$

The unit Ω/smf is used principally for conductors with rectangular cross sections. Even here length is given in feet and width and thickness in mils.

Temperature Factor

The change in resistance with temperature, is non-linear for most resistance heating alloys. Hence, the temperature factor, C_t, is often used instead of temperature coefficient. Temperature factor is defined as the ratio between resistance at some selected temperature θ °C and the resistance at 20 °C *68 °F.*

$C_t = RT/R_{20}$
$C_t = 1 + (\theta\text{-}20)\,\alpha$ (where 0 is in °C)
$C_t = 1 + (\theta\text{-}68)\,\alpha$ where 0 is in °F

C_t is a function of temperature. Values are given in small tabulations above the main tables for each alloy.

Surface Load

The surface load of a heating conductor, p, is its power, P, divided by its surface area, A_c.

$$p = \frac{P}{A_c}$$

In the metric system, the surface load is normally expressed as W/cm^2, and in the imperal as *W/in^2.*

1 W/Cm^2 = *6.45 W/in^2*
1 W/in^2 = 0.155 W/Cm^2

Length (km)

Length = (Qty*4)/(Density*Pi*Ø2)
Length (km)
Qty (Kg)
Density (g/cm^3)
Ø (mm)
Pi = 3.141593

10 Formulas

General formulas

The following formulas apply to all applications.

$$R_{20} = \rho \cdot \frac{l}{q} \qquad [1]$$

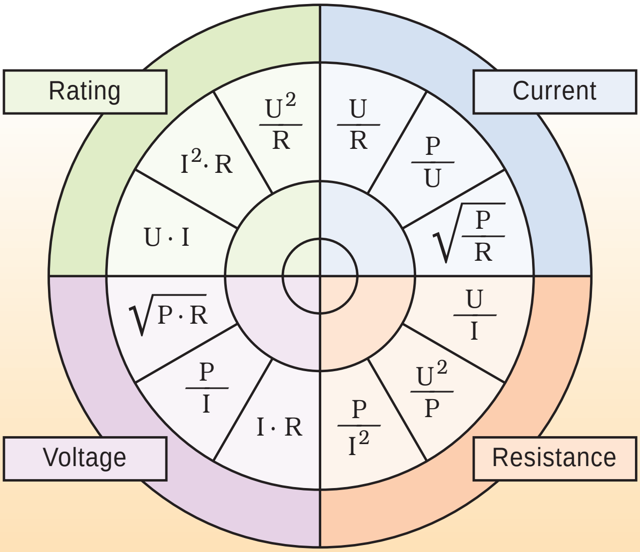
$$R_T = C_t \cdot R_{20} \qquad [2]$$

$$p = \frac{P}{A_C} \qquad [3]$$

$$U = R_T \cdot I \qquad [4]$$

$$P = U \cdot I \qquad [5]$$

Combining equations [4] and [5] gives:



Combining equations [2], [3], [4] and [5] gives:

$$\frac{A_C}{R_{20}} = \frac{I^2 \cdot C_t}{p} \qquad [6]$$

The ratio $\frac{A_C}{R_{20}}$, used for determining wire, strip or ribbon size, is tabulated as cm^2/Ω (in^2/Ω) for all alloys in the Kanthal Handbook.

Round wire

In calculating values for a round wire element, the following formulas may be used:

$$A_C = \pi \cdot d \cdot l \qquad [7]$$

$$q = \frac{\pi}{4} \cdot d^2 \qquad [8]$$

Combining equations [1], [3], [7] and [8] gives the wire diameter, d:

$$d = \sqrt[3]{\frac{4}{\pi^2} \cdot \frac{\rho \cdot P}{p \cdot R_{20}}} \qquad [9]$$

In case ρ is known in the unit $\Omega mm^2/m$ and p in the unit W/cm^2, the figures under the third root have to be divided by 10 prior to taking the third root in order to find the diameter in mm. (In case ρ has the unit Ω/cmf and p the unit W/in^2, d is found in inch if the figures under the third root is divided with $15.28 \cdot 10^6$).

Example:

R = 40 Ω, P = 1000 W, p = 8 W/cm^2 (51.6 W/in^2),
ρ = 1.35 $\Omega m^2/m$ (812 Ω/cmf)

$$d = \sqrt[3]{\frac{4 \cdot 1.35 \cdot 1000}{10 \cdot \pi^2 \cdot 8 \cdot 40}} = 0.55 \text{ mm}$$

$$d = \sqrt[3]{\frac{4 \cdot 812 \cdot 1000}{15.28 \cdot 10^6 \cdot \pi^2 \cdot 51.6 \cdot 40}} = 0.022 \text{ inch}$$

10

A round wire is often wound as a coil. For calculating coil pitch, s, the equation [10] applies:

$$\left[\frac{\pi(D-d)}{s}\right]^2 + 1 = \left(\frac{l}{L_e}\right)^2 \qquad [10]$$

When the pitch is relatively small, $\frac{s}{\pi(D-d)} << 1$,

pi(D-d)equation [10] can be simplified to:

$$s = \frac{\pi(D-d)Le}{l} \qquad [11]$$

The ratio s/d is often used. It is called the relative pitch or the stretch factor, and may affect the heat dissipation from the coil.

The ratio D/d is essential for the coiling operation, as well as the mechanical stability of the coil in a hot state.

Strip and ribbon

For a strip:

$$A_C = 2(b+t)\cdot l \qquad [12]$$

$$q = bt \qquad [13]$$

Since ribbons are made by flattening round wires, their cross-sectional areas are somewhat smaller depending on size, than equation [13] indicates. As a rule of thumb, a factor 0.92 is used ($q = 0.92 \cdot bt$).

Lately, investigations have shown that a more correct way of expressing the cross-sectional area of ribbon is:

$$q = \left(0.985 - \left(\frac{t}{2 \cdot b}\right)^2\right) \cdot b \cdot t \qquad [14]$$

