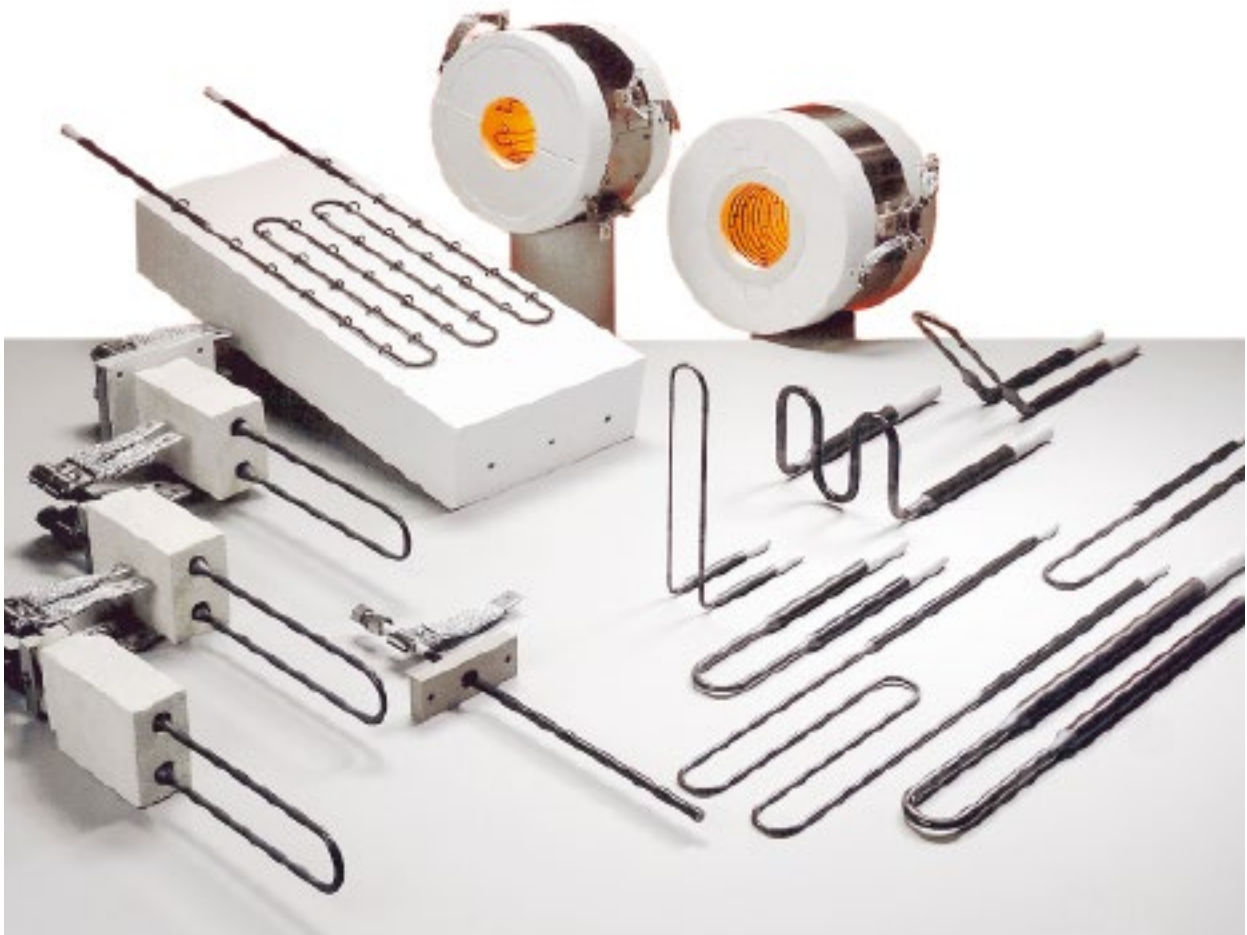


KANTHAL[®]

KANTHAL[®] SUPER ELECTRIC HEATING ELEMENTS

HANDBOOK





Range of Kanthal® Super 6/12, 9/18, 12/24 elements and Superthal® heating modules.

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THIS IS KANTHAL® SUPER

Kanthal® Super is a dense cermet material consisting of molybdenum disilicide (MoSi_2) and an oxide component, mainly a glass phase.

Kanthal® Super heating elements have the ability to with-stand oxidation at high temperatures. This is due to the formation of a thin and adhesive protective layer of quartz glass on the surface. When MoSi_2 reacts with oxygen in the atmosphere, the layer of quartz glass is formed and under this a thin layer of molybdenum silicide with a lower silicon content Mo_5Si_3 .

When Kanthal® Super elements are operated at temperatures around 1200°C (2190°F) the material becomes ductile, whilst at lower temperatures the material is more brittle.

The silica layer possesses the capacity to clean itself from adhering impurities. If the impurities react with silica, the melting point will be lowered. The contaminated layer then flows down the element and drops off. A new silica layer is, however, spontaneously rebuilt.

GRADES FOR DEMANDING APPLICATIONS

Kanthal program of MoSi_2 heating element includes several grades with specific features for use in demanding applications and atmospheres.

KANTHAL® SUPER 1700

Kanthal® Super is a unique material combining the best properties of metallic and ceramic materials. Like metallic materials it has good heat and electrical conductivity and like ceramics it withstands corrosion and oxidation and has low thermal expansion. Maximum temperature 1700°C (3090°F).

KANTHAL® SUPER 1800

Same core characteristics as Kanthal® Super 1700. Maximum temperature 1800°C (3270°F).

KANTHAL® SUPER 1900

Same core characteristics as Kanthal® Super 1700, but has higher purity and a surface with better adhesion. Maximum temperature 1850°C (3360°F).

KANTHAL® SUPER ER

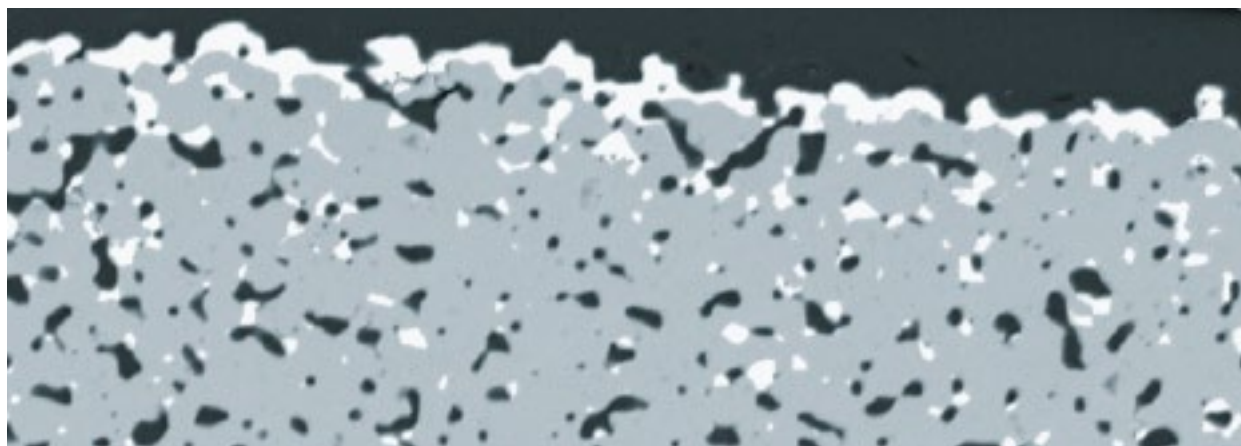
Kanthal® Super ER is a new electric heating element with the unique ability to operate up to 1580°C (2875°F) directly in a wide range of furnace atmospheres from very dry reducing to oxidizing. With Kanthal® Super ER heating elements it is possible, in just one furnace, to operate firing cycles where the atmosphere condition can be altered during the cycle between oxidizing, inert, carburizing, nitriding, reducing and rough vacuum.

KANTHAL® SUPER RA

Kanthal® Super RA offers a long lifetime at high temperature in all reducing and oxygen deficient atmospheres. Specially designed for working in nitrogen atmosphere. Maximum temperature 1700°C (3090°F).

KANTHAL® SUPER HT

Kanthal® Super HT is designed for a longer lifetime of small dimension elements in temperature cycling conditions. The hot strength and form stability is improved. The maximum operating temperature is 1830°C (3330°F), and the element is suitable for furnace temperatures between 1500 – 1750°C (2730 – 3180°F) approximately.



Microstructure of a Kanthal® Super element. Grey = MoSi_2 , white = Mo_5Si_3 , dark = SiO_2 .

PROPERTIES

Kanthal® Super is a unique material combining the best properties of metallic and ceramic materials.

Like metallic materials it has good heat and electric conductivity and like ceramics it withstands corrosion and oxidation and has a low thermal expansion.

It is not affected by thermal shock and is strong enough to withstand many years of service as a heating element.

RESISTIVITY

The resistivity of Kanthal® Super increases sharply with temperature. This means that when the elements are connected to a constant voltage, the power will be higher at lower temperatures and will be gradually reduced with increasing temperature, thus shortening

the time for the furnace to reach operating temperature. Furthermore, as the power of the elements decreases, the danger of over-heating will be reduced.

The resistance of Kanthal® Super elements does not change due to ageing even after having been in operation for a long time at high temperatures. There is only a slight reduction ($\approx 5\%$) during the first period of time.

Due to these properties a failed element can easily be replaced without the performance of other elements connected in series being influenced.

See page 11, diagram "Resistivity for Kanthal® Super".

MAXIMUM ELEMENT TEMPERATURE FOR KANTHAL® SUPER

	KANTHAL® SUPER ER	KANTHAL® SUPER 1700	KANTHAL® SUPER RA	KANTHAL® SUPER 1800	KANTHAL® SUPER HT	KANTHAL® SUPER 1900
Max. element temperature	1580°C (2875°F)	1700°C (3090°F)	1700°C (3090°F)	1800°C (3270°F)	1830°C (3330°F)	1850°C (3360°F)

THE MECHANICAL AND PHYSICAL PROPERTIES OF KANTHAL® SUPER

	KANTHAL® SUPER ER	KANTHAL® SUPER HT	OTHER KANTHAL® SUPER
Tensile strength at 1550°C (2820°F)	–	100 MPa \pm 25%	100 MPa \pm 25%
Bending strength at 20°C (68°F)	450 MPa \pm 10%	350–400 MPa \pm 10%	450 MPa \pm 10%
Compression strength at 20°C (68°F)	1400–1500 MPa	1400–1500 MPa	1400–1500 MPa
Fracture toughness, KIC, at 20°C (68°F)	3–4 MPam ^{1/2}	4 MPam ^{1/2}	3–4 MPam ^{1/2}
Hardness, HV, at 20°C (68°F)	9 GPa	8 GPa	9 GPa
Density	5.6 g/cm ³ 0.20 lb/in ³	7.0 g/cm ³ 0.25 lb/in ³	6.5 g/cm ³ 0.23 lb/in ³
Porosity	< 5%	< 1%	< 1%
Thermal conductivity 20–600°C (68–1110°F)	30 Wm ⁻¹ K ⁻¹	30 Wm ⁻¹ K ⁻¹	30 Wm ⁻¹ K ⁻¹
600–1200°C (1110–2190°F)	15 Wm ⁻¹ K ⁻¹	15 Wm ⁻¹ K ⁻¹	15 Wm ⁻¹ K ⁻¹
Coefficient of linear expansion	7–8 \times 10 ⁻⁶ K ⁻¹	7–8 \times 10 ⁻⁶ K ⁻¹	7–8 \times 10 ⁻⁶ K ⁻¹
Specific heat capacity at 20°C (68°F)	0.42 kJ kg ⁻¹ K ⁻¹	0.42 kJ kg ⁻¹ K ⁻¹	0.42 kJ kg ⁻¹ K ⁻¹
Emissivity	0.75–0.85	0.70–0.80	0.70–0.80
Resistivity as a function of temperature	See page 11, diagram "Resistivity for Kanthal® Super"		

CHEMICAL RESISTANCE

ATMOSPHERES

Kanthal® Super can be used in most furnace atmospheres. Most favorable are oxidizing atmospheres such as air, carbon dioxide and water vapor, but Kanthal® Super elements are also operating successfully in neutral, reducing and carburizing atmospheres.

The diagram below indicates the maximum recommended element temperatures in some common types of furnace atmospheres and gases.

AIR

At low temperatures, an oxidation of molybdenum and silicon on the surface of the elements can occur at temperatures around 500°C (930°F). The oxidation product is a yellowish powder, MoO₃ and has normally no detrimental effect on the performance of Kanthal® Super elements.

WATER VAPOR AND CARBON DIOXIDE

Water vapor and carbon dioxide in any amount in the atmosphere have an oxidizing effect. The presence of water vapor in a controlled atmosphere increases the maximum permissible operating temperature.

SULPHUR DIOXIDE

This gas sometimes occurs as an impurity in the atmosphere. It normally has no harmful effect on Kanthal® Super elements.

ENDOGAS

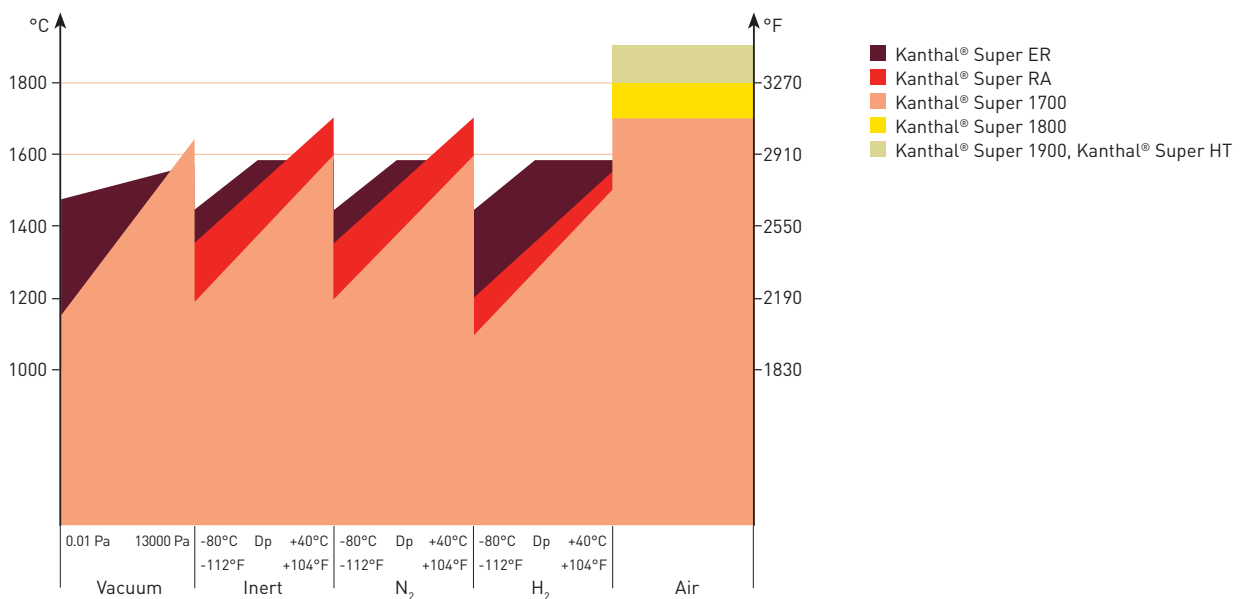
A typical gas composition is: 20% CO, 40% H₂ and balance N₂. Since hydrogen is present in this gas composition, the dew point and gas velocity are important for determining the maximum temperature. A heating solution with Kanthal® Super ER is recommended.

CARBURIZING ATMOSPHERE

Kanthal® Super elements are widely used in carburizing furnaces. The elements are not attacked by the atmosphere which normally consists of an endogas or nitrogen with controlled additions of a carburizing gas such as propane or methanol.

In this type of furnace, the element temperature is normally kept below 1400°C (2550°F). If carbon is built up in the furnace because of high carbon potential, it can lead to element failure. Regular removal of the carbon by firing the furnace under oxidizing conditions is recommended.

Maximum recommended element temperature in different atmospheres



NITROGEN ATMOSPHERE

Nitrogen is used for different purposes such as:

- Nitration of ceramics (reaction)
- Protective gas
- Balancing furnace atmospheres

In the element temperature range of 1250–1550°C (2280–2820°F), nitration of ceramics usually occurs. At such temperatures, when the protective glaze is consumed, silicon in the silicide of the element may react with nitrogen forming silicon nitride (Si_3N_4), which could damage the element by scaling. The elements to be used for this purpose should be specially heat treated by Kanthal in order to reduce nitrogen penetration into the material. This treatment is always advisable when operating in nitrogen and when the dew point is low.

With operation below 1250°C (2280°F) element temperature the reaction is minor. Above 1500°C (2820°F) up to 1700–1800°C (3090–3270°F) the performance of the element very much depends on dew point and time at temperature. In cyclic conditions where the time at temperature is short, the oxide layer on elements can be restored by operating for a short time in air.

When operating for extended periods at temperature (continuous furnaces), the actual formation of a thin layer of Si_3N_4 at the surface of the elements, offers the best protection against further gaseous reaction. When special heat treatment is recommended, it can usually be performed in the furnace where the elements are installed, by operating them in air above 1550°C (2820°F) element temperature for a couple of hours.

A heating solution with Kanthal® Super RA is recommended when running a continuous operation. When running continuous or cyclic operations, a heating solution with Kanthal® Super ER is recommended.

NOBLE GASES, ARGON AND HELIUM

These gases are inert and do not react chemically with Kanthal® Super. However, if there is a gas flow around the elements, it will disturb the chemical equilibrium existing around the elements. At high temperatures the glaze is consumed. When using these gases, a regeneration of the glaze is recommended before the old glaze has disappeared completely. A heating solution with Kanthal® Super ER is recommended.

HYDROGEN

In dry hydrogen the silica layer is reduced and MoSi_2 disintegrates by forming gaseous silicon and silicides with lower silicon content. This reaction is dependent on temperature and the reduction potential of the hydrogen gas. By increasing the dew point the maximum permissible element temperature can be increased (see page 9, diagram “Maximum element temperature in hydrogen atmospheres”). Installation of the elements in niches can reduce the gas flow around the elements, and this can help to reduce the chemical attacks. A heating solution with Kanthal® Super ER is recommended in dry hydrogen atmosphere.

NITROGEN AND HYDROGEN

The mixture of these gases should be considered as hydrogen. Although nitrogen reduces the reactivity of hydrogen, the effect of hydrogen is considerable, especially with extended periods in operation. The dew point of the gas mixture and the gas velocity are always very important (see page 9, diagram “Maximum element temperature in hydrogen atmospheres”). Special heat treatment will improve the performance. A heating solution with Kanthal® Super ER is recommended.

FLUORINE AND CHLORINE

These halogens attack Kanthal® Super strongly, even oxidized elements, already at temperatures below 600°C (1110°F). Both fluorine and chlorine can be formed by dissociation of organic compounds, which may often enter the furnace together with unclean products.

VACUUM

Kanthal® Super elements are not suitable for operation in a high vacuum at high temperatures due to silica vaporization. (Page 9, diagram “Maximum element temperature in vacuum”) shows the maximum permissible element temperatures at different air pressures. A heating solution with Kanthal® Super ER is recommended.

METALS

All metals in direct contact with Kanthal® Super react with MoSi_2 , forming silicides. At higher furnace temperatures, vapors from molten metal, (zinc, copper, bronze) may also attack the elements. Dust from metal oxides in the furnace atmosphere reacts with the glaze. It is also important that the elements are protected from splashes of molten metal. Any metal or alloy with a melting point lower than approximately 1300°C (2370°F) may be melted in a Kanthal® Super furnace if necessary precautions are taken. In small crucible furnaces where the elements are protected from metal fumes approx. 1550°C (2820°F) is possible.

