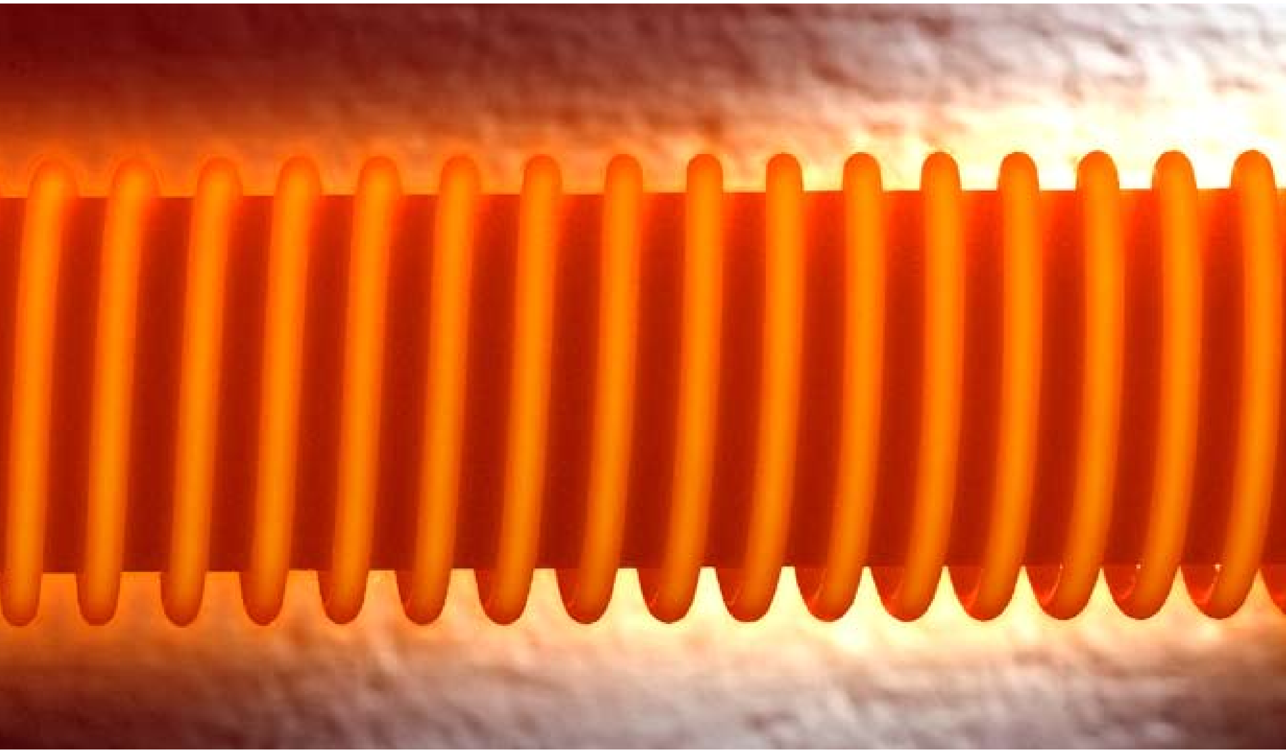
Resistance Heating Alloys and Systems for Industrial Furnaces



KANTHAL

Catalogue 1-A-5B-3 UK 11-08-3000

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The Sandvik Group is a global high technology enterprise with 47,000 employees and annual sales of approximately SEK 86 billion. Sandvik spends about 4 percent of is turnover on research and development. As a member of the Sandvik Group, Kanthal has full access to world-class competence within materials and process technology, as well as Sandvik's R&D-center in Sweden, which is one of the most distinguished in the world. Through Sandvik's global sales organization Kanthal is represented in 130 countries.

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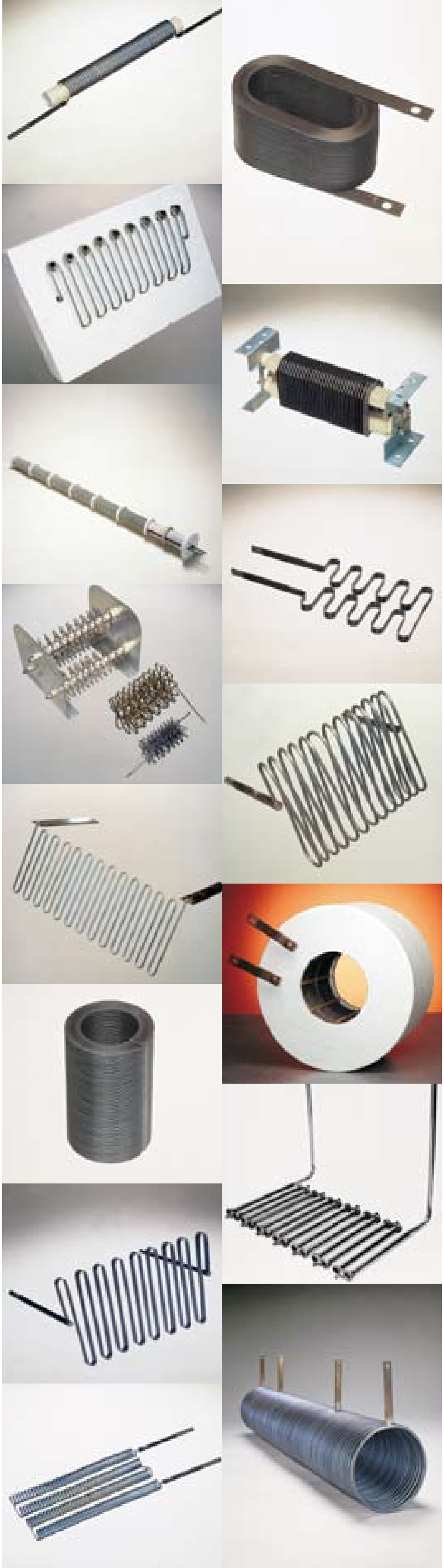


Metallic Heating Elements from Kanthal

This booklet contains technical data for our resistance heating alloys KANTHAL and NIKROTHAL.

We also include some instructions for the calculation and design of heating elements for industrial furnaces as well as examples of support systems and insulation. Out of the KANTHAL PM (powder metallurgical/production route) group tubes are only shortly described, detailed information is found in KANTHAL PM tubes handbook.

The latest product- and application information is found on **www.kanthal.com**.

We can assist you:

- in choosing suitable element material, element type, support system and insulation,
- by supplying complete heating elements ready for installation,
- in upgrading both electrical and gas heated furnaces by delivering technical solutions based on latest material technology rendering maximum productivity and economy
- to replace radiant tubes with KANTHAL APM tubes in both gas- and electrically heated furnaces and to supply complete recuperative burner systems (ECOTHAL® – SER).

Our modern workshops have developed considerable experience in manufacturing heating elements and can manufacture to any specifications.

Our delivery times are short and our service objectives are high.

KANTHAL® or NIKROTHAL®?

There are two main types of electric resistance alloys. Nickel-chromium (e.g. 80 Ni, 20 Cr) called NIKROTHAL was developed around the beginning of the 20th century and was soon used as heating element material in industrial furnaces as well as in electric household appliances.

In the thirties Kanthal introduced a new resistance heating alloy (called KANTHAL) based on iron-chromium-aluminium with a longer life and a higher maximum operating temperature than nickel-chromium. Kanthal manufactures both types of alloys under the names NIKROTHAL (nickel-chromium) and KANTHAL (iron-chromium-aluminium).

The two main types of alloys have their own specific properties, with advantages and disadvantages, and are supplied in many different grades and forms.

In general KANTHAL type alloy is superior to NIKROTHAL in respect of performance and life and is therefore nowadays a standard material choice when it comes to metallic heating elements for industrial furnaces.

The NIKROTHAL alloy may have special advantages if you need a heating element having very good mechanical properties in the hot state. KANTHAL APM has, however, creep strength at elevated temperatures in the same level as NIKROTHAL.