Wire Gauges

10

	Wire Gauges (AWG or B & S)		Standard Wire Gauge (SWG)		
Gauge no	***inch***	**mm**	***inch***	**mm**	**Gauge no**
4-0	*0.460*	11.68	*0.400*	10.16	4-0
3-0	*0.410*	10.40	*0.372*	9.45	3-0
2-0	*0.365*	9.27	*0.348*	8.84	2-0
0	*0.325*	8.25	*0.324*	8.23	0
1	*0.289*	7.35	*0.300*	7.62	1
2	*0.258*	6.54	*0.276*	7.01	2
3	*0.229*	5.83	*0.252*	6.40	3
4	*0.204*	5.19	*0.232*	5.89	4
5	*0.182*	4.62	*0.212*	5.38	5
6	*0.162*	4.11	*0.192*	4.88	6
7	*0.144*	3.67	*0.176*	4.47	7
8	*0.129*	3.26	*0.160*	4.06	8
9	*0.114*	2.91	*0.144*	3.66	9
10	*0.102*	2.59	*0.128*	3.25	10
11	*0.0907*	2.30	*0.116*	2.95	11
12	*0.0808*	2.05	*0.104*	2.64	12
13	*0.0720*	1.83	*0.0920*	2.34	13
14	*0.0641*	1.63	*0.0800*	2.03	14
15	*0.0571*	1.45	*0.0720*	1.83	15
16	*0.0508*	1.29	*0.0640*	1.63	16
17	*0.0453*	1.15	*0.0560*	1.42	17
18	*0.0403*	1.02	*0.0480*	1.22	18
19	*0.0359*	0.912	*0.0400*	1.02	19
20	*0.0320*	0.812	*0.0360*	0.914	20
21	*0.0285*	0.723	*0.0320*	0.813	21
22	*0.0254*	0.644	*0.0280*	0.711	22
23	*0.0226*	0.573	*0.0240*	0.610	23
24	*0.0201*	0.511	*0.0220*	0.559	24
25	*0.0179*	0.455	*0.0200*	0.508	25
26	*0.0159*	0.405	*0.0180*	0.457	26
27	*0.0142*	0.361	*0.0164*	0.417	27
28	*0.0126*	0.321	*0.0148*	0.376	28
29	*0.0113*	0.286	*0.0136*	0.345	29
30	*0.0100*	0.255	*0.0124*	0.315	30
31	*0.00893*	0.227	*0.0116*	0.295	31
32	*0.00795*	0.202	*0.0108*	0.274	32
33	*0.00708*	0.180	*0.0100*	0.254	33
34	*0.00631*	0.160	*0.00920*	0.234	34
35	*0.00562*	0.143	*0.00840*	0.213	35
36	*0.00500*	0.127	*0.00760*	0.193	36
37	*0.00445*	0.113	*0.00680*	0.173	37
38	*0.00397*	0.101	*0.00600*	0.152	38
39	*0.00353*	0.0897	*0.00520*	0.132	39
40	*0.00315*	0.0799	*0.00480*	0.122	40
41	*0.00280*	0.0711	*0.00440*	0.112	41
42	*0.00249*	0.0633	*0.00400*	0.102	42
43	*0.00222*	0.0564	*0.00360*	0.0914	43
44	*0.00198*	0.0502	*0.00320*	0.0813	44
45	*0.00176*	0.0447	*0.00280*	0.0711	45
46	*0.00157*	0.0398	*0.00240*	0.0610	46
47	*0.00140*	0.0355	*0.00200*	0.0508	47
48	*0.00124*	0.0316	*0.00160*	0.0406	48
49	*0.00111*	0.0281	*0.00120*	0.0305	49
50	*0.000986*	0.0250	*0.00100*	0.0254	50
51	*0.000800*	0.0203	*0.000878*	0.0223	51
52	*0.000600*	0.0152	*0.000782*	0.0199	52
53	*0.000500*	0.0127	*0.000697*	0.0177	53
54	*0.000400*	0.0102	*0.000620*	0.0157	54
55	*0.000300*	0.00762	*0.000552*	0.0140	55
56			*0.000492*	0.0125	56
57			*0.000438*	0.0111	57
58			*0.000390*	0.00991	58
59			*0.000347*	0.00881	59
60			*0.000309*	0.00785	60

10 NEMA MW 1000: Dimensional Standards

Insulated Round Magnet Wire

AWG	Bare Wire Diameter (Inches)			Single Build Insulation		
	Minimum	Nominal	Maximum	Min. Increase in Diameter	Nominal Thickness	Maximum Thickness
21	0.0282	0.0285	0.0288	0.0011	0.0298	0.0303
22	0.0250	0.0253	0.0256	0.0011	0.0266	0.0270
23	0.0224	0.0226	0.0228	0.0010	0.0239	0.0243
24	0.0199	0.0201	0.0203	0.0010	0.0213	0.0217
25	0.0177	0.0179	0.0181	0.0009	0.0190	0.0194
26	0.0157	0.0159	0.0161	0.0009	0.0170	0.0173
27	0.0141	0.0142	0.0143	0.0008	0.0153	0.0156
28	0.0125	0.0126	0.0127	0.0008	0.0137	0.0140
29	0.0112	0.0113	0.0114	0.0007	0.0123	0.0126
30	0.0099	0.0100	0.0101	0.0007	0.0109	0.0112
31	0.0088	0.0089	0.0090	0.0006	0.0097	0.0100
32	0.0079	0.0080	0.0081	0.0006	0.0088	0.0091
33	0.0070	0.0071	0.0072	0.0005	0.0078	0.0081
34	0.0062	0.0063	0.0064	0.0005	0.0070	0.0072
35	0.0055	0.0056	0.0057	0.0004	0.0062	0.0064
36	0.0049	0.0050	0.0051	0.0004	0.0056	0.0058
37	0.0044	0.0045	0.0046	0.0003	0.0050	0.0052
38	0.0039	0.0040	0.0041	0.0003	0.0045	0.0047
39	0.0034	0.0035	0.0036	0.0002	0.0039	0.0041
40	0.0030	0.0031	0.0032	0.0002	0.0035	0.0037
41	0.0027	0.0028	0.0029	0.0002	0.0031	0.0033
42	0.0024	0.0025	0.0026	0.0002	0.0028	0.0030
43	0.0021	0.0022	0.0023	0.0002	0.0025	0.0026
44	0.0019	0.0020	0.0021	0.0001	0.0022	0.0024
45	0.00169	0.00176	0.0018	0.00010	0.0019	0.00205
46	0.00151	0.00157	0.0016	0.00010	0.0017	0.00185
47	0.00135	0.00140	0.0015	0.00010	0.0016	0.00170
48	0.00119	0.00124	0.0013	0.00010	0.0014	0.00150
49	0.00107	0.00111	0.0012	0.00010	0.0012	0.00130
50	0.00095	0.00099	0.00103	0.00010	0.0011	0.00120
51	0.00085	0.00088	0.00092	0.00010	0.0010	0.00110
52	0.00075	0.00078	0.00081	0.00010	0.0009	0.00100
53	0.00067	0.00070	0.00073	0.00005	0.0008	0.00085
54	0.00060	0.00062	0.00065	0.00005	0.0007	0.00075
55	0.00053	0.00055	0.00057	0.00005	0.0006	0.00070
56	0.00047	0.00049	0.00051	0.00005	0.0006	0.00065
57	0.00042	0.00044	0.00046	0.00004	0.0005	0.00056
58	0.00038	0.00039	0.00041	0.00004	0.0005	0.00051

• Sizes finer than 44 AWG based on the theoretical resistance (10.371 Ohms-Circular Mil/foot) of a copper conductor.