ALKALI

Compounds such as K_2O and Na_2O in the furnace atmosphere will act as a fluxing agent on the silica layer and attack the elements. Their salts also attack elements which may occur in glass melting furnaces.

The choice of lining material for furnaces operating at temperatures above 1550–1600°C (2820–2910°F) in particular is very important. Castables always contain alkalis. Due to how these are chemically bound in the castable they could be more or less aggressive to the Kanthal® Super elements.

Avoid castables containing alkali above 1550–1600°C (2820–2910°F) furnace temperature.

CERAMICS

As the operating temperature of Kanthal® Super elements is normally rather high, reactions can easily take place between the silica layer on the element surface and most salts and oxides. This is of particular importance when the elements are supported by ceramics.

The ceramics in these cases must consist of stable compounds, silicates, which do not react with silica. Suitable ceramics are sillimanite and mullite. At element temperatures exceeding 1600°C (2910°F) reactions can nevertheless occur. This element temperature should not be exceeded when the element rests on a ceramic support.

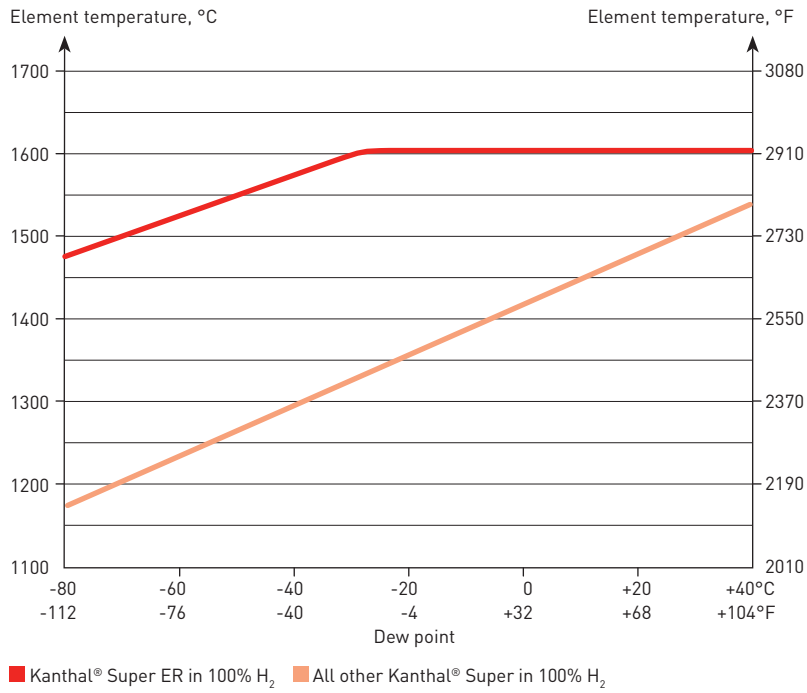
Firing of ceramics

Green ceramics (before firing) contain binders or similar, which during firing fume off, developing residual products. These residual products must be removed in order to minimize the contamination of furnace atmosphere and walls. At higher element temperatures, these residual products may attack the elements.

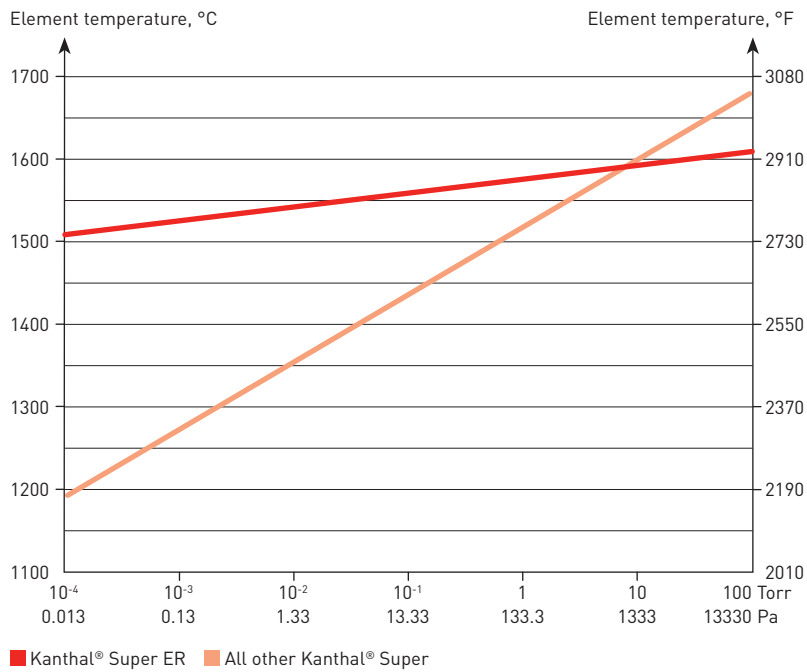
Glass

The atmosphere in a glass furnace normally has a slightly fluxing effect on the silica layer, thus lowering the viscosity and causing the glaze to flow slowly down the element. However, this normally has no detrimental effect on the life of the element.

Maximum element temperature in hydrogen atmospheres



Maximum element temperatures in vacuum



PERFORMANCE

TEMPERATURE DEPENDENCE OF RESISTIVITY

The diagram on page 11 shows that the resistivity of Kanthal® Super increases sharply with temperature.

ELEMENT SURFACE LOAD

The curves shown in the diagrams on page 12, which apply to furnaces with suspended, freely radiating Kanthal® Super elements show the approximate element temperature at various furnace temperatures, element surface loads and currents.

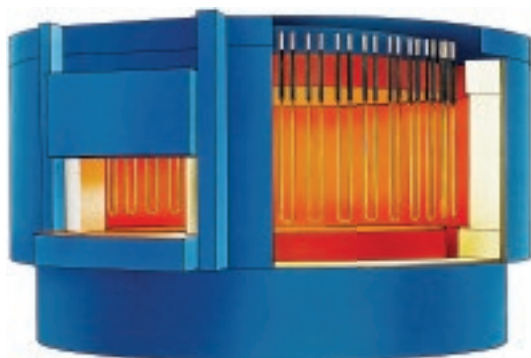
For example, at an element surface load of 14.4 W/cm^2 (92.9 W/in^2) and a furnace temperature of 1300°C (2370°F) the element temperature of Kanthal® Super 1700 will be 1525°C (2780°F) with a current of 156 A for 6 mm \varnothing and 286 A for 9 mm \varnothing .

WALL LOADING

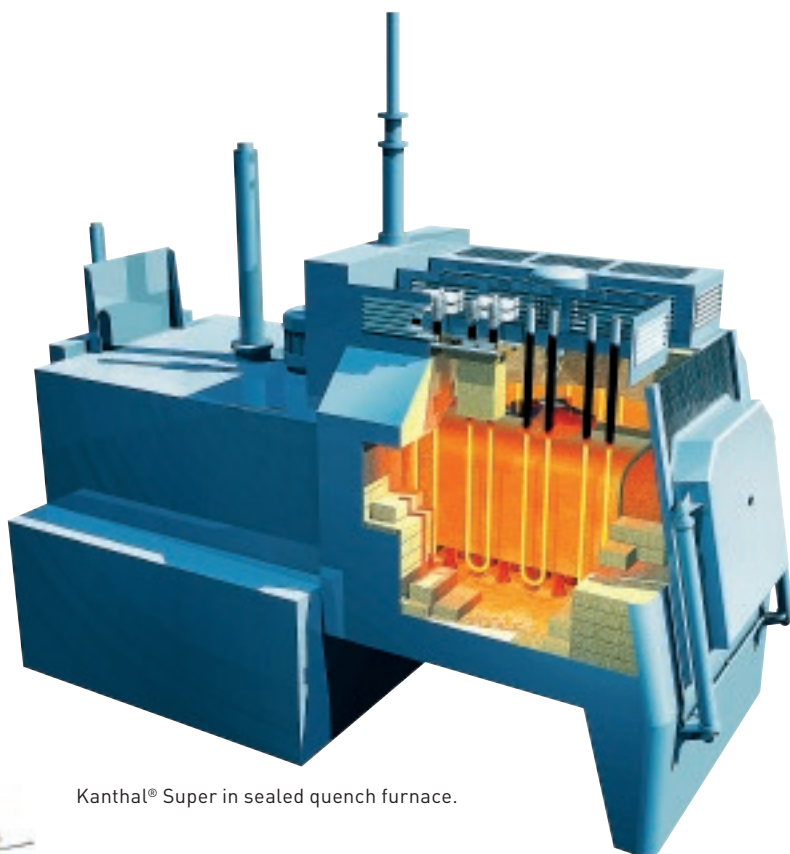
A characteristic property of furnaces equipped with Kanthal® Super elements is that the surface load on the furnace walls can be much higher than with metallic elements. This is due to the high maximum operating temperature of the Kanthal® Super elements. Consequently, the heating-up time can be considerably reduced.

The wall loading is also dependent on how the elements are installed: along the walls or perpendicular.

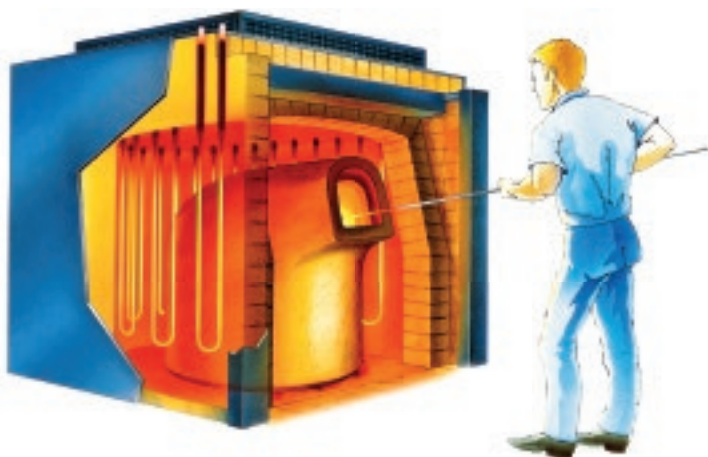
The diagrams on page 13 shows maximum recommended wall loading as a function of the furnace temperature for different element diameters and mode of installation.



Kanthal® Super in rotary hearth furnace.



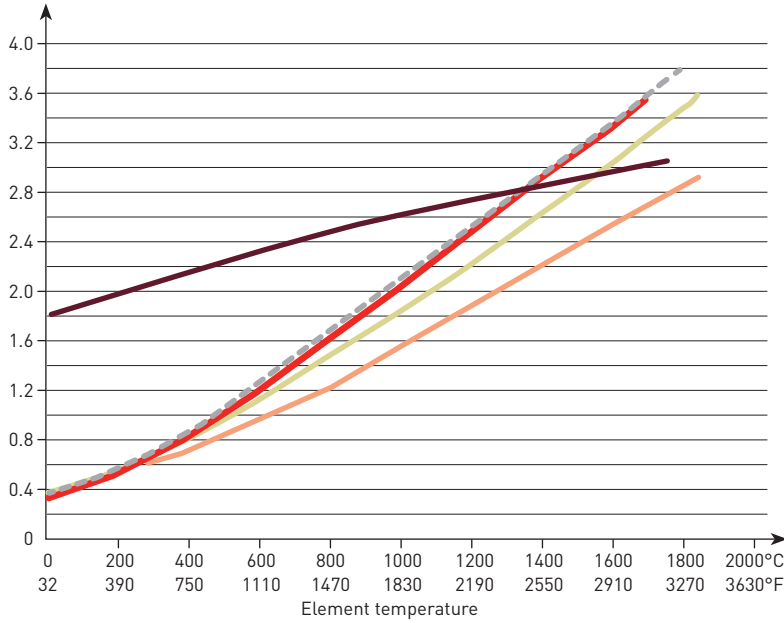
Kanthal® Super in sealed quench furnace.



Kanthal® Super in pot melting furnace.

Resistivity of Kanthal® Super

Resistivity, $\Omega \text{mm}^2/\text{m}$



$$r = \frac{\rho \times l \times 4}{\pi \times d^2}$$

r = resistance, Ω/m
 ρ = from diagram
 l = rod length, m
 d = diameter, mm

■ Kanthal® Super ER ■ Kanthal® Super 1700 and RA ■ Kanthal® Super HT ■ Kanthal® Super 1800 ■ Kanthal® Super 1900

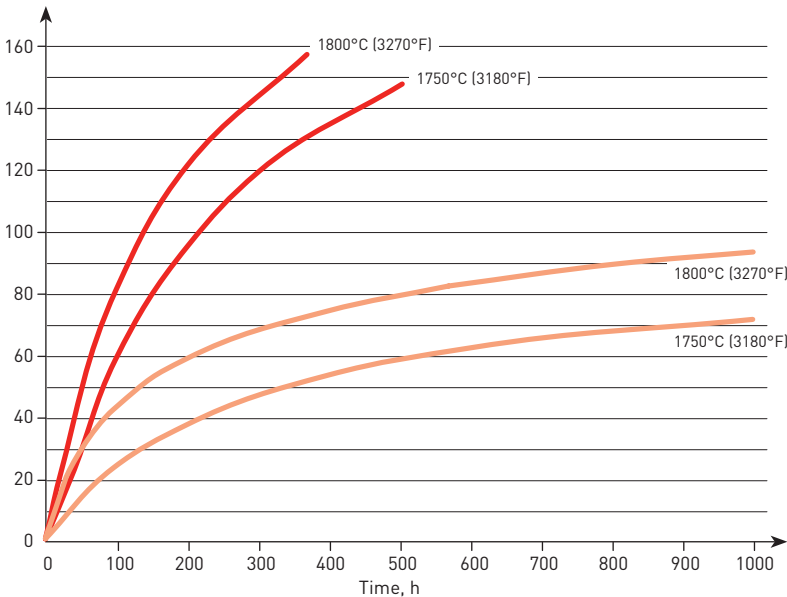
OXIDE GROWTH

For Kanthal® Super grades the oxide growth at certain temperature as function of time have a parabolic growth. The growth of the oxide layer, the glaze, of Kanthal® Super HT is much reduced, compared to Kanthal® Super 1800 and 1900, see diagram below.

A thin oxide layer results in a much-improved service life, because the tension is reduced between the base material and the surrounding oxide, depending on the different thermal expansion coefficient.

Oxidation properties

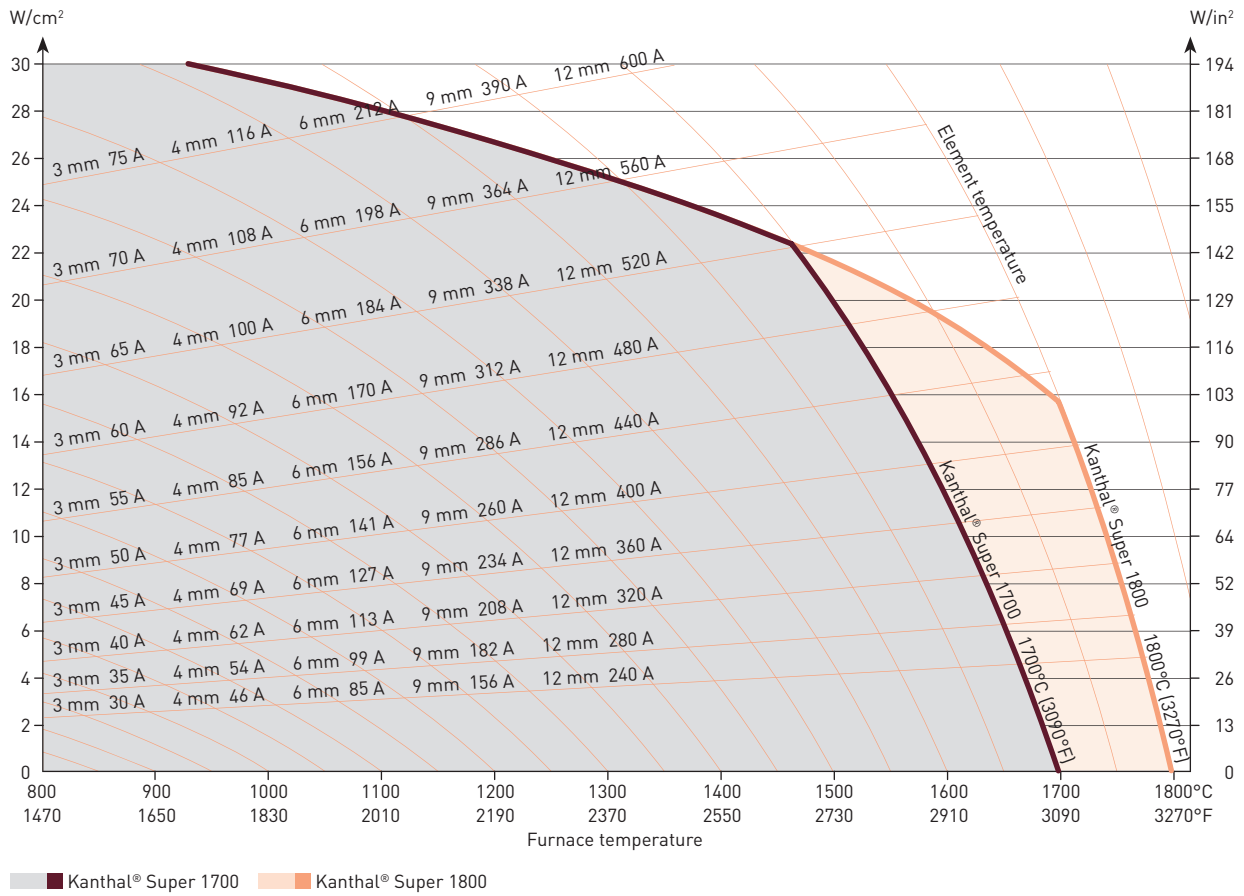
Oxide thickness, μm



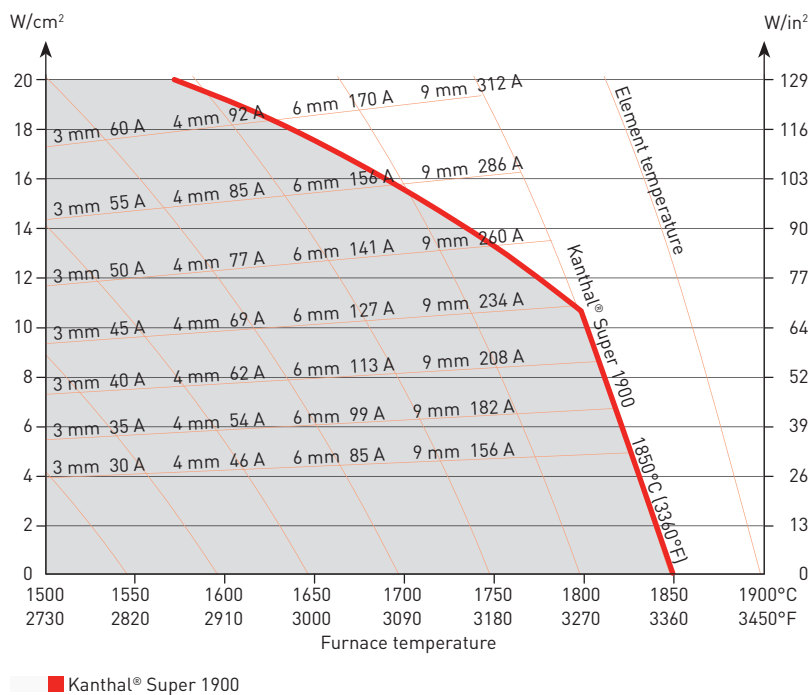
■ Kanthal® Super HT ■ All other Kanthal® Super