For the furnace user, using KANTHAL results in less amount of material at a lower price and also – a longer life. Table 1 shows an example of weight saving – and lower cost – obtained by using KANTHAL instead of nickel-chromium alloys. This lower element weight will also result in considerable cost savings regarding support system, because fewer suspension hooks are necessary.

The most important advantages with KANTHAL type alloy are:

- Higher maximum temperature of 1425°C compared to 1250°C
- Longer life (2–4 times)
- Higher surface load
- Higher resistivity
- Lower density
- No spalling oxide, which may contaminate the goods and the furnace and also cause short circuit or failure of elements and gas burners.

Weight saving based on same wire diameter:

[kg]

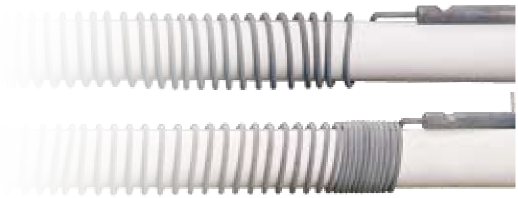
$$\frac{44.4-29.6}{44.4} = 33\,\%$$

Element Data	NIKROTHAL	KANTHAL
Furnace temperature [°C]	1000	1000
Element temperature [°C]	1068	1106
Hot resistance [R_w]	3.61	3.61
Temperature factor [C_t]	1.05	1.06
Cold resistance [R_{20}]	3.44	3.41
Wire diameter [mm]	5.5	5.5
Surface load [W/cm^2]	3.09	3.98
Wire length [m] 3 elements	224.9	174.6
Wire weight [kg] 3 elements	44.4	29.6

Table 1 A 120 kW furnace equipped with R.O.B. elements. 3 elements of 40 kW each, 380 V.

KANTHAL APM™ Heating Material

KANTHAL APM is a resistance material which can be used to improve the performance at high temperatures, where conventional metallic elements are getting problems like bunching, creeping, oxide spallation and to open up new applications where metallic elements are not used today.



Comparison between KANTHAL APM (top) and conventional FeCrAl after 1250 h at max 1225°C element temperature.

The Great Advantages of KANTHAL APM are:

Improved hot strength, giving:

- much better form stability of the heating element
- less need for element support
- low resistance change (ageing)
- longer element life

Excellent oxide, giving:

- good protection in most atmospheres, especially corrosive atmospheres
- no scaling and impurities
- a longer element life

Creep Rupture Strength for Industrial Wire 4 mm

Time [h]	Temp. 1000°C [MPa]
100	5.0
1000	3.1
10000	2.1

Time [h]	Temp. 1200°C [MPa]
100	3.3
1000	1.6
10000	0.6

Time [h]	Temp. 1400°C [MPa]
100	1.3
1000	0.5

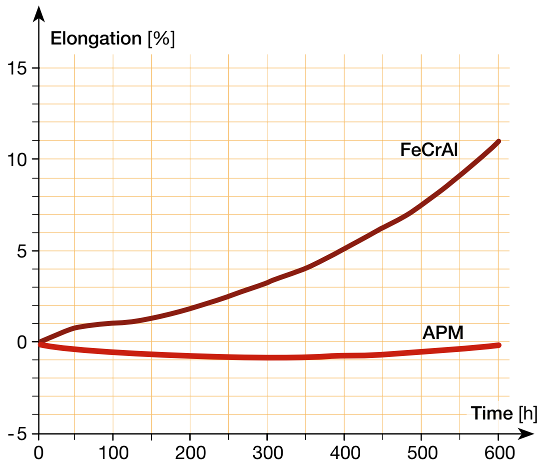


Fig. 1 Elongation at 1300°C element temperature.

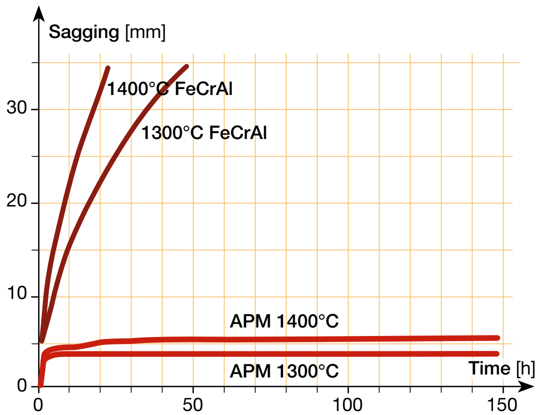


Fig. 2 Sagging test diam. 9.5 mm, 1300°C and 1400°C, 300 mm between supports.

Physical and Mechanical Properties

KANTHAL and NIKROTHAL alloys are generally available in wire, ribbon or strip form. Physical and mechanical properties of the alloys are listed in Table 2. C_t factor see page 23 and following.

		KANTHAL APM	KANTHAL A-1	KANTHAL AF	KANTHAL D	NIKROTHAL 80	NIKROTHAL 70	NIKROTHAL 60	NIKROTHAL 40
Max continuous operating temp.	[°C]	1425	1400	1300	1300	1200	1250	1150	1100
Nominal composition	[%] Cr	22	22	22	22	20	30	15	20
	Al	5.8	5.8	5.3	4.8	–	–	–	–
	Fe	Balance	Balance	Balance	Balance	–	5 %	Balance	Balance
	Ni	–	–	–	–	Balance	Balance	60	35
Resistivity at 20°C	[$\Omega mm^{-2} m^{-1}$]	1.45	1.45	1.39	1.35	1.09	1.18	1.11	1.04
Density	[g/cm^3]	7.10	7.10	7.15	7.25	8.3	8.1	8.2	7.9
Coefficient of thermal expansion, K-1	20–750°C	14×10^{-6}	14×10^{-6}	14×10^{-6}	14×10^{-6}	16×10^{-6}	16×10^{-6}	16×10^{-6}	18×10^{-6}
	20–1000°C	15×10^{-6}	15×10^{-6}	15×10^{-6}	15×10^{-6}	17×10^{-6}	17×10^{-6}	17×10^{-6}	19×10^{-6}
Thermal conductivity at 20°C	[$W m^{-1} K^{-1}$]	13	13	13	13	15	13	13	13
Specific heat capacity at 20°C	[$KJ kg^{-1} K^{-1}$]	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.50
Melting point	[°C]	1500	1500	1500	1500	1400	1380	1390	1390
Mechanical properties (approx.)*									
Tensile strength	[$N mm^{-2}$]	680	680	680	650	810	820	730	675
Yield point	[$N mm^{-2}$]	470	475	475	450	420	430	370	340
Hardness	[Hv]	230	230	230	230	180	185	180	180
Elongation at rupture	[%]	20	18	18	18	30	30	35	35
Tensile strength at 900°C	[$N mm^{-2}$]	40	34	37	34	100	120	100	120
Creep strength at 800°C	[$N mm^{-2}$]	11	6	8	6	15	15	15	20
at 1000°C	[$N mm^{-2}$]	3.4	1	1.5	1	4	4	4	4
Magnetic properties		Magnetic (Curie point 600°C)				Non	Non	Slightly	Non
Emissivity, fully oxidized condition		0.70	0.70	0.70	0.70	0.88	0.88	0.88	0.88

* The values given apply for wire sizes of 4 mm diameter for the KANTHAL alloys and of 1 mm for the NIKROTHAL alloys.

Table 2 KANTHAL and NIKROTHAL basic data.

Furnace Wall Loading

Figure 3 shows the maximum recommended wall loading for four different element types. Please note that the furnace wall loading depends on both element type and element surface load. The lower the surface load, the longer the element life will be. (For description of the element types, see page 9).