10

AWG	Heavy Build Insulation			Triple Build Insulation		
	Min. Increase in Diameter	Nominal Thickness	Maximum Thickness	Min. Increase in Diameter	Nominal Thickness	Maximum Thickness
21	0.0022	0.0309	0.0314	0.0033	0.0321	0.0326
22	0.0021	0.0276	0.0281	0.0032	0.0288	0.0293
23	0.0020	0.0249	0.0253	0.0030	0.0259	0.0264
24	0.0019	0.0223	0.0227	0.0029	0.0233	0.0238
25	0.0018	0.0199	0.0203	0.0027	0.0209	0.0214
26	0.0017	0.0178	0.0182	0.0026	0.0188	0.0193
27	0.0016	0.0161	0.0164	0.0024	0.0169	0.0173
28	0.0016	0.0144	0.0147	0.0023	0.0152	0.0156
29	0.0015	0.0130	0.0133	0.0022	0.0138	0.0142
30	0.0014	0.0116	0.0119	0.0021	0.0124	0.0128
31	0.0013	0.0105	0.0108	0.0017	0.0110	0.0114
32	0.0012	0.0095	0.0098	0.0016	0.0099	0.0103
33	0.0011	0.0085	0.0088	0.0014	0.0088	0.0092
34	0.0010	0.0075	0.0078	0.0013	0.0079	0.0082
35	0.0009	0.0067	0.0070	0.0012	0.0071	0.0074
36	0.0008	0.0060	0.0063	0.0011	0.0064	0.0067
37	0.0008	0.0055	0.0057	0.0010	0.0057	0.0060
38	0.0007	0.0049	0.0051	0.0009	0.0051	0.0054
39	0.0006	0.0043	0.0045	0.0008	0.0045	0.0048
40	0.0006	0.0038	0.0040	0.0008	0.0041	0.0043
41	0.0005	0.0034	0.0036	0.0007	0.0037	0.0039
42	0.0004	0.0030	0.0032	0.0007	0.0033	0.0035
43	0.0004	0.0027	0.0029	0.0006	0.0030	0.0032
44	0.0004	0.0025	0.0027	0.0006	0.0027	0.0029
45	0.00030	0.00215	0.00230			
46	0.00030	0.00196	0.00210			
47	0.00030	0.00178	0.00190			
48	0.00020	0.00155	0.00170			
49	0.00020	0.00139	0.00150			
50	0.00020	0.00128	0.00140			
51	0.00020	0.00117	0.00129			
52	0.00020	0.00105	0.00115			
53	0.00013	0.00092	0.00103			
54	0.00013	0.00084	0.00095			
55	0.00013	0.00077	0.00087			
56	0.00013	0.00071	0.00081			
57						
58						

• The nominal coated wire thickness is based on the average of the minimum coating thickness increase on a minimum bare wire diameter and the maximum coated wire thickness.

10 NEMA MW 1000: Dimensional Standards

Single Build Self-Bonding Wire

AWG	Bare Wire Nominal Diameter		Minimum Increase in Diameter Insulation	
	Inches	mm	*Inches*	mm
21	*0.02850*	0.7240	*0.0011*	0.0280
22	*0.02530*	0.6430	*0.0011*	0.0280
23	*0.02260*	0.5740	*0.0010*	0.0250
24	*0.02010*	0.5110	*0.0010*	0.0250
25	*0.01790*	0.4550	*0.0009*	0.0230
26	*0.01590*	0.4040	*0.0009*	0.0230
27	*0.01420*	0.3610	*0.0008*	0.0200
28	*0.01260*	0.3200	*0.0008*	0.0200
29	*0.01130*	0.2870	*0.0007*	0.0180
30	*0.01000*	0.2540	*0.0007*	0.0180
31	*0.00890*	0.2260	*0.0006*	0.0150
32	*0.00800*	0.2030	*0.0006*	0.0150
33	*0.00710*	0.1800	*0.0005*	0.0130
34	*0.00630*	0.1600	*0.0005*	0.0130
35	*0.00560*	0.1420	*0.0004*	0.0100
36	*0.00500*	0.1270	*0.0004*	0.0100
37	*0.00450*	0.1140	*0.0003*	0.0080
38	*0.00400*	0.1020	*0.0003*	0.0080
39	*0.00350*	0.0890	*0.0002*	0.0050
40	*0.00310*	0.0790	*0.0002*	0.0050
41	*0.00280*	0.0710	*0.0002*	0.0050
42	*0.00250*	0.0640	*0.0002*	0.0050
43	*0.00220*	0.0560	*0.0002*	0.0050
44	*0.00200*	0.0510	*0.0001*	0.0025
45	*0.00176*	0.0447	*0.0001*	0.0025
46	*0.00157*	0.0399	*0.0001*	0.0025
47	*0.00140*	0.0356	*0.0001*	0.0025
48	*0.00124*	0.0315	*0.0001*	0.0025
49	*0.00111*	0.0282	*0.0001*	0.0025
50	*0.00099*	0.0251	*0.0001*	0.0025
51	*0.00088*	0.0224	*0.0001*	0.0025
52	*0.00078*	0.0198	*0.0001*	0.0025
53	*0.00070*	0.0178	*0.0001*	0.0025
54	*0.00060*	0.0152	*0.0001*	0.0025
55	*0.00050*	0.0127	*0.0001*	0.0025
56	*0.00040*	0.0102	*0.0001*	0.0025

- *Sizes finer than 44 AWG based on the theoretical resistance (10.371 Ohms-Circular Mil/foot) of a copper conductor.*
- *AWG sizes 53 to 56 are not standard NEMA dimensions.*

10

AWG	Minimum Increase in Diameter Thermoplastic		Maximum Overall Diameter	
	Inches	mm	*Inches*	mm
21	*0.00050*	0.0130	*0.03140*	0.7980
22	*0.00050*	0.0130	*0.02810*	0.7140
23	*0.00050*	0.0130	*0.02530*	0.6430
24	*0.00050*	0.0130	*0.02270*	0.5770
25	*0.00050*	0.0130	*0.02030*	0.5160
26	*0.00050*	0.0130	*0.01820*	0.4620
27	*0.00050*	0.0130	*0.01640*	0.4170
28	*0.00050*	0.0130	*0.01470*	0.3730
29	*0.00040*	0.0100	*0.01330*	0.3380
30	*0.00040*	0.0100	*0.01190*	0.3020
31	*0.00040*	0.0100	*0.01080*	0.2740
32	*0.00040*	0.0100	*0.00980*	0.2490
33	*0.00040*	0.0100	*0.00880*	0.2240
34	*0.00030*	0.0080	*0.00780*	0.1980
35	*0.00030*	0.0080	*0.00700*	0.1780
36	*0.00030*	0.0080	*0.00630*	0.1600
37	*0.00030*	0.0080	*0.00570*	0.1450
38	*0.00020*	0.0050	*0.00510*	0.1300
39	*0.00020*	0.0050	*0.00450*	0.1140
40	*0.00020*	0.0050	*0.00400*	0.1020
41	*0.00020*	0.0050	*0.00360*	0.0910
42	*0.00020*	0.0050	*0.00320*	0.0810
43	*0.00010*	0.0025	*0.00290*	0.0740
44	*0.00010*	0.0025	*0.00270*	0.0690
45	*0.00010*	0.0025	*0.00230*	0.0584
46	*0.00010*	0.0025	*0.00210*	0.0533
47	*0.00010*	0.0025	*0.00190*	0.0483
48	*0.00010*	0.0025	*0.00170*	0.0432
49	*0.00010*	0.0025	*0.00150*	0.0381
50	*0.00010*	0.0025	*0.00140*	0.0356
51	*0.00010*	0.0025	*0.00130*	0.0330
52	*0.00005*	0.0013	*0.00115*	0.0292
53	*0.00005*	0.0013	*0.00107*	0.0271
54	*0.00005*	0.0013	*0.000995*	0.0253
55	*0.00005*	0.0013	*0.000985*	0.0250
56	*0.00005*	0.0013	*0.000975*	0.0248

10 Temperature Conversion Table

The numbers in the colored area indicate the temperatures as read. The corresponding temperatures in Celsius are given on the left and those in Fahrenheit on the right.