TEMPERATURE LOADING DIAGRAMS

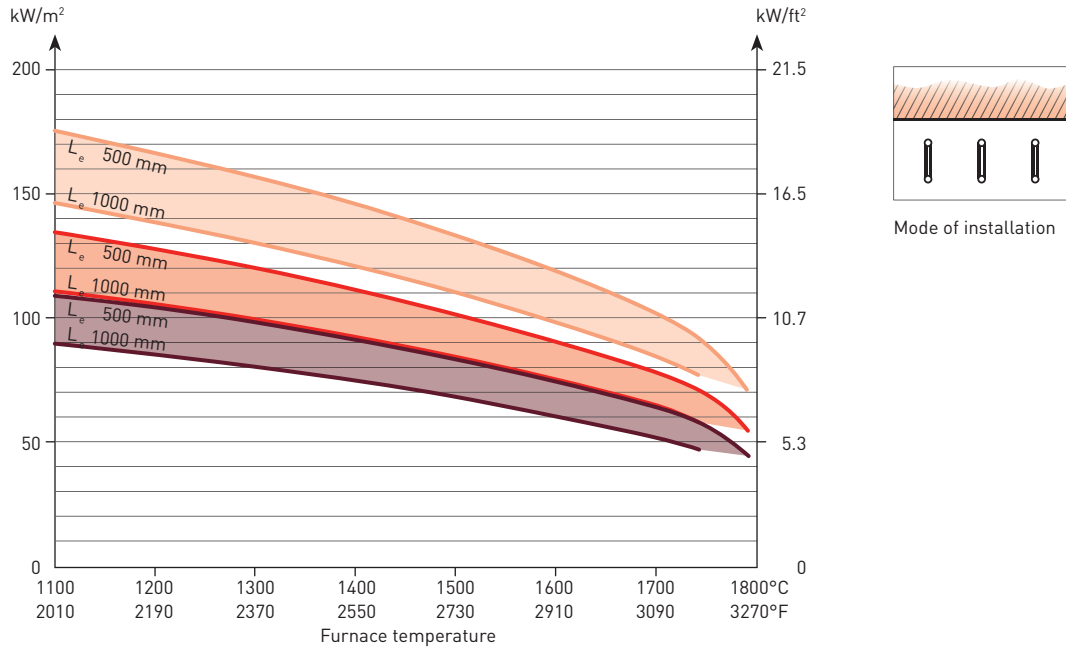
Temperature loading diagram for Kanthal® Super 1700 and 1800



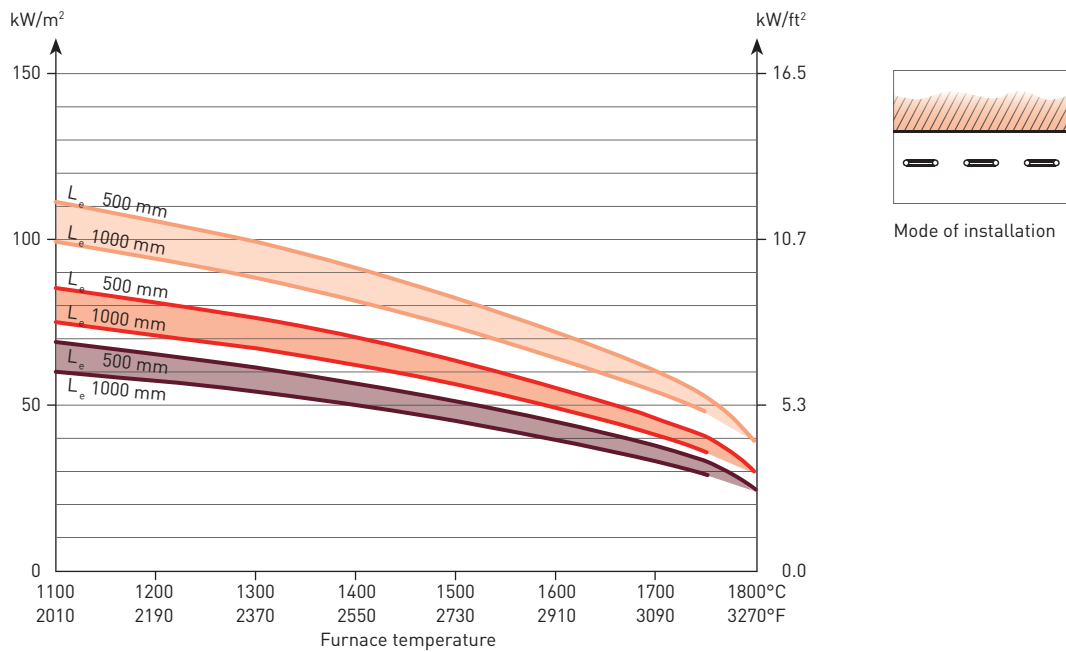
Temperature loading diagram for Kanthal® Super 1900



Maximum recommended wall loading as a function of the furnace temperature for different element diameters and mode of installation



Element diameter: ■ 6/12 ■ 9/18 ■ 12/24



Element diameter: ■ 6/12 ■ 9/18 ■ 12/24

NECESSARY DISTANCES

DISTANCE TO WALL

It is important that the distance between wall and heating zone of the element is large enough to avoid contact. In the case of long elements at high temperatures, electro-magnetic forces and bad centering when installing the elements may cause the elements to come in contact with the walls, causing damage.

The minimum distance, e , between the heating zone of the element and the furnace walls depends on the length of the element (see the figures to the right).

When installed **along the wall** it is:

For $L_e < 1000$ mm (39.4 in); $e = L_e/20$

For $L_e < 300$ mm; $e = \text{min. } 15$ mm (0.6 in)

For $L_e > 1000$ mm (39.4 in); $e = \text{min. } 50$ mm (1.97 in)

When installed **perpendicular to the wall**, the deformation due to the electromagnetic forces must also be considered. The reason is that the deformation causes reduction of the distance between part of the heating zone and the wall. After calculating the magnitude of deformation (see the figure on page 15 "Deformation of Kanthal® Super elements"), the distance E can be calculated and e is estimated in the same way as for elements installed parallel to the wall.

$$E_{\min} = e + \frac{A - a}{2}$$

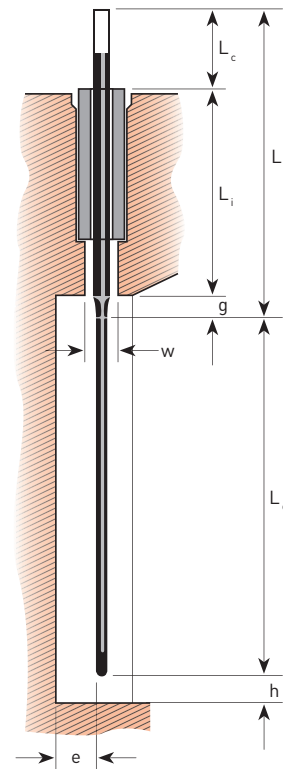
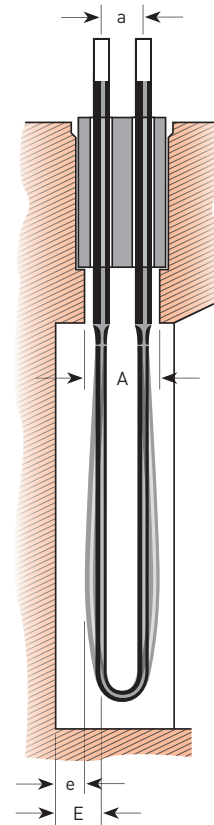
DISTANCE TO BOTTOM

In order to prevent the elements from coming into contact with any material deposited on the bottom of the furnace and to compensate for the elongation of the elements at high temperatures, the recommended vertical distance h between the element bend and the furnace floor should be at least:

$$h \geq \frac{L_e}{20}; \text{ min. } 10 \text{ mm}$$

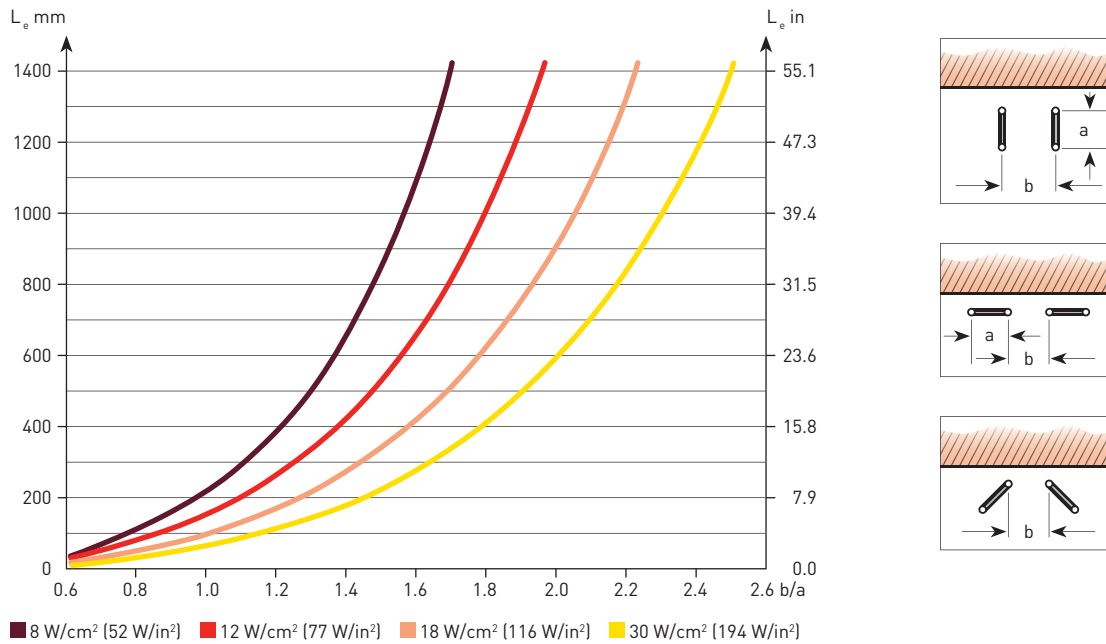
DISTANCE BETWEEN ELEMENTS

Minimum distances, b , between adjacent elements are given in the figure on page 15 "Necessary distances".

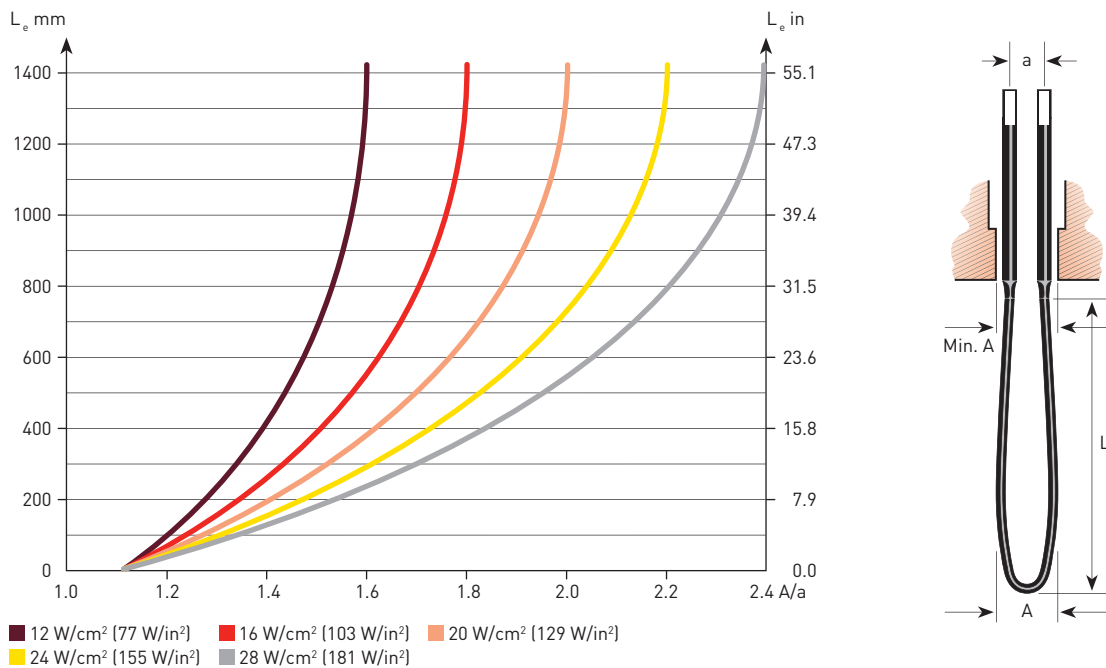


Installation parameters.

NECESSARY DISTANCES, B, TO COUNTERACT THE EFFECT OF THE ELECTROMAGNETIC FORCE ON KANTHAL® SUPER ELEMENTS



DEFORMATION OF KANTHAL® SUPER ELEMENTS DUE TO ELECTROMAGNETIC FORCES, VALID FOR ALL SIZES



IMPORTANT INSTALLATION PARAMETERS FOR PASSAGE BRICK AND SKEW BRICK

ELEMENT SIZE	3/6		4/9		6/12		9/18		12/24	
	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN
Hole diameter of passage brick	9	0.35	12	0.5	15	0.6	23	0.9	30	1.2
Recommended min. width of opening in skew brick, w	15	0.6	20	0.8	25	1.0	30	1.2	40	1.6

The minimum length of opening A is calculated according to the diagram above.

ELEMENTS AND TUBES

The most commonly used design is a two-shank U-shaped element (fig. 1, page 17). The heating zone is welded to terminals which normally have a diameter double that of the heating zone.

The two-shank element can be bent 45° or 90° either in the heating zone or in the terminals (fig. 2–5, pages 17–18).

Four-shank elements are used only horizontally (fig. 5). Kanthal® Super is also available as a Superthal™ heating unit.

TWO-SHANK ELEMENTS

Two-shank elements with straight terminals are defined by:

- The quality
- Heating zone diameter, mm (in)
- Terminal diameter, mm (in)
- Terminal length, Lu, mm (in)
- Heating zone length, Le, mm (in)
- Center distance between shanks, a, mm (in)

Example:

Kanthal® Super 1700 9/18 Lu = 450 mm (17.7 in)
 Le = 560 mm (22 in)
 a = 60 mm (2.36 in)

The maximum length of the heating zone depends on the element temperature. The diagram on page 18, “Maximum recommended heating zone lengths”, shows the maximum recommended heating zone lengths for vertically suspended 6/12, 9/18 and 12/24 elements.

* Note: 3/6 and 4/9 mm Kanthal® Super 1800 elements are not normally manufactured with a heating zone Le longer than 400 mm (15.8 in).

TWO-SHANK BENT ELEMENTS

Bent elements are used when the electrical connections for some reason cannot be made above the roof.

When the furnace is too high to permit installation of elements suspended from the roof, due to the limitation regarding the maximum permitted heating zone length, it may also be necessary to install elements with bent terminals or heating zones. By installing several rows of such elements it is also possible to control the power at different levels in the furnace.

The terminals are supported by brick or fiber, which normally limits the maximum temperature to 1600°C (2910°F) furnace temperature.

FOUR-SHANK ELEMENTS

FOUR-SHANK KANTHAL® SUPER 1700 ELEMENTS FOR HORIZONTAL USE

In many cases, particularly in furnaces with a low chamber height, the best choice is horizontally mounted elements.

The advantage of this shape is that fewer elements are needed than in the case of two-shank elements, with lower terminal losses, making the four-shank elements more economical. Maximum element temperature 1600°C (2910°F). Available as 6/12, 9/18 and 12/24 elements.

Four-shank elements with straight terminals (fig. 5, page 18) are defined by:

- The quality
- Heating zone diameter, mm
- Terminal diameter, mm
- Terminal length, Lu, mm (in)
- Heating zone length, Le, mm (in)
- Heating zone length, B, mm (in)
- Center distances between shanks, a, mm (in)

Example:

Kanthal® Super 1700 9/18 Lu = 450 mm (17.7 in)
 Le = 450 mm (17.7 in)
 B = 400 mm (15.8 in)
 a = 3 × 60 mm (3 × 2.36 in)

RANGE OF KANTHAL® SUPER ELEMENTS

GRADE	ELEMENT SIZE, MM HEATING ZONE DIAMETER/TERMINAL DIAMETER				
	3/6	4/9	6/12	9/18	12/24
Kanthal® Super 1700	–	–	•	•	•
Kanthal® Super 1800	•	•	•	•	•
Kanthal® Super 1900	•	•	•	•*	–
Kanthal® Super RA	–	–	•	•	•
Kanthal® Super ER	•	•	•	•	–
Kanthal® Super HT	•	•	•	–	–

* 9/12/18

TERMINAL SHAPES

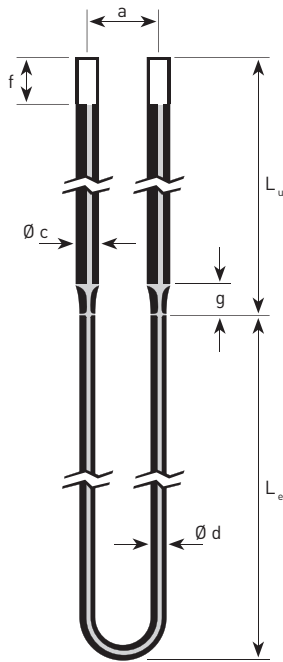


Fig. 1 Straight terminals.

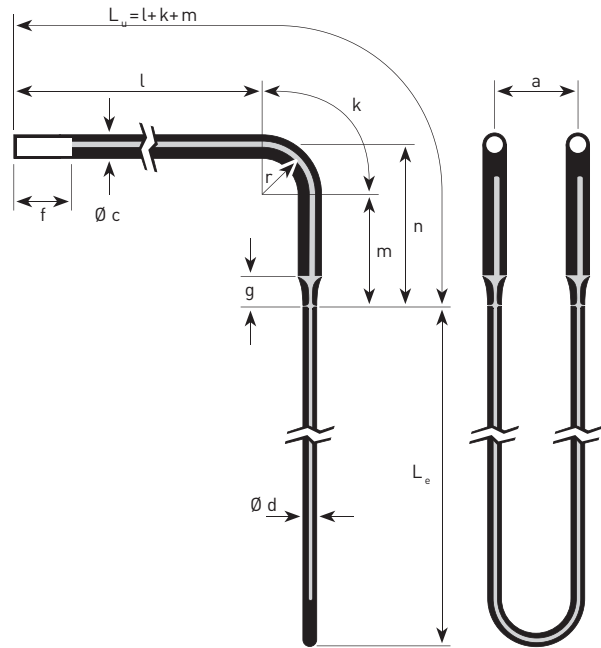


Fig. 2 Element bent 90° at the terminals.