When elements are placed on the base of a furnace, special attention must be paid to avoid overheating of the elements. For example, with a hearth plate having a thermal conductivity of (λ)=1.0 $Wm^{-1} K^{-1}$ 6.39 and thickness of 15 mm *(at a power concentration on the bottom surface of 15 kW/m²)* a temperature drop of 225°C is obtained through the plate. The total temperature difference between the base elements and the furnace temperature would thus be about 375°C. This imposes a furnace operating temperature of 1000°C even when using the high-temperature KANTHAL A-1 alloy, since the element temperature will be about 1375°C.

The example illustrates the significance of choosing a hearth plate of a material having good thermal conductivity, for example silicon carbide or heat-resistant steel. Beside measuring the temperature in the furnace chamber, it may also be advisable to measure the temperature of the base elements by a separate thermocouple.

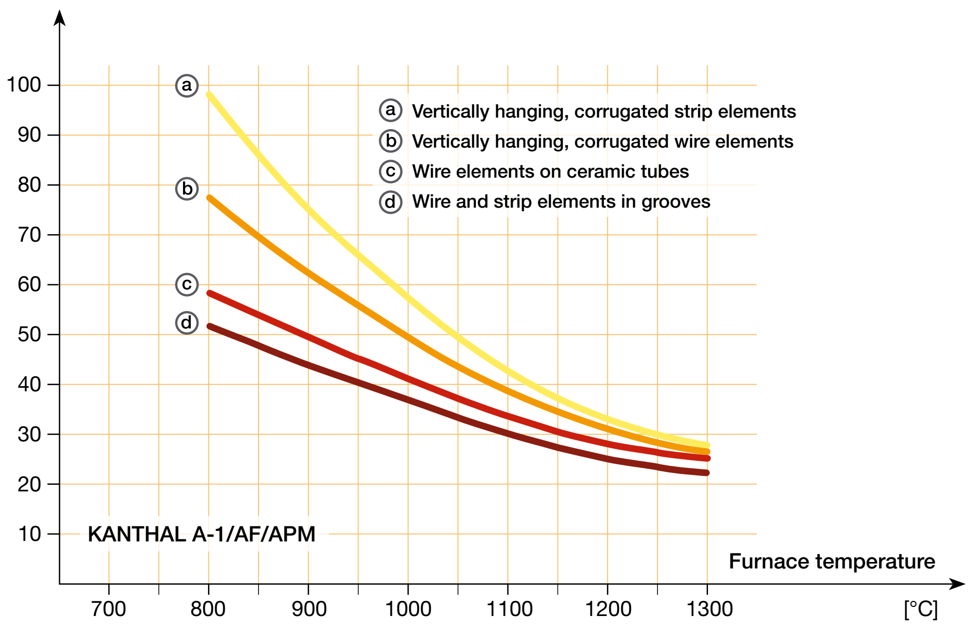


Fig. 3 Maximum recommended wall loading as a function of furnace temperature for different element types.

Element Surface Load

Since KANTHAL alloys can be operated at higher temperatures than NIKROTHAL alloys, a higher surface load can be accepted without jeopardizing the life. Element design is also of great importance. The more freely radiating the element form, the higher the maximum surface load can be. Therefore the R.O.B. (Rod Over Bend) type element (corrugated heavy wire, mounted on the surface), can be loaded the highest, followed by the corrugated strip element.

Spiral elements on ceramic tubes can be loaded higher than spiral elements in grooves. The values in Figure 4 are given for the following design conditions:

Element types a (heavy wire) and b (strip): Strip thickness min. 2.5 mm. Wire diameter min. 5 mm. Pitch min. 50 mm at maximum loop length and maximum surface load.

Maximum recommended loop length:

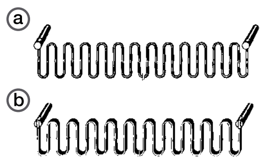
< 900°C	300 mm
1000°C	250 mm
1100°C	200 mm
1200°C	150 mm
1300°C	100 mm

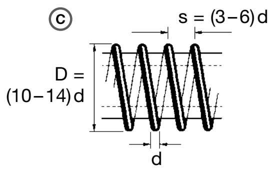
For finer wire diameters and smaller strip thicknesses lower surface loads and shorter loop lengths must be chosen to avoid element deformation and subsequent shorter element life.

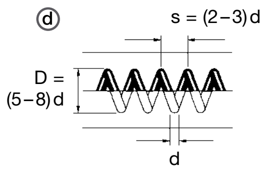
Element type c: Wire element on ceramic tube. Wire diameter min. 3 mm.

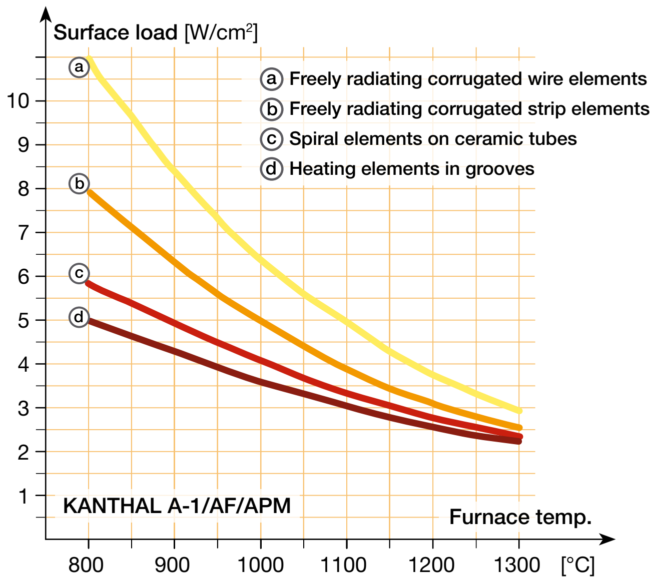
Element type d: Wire and strip element in grooves. Wire diameter min. 3 mm, strip thickness min. 2 mm.

Note: The diagram is valid for thyristor control. For on-off control lower surface loads should be chosen (about –20 %).









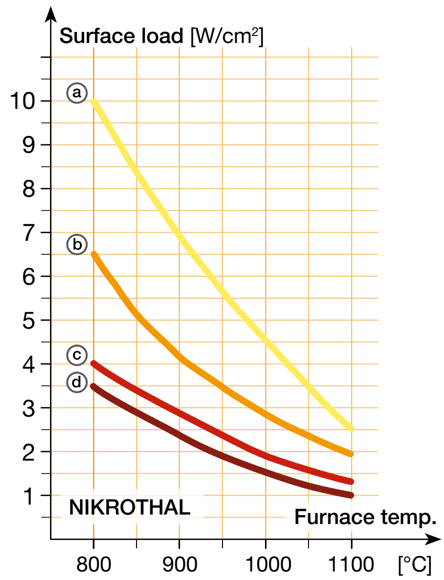


Fig. 4 Maximum recommended surface loads for KANTHAL and NIKROTHAL alloys in industrial funaces.

Operating Life and Maximum Permissible Temperature

When heated, resistance heating alloys form an oxide layer on their surface, which prevents further oxidation of the material. To accomplish this function the oxide layer must be dense and resist the diffusion of gases. It must also be thin and adhere to the metal under temperature fluctuations.

In these respects the aluminium oxide formed on KANTHAL alloys is might be even better than the oxide formed on NIKROTHAL alloys, which contributes to the much longer operating life of Kanthal heating elements. Figure 5 shows the comparative element life.

Below you will find some general advice to obtain as long element life as possible.

Use KANTHAL Alloys

Heating elements made of KANTHAL alloys have 2–4 times longer life than heating elements made of nickel-chromium material. The higher the temperature, the greater the difference.

Avoid Temperature Fluctuations

The operating life of the heating elements will be reduced by rapid temperature fluctuations. It is therefore advisable to choose an electric control equipment, which gives as even a temperature as possible, e.g. by using thyristors.

Choose Thick Element Material

The material thickness has a direct relationship to the element life, in that, as the wire diameter is increased, more alloying element is available per surface unit to form a new oxide. Thus, at given temperature, thicker wires will give a longer life than thinner wires. Accordingly, for strip elements, increased thickness gives a longer life. As a general rule, we recommend min. 3 mm wire diameter and 2 mm strip thickness.