°C		°F	°C		°F	°C		°F	°C		°F	°C		°F	°C		°F
–17.8	0	32	1.67	35	95.0	21.1	70	158.0	66	150	302	254	490	914	449	840	1544
–17.2	1	33.8	2.22	36	96.8	21.7	71	159.8	71	160	320	260	500	932	454	850	1562
–16.7	2	35.6	2.78	37	98.6	22.2	72	161.6	77	170	338	266	510	950	460	860	1580
–16.1	3	37.4	3.33	38	100.4	22.8	73	163.4	82	180	356	271	520	968	468	870	1598
–15.6	4	39.2	3.89	39	102.2	23.3	74	165.2	88	190	374	277	530	986	471	880	1816
–15.0	5	41.0	4.44	40	104.0	23.9	75	167.0	93	200	392	282	540	1004	477	890	1634
–14.4	6	42.8	5.00	41	105.8	24.4	76	168.8	99	210	410	288	550	1022	482	900	1652
–13.9	7	44.6	5.56	42	107.6	25.0	77	170.6	100	212	413	293	560	1040	488	910	1670
–13.3	8	46.4	6.11	43	109.4	25.6	78	172.4	104	220	428	299	570	1058	493	920	1688
–12.8	9	48.2	6.67	44	111.2	26.1	79	174.2	110	230	446	304	580	1076	499	930	1706
–12.2	10	50.0	7.22	45	113.0	26.7	80	176.0	116	240	464	310	590	1094	504	940	1724
–11.7	11	51.8	7.78	46	114.8	27.2	81	177.8	121	250	482	316	600	1112	510	950	1742
–11.1	12	53.6	8.33	47	116.6	27.8	82	179.6	127	260	500	321	610	1130	516	960	1760
–10.6	13	55.4	8.89	48	118.4	28.3	83	181.4	132	270	518	327	620	1148	521	970	1778
–10.0	14	57.2	9.44	49	120.2	28.9	84	183.2	138	280	536	332	630	1166	527	980	1796
–9.44	15	59.0	10.0	50	122.0	29.4	85	185.0	143	290	554	338	640	1184	532	990	1814
–8.89	16	60.8	10.6	51	123.8	30.0	86	186.8	149	300	572	343	650	1202	538	1000	1832
–8.33	17	62.6	11.1	52	125.6	30.6	87	188.6	154	310	590	349	660	1220	543	1010	1850
–7.78	18	64.4	11.7	53	127.4	31.1	88	190.4	160	320	608	354	670	1238	549	1020	1868
–7.22	19	66.2	12.2	54	129.2	31.7	89	192.2	166	330	626	360	680	1256	554	1030	1886
–6.67	20	68.0	12.8	55	131.0	32.2	90	194.0	171	340	644	366	690	1274	560	1040	1904
–6.11	21	69.8	13.3	56	132.8	32.8	91	195.8	177	350	662	371	700	1292	566	1050	1922
–5.56	22	71.6	13.9	57	134.6	33.3	92	197.6	182	360	680	377	710	1310	571	1060	1940
–5.00	23	73.4	14.4	58	136.4	33.9	93	199.4	188	370	698	382	720	1328	577	1070	1958
–4.44	24	75.2	15.0	59	138.2	34.4	94	201.2	193	380	716	388	730	1346	582	1080	1976
–3.89	25	77.0	15.6	60	140.0	35.0	95	203.0	199	390	734	393	740	1364	588	1090	1994
–3.33	26	78.8	16.1	61	141.8	35.6	96	204.8	204	400	752	399	750	1382	593	1100	2012
–2.78	27	80.6	16.7	62	143.6	36.1	97	206.6	210	410	770	404	760	1400	599	1110	2030
–2.22	28	82.4	17.2	63	145.4	36.7	98	208.4	216	420	788	410	770	1418	604	1120	2048
–1.67	29	84.2	17.8	64	147.2	37.2	99	210.2	221	430	806	416	780	1436	610	1130	2066
–1.11	30	86.0	18.3	65	149.0	38	100	212	227	440	824	421	790	1454	616	1140	2084
–0.56	31	87.8	18.9	66	150.8	43	110	230	232	450	842	427	800	1472	621	1150	2102
–0	32	89.6	19.4	67	152.6	49	120	248	238	460	860	432	810	1490	627	1160	2120
0.56	33	91.4	20.0	68	154.4	54	130	266	243	470	878	438	820	1508	632	1170	2138
1.11	34	93.2	20.6	69	156.2	60	140	284	249	480	896	443	830	1526	638	1180	2156