THE FOLLOWING PARAMETERS ARE VALID FOR ALL KANTHAL® SUPER ELEMENTS (METRIC)

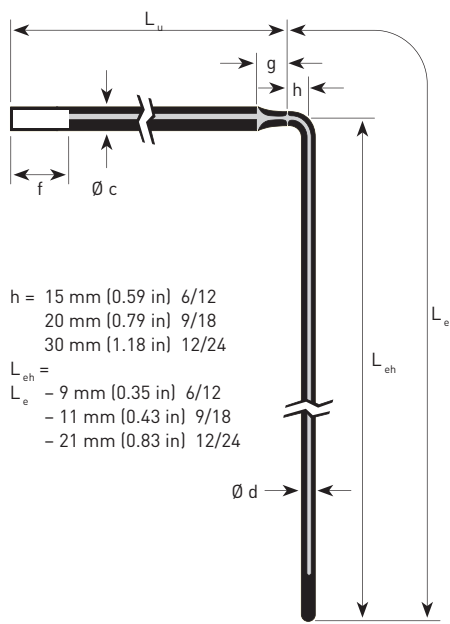
ELEMENT SIZE	A, MM		C MM	D MM	F MM	G MM	K _{90°} MM	K _{45°} MM	M, MM	N, MM		R, MM	
	STAND.	MIN.								STAND.	MIN.	STAND.	MIN.
3/6	25	16	6	3	25	15	19	9	30	42	30	12	
4/9	25	19	9	4	25	15	19	9	35	47	42	12	
6/12	50	26	12	6	45	25	47	24	60	90	70	30	20
9/18	60	38	18	9	75	30	71	35	90	135	100	45	30
12/24	80	54	24	12	100	40							

Dimensional tolerances ± 5% (except c and d)

THE FOLLOWING PARAMETERS ARE VALID FOR ALL KANTHAL® SUPER ELEMENTS (IMPERIAL)

ELEMENT SIZE	A, IN		C IN	D IN	F IN	G IN	K _{90°} IN	K _{45°} IN	M, IN	N, IN		R, IN	
	STAND.	MIN.								STAND.	MIN.	STAND.	MIN.
3/6	0.98	0.63	0.24	0.12	0.98	0.59	0.75	0.35	1.18	1.65	1.18	0.47	
4/9	0.98	0.75	0.35	0.16	0.98	0.59	0.75	0.35	1.38	1.85	1.65	0.47	
6/12	1.97	1.02	0.47	0.24	1.77	0.98	1.85	0.94	2.36	3.55	2.76	1.18	0.79
9/18	2.36	1.50	0.71	0.35	2.95	1.18	2.80	1.38	3.71	5.31	3.94	1.77	1.18
12/24	3.15	2.13	0.95	0.47	3.94	1.57							

Dimensional tolerances ± 5% (except c and d)



$h = 15 \text{ mm (0.59 in) } 6/12$
 $20 \text{ mm (0.79 in) } 9/18$
 $30 \text{ mm (1.18 in) } 12/24$
 $L_{eh} =$
 $L_e - 9 \text{ mm (0.35 in) } 6/12$
 $- 11 \text{ mm (0.43 in) } 9/18$
 $- 21 \text{ mm (0.83 in) } 12/24$

Fig. 3 Element bent 90°.

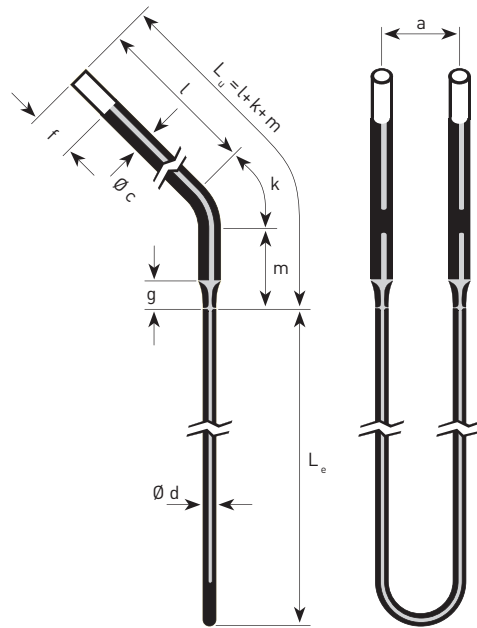


Fig. 4 Element bent 45° at the terminals.

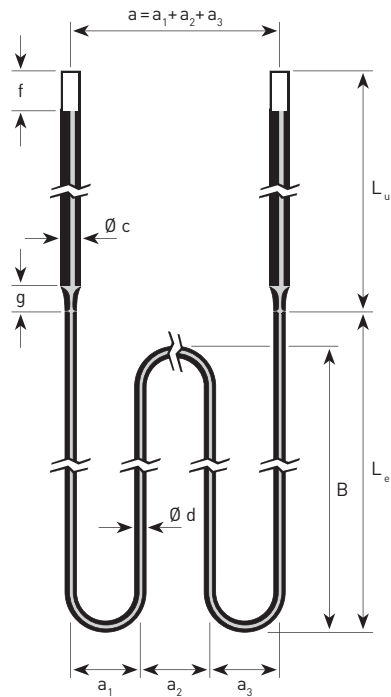
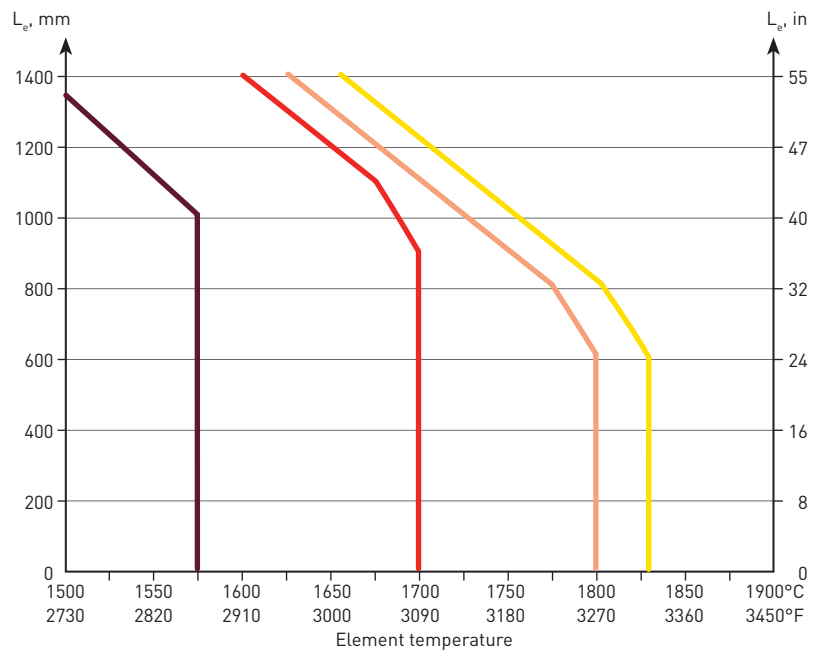


Fig. 5 Four-shank element for horizontal use.

MAXIMUM RECOMMENDED HEATING ZONE LENGTHS FOR VERTICALLY SUSPENDED 6/12, 9/18 AND 12/24 MM ELEMENTS



■ Kanthal® Super ER ■ Kanthal® Super 1700 and Kanthal® Super RA ■ Kanthal® Super 1800
■ Kanthal® Super 1900 and Kanthal® Super HT

TUBES

Tubes are normally manufactured in a quality corresponding to Kanthal® Super 1700. As the same material is used in the tubes as in the elements the data regarding properties previously given in the handbook is also valid for tubes. Standard sizes are manufactured as per table to the right.

MAXIMUM LENGTHS

For outer diameter 7–25 mm (0.28–0.98 in) maximum 2000 mm (78.7 in).

KANTHAL® SUPER BUBBLE TUBES

The standard Kanthal® Super bubbler tube has an ID of 3 mm (0.12 in) and OD 12 mm (0.47 in). Some glass works inquire smaller end holes for generation of smaller air bubbles.

Kanthal can now supply 12/3 tubes with a 5 mm (0.20 in) welded end cap with a min 0.7 mm (0.03 in) hole made by water jet.

KANTHAL® SUPER TYPICAL TUBE SIZES

OUTSIDE DIAMETER ± 5%		INSIDE DIAMETER ± 5%	
MM	IN	MM	IN
12	0.47	3	0.12
12	0.47	6	0.24
22	0.87	13	0.51
25	0.98	15	0.59

EXAMPLES OF APPLICATIONS FOR KANTHAL® SUPER TUBES



Bubbler tubes for glass melting.



Protection tubes for thermocouples.



Tubes for electrodes for glass melting.

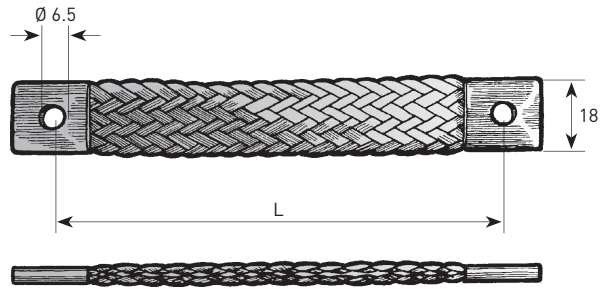
ACCESSORIES

ELEMENT SIZE 3/6 MM AND 4/9 MM

CONTACT STRAPS

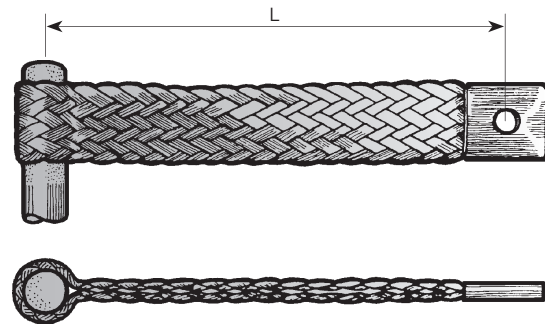
Type 5826

Lengths (L): 100, 150, 200



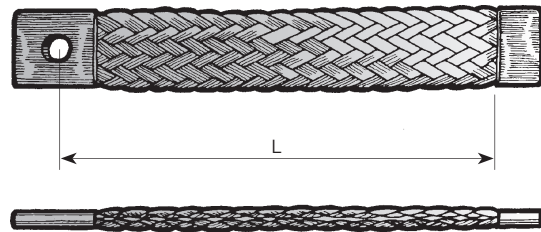
Type 5827

Lengths (L): 75, 100, 150, 200



Type 5828

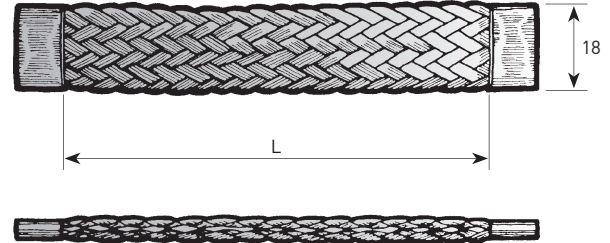
Lengths (L): 75, 100, 150, 200



Type 5829

Lengths (L): 75, 100, 150, 200

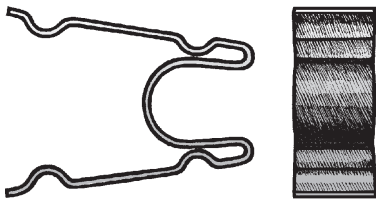
Spring clips to be used at both ends.



SPRING CLIPS

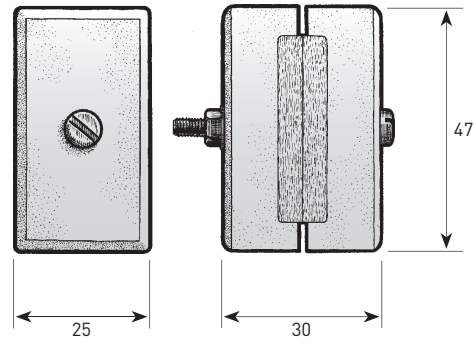
Type 10434
for element size 3/6 mm

Type 10435
for element size 4/9 mm



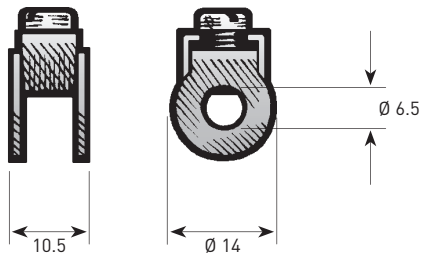
ELEMENT HOLDER

Type 5830

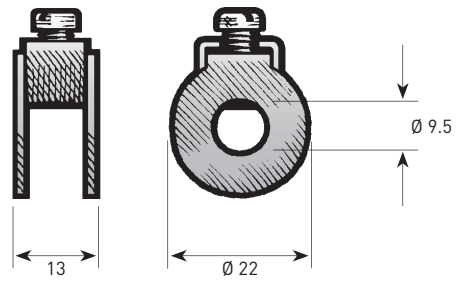


SINGLE-SHANK HOLDERS

Type 10421
for element size 3/6 mm



Type 10424
for element size 4/9 mm

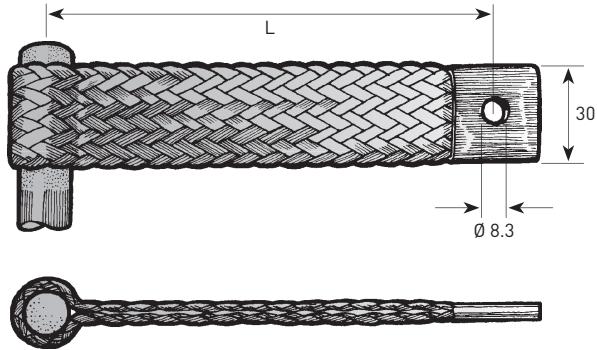


ELEMENT SIZE 6/12 MM

CONTACT STRAPS

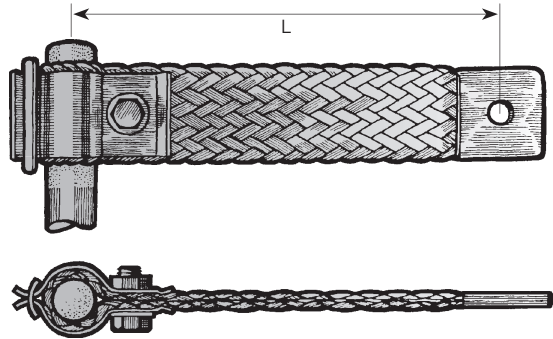
Type 5766

Lengths (L): 80, 100, 150, 200, 250, 300



Type 3579

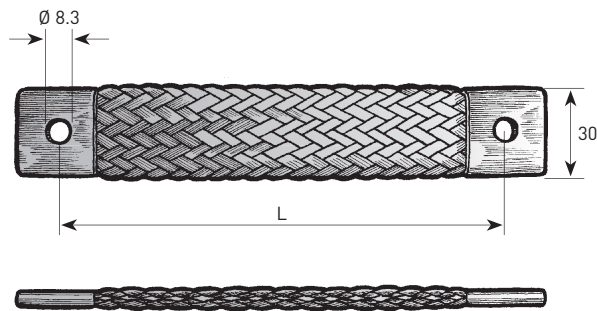
Lengths (L): 80, 100, 150, 200, 250, 300