Adjust the Element Temperature to the Furnace Atmosphere

Table 3 shows some common furnace atmospheres and their influence on the maximum operating temperature of the heating elements. NIKROTHAL should not be used in furnaces having a CO-containing protective gas atmosphere due to the risk of "green rot" at 800–950°C.

In such cases KANTHAL alloys are recommended, provided the heating elements are preoxidized in air at 1050°C for 7–10 hours. Reoxidation of the heating elements should be carried out at regular intervals.

Avoid Corrosion from Solid Substances, Fluids and Gases

Impurities in the furnace atmosphere, for instance oil, dust, volatiles or carbon deposits can damage the heating elements.

Sulphur is harmful to all nickel alloys. Chlorine in different forms will attack both KANTHAL and NIKROTHAL alloys. Splashes of molten metal or salt may also damage the heating elements.

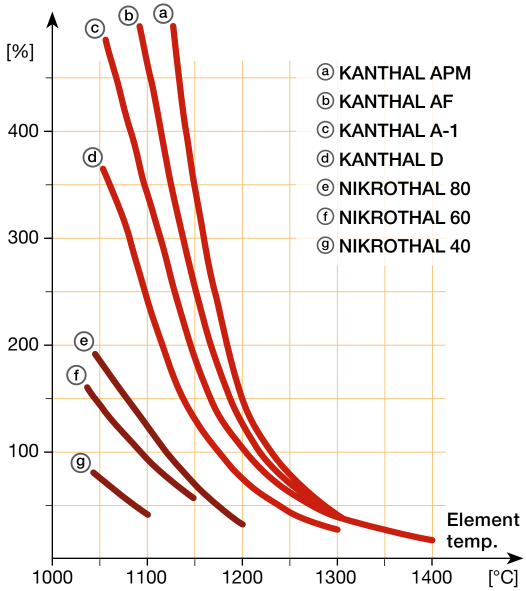


Fig. 5 Comparative life (KANTHAL A-1 at 1200°C = 100%)

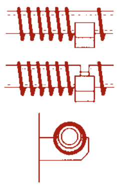
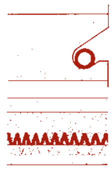
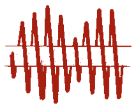
	KANTHAL A-1 and APM [°C]	KANTHAL AF [°C]	KANTHAL D [°C]	NIKROTHAL 80 and 70 [°C]	NIKROTHAL 60 [°C]	NIKROTHAL 40 [°C]
Oxidizing:						
Air, dry	1400[a]	1300	1300	1200[d]	1150	1100
Air, moist	1200	1200	1200	1150	1100	1050
Neutral:						
N_2, Nitrogen[b]	1200	1250	1150	1250	1200	1150
Ar, Argon	1400[a]	1300	1300	1250	1200	1150
Exothermic:						
10 CO, 15 H_2, 5 CO_2, 70 N_2	1150	1150	1100	1100[c]	1100	1100
Reducing:						
Endothermic:						
20 CO, 40 H_2, 40 N_2	1050	1050	1000	1100[c]	1100	1100
H_2, Hydrogen	1400[a]	1300	1300	1250	1200	1150
Cracked ammonia:[e]						
75 H_2, 25 N_2	1200	1200	1100	1250	1200	1150
Vacuum:						
10^{-3} torr	1150	1200	1100	1000	900	900

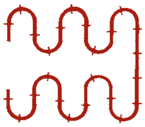
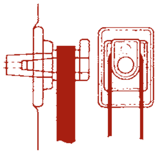
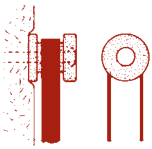
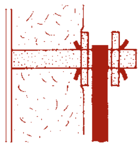
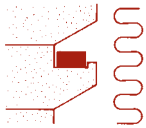
a) Max 1425°C for APM
b) The higher values apply for pre-oxidized material
c) Please note risk of “green rot” formation in carburizing atmospheres. Use KANTHAL AF or NIKROTHAL 70
d) 1250°C for NIKROTHAL 70
e) An atmosphere created by cracked ammonia, that contains uncracked ammonia, will lower the max. permissible temperature

Table 3 Maximum permissible temperatures in various atmospheres.

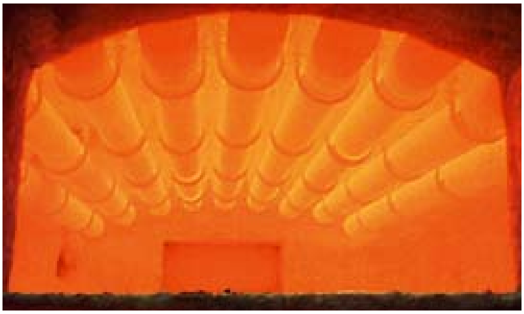
Key Data for Kanthal Elements

Table 4

Wire Elements					
Element Systems		**Spiral**	**Spiral**	**Porcupine**	**Rod over Bend**
Supports		Ceramic tubes	Grooves	Ceramic tubes	Metallic rods
					
Material		Sillimanite	Chamotte Grade 28	Sillimanite	KANTHAL APM
Max. furnance temperature	**[°C]**	1300	1250	800	1300
Max. wall loading at 1000°C furnace temperature	**[kW/m²]**	40	35	–	50
Max. surface load at 1000°C furnace temperature	**[W/cm²]**	3–4	3–4	–	5–6
Wire diameter (d)	**[mm]**	2.0–6,5	2.0–5.0	1.0–6.5	≥5.0
Strip thickness (t)	**[mm]**	–	–	–	–
Strip widht (w)	**[mm]**	–	–	–	–
Outer coil diameter (D)	**[mm]**	(12–14) d	(5–6) d	–	–
Max. loop length at 1000°C furnace temperature	**[mm]**	–	–	–	250
Min. pitch at max. loop length	**[mm]**	3d	2d	3d	40

		Strip Elements			
Corrugated	**Looped**	**Deep-Corrugated**	**Deep-Corrugated**	**Deep-Corrugated**	**Corrugated**
Metallic staples	Ceramic tubes	Ceramic cup locks	Ceramic bushes	Ceramic tubes	Grooves
					
U-shaped Kanthal-nails	Sillimanite	Cordierite or Mullite	Cordierite or Mullite	Sillimanite	Chamotte Grade 28
1300	1300	1300	1300	1300	1300
50	60	60	60	60	20–40
3–6	5–6	5–6	5–6	5–6	3–4
2.0–5.0	≥5.0	–	–	–	–
–	–	2.0–3.0	2.0–3.0	2.0–3.0	1.5–3.0
–	–	(8–12) t	(8–12) t	(8–12) t	(8–12) t
–	–	–	–	–	–
100	250	250	250	250	(2–3) w
40	40	50	50	50	1.5 w

Kanthal TUBOTHAL® – the Most Powerful Metallic Element System



Kanthal TUBOTHAL is an ideal electric element used in combination with PM tubes because of its great advantages, such as – very high power – long life – low weight – easy to design to existing power controls and supply. Combined with APM tubes, a "maintenance free system" is obtained with high reliability and with no need to remove elements, clean or rotate tubes, if correctly designed.

The variety of applications where the TUBOTHAL system can be used is vast. The main areas of use are in heat treatment, aluminium and steel industry furnaces.

The high loading capabilities of both TUBOTHAL elements and KANTHAL APM tubes can be exploited to the full in new furnaces and conversions from traditional radiant tube designs. In both cases, higher power and/or higher temperatures can be obtained, or a similar output can be achieved with fewer assemblies installed, leading to improved furnace flexibility and lower costs. The longer life obtained with the TUBOTHAL system, ensures highly reliable production and uninterrupted furnace operation.