10

°C		°F	°C		°F	°C		°F	°C		°F	°C		°F	°C		°F
643	1190	*2174*	838	1540	*2804*	1032	1890	*3434*	1227	2240	*4064*	1421	2590	*4694*	1616	2940	*5324*
649	1200	*2192*	843	1550	*2822*	1038	1900	*3452*	1232	2250	*4082*	1427	2600	*4712*	1621	2950	*5342*
654	1210	*2210*	849	1560	*2840*	1043	1910	*3470*	1238	2260	*4100*	1432	2610	*4730*	1627	2960	*5360*
660	1220	*2228*	854	1570	*2858*	1049	1920	*3488*	1243	2270	*4118*	1438	2620	*4748*	1632	2970	*5376*
666	1230	*2246*	860	1580	*2876*	1054	1930	*3506*	1249	2280	*4138*	1443	2630	*4766*	1638	2980	*5396*
671	1240	*2264*	866	1590	*2894*	1060	1940	*3524*	1254	2290	*4154*	1449	2640	*4784*	1643	2990	*5414*
677	1250	*2282*	871	1600	*2912*	1066	1950	*3542*	1260	2300	*4172*	1454	2650	*4802*	1649	3000	*5432*
682	1260	*2300*	877	1610	*2930*	1071	1960	*3560*	1266	2310	*4190*	1460	2660	*4820*			
688	1270	*2318*	882	1820	*2948*	1077	1970	*3578*	1271	2320	*4208*	1466	2670	*4838*			
693	1280	*2336*	888	1630	*2966*	1082	1980	*3596*	1277	2330	*4226*	1471	2680	*4856*			
699	1290	*2354*	893	1640	*2984*	1088	1990	*3614*	1282	2340	*4244*	1477	2690	*4874*			
704	1300	*2372*	899	1650	*3002*	1093	2000	*3632*	1288	2350	*4262*	1482	2700	*4892*			
710	1310	*2390*	904	1660	*3020*	1099	2010	*3650*	1293	2360	*4280*	1488	2710	*4910*			
716	1320	*2408*	910	1670	*3038*	1104	2020	*3668*	1299	2370	*4298*	1493	2720	*4928*			
721	1330	*2426*	916	1680	*3058*	1110	2030	*3686*	1304	2380	*4316*	1499	2730	*4946*			
727	1340	*2444*	921	1690	*3074*	1116	2040	*3704*	1310	2390	*4334*	1504	2740	*4964*			
732	1350	*2462*	927	1700	*3092*	1121	2050	*3722*	1316	2400	*4352*	1510	2750	*4982*			
738	1360	*2480*	932	1710	*3110*	1127	2060	*3740*	1321	2410	*4370*	1516	2760	*5000*			
743	1370	*2498*	938	1720	*3128*	1132	2070	*3758*	1327	2420	*4388*	1521	2770	*5018*			
749	1380	*2516*	943	1730	*3146*	1138	2080	*3776*	1332	2430	*4406*	1527	2780	*5036*			
754	1390	*2534*	949	1740	*3164*	1143	2090	*3794*	1338	2440	*4424*	1532	2790	*5054*			
760	1400	*2552*	954	1750	*3182*	1149	2100	*3812*	1343	2450	*4442*	1538	2800	*5072*			
766	1410	*2570*	960	1760	*3200*	1154	2110	*3830*	1349	2460	*4460*	1543	2810	*5090*			
771	1420	*2588*	966	1770	*3218*	1160	2120	*3848*	1354	2470	*4478*	1549	2820	*5108*			
777	1430	*2606*	971	1780	*3236*	1166	2130	*3866*	1360	2480	*4496*	1554	2830	*5126*			
782	1440	*2624*	977	1790	*3254*	1171	2140	*3884*	1366	2490	*4514*	1560	2840	*5144*			
788	1450	*2842*	982	1800	*3272*	1177	2150	*3902*	1371	2500	*4532*	1566	2850	*5162*			
793	1460	*2660*	988	1810	*3290*	1182	2160	*3920*	1377	2510	*4550*	1571	2860	*5180*			
799	1470	*2678*	993	1820	*3308*	1188	2170	*3938*	1382	2520	*4568*	1577	2870	*5198*			
804	1480	*2696*	999	1830	*3326*	1193	2180	*3956*	1388	2530	*4586*	1582	2880	*5216*			
810	1490	*2714*	1004	1840	*3344*	1199	2190	*3974*	1393	2540	*4604*	1588	2890	*5234*			
816	1500	*2732*	1010	1850	*3362*	1204	2200	*3992*	1399	2550	*4622*	1593	2900	*5252*			
821	1510	*2750*	1016	1860	*3380*	1210	2210	*4010*	1404	2560	*4640*	1599	2910	*5270*			
827	1520	*2768*	1021	1870	*3398*	1216	2220	*4028*	1410	2570	*4658*	1604	2920	*5288*			
832	1530	*2786*	1027	1880	*3416*	1221	2230	*4046*	1416	2580	*4676*	1610	2930	*5306*			

INTERPOLATION TABLE

°C		°F
0.56	**1**	***1.8***
1.11	**2**	***3.6***
1.67	**3**	***5.4***
2.22	**4**	***7.2***
2.78	**5**	***9.0***
3.33	**6**	***10.8***
3.89	**7**	***12.6***
4.44	**8**	***14.4***
5.00	**9**	***16.2***
5.56	**10**	***18.0***

10 Conversion Factors

Convert From	To	Multiply By
ampere-turns	gilberts	1.2566
atmospheres	torr	760.00
btu's	kilogram-calories	0.25200
btu's	foot-pounds	778.17
btu's	horsepower-hours	0.00039308
btu's	joules	1054.0
btu's	kilogram-meters	107.59
btu's	kilowatt-hours	0.00029307
btu's	gram-calories	252.00
btu's	watt-hours	0.29307
btu's/hour	watts	0.29307
btu's/minute	watts	17.584
btu's/minute	foot-pounds/sec	12.961
btu's/sq ft	watt-hours/sq meter	3.1546
btu's/(sq ft)(min)	watts/sq inch	0.12203
btu's/(hr)(sq ft)	watts/sq meter	3.1525
btu's/(hr)(sq ft)(°F)	gm-cals/(sec)(sq m)(°C)	1.3562
calories	joules	4.1840
Centigrade	Fahrenheit	0.555 x (°F-32)
centipoise	pascal-seconds	0.001
circular mils	square centimeters	0.000005067
circular mils	square inches	0.0000007854
circular mils	square mils	0.78540
cubic cm	cubic inches	0.061024
degrees (angle)	radians	0.017453
degrees/sec	revolutions/min	0.16667
dynes	grams	0.0010197
dynes	newtons	0.00001
dynes	pounds	0.0000022481
dynes/sq cm	kgs/sq meter	0.010197
dynes/sq cm	pounds/sq foot	0.0020885
dynes/sq cm	pounds/sq inch	0.000014503
Fahrenheit	Centigrade	1.8 x (°C + 32)
fathoms	feet	6
foot-pounds	horsepower-hours	0.00000050505
foot-pounds	joules	1.3558
foot-pounds	newton-meters	1.3558
foot-pounds	kilogram-calories	0.00032383
foot-pounds	kilogram-meters	0.13826
foot-pounds	kilowatt-hours	0.00000037662
foot-pounds/min	horsepower	0.000030303
foot-pounds/min	kilowatts	0.000022597
foot-pounds/sec	horsepower	0.0018182
foot-pounds/sec	kg-calories/min	0.019443
foot-pounds/sec	kilowatts	0.0013558
furlongs	miles	0.125
gallons (U.S.)	gallons (Brit.)	0.83267
gallons	liters	3.7854
gallons	pints (liquid)	8
gallons	quarts (liquid)	4
gallons/min	cubic feet/sec	0.0022280
gallons/min	liters/sec	0.063090
gauss	lines/sq inch	6.4516
gauss	webers/sq meter	0.0001
grams	ounces	0.035274
grams	ounces (troy)	0.032151
grams	poundals	0.070932
grams	pounds	0.0022046
gram-centimeters	btu's	0.00000009301

Convert From	To	Multiply By
gram-centimeters	foot-pounds	0.000072330
gram-centimeters	joules	0.000098067
gram-centimeters	kilogram-meters	0.00001
grams/cm	pounds/inch	0.0055997
grams/cu cm	pounds/cu foot	62.428
grams/cu cm	pounds/cu inch	0.036127
grams/cu cm	pounds/circ mil foot	0.00000034049
horsepower (electric)	horsepower (metric)	1.0143
horsepower	kg-calories/min	10.686
horsepower	horsepower (metric)	1.0139
horsepower	kilowatts	0.7457
horsepower	watts	745.7
horsepower-hours	joules	2684520
horsepower-hours	kilogram-calories	641.19
horsepower-hours	kilogram-meters	273745
hours	seconds	3600
inches	centimeters	2.54
inches	mils	1000
inches	millimeters	25.4
joules	kilogram-calories	0.00023866
joules	volt-coulombs	0.99984
joules	watt-hours	0.00027778
joules	watt-seconds	1
kilograms	dynes	980665
kilograms	poundals	70.932
kilograms	pounds	2.2046
kilograms	pounds (troy)	2.6792
kilograms	tons (short)	0.0011023
kilograms	tons (long)	0.00098421
kilogram-calories	kilogram-meters	426.93
kilogram-calories	kilowatt-hours	0.001163
kg-cals/minute	kilowatts	0.06978
kilogram-meters	kilowatt-hours	0.0000027241
kgs/cu meter	grams/cu cm	0.001
kgs/cu meter	pounds/cu foot	0.062428
kgs/cu meter	pounds/cu inch	0.000036127
kgs/meter	pounds/foot	0.67197
kgs/sq centimeter	pounds/sq inch	14.223
kgs/sq meter	pounds/sq foot	0.20482
kgs/sq meter	pounds/sq inch	0.0014223
kilopascals	pounds/sq in	0.14504
kilowatt	btu's/min	56.878
kilowatt-hours	btu's	3413
kilowatt-hours	horsepower-hours	1.3410
kilowatt-hours	kilogram-calories	860
kilowatt-hours	joules	3600000
liter	cubic cm	1000
liter	cubic inches	61.023
liters	quarts (liquid)	1.0567
liters/minute	cubic feet/sec	0.00058858
liters/minute	gallons/sec	0.0044029
meters	inches	39.370
meters	kilometers	0.001
meters	yards	1.0936
meter-kilograms	pound-feet	7.2330
meters/second	miles/hour	2.2369
meters/second	feet/minute	196.85
meters/second	kilometers/hour	3.6
meters/second	miles/minute	0.037282