Type 5768

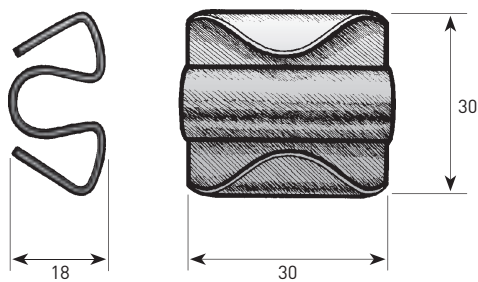
Lengths (L): 150, 200, 250, 300

Note: Two pcs per shank for 9/18



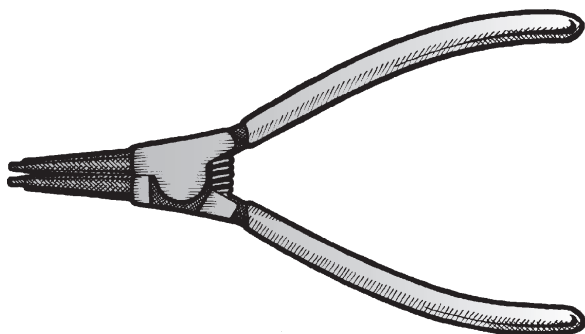
CONTACT CLAMP

Type 5758



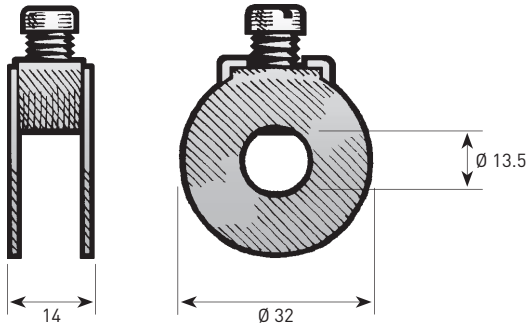
EXPANSION TOOL FOR CLAMPS

Type 21690

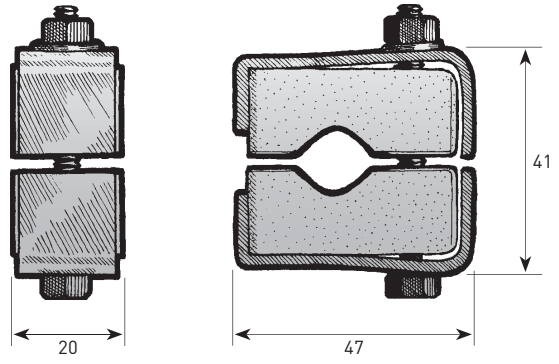


SINGLE-SHANK HOLDERS

Type 6248



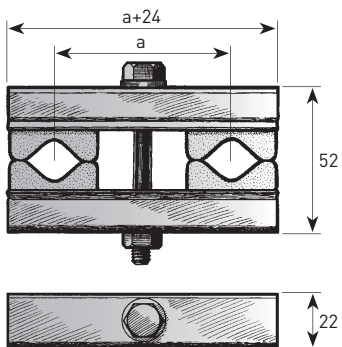
Type 5778



TWO-SHANK HOLDER

Type 5776

a = 40, 45, 50, 55, 60

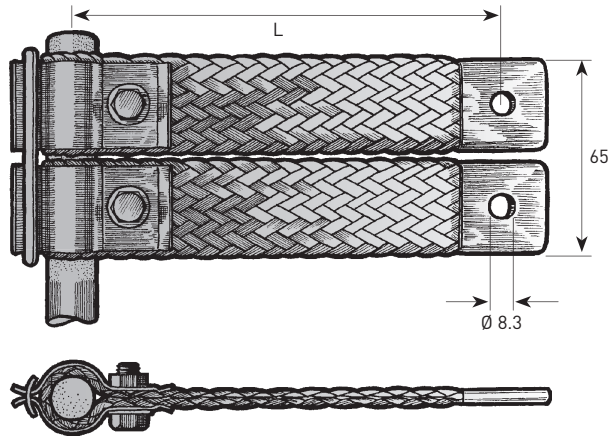


ELEMENT SIZE 9/18 MM

CONTACT STRAPS

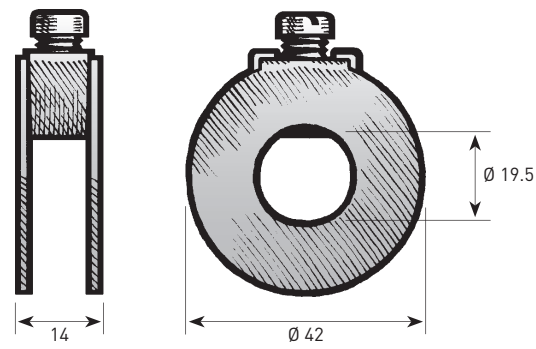
Type 3801

Lengths (L): 100, 150, 200, 250, 300

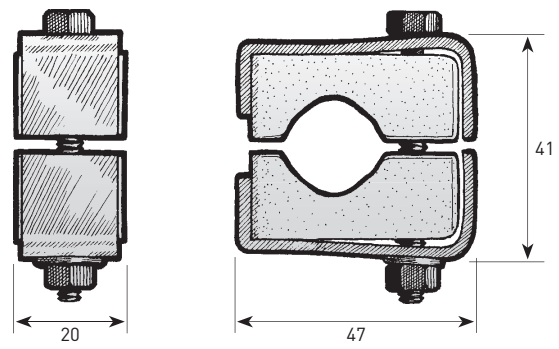


SINGLE-SHANK HOLDERS

Type 6249



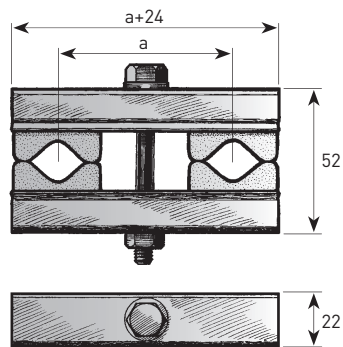
Type 5779



TWO-SHANK HOLDERS

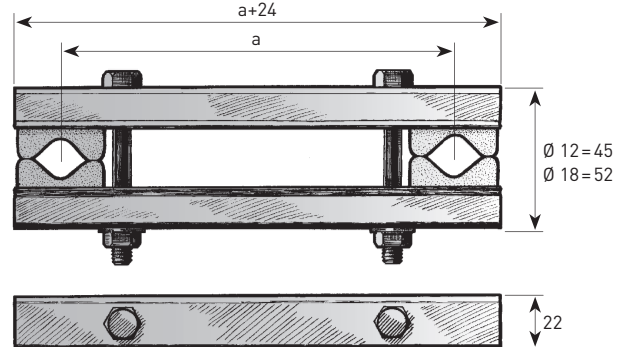
Type 5776

a = 40, 45, 50, 55, 60



Type 5777

a = 80 and 150 for element size 6/12 also



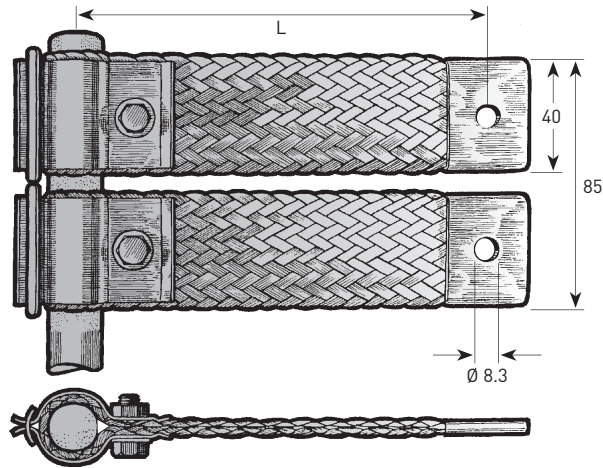
ELEMENT SIZE 12/24 MM

CONTACT STRAPS

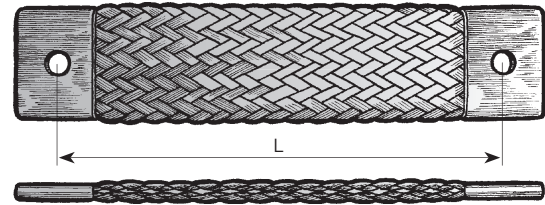
Type 10432

Lengths (L): 150, 200, 250, 300

Note: Two per shank

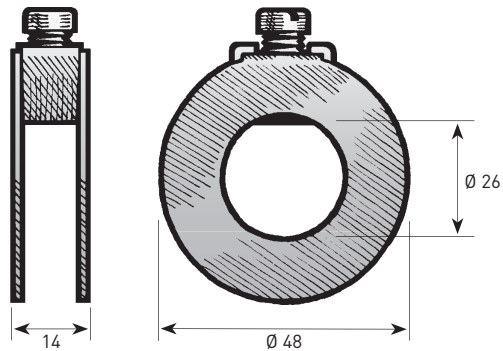


Type 10439



SINGLE-SHANK HOLDER

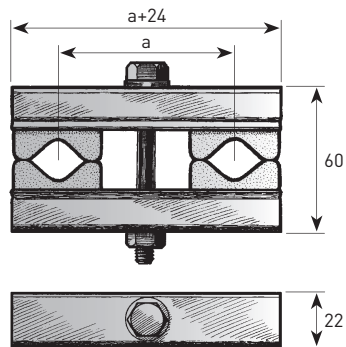
Type 10433



TWO-SHANK HOLDERS

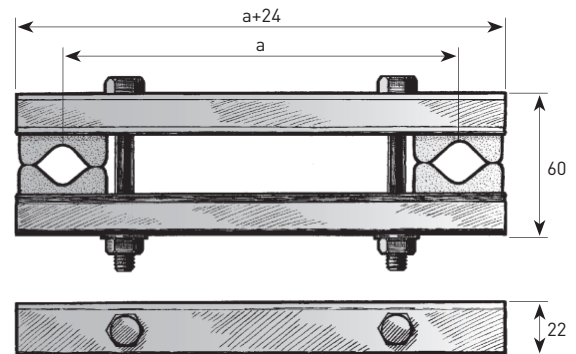
Type 10437

a = 60



Type 10438

a = 80

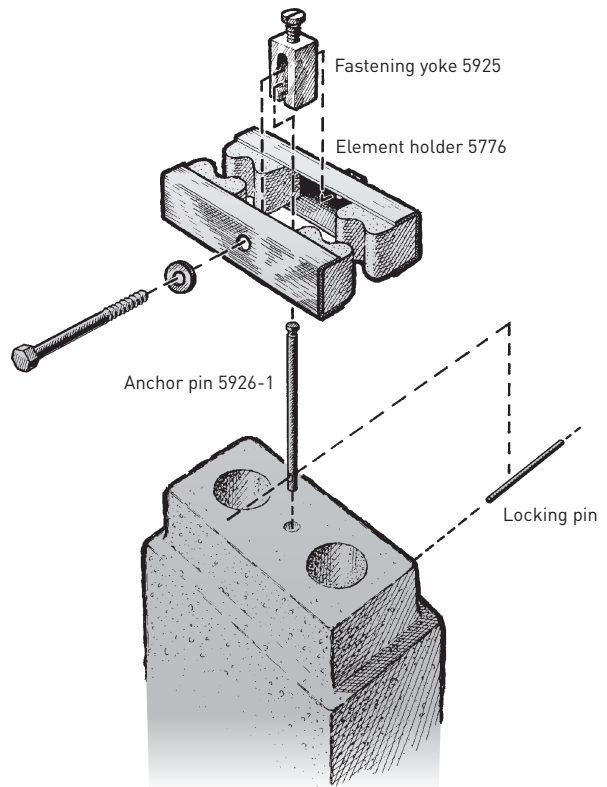


ANCHOR SYSTEMS

STANDARD ANCHOR SYSTEM

Type 5987

Element holder
Standard design



AIR COOLED ANCHOR SYSTEM

Type 5927

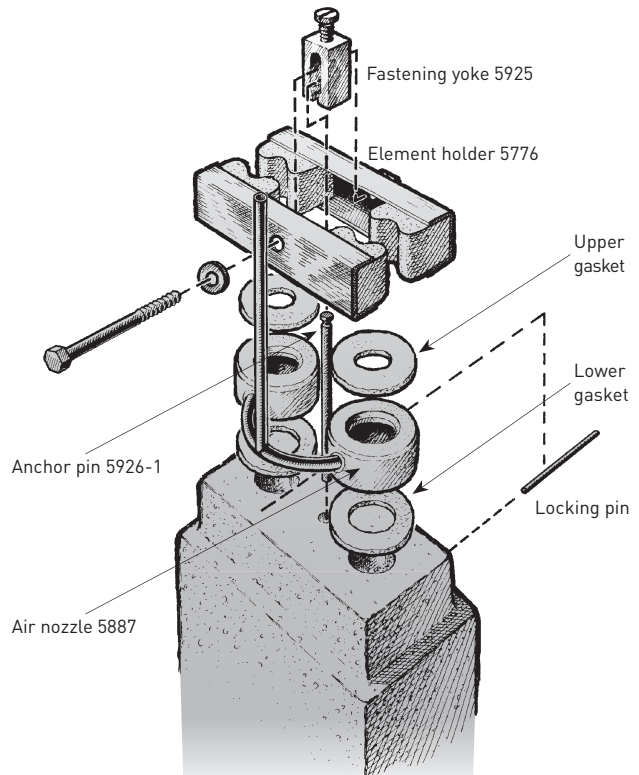
Element holder with air nozzle for
Kanthal® Super 9/18 mm a = 60

Type 6031

Element holder for
Kanthal® Super 6/12 mm a = 50

Type 6033

Element holder for
Kanthal® Super 6/12 mm a = 40



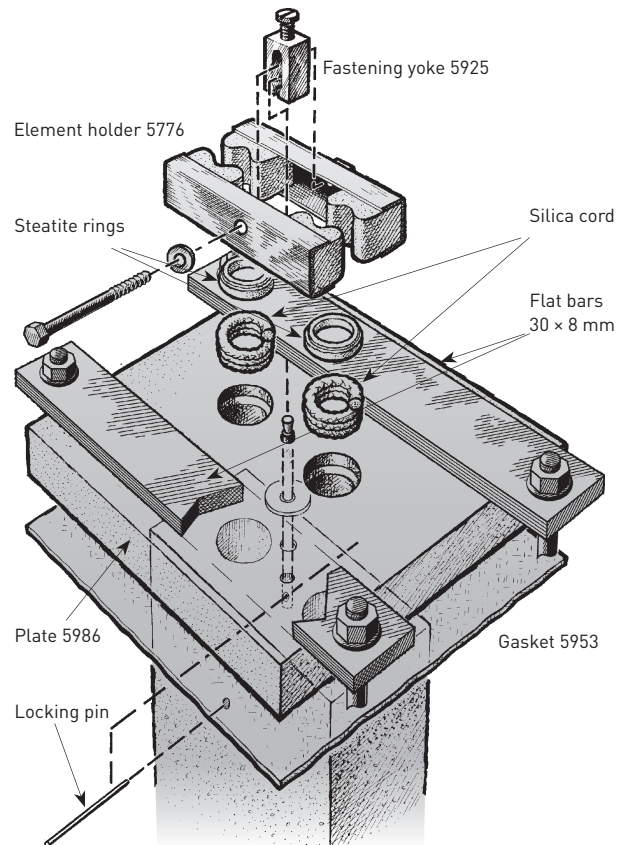
SEALED ELEMENT ANCHOR SYSTEM

Type 5965

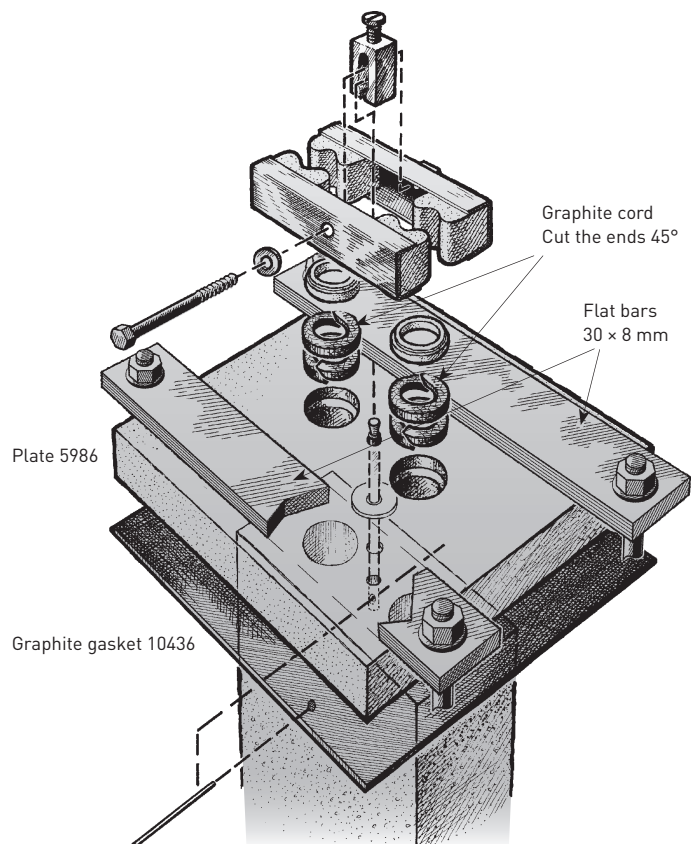
Element holder with sealed terminal lead through for Kanthal® Super 9/18 mm a = 60

Type 6037

Element holder with sealed terminal lead through for Kanthal® Super 6/12 mm a = 50



GRAPHITE ALTERNATIVE



PASSAGE BRICKS

Note: Under certain conditions, long passage bricks may result in excessive temperatures on the terminals, unless special precautions are taken when designing the furnace.

FOR ANCHOR SYSTEMS, SEALED DESIGN

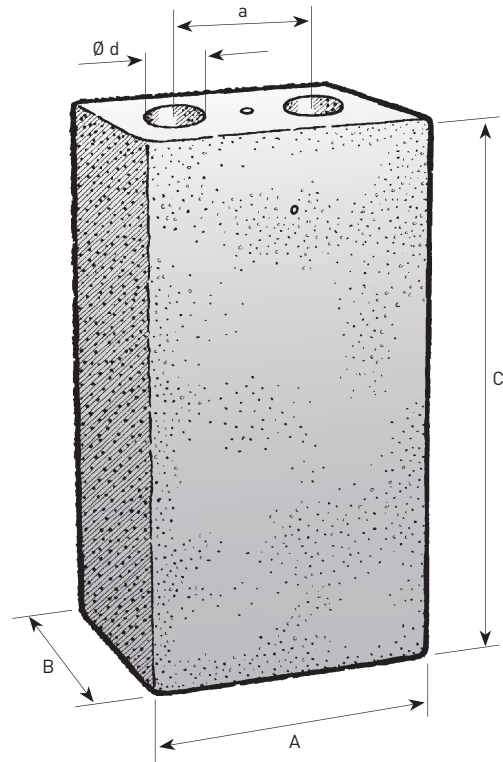
Type 6038

for 6/12 mm

Type 5984

for 9/18 mm

TYPE NO.	GRADE	A	B	C	A	D	ELEMENT SIZE
6038-1	28	115	64	229	50	15	6/12
5984-1	28	115	64	229	60	23	9/18
5984-2	28	115	76	229	60	23	9/18
5984-3	28	152	76	305	60	23	9/18



FOR ANCHOR SYSTEMS, TYPICAL DESIGN

Type 6036

for 6/12 mm

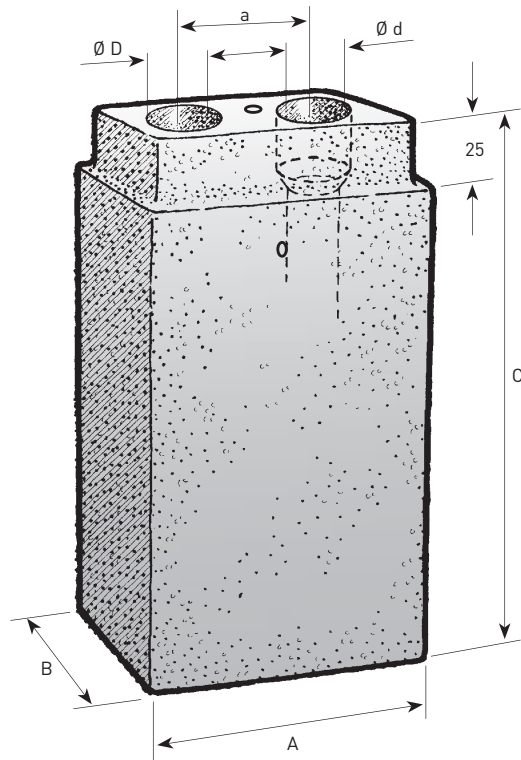
Type 5985

for 9/18 mm

Type 10943

for 12/24

TYPE NO.	GRADE	A	B	C	A	D	D	ELEMENT SIZE
6036-1, -3, -6	G28,30,33	115	64	229	40	15	25	6/12
6036-9, -4, -8	G28,30,33	115	64	229	45	15	25	6/12
6036-2, -5, -7	G28,30,33	115	64	229	50	15	25	6/12
5985-1, -4, -8	G28,30,33	115	64	229	60	23	35	9/18
5985-2, -5, -10	G28,30,33	115	76	229	60	23	35	9/18
5985-3, -6, -11	G28,30,33	152	76	305	60	23	35	9/18
10943-1, -4, -7	G28,30,33	115	64	229	60	30	40	12/24
10943-2, -5, -8	G28,30,33	115	76	229	60	30	40	12/24
10943-3, -6, -9	G28,30,33	152	76	305	80	30	40	12/24



FOR ANCHOR SYSTEMS, AIR COOLED DESIGN

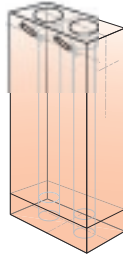
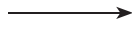
Type 6035

for 6/12 mm

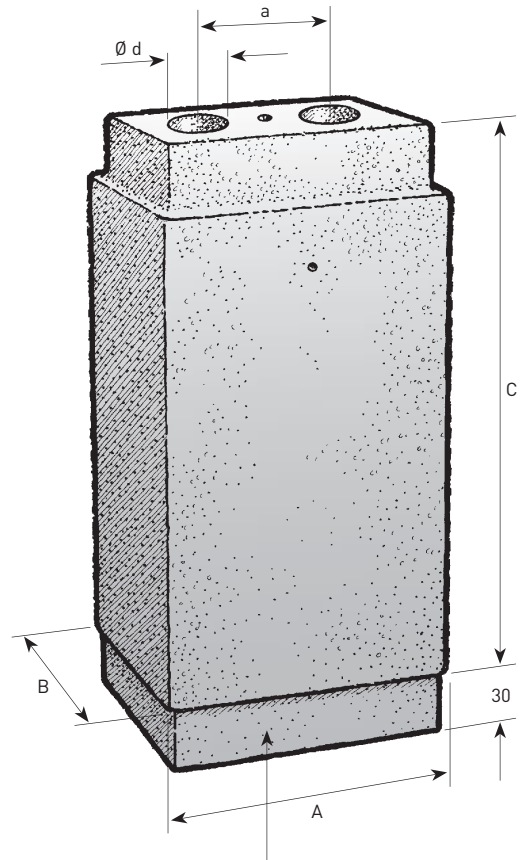
Type 5930

for 9/18 mm

for 12/24 mm



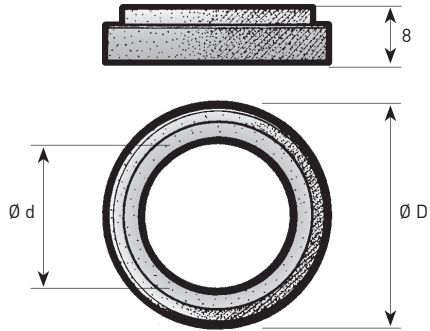
TYPE NO.	GRADE	A	B	C	A	D	D	ELEMENT SIZE
6035-1, -3,-6	G28,30,33	115	64	229	40	15	25	6/12
6035- -4,-7	G28,30,33	115	64	229	45	15	25	6/12
6035-2, -5,-8	G28,30,33	115	64	229	50	15	25	6/12
5930-1, -4,-7	G28,30,33	115	64	229	60	23	35	9/18
5930-2, -5,-8	G28,30,33	115	76	229	60	23	35	9/18
5930-3, -6,-9	G28,30,33	152	76	305	60	23	35	9/18



Bottom plate: Alfrax coated grade 33

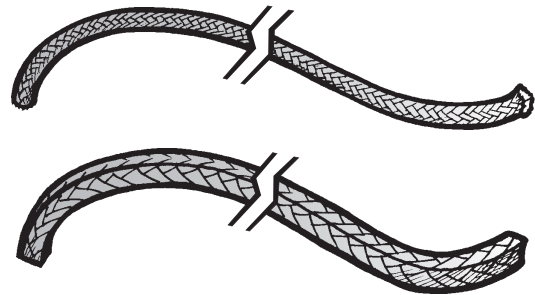
OTHER ACCESSORIES

STEATITE RINGS



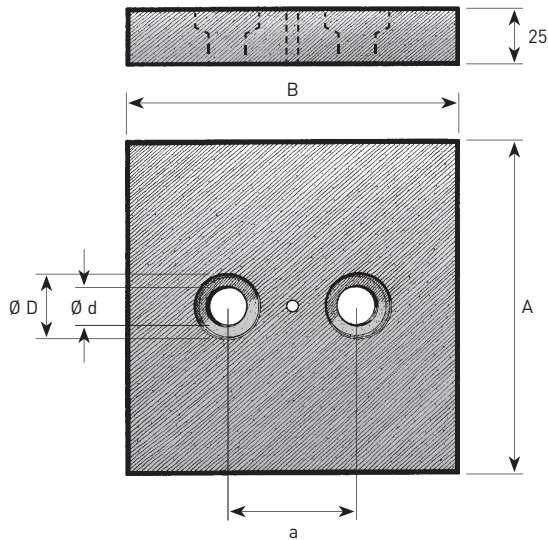
ELEMENT SIZE	6/12	9/18
D	20	27
d	13	19

SILICA CORD AND GRAPHITE CORD



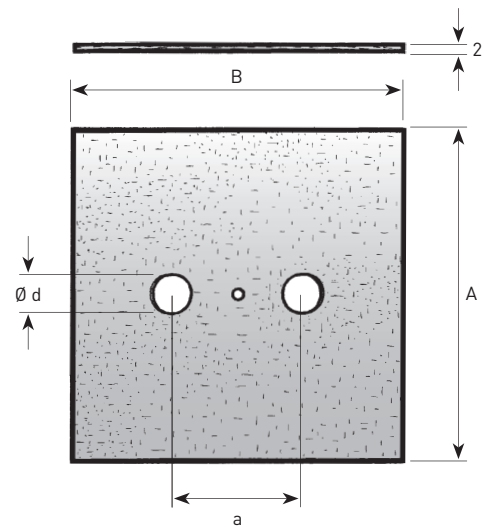
ELEMENT SIZE	6/12	9/18
Length of silica cord	2×180	2×230
Length of graphite cord	4×60	4×80