TUBOTHAL element assemblies are available in a wide range of standard diameters, to suit the sizes of tubes currently available. In principle, the length of element is virtually unlimited, but the practicalities of packing, shipping and installation may impose restrictions on the usable length. TUBOTHAL elements are suitable for both horizontal and vertical installations.

Normally, horizontal tubes are simply supported at both ends. With very long radiant tubes, it may be

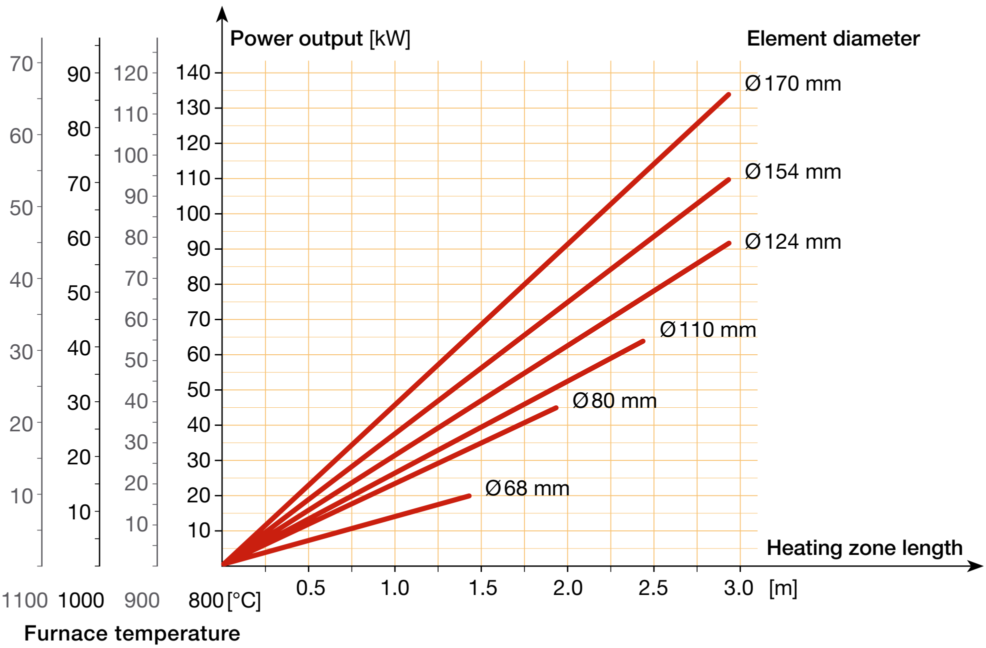


Fig. 13 Maximum design power outputs for all standard element diameters at different furnace temperatures.

necessary to provide supports along the tube length. KANTHAL APM rod has proved ideal for fabricating suitable support systems, hooks, etc.

Higher Power Output

TUBOTHAL elements will operate at a far higher power output than standard designs of radiant tube elements. A single TUBOTHAL assembly may be capable of replacing up to three heaters of a more conventional design, leading to major savings in replacement and maintenance costs.

In other cases, a change to TUBOTHAL, combined with uprated power input to the existing furnace, has resulted in improved furnace capacity at a much lower cost compared to a completely new furnace.

Fitting a few TUBOTHAL assemblies in an existing furnace can increase productivity by over 50%, in some cases.

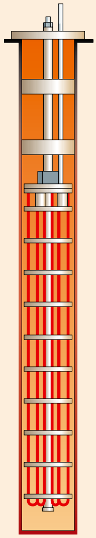
The power output for standard TUBOTHAL elements is a function of element diameter, effective heating length and operating temperature of the furnace. Figure 11, illustrates suggested maximum design power outputs for all standard element diameters, at furnace temperatures between 800°C and 1100°C.

Power Supply

Although individual elements can operate at a voltage lower than that of the supply. In multiple element installations, groups of elements can be series – connected directly to the main voltage without the need of transformers. There is no significant ageing of the APM elements, so a variable voltage supply is not required. On/off control can be used, but three-term control, using fast or slow, cycle fired thyristors, will ensure a more stable element temperature and a longer element life, as well as offering better control of the furnace temperature.

Kanthal TUBOTHAL Benefits

- Very high power levels
- Long life
- "Maintenance free", longer service intervals
- Low ageing
- Low element weight
- Low thermal mass
- Standardised product for fast delivery and reliability
- Design flexibility
- KANTHAL PM tubes can also be used for gas heated solutions based on that the system is well prepared for changes depending on energy prices.



Vertical and horizontal TUBOTHAL element systems.

KANTHAL PM Material

The Kanthal family of high temperature materials is aimed initially at the manufacture of resistance wire and strip for electric furnace applications. The KANTHAL PM (Powder metallurgy) tubes, APM and APMT, are seamless and produced by extrusion. KANTHAL PM tubes are suitable for a wide range of temperatures and atmospheres, covering many applications and processes in various industries.

KANTHAL PM materials are based on the well-known Kanthal FeCrAl alloy, the basis for electric elements in many different types of kiln and furnace for over 70 years. The PM materials are produced by an Advanced Powder Metallurgy process route. The PM alloys maintain all of the benefits of the traditional Kanthal alloys and add many more. The most obvious benefit is the higher mechanical strength achieved by dispersion strengthening.

KANTHAL APMT is a further development of KANTHAL APM, designed for specially demanding applications. The alloy has the same excellent high temperature corrosion resistance as APM, but with even higher strength.

More Power, Longer Life Less Maintenance

Kanthal metallic PM material has been successfully used for many years in the form of wire, strip, radiant and protection tubes. Used mainly in the heat treatment, steel and aluminium industries, KANTHAL PM tubes contribute to much higher furnace productivity by offering more power, less maintenance and longer service life.

The KANTHAL PM tube range includes APM suitable for most types of processes, and APMT, an alloy with improved hot strength for extra demanding horizontal applications. KANTHAL PM tubes are suited to both gas and electrically heated furnaces.

Extra High Temperature

Can operate at temperatures up to 1250°C.

High Loading Potential

At a furnace temperature of 1000°C, the loading can be more than double that of NiCr and FeNiCr tubes. This allows more flexible furnace designs and conversion of existing heating systems to higher furnace power. Fewer tubes are needed for the same power rating.

Less Maintenance

The oxide is non-spalling, hence no scaling and no impurities inside the tube to contaminate the heating element or gas burner. No need for downtime to clean the tubes. No scaling on the outside and no contamination of the goods in the furnace.

Long Life

When heated, KANTHAL PM materials form an aluminium oxide (Al_2O_3) scale that protects the alloy from further corrosion and prolongs the service life, compared with ordinary NiCr or FeNiCr tubes.

No Tube Carburisation

The alumina oxide protects the alloy from carburisation in high carbon-potential atmospheres.

KANTHAL PM materials withstand coking and metal dusting.

No Weak Spots

Tubes are extruded, so there are no welded seams, eliminating a source of potential failure.