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Convert From	To	Multiply By
micrograms	grams	0.000001
microhms	ohms	0.000001
microinches	inches	0.000001
microinches	microns	25.4
microinches	millimeters	0.0254
microliters	liters	0.000001
microns	inches	0.000039370
microns	meters	0.000001
microns	millimeters	0.001
miles	feet	5280
millibars	torr	0.75006
millibars	pascals	100
millihenries	henries	0.001
millimeters	mils	39.370
nautical miles	kilometers	1.852
newtons	pounds	0.22481
oersteds	amperes/meter	79.577
ohm - circular mil/foot	ohm - square mil/foot	1.273
ohm - circular mil/foot	ohm - square mm/meter	0.00166
ohm - circular mil/foot	microhm cm	0.16624
ohms/foot	ohms/meter	3.2808
ounces	pounds	0.0625
ounces (fluid)	cubic inches	1.8047
ounces (fluid)	liters	0.02957
ounces (troy)	grains	480
ounces (troy)	pounds (troy)	0.083333
pound	grams	453.59
pound	grains	7000
pound	kilograms	0.45359
pounds (troy)	pounds (avdp)	0.82286
pounds/sq foot	pounds/sq inch	0.0069444
pounds/sq inch	newton/sq meter	6894.8
pounds/cubic foot	kilograms/cubic meter	16.019
pounds/cubic inch	grams/cubic cm	27.680
radians	revolutions	0.15915
radians/sec	revolutions/min	9.5493
slugs	kilograms	14.594
square centimeters	square inches	0.15500
square feet	square meters	0.092903
square millimeters	circular mils	1973.5
square mils	circular mils	1.2732
square mils	square centimeters	0.0000064516
square mils	square inches	0.000001
stones	pounds	14
watts	ergs/second	10000000
watts	foot-pounds/min	44.254
watts	foot-pounds/sec	0.73756
watts	kg-calories/min	0.014331
watt-hours	foot-pounds	2655.2
watt-hours	kilogram-calories	0.85985

Industry Standard Specifications

The following specifications can be found in the Book of A.S.T.M. Standards. They describe methods of testing heat-resistant metals in various forms. Those which apply to Kanthal Precision Wire alloys are used regularly in our production and testing departments. We strongly recommend that these methods be consulted, before the development of Purchasing Specifications.

B 70 Method for Change of Resistance with Temperature of Metallic Materials for Electrical Heating.

B 84 Method for Temperature Resistance Constants of Alloy Wires for Precision Resistors.

B 95 Method for Linear Expansion of Metals

B 267 Specification for Wire for Use in Wire - Wound Resistors.

B 344 Specification for Drawn or Rolled Nickel - Chromium and Nickel - Chromium - Iron Alloys for Electrical Heating Elements

F 30 Specification for Iron - Nickel Sealing Alloys.

Lloyd's Register Quality Assurance

CERTIFICATE OF APPROVAL

This is to certify that the Quality Management System of:

Kanthal AB
Hallstahammar, Sweden

has been approved by Lloyd's Register Quality Assurance Limited to the following Quality Management System Standards:

ISO 9001:1994
EN ISO 9001:1994
SS-EN ISO 9001:1994

The Quality Management System is applicable to:

Design and manufacture of metallic alloys, ceramic materials for electrical heating elements and bimetallic materials for temperature control.

Approval Certificate No: [illegible]

Original Approval: [illegible]
Current Certificate: [illegible]
Certificate Expiry: [illegible]

on behalf of LRQA

Kanthal AB is multi-site certified by Lloyd´s to ISO 9001.

The Kanthal Head Office and main plant in Hallstahammar, Sweden.

The Complete Kanthal Product Range

Heating Alloys

Appliance Wire
0.12-2 mm *0.00468-0.078 in*

Ribbon

Thin Strip
The heating source in most electric household appliances such as ovens, toasters, hair dryers, washing machines etc.

Industrial Wire
1-10 mm *0.039-0.47 in*

Strip
Heating elements in industrial furnaces and processes.

Alloy	Max temperature	
KANTHAL APM	1425 °C	*2595 °F*
KANTHAL A-1	1400 °C	*2550 °F*
KANTHAL A	1350 °C	*2460 °F*
KANTHAL AE	1300 °C	*2370 °F*
KANTHAL AF	1300 °C	*2370 °F*
KANTHAL D	1300 °C	*2370 °F*
ALKROTHAL	1100 °C	*2010 °F*
NIKROTHAL 80	1200 °C	*2190 °F*
NIKROTHAL 70	1250 °C	*2280 °F*
NIKROTHAL 60	1150 °C	*2100 °F*
NIKROTHAL 40	1100 °C	*2010 °F*
NIFETHAL 70	600 °C	*1110 °F*
NIFETHAL 52	600 °C	*1110 °F*

Special Alloys

Copper-nickel, Nickel-iron, Spark plug electrode alloys, Thermocouple alloys.

Precision Wire

0.010-0.51 mm *0.0004-0.0201 in*

This wire is used in electronic components such as resistors and potentiometers, in computer disk drives, for low temperature heating, in guitar strings etc.

A 0.015 mm wire is seen in the eye of a needle on page 5.

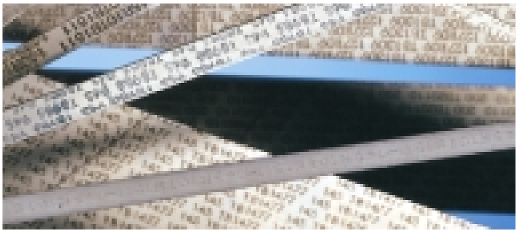
Thermostatic Bimetal

Bimetal consists of two or more metallic strips with different thermal expansion bonded together. When heated up it bends in a pre-determined manner and can be used to monitor, measure or regulate heat in thermostats for room heaters or water mixing, to control toasters and indicators in automobiles etc.