PLATES



TYPE	A	B	A	D	D
5986-1	150	150	60	20	28
5986-2	160	160	60	20	28
5986-3	180	180	60	20	28
5986-4	160	200	60	20	28
5986-5	130	180	60	20	28
5986-10	150	150	50	13	21

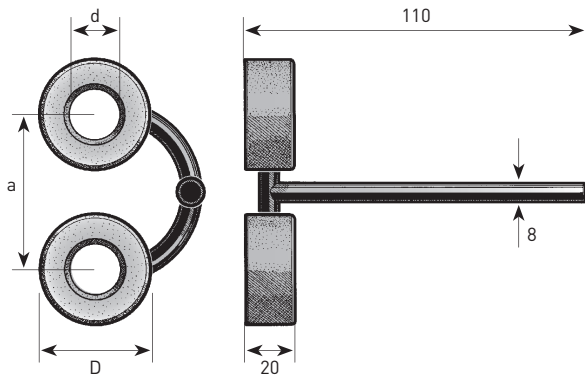
GASKET FOR PLATES



GRAPHITE	CERAMIC FIBER	A	B	A	D
10436-1	5953-1	150	150	60	18
10436-2	5953-2	160	160	60	18
10436-3	5953-3	180	180	60	18
10436-4	5953-4	160	200	60	18
10436-5	5953-5	130	180	60	18
10436-10	5953-10	150	150	50	12

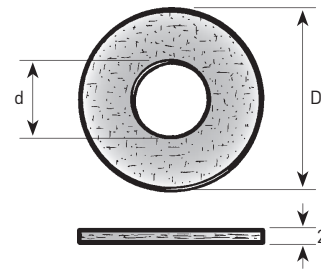
10436-1-5 d = 30 mm
10436-10 d = 24 mm

AIR NOZZLES



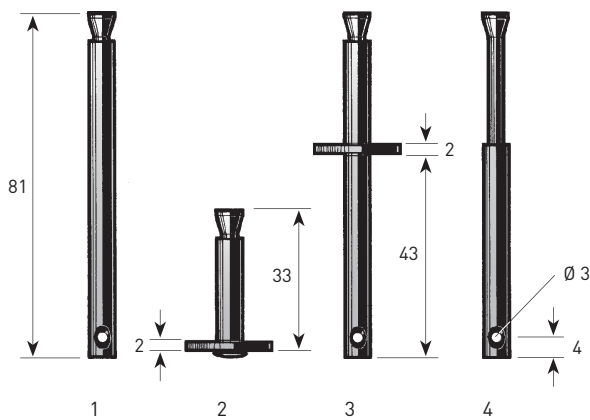
TYPE	ELEMENT SIZE	A	D	D
5887-A	6/12	40	36	13.5
5887-B	6/12	50	36	13.5
5887-C	9/18	60	42	19.5

GASKETS FOR AIR NOZZLES



ELEMENT SIZE	6/12		9/18	
	D	D	D	D
Upper gasket	11	32	17	38
Lower gasket	16	36	22	42

Anchor pins



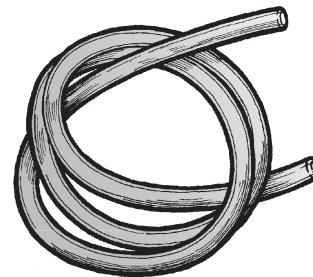
TYPE	ANCHOR SYSTEM
5926-1	Standard and air cooled
5926-2	Sealed ¹⁾
5926-3	Sealed
5926-4	Air cooled ²⁾

1) Without locking pin.

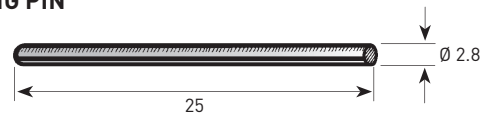
2) Element size 6/12 mm and distance between shanks (a) = 40 mm

SILICON RUBBER HOSE

For connection to air nozzles.

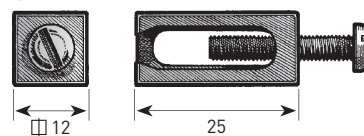


LOCKING PIN

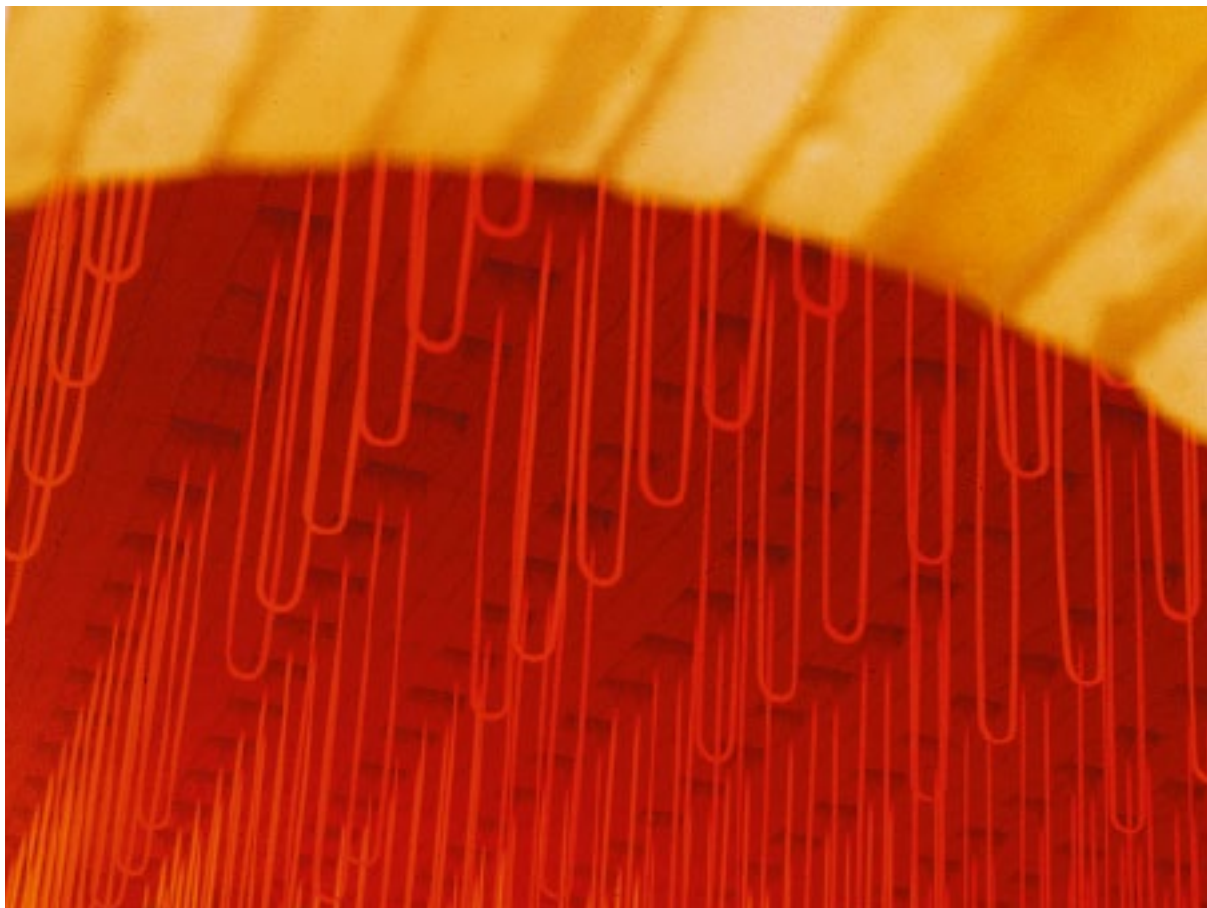


FASTENING YOKE

Type 5925



INSTALLATION



Two-shank Kanthal® Super elements installed across the width of the furnace.

VERTICALLY MOUNTED ELEMENTS

The exceptional properties of Kanthal® Super elements can best be utilized when the elements freely radiate in the furnace chamber.

U-shaped elements fitted through the furnace roof and vertically suspended in the furnace should be considered as the standard design for a Kanthal® Super furnace (fig. 1, page 34). The elements are normally placed along the side walls, but in wide furnaces it may be necessary to place elements across the width of the furnace to provide the power required.

Certain furnace designs do not permit elements to be fitted through the roof. The internal height of the furnace may be such that more than one level of elements must be installed. In these cases elements with bent terminals or heating zones are available (fig. 2–4, pages 34 and 35).

HORIZONTALLY MOUNTED ELEMENTS

In some types of furnaces where the roof height is low, horizontally installed Kanthal® Super elements may be the most economical and efficient alternative.

As Kanthal® Super elements start to soften at temperatures around 1200°C (2190°F), they must generally be supported when used horizontally. This limits their maximum operating temperature because of possible reactions with the supporting material. If a reaction occurs between the silica layer on the element and the supporting brick, the element may adhere to the brick and fracture when cooling down. Even when suitable dense bricks of sillimanite or mullite type are used, the maximum element temperature must not exceed 1600°C (2910°F). Sillimanite or mullite grains (≈ 3 mm/0.12 in) can be used on the supporting surface where applicable.

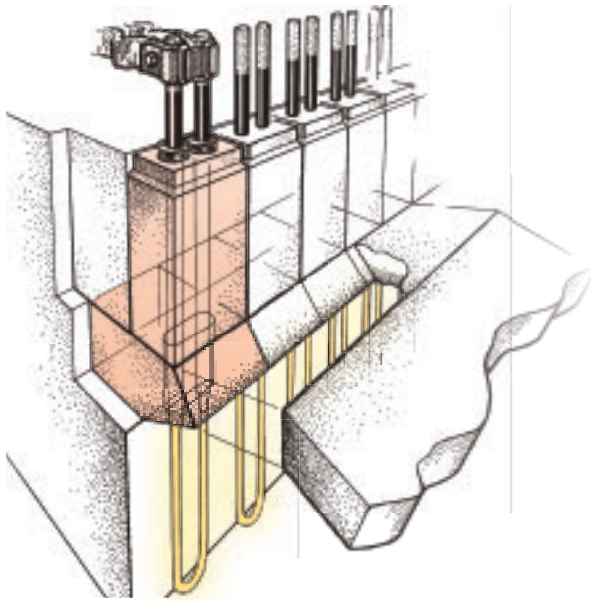


Fig. 1 Kanthal® Super element installation with standard passage bricks in a brick lined furnace.

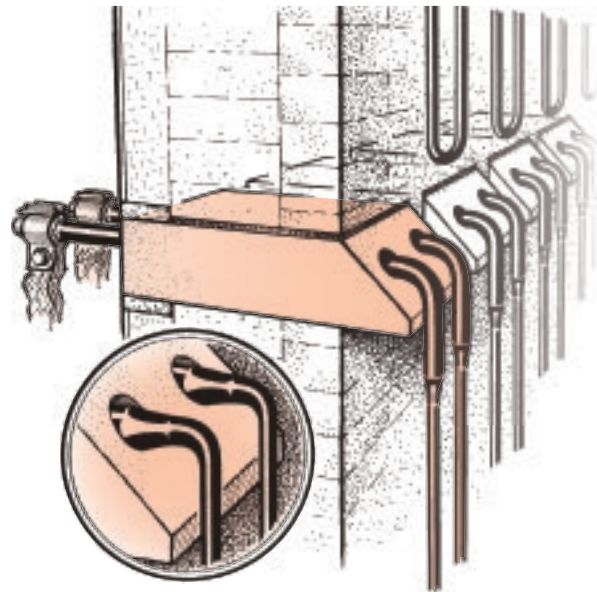


Fig. 2 Kanthal® Super elements, with terminals bent 90°, installed in a brick lined furnace.

BRICK LINED FURNACES

To facilitate the installation of Kanthal® Super elements in brick lined furnaces, passage bricks are used. They are installed in openings in the roof or side wall (fig. 1 and 2). The passage bricks mounted through the roof often rests on a skew brick, which has oval holes for the elements. The passage bricks are made of heavy duty insulating firebrick of a quality matched to the furnace temperature.

CERAMIC FIBER LINED FURNACES

In fiber lined industrial furnaces, e.g. forging furnaces, if passage plugs of fiber or refractory bricks are used, then the complete element assembly also needs to be supported by the furnace roof or side walls, fig. 3–6, pages 35 and 36.

In small fiber lined furnaces, e.g. laboratory furnaces, it may be sufficient to introduce the Kanthal® Super elements through slots in the insulation and fill the space around and between the terminals with loose ceramic fiber (fig. 7, page 36).

In furnaces for temperatures above 1700°C (3090°F), it is important to relieve the hot face lining of the roof from the weight of the element assembly. It is recommended to use a divided passage plug of ceramic fiber (fig. 8, page 37) or a passage plug supported by the cold side of the roof (fig. 9, page 37).

The weight of the element sets is carried by the outer lining. Especially useful in furnaces for very high temperatures.

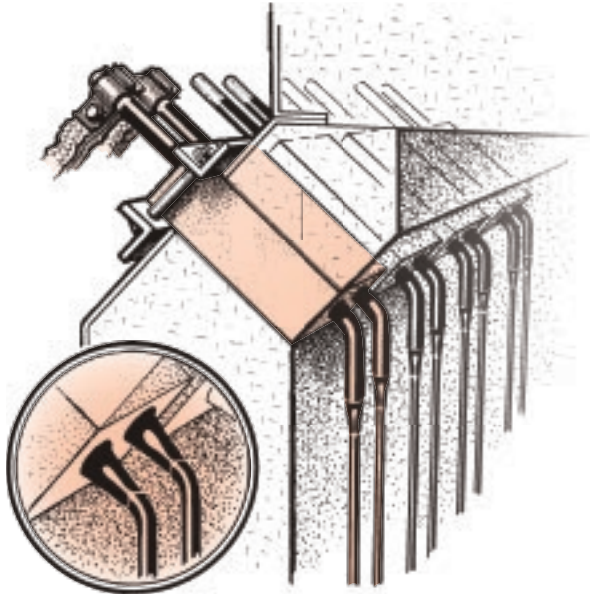


Fig. 3 Kanthal® Super elements, with terminals bent 45°, installed in ceramic fiber insulated furnace.

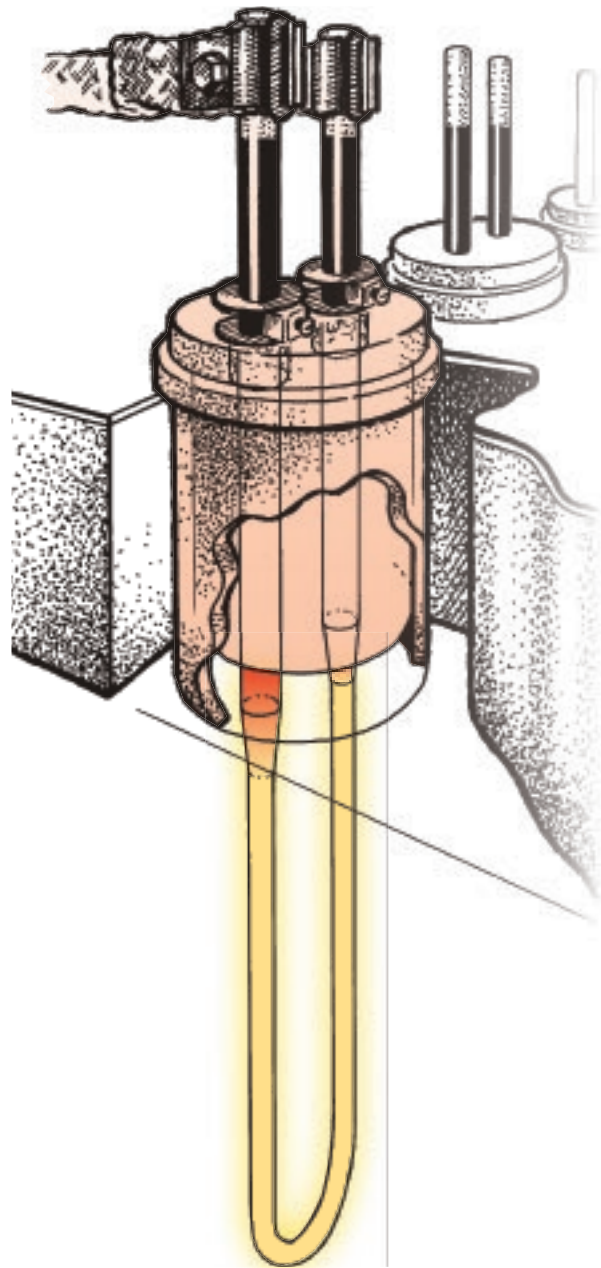


Fig. 5 Kanthal® Super elements in ceramic fiber lined furnaces. The passage plugs with a flange are made of ceramic fiber and fitted into ceramic fiber sleeves.

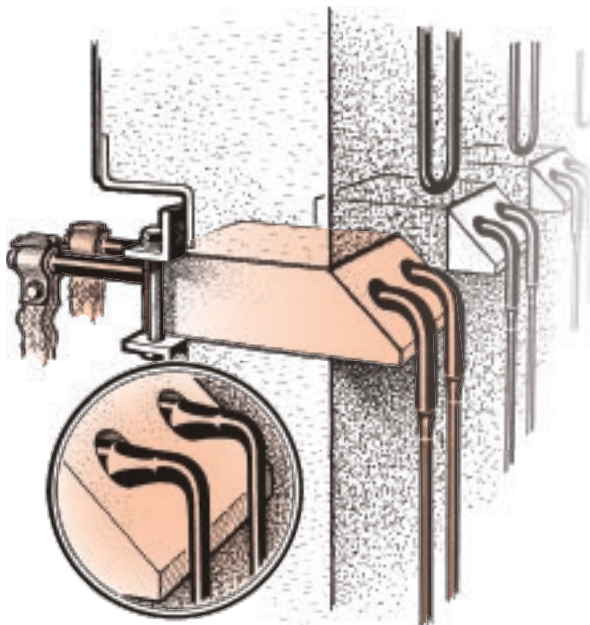


Fig. 4 Kanthal® Super elements, with terminals bent 90°, installed through a furnace wall in a fiber lined furnace.