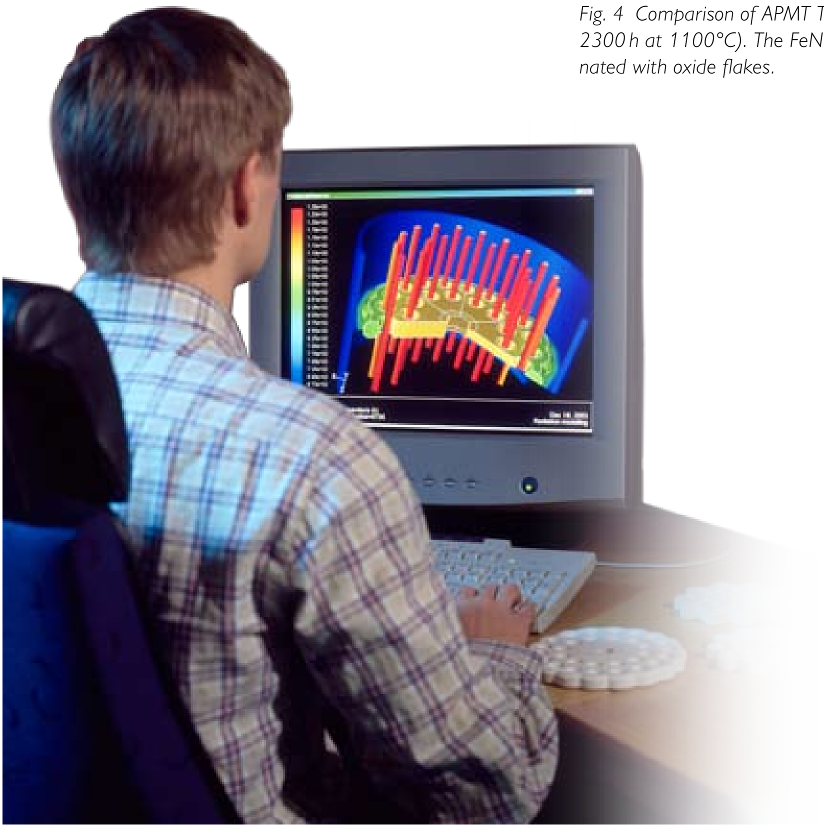
Excellent Form Stability

Excellent form stability even at elevated temperatures.

Low Weight

KANTHAL PM tubes weigh less than equivalent NiCr and FeNiCr tubes of the same dimension.

Fig. 4 Comparison of APMT Tube vs. Fe-35Ni-25Cr (after 2300 h at 1100°C). The FeNiCr tube is severely contaminated with oxide flakes.



Gas Fired Systems

Straight Through Tubes

In its simplest form, a radiant tube consists of a straight tube, with the burner fitted at one end and the exhaust chamber at the outlet. These straight through tubes, although simple and relatively inexpensive, are inherently inefficient, as the temperature of the exhaust gases is significantly higher than the furnace temperature, and the majority of the energy of combustion is lost to the surroundings.

Radiant Tubes for Recuperative Systems – SER Burner Systems

The majority of burners in use today are of a single ended design, where the burner and exhaust chamber are situated on the same side of the furnace. With these designs, the exhaust gases can be used to pre-heat the air required for combustion. This results in a major improvement in system efficiency, by exhausting only low temperature gases into the atmosphere. Common designs are U, W, and P shaped tubes, but these are gradually being replaced by less expensive and lighter single-ended recuperative burners, SER. With this design, the recuperator is integrated within the tube. Recovery of heat from the exhaust gases takes place within the furnace wall, minimising heat loss in the process.

Modern, high efficiency SER burner systems offer efficiencies in excess of 80 % and are highly cost effective compared with direct fired systems and straight through designs of radiant tubes. The inherent reliability and temperature capability of KANTHAL PM tubes make them an ideal partner and the preferred choice for the most modern burner systems.

With SER burners, the limiting factor in the design is normally the inner tube, which operates at a significantly higher temperature than the outer tube. Even in low temperature applications, the inner tube temperature can exceed the practical maximum for Ni-Cr materials, especially when the burner output is high. This has imposed severe limitations on the output of radiant tube designs.

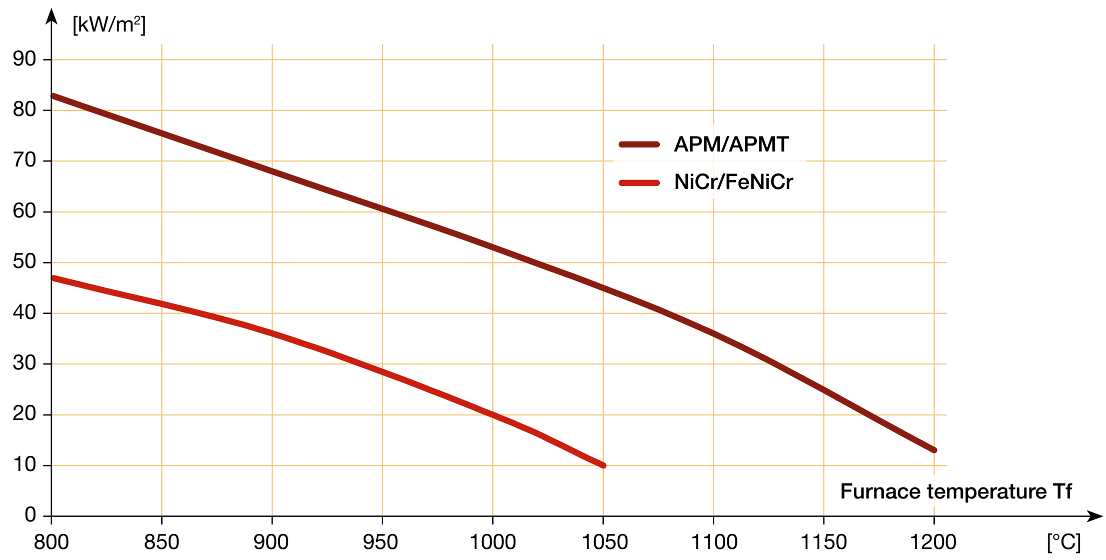


Fig. 10 Power output SER-burner systems.

KANTHAL PM radiant tubes however, are capable of far higher operating temperatures than NiCr. This has allowed burner manufacturers to exploit the higher outputs of modern designs to the full, dissipating the same power input in the furnace with fewer tubes, or uprating the input to existing systems (Figure 10). The potential benefits, in terms of productivity and installed costs, are immense and the use of KANTHAL PM materials has extended the temperature range of radiant tube assemblies.

Silicon Carbide Inner Tubes

Silicon carbide can be combined with KANTHAL PM tubes in gas applications, where the temperature is higher or the power loading is higher than metallic tubes can endure. SER burner systems that work at very high temperature or high loading can be designed with a ceramic flame tube (inner). The flame tube is the part in the system that works at the highest temperature, often 100–200°C warmer than the outer tube. As outer tubes,

KANTHAL PM tubes can work under tougher conditions than other metallic tubes and have better resistance to thermal shock than ceramic tubes. Flanges, end caps and support systems are much cheaper and easier to install for metallic systems compared to ceramic.

Vertical SER

Straight through

Horizontal SER


KANTHAL

KANTHAL APM-Tubes Standard Product Range

OD [mm]	Wall thickness [mm]	Weight APM [kg/m]	Weight APMT [kg/m]	Max. length [m]	APM standard stock	APMT standard stock
26.67	2.87	1.52		13.0	•	
33.4	3.38	2.26		13.0	•	
33.7	6.0	3.71		10.5	•	
40	3.0	2.48		13.0	•	
50.8	6.35	6.30	6.39	7.0	•	•
60.33	3.91	4.92		8.0	•	
64	4.0	5.35	5.43	7.0	•	•
75	4.5	7.08	7.19	12.0	•	•
83	5.0	8.70	8.83	12.0	•	•
89	5.5	10.2	10.4	12.0	•	•
100	5.0	10.6	10.8	11.5	•	•
109	5.0	11.6		10.0	•	
115	5.5	13.4	13.6	8.0	•	•
128	5.5	15.0		12.0	•	
146	6.0	18.7		9.5	•	
154	6.0	19.8	20.1	8.0	•	•
164	6.0	21.2		7.0	•	
178	8.0	30.3		6.5	•	
198	9.0	37.9		5.0	•	

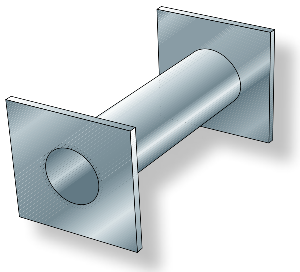
Tolerances

Tubes ≤ OD 50 mm

OD	± 1.5 %, min ± 0.75 mm
Wall thickness	± 15 %, min ± 0.6 mm
Straightness	Max height of arc 3 mm/1000 mm

Tubes > OD 50 mm

OD	± 1 %
Wall thickness	± 15%
Straightness	Max height of arc 3 mm/1000 mm



PM tubes are also successfully used as muffles in sintering and mesh belt furnaces.