Kanthal offers a wide range of some 30 standard types of thermostatic bimetal with different specific deflection, manufactured in widths ranging between 1.0 and 170 mm *0.039–6.63 in* and in thickness between 0.10 and 2.5 mm *0.0039–0.097 in.*

Bimetal is also manufactured as disc material to ver y close tolerances which give a snap action at a given temperature.

Kanthal Bimetal - Wire and Strip



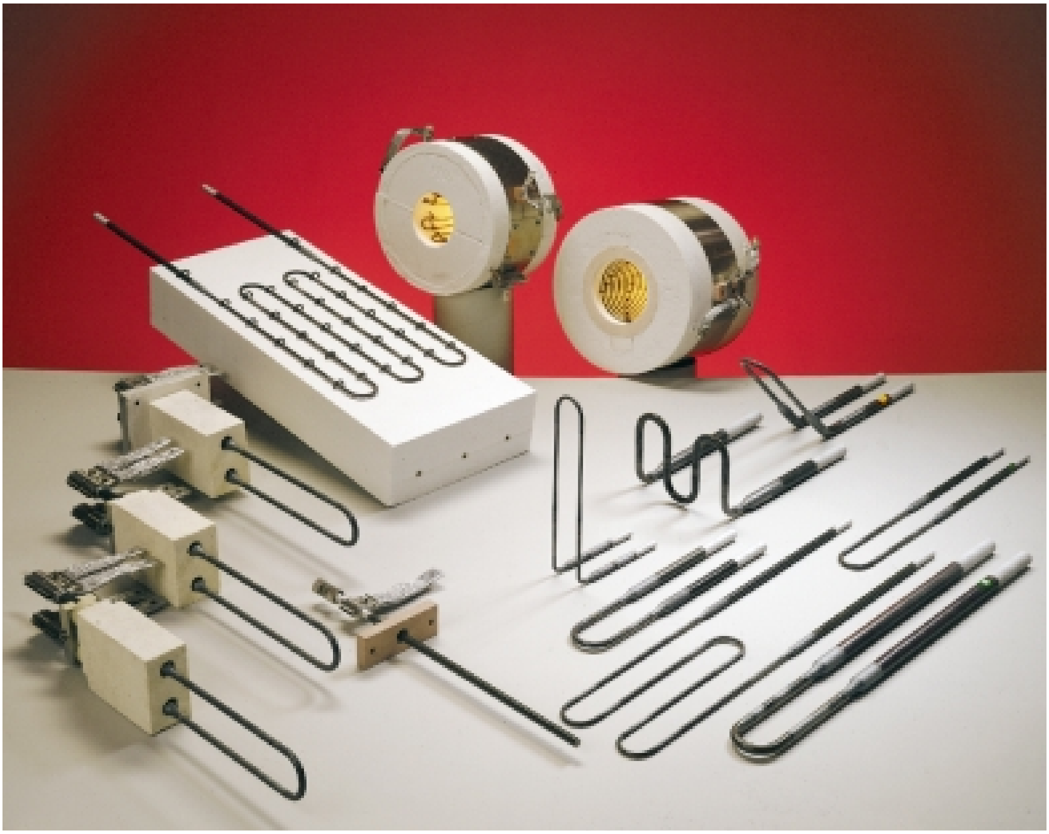
11

Kanthal Super, Superthal®

High power and long life electric heating elements for use up to 1850 °C *3360 °F*. Manufactured as ready-made elements, straight or bent in a broad range of standard dimensions. Superthal heating modules with Kanthal Super elements and ceramic fibre in the form of half-cylinders, cylinders, panels or completely tailor made for use up to 1550 °C *2820 °F*. Used mainly in laborator y furnaces and production furnaces in the glass-, electronics-, steel-, ceramics and heat treatment industry.

Quality	Max temperature	
Kanthal Super 1700	1700 °C	*3090 °F*
Kanthal Super 1800	1800 °C	*3270 °F*
Kanthal Super 1900	1850 °C	*3360 °F*

Kanthal Super, Superthal



Metallic Elements

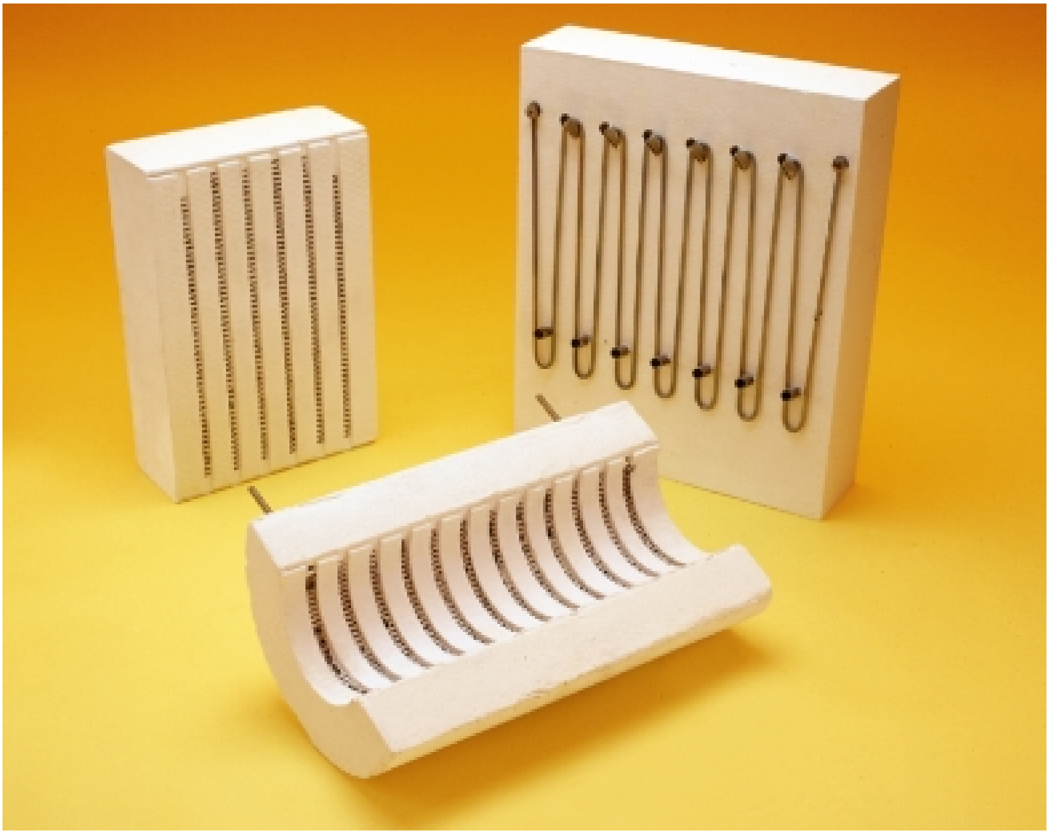
Metallic Elements

Ready-made furnace elements manufactured in Kanthal workshops from Kanthal or Nikrothal alloys for furnace temperatures between 50 – 1350 °C *120 – 2460 °F.*

Fibrothal®

A complete modular system comprising heating elements and insulation for furnaces and processes up to 1200 °C *2190 °F.*

Fibrothal



11

Tubothal®

Powerful metallic element heaters for use inside all types of radiant tubes, ideally Kanthal APM. Available in standard dimensions from 68 to 170 mm *2.6 – 6.6 in* diameter.