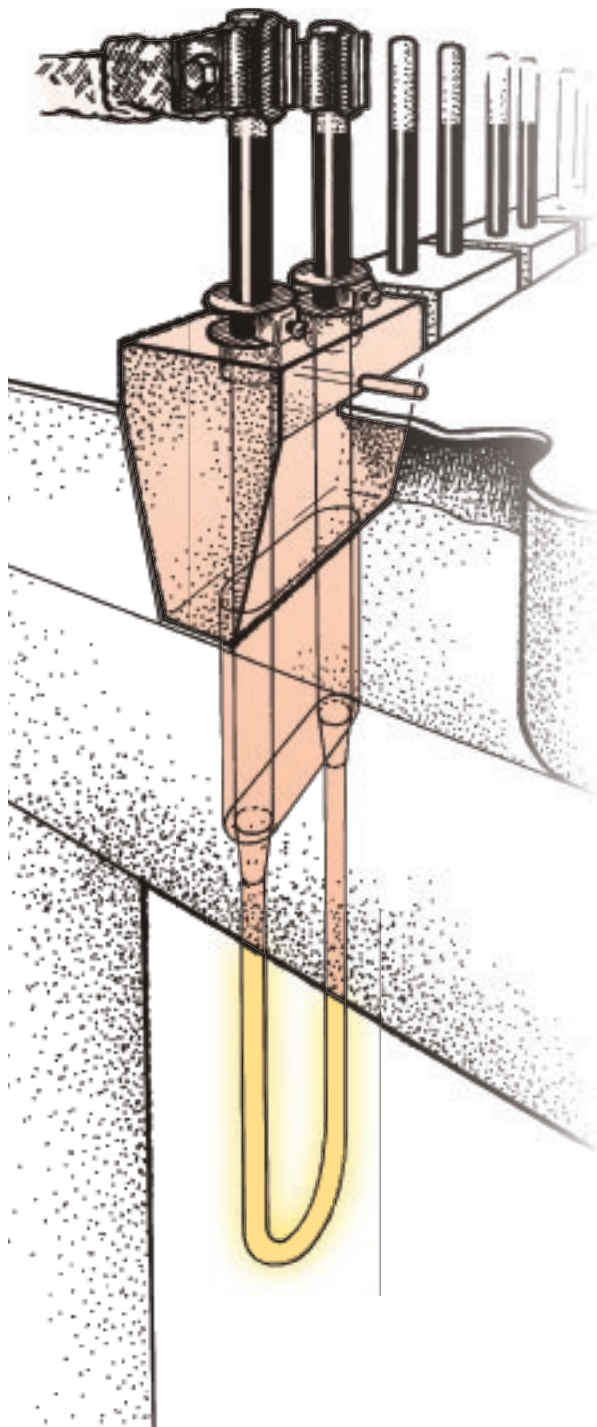


Fig. 6 Kanthal® Super elements in ceramic fiber lined furnaces. The passage plugs made of a heavy duty insulating firebrick are suspended by the cold side of the roof.

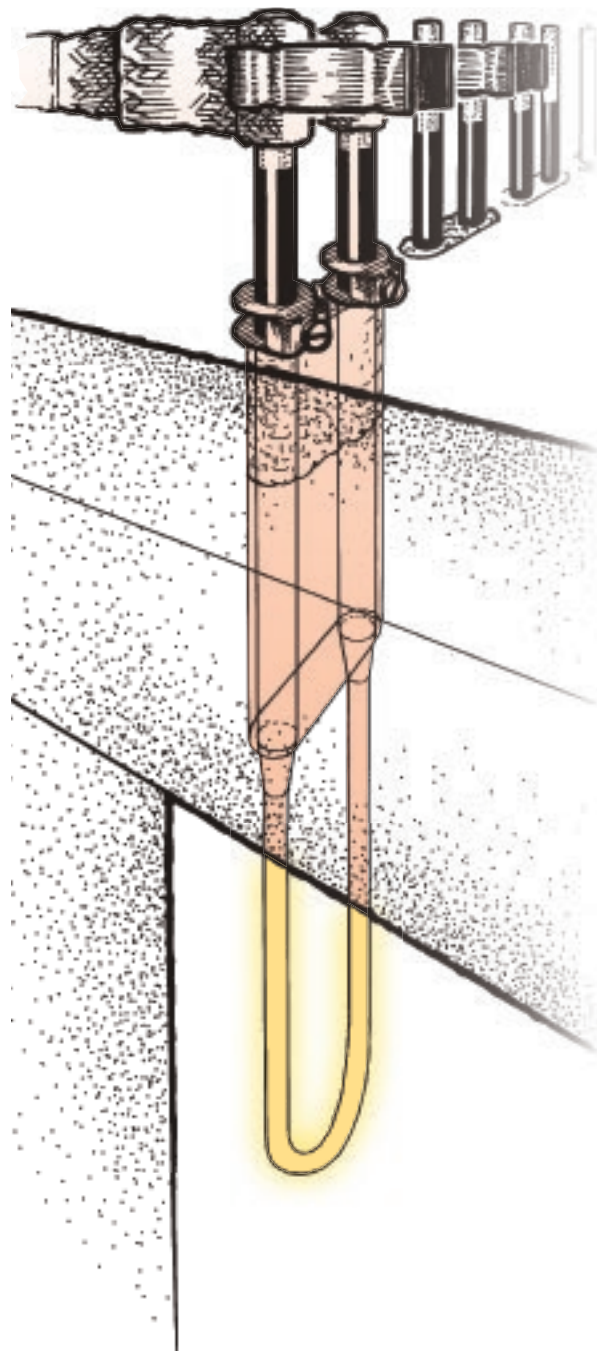


Fig. 7 Kanthal® Super elements in ceramic fiber lined furnaces installed through oval slots in the roof.

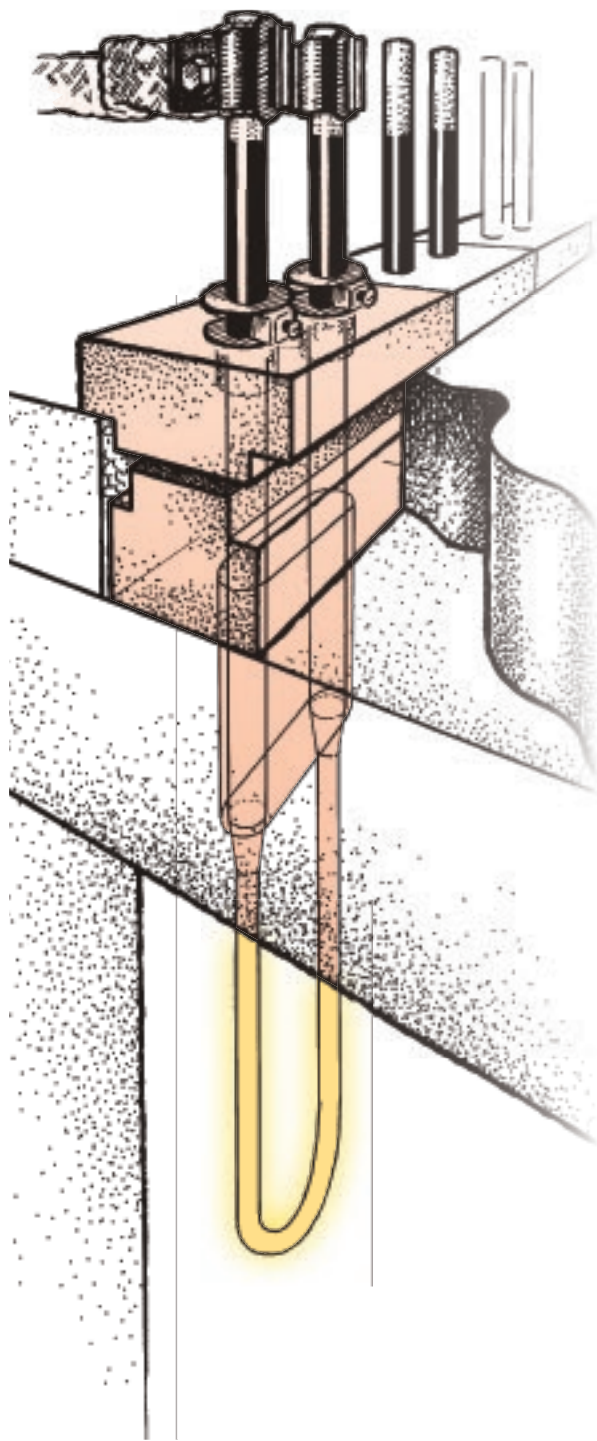


Fig. 8 Kanthal® Super elements in ceramic fiber lined furnaces. The passage plugs are divided in two pieces.

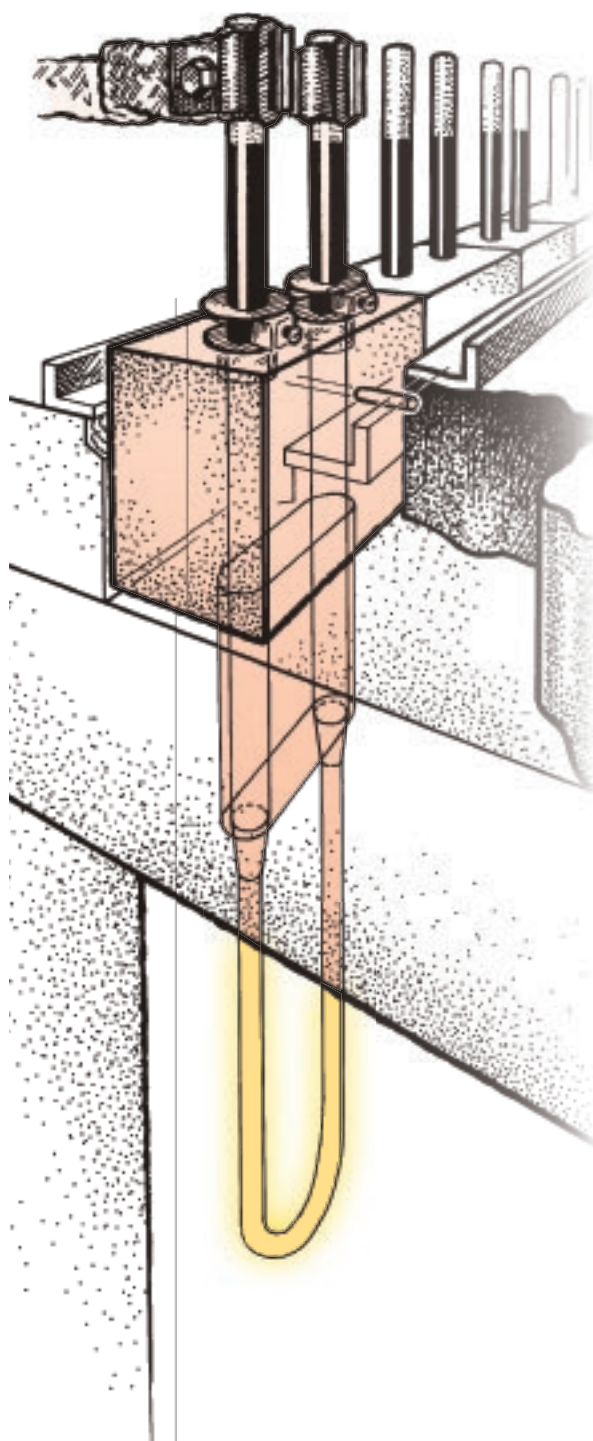


Fig. 9 Kanthal® Super elements in ceramic fiber lined furnaces. The passage plugs and elements are supported by the cold side of the roof.

ELEMENT HOLDERS AND ANCHOR SYSTEMS

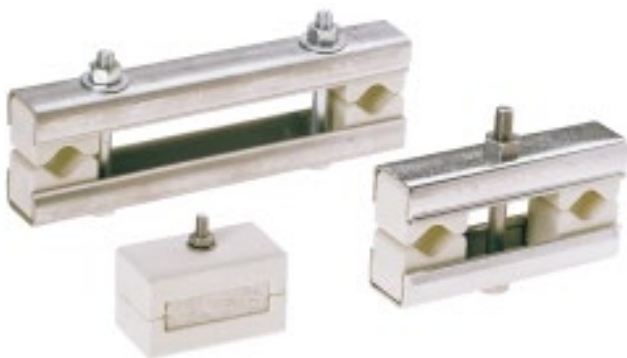
SINGLE-SHANK HOLDERS

Single-shank holders can be used for all kinds of Kanthal® Super qualities. It is essential that the terminals are able to move freely and independently of each other, otherwise mechanical stresses may cause the element to break.

This is important at very high temperatures.



Single-shank holders.



Two-shank holders.

TWO-SHANK HOLDERS

Two-shank holders are used when the elements need to be anchored to the passage brick.

Standard anchor system

When Kanthal® Super elements are used in an air atmosphere the standard anchor system is recommended in brick lined furnaces.

A fastening yoke holds the anchor pin, which is secured in the passage brick by a locking pin.



Element holder and anchor system, standard design.

“AIR COOLED” ANCHOR SYSTEM

By using the “air cooled” design it is possible to blow cooling air down along the terminals. In furnaces where impurities in the form of dust or fumes occur, e.g. glass melting furnaces, it is essential that such substances be prevented from depositing and condensing in the holes of the passage bricks; otherwise, corrosion may occur on the element terminals. The element may also be jammed in the hole, thus preventing free movement and possibly leading to element breakage. This is particularly important in glass melting furnaces, since glass fumes readily condense, resulting in damage to Kanthal® Super elements.

Normal overpressure of the air is 200–700 Pa at a flow rate of 3–4 liters/minute for each element.

SEALED ANCHOR SYSTEM

Kanthal® Super elements are often used in furnaces with controlled atmospheres. When the elements operate directly in the atmosphere, it is essential that the terminals be sealed. A lead-through, which is sealed and bolted to the shell of the furnace, is shown in the figure below.



Element holder and anchor system, air cooled design.



Element holder and anchor system, sealed design.

CONTACTS

Each contact consists of a double-folded aluminum braid, which is secured around the aluminized end of the terminal by means of a spring or screw clamp.

The busbar end of the braid is reinforced with an aluminum sleeve.

The standard sizes and types available are shown in Part I: Products and accessories, pages 20–31.

It is essential that no mechanical stresses should be transmitted to the elements through the aluminum braids. The length of the braid should therefore be longer than the straight distance between the element and the busbar. When tightening the bolts at the element terminal, it is important that the terminal should not be twisted or bent.

In order to avoid breakage of the elements, **DIRECT CONNECTION OF ELEMENT TO ELEMENT IS NOT RECOMMENDED**. They should be connected to busbars or with individual braids which are bolted together. See image below.

The aluminum braids should not be connected to copper busbars. Stainless steel screws and aluminum busbars are recommended.

When using Kanthal® Super elements the current is high. Consequently, the transition resistance between contact and terminal must be kept low. The voltage drop across the contact should not exceed 0.01 V. Aluminum oxidizes easily, and the alumina layer built up on the surface is a good insulator. Furthermore, the creep strength of aluminum is low and the temperature at **THE CONTACTS SHOULD NOT EXCEED 300°C (570°F)**. When screw clamps are used, it is essential that the bolts be fully tightened.

The contacts are designed for a continuous current of:

Element size	3/6	4/9	6/12	9/18	12/24
Current, A	75	115	200	365	560

In order to avoid overheating of the contacts due to radiation and conduction through the terminals, the minimum length of the terminal protruding from the passage brick, L_c , should be as shown in the table on page 41.



Kanthal® Super elements connected to busbars.

If a contact becomes damaged, it should be replaced. If the aluminized layer on the terminal is damaged, it should be removed by careful grinding with emery cloth. Then a new contact should be fitted.

An excessive temperature in the busbar housing may cause overheating of the contacts. This may be due to insufficient ventilation. If natural convection is not sufficient, forced convection is recommended.

A common cause of overheating of the contacts is poor sealing between the terminals and the passage brick, and between the passage brick and the roof, resulting in a "chimney" effect. This not only causes overheating of the contacts but also increases the temperature of the terminal, which leads to excessive heat generation in the roof.

Sealing, therefore, must be carefully carried out using high duty ceramic fiber. In the standard passage bricks there are recesses around the terminals as well as a shoulder around the top to facilitate efficient sealing.

Should overheating of the contacts be caused by poor insulation of the roof, forced air cooling of the contacts will be necessary if it is not possible to improve the insulation.

TERMINAL LENGTH

When determining the terminal length L_u , it is necessary to know the distance from the hot face of the furnace roof to the cold face of the passage brick, L_i or passage plug. The tapered part of the terminal must come fully below the hot face of the lining.

The following table gives information about the length of taper g , and the minimum length of terminal protruding above the passage brick $L_{c\ min}$.

TERMINAL LENGTH

ELEMENT SIZE	3/6		4/9		6/12		9/18		12/24	
	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN
Length of taper	16.5 ±1.0	0.6 ±0.04	17.5 ±1.0	0.7 ±0.04	20.5 ±0.5	0.8 ±0.05	25.5 ±1.5	1.0 ±0.05	35.5 ±1.5	1.4 ±0.05
$L_{c\ min}$ *	50	2	50	2	75	3	125	5	150	6

* For holders of "air cooled" and sealed design $L_{c\ min}$ for 6/12 is 100 mm (4 in) and 9/18 140 mm (5.5 in).

FIXED CONTACTS KANTHAL® SUPER

Kanthal has been developing a fixed contact as an alternative to the standard bolted on contacts. These can be utilized, where the temperature of different reasons is high.

Fixed contacts are designed to assure safe and reliable electrical connections. The fixed contact consists of an aluminum braid with a cable clip attached to one end and a metallic sleeve attached to the other. The metallic sleeve is soldered to the terminal end.

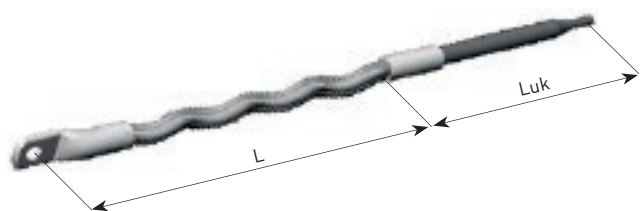
The fixed contacts can withstand temperatures up to 400°C (750°F) which is 100°C (180°F) higher than what is recommended for standard contacts.

Fixed contacts are available for all terminal diameters and the length of the braid can be adapted to the customers demand. The length should be long enough to enable a good installation with some slack of the braid,

usually longer than 100 mm (3.94 in). It is important that no mechanical stresses should be transmitted to the elements through the alumina braids.

The braid fibers diameter is 0.16 mm (0.006 in) to get the correct stiffness of the braid.

It is not possible to install the element with fixed contacts through bricks or fiber with normal hole diameter. The insulation needs either to have larger holes, with increased risk of heat leakage or be parted into two half's with slots for the element.



ASSEMBLING OF KANTHAL® SUPER ELEMENT



1. Kanthal® Super elements should not be unpacked until the furnace and the busbars are ready. Pages 42–43 show the practice employed when assembling vertically suspended Kanthal® Super elements with passage bricks.



2. When unpacking, care should be taken to avoid any bending or twisting.

3. The element is placed horizontally on a table and the terminals are carefully inserted in the holes in the passage brick ensuring that the correct length of terminals are protruding from the top of the brick.



4. After packing heavy-duty ceramic fiber loosely into the recesses of the terminal holes...



5. ...single- or two-shank element holders should be fixed to the terminals.



6. When determining the position of the element holder, it is of the utmost importance to ensure that the tapered transition between terminal and heating zone comes fully below the hot face of the furnace lining. If not, there is a risk that the part of the heating zone which is inside the lining may become overheated. When connecting the installed elements, the aluminum braids should first be bolted to the elements and then to the busbars.



7. Before inserting the element assembly...

...it is necessary to check the size of the corresponding holes in the roof. When fastening the contact bolts the elements must not be bent or twisted. Finally, check that the installed elements can move freely!

FURNACE OPERATION

INITIAL START-UP PROCEDURE RECOMMENDATIONS

- Review the installation instructions of the furnace to verify that it is in operating condition.
- Become familiar with the various adjustments on the controller or programmer before operating the furnace for the first time.
- Do not leave the furnace unattended during the initial break-in period.
- Check the current limit of the power controller. Generally the current limit is pre adjusted before shipping.
- Note that fibrous insulation is fragile and that the Kanthal® Super heating elements are also subject to breakage if handled improperly. Take special care with all furnace components at all times.