KANTHAL A-1 and APM

Wire Standard Stock Items. Strip Standard Sizes.

Resistivity 1.45 Ω mm^2 m^{-1}. Density 7.1 g cm^{-3}. To obtain resistivity at working temperature, multiply by factor C_t in following table.

°C	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
C_t	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.04	1.05

Wire (at 20°C)

Diameter [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
10.0	0.0185	17017	558
9.5	0.0205	14590	503
8.25	0.0271	9555	380
8.0	0.0288	8712	357
7.35	0.0340	6790	300
7.0	0.0377	5837	273
6.5	0.0437	4673	236
6.0	0.0513	3676	201
5.5	0.0610	2831	169
5.0	0.0738	2127	139
4.75	0.0818	1824	126
4.5	0.0912	1550	113
4.25	0.102	1306	101
4.0	0.115	1090	89.2
3.75	0.131	897	78.4
3.5	0.151	730	68.3
3.25	0.175	584	58.9
3.0	0.205	460	50.2
2.9	0.220	416	46.9
2.8	0.235	374	43.7
2.6	0.273	299	37.7
2.5	0.295	266	34.9
2.4*	0.321	235	32.1
2.3	0.349	207	29.5
2.2	0.381	181	27.0
2.0	0.462	136	22.3
1.8	0.570	99.2	18.1
1.7	0.639	83.6	16.1

* only A-1

Strip** (at 20°C)

Width [mm]	Thickness [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
50	3.0	0.001	109655	1065
40	3.0	0.012	71172	852
30	3.0	0.016	40966	639
25	3.0	0.019	28966	533
20	3.0	0.024	19035	426
15	3.0	0.032	11172	320
50	2.5	0.012	90517	888
40	2.5	0.015	58621	710
30	2.5	0.019	33621	533
25	2.5	0.023	23707	444
20	2.5	0.029	15517	355
15	2.5	0.039	9052	266
50	2.0	0.015	71724	710
40	2.0	0.018	46345	568
30	2.0	0.024	26483	426
25	2.0	0.029	18621	355
20	2.0	0.036	12138	284
15	2.0	0.048	7035	213
50	1.5	0.019	53276	533
40	1.5	0.024	34345	426
30	1.5	0.032	19552	320
25	1.5	0.039	13707	266
20	1.5	0.048	8897	213
15	1.5	0.064	5121	160
50	1.0	0.029	35172	355
40	1.0	0.036	22621	284
30	1.0	0.048	12828	213
25	1.0	0.058	8966	178
20	1.0	0.073	5793	142
15	1.0	0.097	3310	107

** Thickness < 2.5 mm only A-1

For minor dimensions please contact Kanthal directly. Contact information can be found on the back cover.

KANTHAL AF

Wire Standard Stock Items. Strip Standard Sizes.

Resistivity 1.39 Ω mm² m⁻¹. Density 7.15 g cm⁻³. To obtain resistivity at working temperature, multiply by factor C_t in following table.

°C	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
C_t	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	1.07

Wire (at 20°C)

Diameter [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
8.25	0.0260	9968	382
8.0	0.0277	9089	359
7.5	0.0315	7489	316
7.35	0.0328	7048	303
7.0	0.0361	6089	275
6.5	0.0419	4875	237
6.0	0.0492	3834	202
5.5	0.0585	2953	170
5.0	0.0708	2219	140
4.75	0.0784	1902	127
4.5	0.0874	1618	114
4.25	0.0980	1363	101
4.0	0.111	1136	89.8
3.75	0.126	936	79.0
3.5	0.144	761	68.8
3.25	0.168	609	59.3
3.0	0.197	479	50.5
2.9	0.210	433	47.2
2.8	0.226	390	44.0
2.6	0.262	312	38.0
2.5	0.283	277	35.1
2.4	0.307	245	32.3
2.3	0.335	216	29.7
2.2	0.366	189	27.2
2.0	0.442	142	22.5
1.9	0.490	122	20.2
1.8	0.546	104	18.2
1.7	0.612	87.2	16.2

Strip (at 20°C)

Width [mm]	Thickness [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
50	3.0	0.009	114389	1073
40	3.0	0.012	74245	858
30	3.0	0.015	42734	644
25	3.0	0.019	30216	536
20	3.0	0.023	19856	429
15	3.0	0.031	11655	322
50	2.5	0.011	94425	894
40	2.5	0.014	61151	715
30	2.5	0.019	35072	536
25	2.5	0.022	24730	447
20	2.5	0.028	16187	358
15	2.5	0.037	9442	268
50	2.0	0.014	74820	715
40	2.0	0.017	48345	572
30	2.0	0.023	27626	429
25	2.0	0.028	19425	358
20	2.0	0.035	12662	286
15	2.0	0.046	7338	215
50	1.5	0.019	55576	536
40	1.5	0.023	35827	429
30	1.5	0.031	20396	322
25	1.5	0.037	14299	268
20	1.5	0.046	9281	215
15	1.5	0.062	5342	161
50	1.0	0.028	36691	358
40	1.0	0.035	23597	286
30	1.0	0.046	13381	215
25	1.0	0.056	9353	179
20	1.0	0.070	6043	143
15	1.0	0.093	3453	107

For minor dimensions please contact Kanthal directly. Contact information can be found on the back cover.

KANTHAL D

Wire Standard Stock Items. Strip Standard Sizes.

Resistivity 1.35 Ω mm^2 m^{-1}. Density 7.25 g cm^{-3}. To obtain resistivity at working temperature, multiply by factor C_t in following table.

°C	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300
C_t	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.05	1.06	1.06	1.07	1.07	1.08	1.08

Wire (at 20°C)

Diameter [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
10.0	0.0172	18277	569
8.0	0.0269	9358	364
7.5	0.0306	7711	320
7.0	0.0351	6269	279
6.5	0.0407	5019	241
6.0	0.0477	3948	205
5.5	0.0568	3041	172
5.0	0.0688	2285	142
4.75	0.0762	1959	128
4.5	0.0849	1665	115
4.25	0.0952	1403	103
4.0	0.107	1170	91.1
3.75	0.122	964	80.0
3.5	0.140	784	69.8
3.25	0.163	627	60.1
3.0	0.191	493	51.2
2.8	0.219	401	44.6
2.6	0.254	321	38.5
2.5	0.275	286	35.6
2.3	0.325	222	30.1
2.0	0.430	146	22.8
1.8	0.531	107	18.4
1.7	0.595	89.8	16.5
1.6	0.671	74.9	14.6

Strip (at 20°C)

Width [mm]	Thickness [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
50	3.0	0.009	117778	1088
40	3.0	0.011	76444	870
30	3.0	0.015	44000	653
25	3.0	0.018	31111	544
20	3.0	0.023	20444	435
15	3.0	0.030	12000	326
50	2.5	0.011	97222	906
40	2.5	0.014	62963	725
30	2.5	0.018	36111	544
25	2.5	0.022	25463	453
20	2.5	0.027	16667	363
15	2.5	0.036	9722	272
50	2.0	0.014	77037	725
40	2.0	0.017	49778	580
30	2.0	0.023	28444	435
25	2.0	0.027	20000	363
20	2.0	0.034	13037	290
15	2.0	0.045	7556	218
50	1.5	0.018	57222	544
40	1.5	0.023	36889	435
30	1.5	0.030	21000	326
25	1.5	0.036	14722	272
20	1.5	0.045	9556	218
15	1.5	0.060	5500	163
50	1.0	0.027	37778	363
40	1.0	0.034	24296	290
30	1.0	0.045	13778	218
25	1.0	0.054	9630	181
20	1.0	0.068	6222	145
15	1.0	0.090	3556	109

For minor dimensions please contact Kanthal directly. Contact information can be found on the back cover.