Tubes

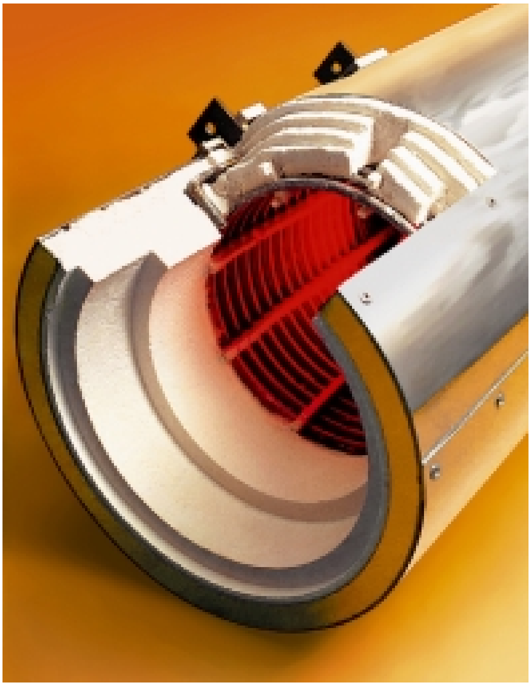
Kanthal APM and Sandvik 353/253 extruded radiant tubes for gas-or electrically heated furnaces. Complete assemblies with inner tubes (gas)or suitable electric heating elements. Standard dimensions from 26 to 260 mm outer diameter *1.02 – 10.2 in.*

Tubothal

APM extruded radiant tubes for gas or electric heating

Heating Elements

Furnace systems and complete heating elements for semiconductor wafer processing. Furnace rebuilds, upgrades and new replacement furnace systems to provide larger wafer processing capabilities.



Silicon Carbide

Heating elements in a broad range for use up to 1650 °C *3000 °F*. Manufactured in straight, spiralled, single or multishank designs for a variety of heat treatment and melting furnaces. Kanthal SiC is the standard element for production of float-glass.

HOT ROD®
GLOBAR®
CRUSILITE®
SILIT®
FLOAT

Silicon Carbide Heating element

11

Kanthal Machinery

Kanthal Machinery offers a complete range of machines for manufacturing metal sheathed tubular elements and thin walled tubes. Available as either standard or custom built stand-alone machines to complete turnkey factor y production lines.

Coiling Machine

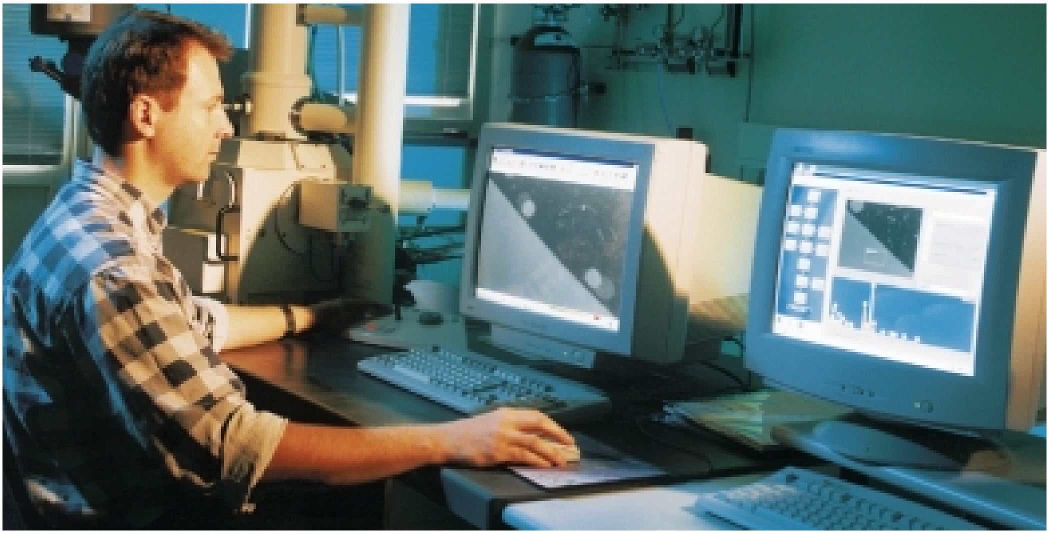
Tube welding mill.

11

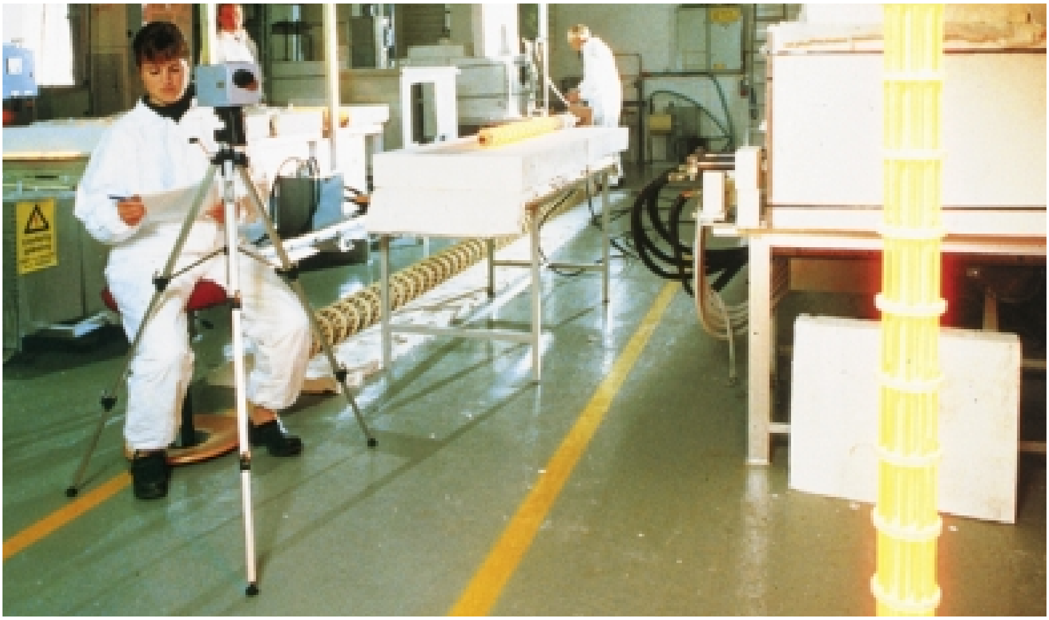
Customer Service

Kanthal not only offers a complete range of products to generate or protect against heat, but of equal impor tance is the technical and commercial service we extend to our customers. Examples of this includes advice on choice of material, design of elements, trouble-shooting, design and manufacturing of complete heating systems, development of new elements and alloys, installation ser vice and follow-up.

Scanning Electron Microscope



Technical Centre



Notes

Useful URL

www.kanthal.com

www.kanthalpalmcoast.com

www.sandvik.com

Notes

Notes

KANTHAL