NIKROTHAL 80

Wire Standard Stock Items. Strip Standard Sizes.

Resistivity 1.09 Ω mm^2 m^{-1}. Density 8.30 g cm^{-3}. To obtain resistivity at working temperature, multiply by factor C_t in following table.

°C	20	100	200	300	400	500	600	700	800	900	1000	1100	1200
C_t	1.00	1.01	1.02	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.06	1.07

Wire (at 20°C)

Diameter [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
10.0	0.0139	22601	652
8.0	0.0217	11590	417
7.0	0.0283	7764	319
6.5	0.0328	6217	275
6.0	0.0386	4890	235
5.5	0.0459	3766	197
5.0	0.0555	2830	163
4.5	0.0685	2063	132
4.25	0.0768	1738	118
4.0	0.0867	1449	104
3.75	0.0987	1194	91.7
3.5	0.113	971	79.9
3.25	0.131	777	68.9
3.0	0.154	611	58.7
2.8	0.177	497	51.1
2.6	0.205	398	44.1
2.5	0.222	354	40.7
2.3	0.262	275	34.5
2.2	0.287	241	31.6
2.0	0.347	181	26.1
1.8	0.428	132	21.1

Strip (at 20°C)

Width [mm]	Thickness [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
50	3.0	0.007	145872	1245
40	3.0	0.009	94679	996
30	3.0	0.012	54495	747
25	3.0	0.015	38532	623
20	3.0	0.018	25321	498
15	3.0	0.024	14862	374
50	2.5	0.009	120413	1038
40	2.5	0.011	77982	830
30	2.5	0.015	44725	623
25	2.5	0.017	31537	519
20	2.5	0.022	20642	415
15	2.5	0.029	12041	311
50	2.0	0.011	95413	830
40	2.0	0.014	61651	664
30	2.0	0.018	35229	498
25	2.0	0.022	24771	415
20	2.0	0.027	16147	332
15	2.0	0.036	9358	249
50	1.5	0.015	70872	623
40	1.5	0.018	45688	498
30	1.5	0.024	26009	374
25	1.5	0.029	18234	311
20	1.5	0.036	11835	249
15	1.5	0.048	6812	187
50	1.0	0.022	46789	415
40	1.0	0.027	30092	332
30	1.0	0.036	17064	249
25	1.0	0.044	11927	208
20	1.0	0.055	7706	166
15	1.0	0.073	4404	125

For minor dimensions please contact Kanthal directly. Contact information can be found on the back cover.

NIKROTHAL 70

Wire on Special Order Only. Strip Standard Sizes.

Resistivity 1.18 Ω mm^2 m^{-1}. Density 8.10 g cm^{-3}. To obtain resistivity at working temperature, multiply by factor C_t in following table.

°C	20	100	200	300	400	500	600	700	800	900	1000	1100	1200
C_t	1.00	1.01	1.02	1.03	1.04	1.05	1.05	1.04	1.04	1.04	1.05	1.05	1.06

Wire (at 20°C)

Diameter [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
9.0	0.0185	15244	515
8.25	0.0221	11741	433
8.0	0.0235	10706	407
7.5	0.0267	8822	358
7.35	0.0278	8303	344
7.0	0.0307	7172	312
6.5	0.0356	5742	269
6.0	0.0417	4517	229
5.5	0.0497	3479	192
5.0	0.0601	2614	159
4.75	0.0666	2241	144
4.5	0.0742	1905	129
4.25	0.0832	1605	115
4.0	0.0939	1338	102
3.75	0.107	1103	89.5
3.5	0.123	897	77.9
3.25	0.142	718	67.2
3.0	0.167	565	57.3
2.8	0.192	459	49.9
2.6	0.222	368	43.0
2.5	0.240	327	39.8
2.2	0.310	223	30.8
2.0	0.376	167	25.4
1.9	0.416	143	23.0
1.8	0.464	122	20.6
1.7	0.520	103	18.4
1.6	0.587	85.6	16.3
1.5	0.668	70.6	14.3
1.4	0.767	57.4	12.5
1.3	0.889	45.9	10.8
1.2	1.04	36.1	9.16
1.1	1.24	27.8	7.70
1.0	1.50	20.9	6.36

Strip (at 20°C)

Width [mm]	Thickness [mm]	Resistance [Ω/m]	Resistivity [cm²/Ω]	Weight [g/m]
50	3.0	0.008	134746	1215
40	3.0	0.001	87458	972
30	3.0	0.013	50339	729
25	3.0	0.016	35593	608
20	3.0	0.020	23390	486
15	3.0	0.026	13729	365
50	2.5	0.009	111229	1013
40	2.5	0.012	72034	810
30	2.5	0.016	41314	608
25	2.5	0.019	29131	506
20	2.5	0.024	19068	405
15	2.5	0.031	11123	304
50	2.0	0.012	88136	810
40	2.0	0.015	56949	648
30	2.0	0.020	32542	486
25	2.0	0.024	22881	405
20	2.0	0.030	14915	324
15	2.0	0.039	8644	243
50	1.5	0.016	65466	608
40	1.5	0.020	42203	486
30	1.5	0.026	24025	365
25	1.5	0.031	16843	304
20	1.5	0.039	10932	243
15	1.5	0.052	6292	182
50	1.0	0.024	43220	405
40	1.0	0.030	27797	324
30	1.0	0.039	15763	243
25	1.0	0.047	11017	203
20	1.0	0.059	7119	162
15	1.0	0.079	4068	122

For minor dimensions please contact Kanthal directly. Contact information can be found on the back cover.

Terminals

Resistance and Weight Data.

KANTHAL A-1 and APM

Dimension [mm]	Resistance [Ω/m]	Weight [g/m]
8	0.0288	357
10	0.0185	558
12	0.0128	803
16	0.0072	1428
20 (APM only)	0.0046	2231
30 (A-1 only)	0.0021	5019
40 (APM only)	0.0012	8922

KANTHAL D

Dimension [mm]	Resistance [Ω/m]	Weight [g/m]
8	0.0269	364
10	0.0172	569
12	0.0119	820
16	0.0067	1460
20	0.0043	2280

NIKROTHAL 80

Dimension [mm]	Resistance [Ω/m]	Weight [g/m]
8	0.0217	417
10	0.0172	652
12	0.0119	939
16	0.0067	1670
20	0.0043	2610

NIKROTHAL 40

Dimension [mm]	Resistance [Ω/m]	Weight [g/m]
8	0.0207	397
10	0.0132	620
12	0.0092	893

Kanthal – a World-Renowned Name Within the Field of Electric Heating

Since the early thirties, Kanthal has developed market leading, electric resistance alloy products and materials.

Our R&D efforts have always been directed at improving our materials to function fully at ever higher temperatures.

The centre for production, product development and metallurgy is in Hallstahammar, Sweden, whilst sales and production finishing plants are located around the world, close to our customers and operated through our subsidiaries and local representatives.

Kanthal – a Member of the Sandvik Group

The Sandvik Group is a global high technology enterprise with 47,000 employees and annual sales of approximately SEK 86 billion. Sandvik's operations are concentrated on its three core businesses of Sandvik Tooling, Sandvik Mining and Construction and Sandvik Materials Technology. Sandvik spends about 4 percent of is turnover on research and development.

Kanthal is a part of the business area Sandvik Materials Technology – a world-leading manufacturer of high-value-added products in advanced stainless steels, special alloys, metallic and ceramic resistance materials, as well as process plants and sorting systems.

As a member of the Sandvik Group, Kanthal has got full access to world-class competence within materials and process technology, as well as Sandvik Materials Technology's R&D-center in Sweden, which is one of the most distinguished in the world. Through Sandvik's global sales organisation Kanthal is represented in 130 countries.

Kanthal – Head office and main facility in Hallstahammar, Sweden

West facility in Hallstahammar, Sweden

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