STARTING UP A NEWLY-BUILT FURNACE

When starting up a furnace for the first time or after it has been relined, it is necessary to dry it out so that the lining is not damaged. This is especially important when the furnace is brick lined. As far as the Kanthal® Super elements are concerned, the quicker the furnace can be brought up to full operating temperature, the better. The elements may also be attacked by gases and dust given off from the lining during the first firing of a furnace. It is therefore very important to ventilate the furnace thoroughly during the drying-out process.

We recommend the following procedure as suitable for starting most Kanthal® Super furnaces.

STEP-DOWN TRANSFORMER AND ON/OFF CONTROL

Open the furnace door slightly and switch on the starting voltage (1/3 or 1/4 of operating voltage) for the first drying-out period at 100–200°C (210–390°F).

Switch over to an intermediate voltage (2/3 or 1/2 of operating voltage). This must be done quickly in order to avoid too much reduction in element temperature and the resulting high current surges which may cause damage.

Allow the furnace door to remain slightly open for ventilation to continue while the furnace temperature rises gradually to 800°C (1470°F). When the furnace has reached this temperature, close the furnace door and allow the furnace to run up to full temperature at operating voltage.

THYRISTOR CONTROL

When thyristor control is used, the remarks regarding operating voltage do not apply. It is advisable to reduce the current limit during the drying-out period. Otherwise, the same considerations apply as with a furnace with step-down transformer and on/off control.

For Kanthal® Super elements it is advantageous if they are allowed to work at an element temperature of at least 1500°C (2730°F) for one half to one hour as part of the initial start-up procedure.

Naturally, these basic instructions are not applicable to all furnaces. On large furnaces it is often advisable to dry out the brickwork by means of a separate source of heat before installing the Kanthal® Super elements.

REPLACEMENT OF ELEMENTS

One of the greatest advantages of Kanthal® Super elements is that a defective element can easily be replaced without the furnace having to be cooled down. Vertically mounted elements are replaced as follows:

After having located the defective element, unbolt the contacts from the busbars and remove the ceramic fiber around the upper part of the passage brick, after which the element and the passage brick may be lifted out. A previously assembled unit consisting of a new element complete with passage brick and element holders now should be inserted through the hole in the furnace roof.

The contacts which have been removed from the damaged element can be used again providing that they are undamaged. If the contact surfaces are oxidized or damaged to such an extent that they cannot be restored to a serviceable condition, they should be replaced.

TEMPERATURE CONTROL

The type of thermocouple used for temperature control depends on the furnace temperature. Type K has good stability to 1200°C (2190°F) and can be used in many heat treating furnaces. Temperature measuring above 1200°C (2190°F) is usually performed with thermocouples made of platinum-platinum/rhodium.

Thermocouples age faster the higher the furnace temperature is. In Pt-Pt/Rh thermocouples there is a structural change in the platinum and diffusion of rhodium occurs at the junction. Problems with temperature corrosion and overheated Kanthal® Super elements are often related to ageing thermocouples.

By alloying the platinum with rhodium the usable temperature increases. A high content of rhodium in both shanks gives the highest permissible furnace temperature. When the rhodium content is increased, the EMF (electromotive force) decreases and this affects the accuracy of the measurement. When thermocouples are utilized at the maximum classifying temperatures, it is important to check the EMF frequently in order to avoid increased furnace temperature due to the ageing. In high temperature furnaces with Kanthal® Super 1900 elements operating at furnace temperatures above 1750°C (3180°F), using Pt/20% Rh – Pt/40% Rh, it has been found that the EMF can have decreased significantly after only 4–5 hours at furnace temperature. By the time this has occurred, the thermocouple has become more stable and the change is slower with time. This thermocouple has a low thermoelectric output and small changes can lead to large variations in the furnace temperature and element temperature with subsequent element problems.

SAFETY PRECAUTIONS

Use dark glasses when observing glowing Kanthal® Super elements. The eyes are subjected to great strain when observing temperatures above 1400°C (2550°F).

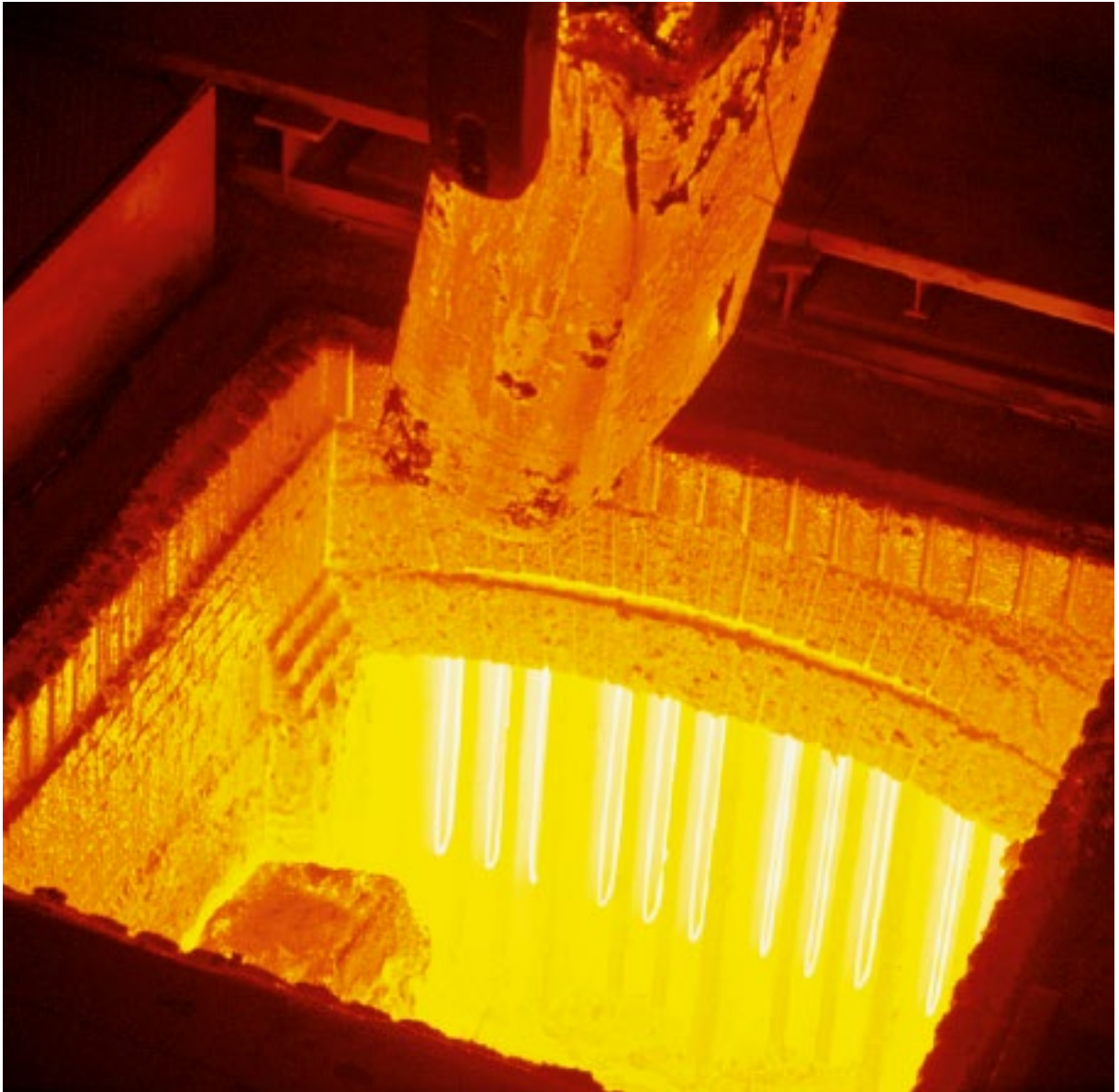
Kanthal® Super elements which have been operating for a long time at high temperature and have then cooled down sometimes have internal stresses which cause the glaze to splinter into small fragments. There have been instances where elements which have been cold for several days have emitted a shower of fine glaze particles when touched.

Always use eye protection even when handling cooled down Kanthal® Super elements.

For high temperature furnaces we recommend two thermocouple positions close to each other in the roof. One thermocouple for the controller and the SCR, the other to check the operating thermocouple and the actual furnace temperature. It is important that the thermocouple for checking is exposed to the furnace temperature only when the checks are being carried out.

STANDARD PLATINUM – PLATINUM/RHODIUM THERMOCOUPLES

	MAX. SERVICE TEMPERATURE			
	CONTINUOUS		INTERMITTENT	
	°C	°F	°C	°F
Pt/Pt 10 Rh, Type S	1400	2550	1650	3000
Pt/Pt 13 Rh, Type R	1400	2550	1650	3000
Pt 6 Rh/Pt 30 Rh, Type B	1500	2730	1800	3270
Pt 20 Rh/Pt 40 Rh	1600	2910	1800	3270



Kanthal® Super furnace for ingot heating.

TROUBLESHOOTING

Kanthal® Super is a long lasting heating element due to its low ageing rate. Installed according to our recommendations, their life is to most operator's satisfaction.

Element life is limited due to several reasons, but the major reason for failure is rarely due to material faults or workmanship.

The design of the element lead through is critical for optimum element life.

The most common reasons for element failure, which we have seen have been due to:

CARELESS HANDLING

- Handling of element packages by the carriers whilst in transit.
- Handling of elements by the customer after being removed from the package.

MECHANICAL DAMAGE

Breakage of elements after being installed in the furnace e.g. bumping into an element with a wrench or elbow when carrying out repair work inside a furnace. Also, breakages when elements are removed before relining a furnace.

MECHANICAL STRESS

- All roof suspended elements should be hung freely to allow unrestricted movement of the element shanks during expansion and contraction due to electromagnetic forces and thermal expansion.
- Any binding-sticking of the elements during thermal cycling can result in mechanical and thermal stresses. If this is the case, the element will typically break around the fusion welded joint between the heating zone and terminals.
- The contact straps should be long enough so that no stresses are transferred to the elements. If there is sufficient space available, it is preferable to use busbars or terminal posts for series connecting elements as the risk of damaging adjacent elements will be reduced when replacing individual elements.

CHEMICAL ATTACK

Compounds and gases, which may have a detrimental effect on Kanthal® Super material is covered in Part I: Products and accessories, pages 6–9.

OVERHEATED ELEMENTS

When the element temperature exceeds the limit for each of the three qualities, the silica in the material starts to boil. The MoSi₂ depletes through evaporation of the silica and the hot zone shows signs of surface cracking and is pitted in appearance. The effect is the same if part of the hot zone is restricted to radiate freely. If one side of the hot zone is too close either to the furnace wall or some other restriction, this side can show signs of overheating.

OVERHEATED CONTACTS

Either one or a combination of the following items can cause too high a temperature on the contacts:

- Chimney effect.
- Terminal length protruding outside the furnace being too short.
- Contacts become loose.
- Poor roof insulation (insufficient thickness, quality, cracking or degradation).
- Poor ventilation over the contacts.

CHIMNEY EFFECT

The terminals should be sealed at the cold face with ceramic fiber to prevent convective and radiant heat losses (elements must still be able to move freely).

TERMINAL LENGTH TOO SHORT

It is quite common to see installations where the contacts are very close to the holders.

LOOSE CONTACTS

Can cause thermal shock breakages due to sparking between contact and terminal end. Symptoms: partly melted contacts, thermal cracking of terminal end due to arcing.

When low temperature oxidation (pest) occurs underneath the aluminizing, the temperature has been far too high. The effect is the same as with loose contacts.

CONTROL, POWER SUPPLY AND WIRING



MATERIAL CHARACTERISTICS

Kanthal® Super has two basic material properties that call for special attention when designing the control system.

1. The resistivity increases steeply with temperature (see resistivity curve in the diagram on page 11 in Part I: Products and accessories, "Resistivity of Kanthal® Super"). The resistance of an element at 20°C is about 11 times lower than the resistance of the same element at 1500°C (2730°F). Hence, if full voltage is applied when starting, a peak current of 11 times the nominal current will flow through the element. This would cause fuse blowing or thyristor failure.
2. The material is brittle at low temperature which means that excessive amperage may cause electromagnetic forces large enough to fracture the element.

CONTROL IN GENERAL

The low cold resistivity of Kanthal® Super implies that full operational voltage cannot be applied to a cold furnace.

In the past, only tapped transformers were available, allowing a reduced voltage to be applied when the furnace was cold, and then the voltage was gradually increased as the elements heated up, thus maintaining currents within manageable levels.

With the advent of modern thyristor (SCR) power control units and the various feedback control features available today, we now have a reasonably economical and reliable means of limiting the start-up currents and taking full advantage of the rapid heat-up capability of Kanthal® Super.

Today furnaces equipped with Kanthal® Super elements are controlled in the following ways:

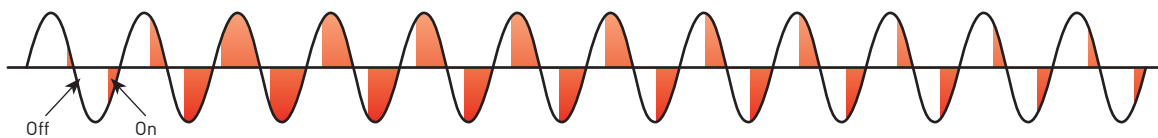
THYRISTOR CONTROL

1. Phase-angle fired thyristors with or without a transformer.
2. Burst fired thyristors with phase-angle start with or without a transformer.

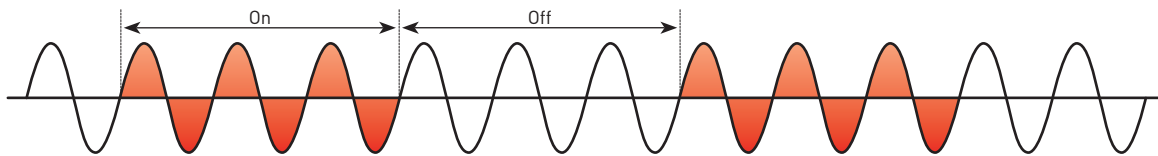
ON/OFF CONTROL

3. Tapped transformer.
4. Contactor switch, changing the element connection.

a) Phase-angle firing



b) Burst firing



c) Burst firing with phase-angle start

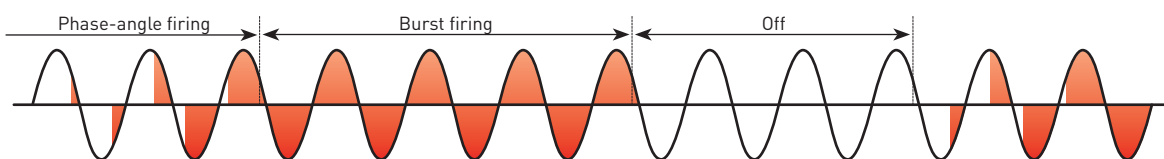


Fig. 1 Thyristor firing modes.

THYRISTOR CONTROL

PHASE-ANGLE FIRING

In phase-angle firing the power is controlled by allowing the thyristors to conduct for a part of the AC cycle only (see fig. 1a). The thyristor should have a current ramp turn on function and a RMS (root mean square) current limit facility. It should be noted that this is not the same as the ramp function of the temperature controller.

The thyristor starts to conduct with a small conduction angle and then it increases towards maximum conduction during a number of periods. The more power needed, the larger part of the sinusoid is allowed to pass through the thyristors. If maximum permitted current is attained before full wave, the current limit facility does not permit further increase of the conduction angle.

It is essential that the current is both measured and limited in the RMS method. The reason for this is that in phase-angle firing, one is working with distorted current wave forms, and then the RMS method of current measuring is the only way to obtain a correct and meaningful value.

The ramp turn on function is required for the thyristor to work properly and gives the current limit function time to work.

The main disadvantage of phase-angle firing is that it generates radio frequency interference that may cause malfunction in sensitive electronic equipment.

BURST FIRING WITH PHASE-ANGLE START

In burst firing the power is controlled by allowing the thyristors to be conductive for one or more complete cycles and then non-conductive for one or more cycles. The higher the power needed, the more conductive cycles and the fewer non-conductive there are (see fig. 1b).

A burst fired thyristor switches on and off when the instantaneous current is zero and therefore creates less transients than non-synchronized equipment.

A usual method of dealing with the disadvantages of phase-angle firing and burst firing is to use a combination of them (see fig. 1c). Phase-angle firing is used during the heating up of the furnace so that the current can be sufficiently limited without using a step-down transformer with different voltage taps. When the furnace reaches a preset temperature below furnace temperature, at least at 600–800°C (1110–1470°F), an automatic switch is turned to burst firing mode. In this way negligible radio frequency interference is created once the furnace is hot.

Fig. 2 and 3 on pages 51–52 show applications with thyristor control.

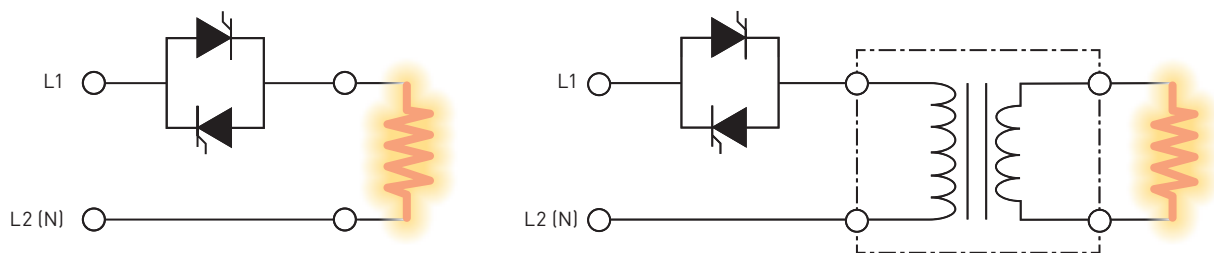
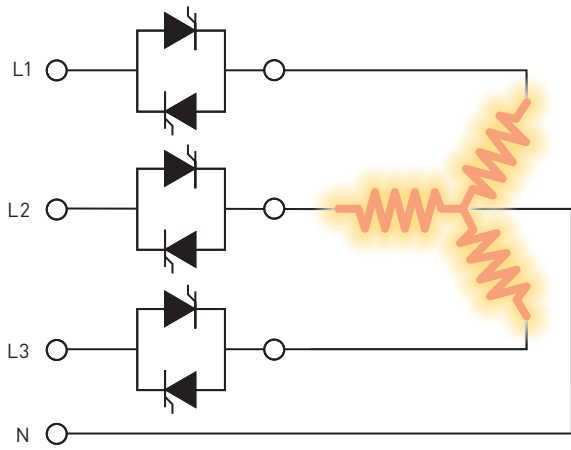
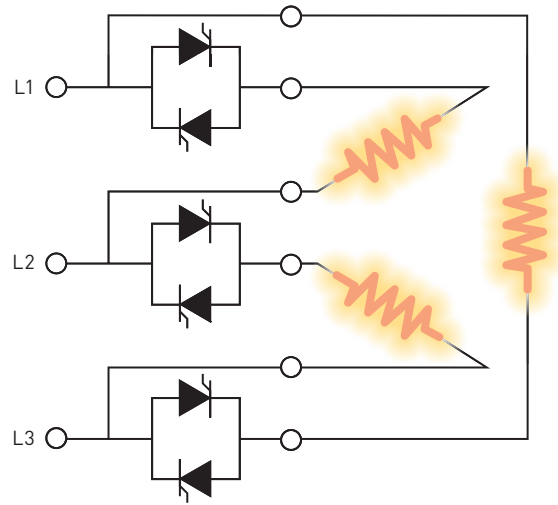


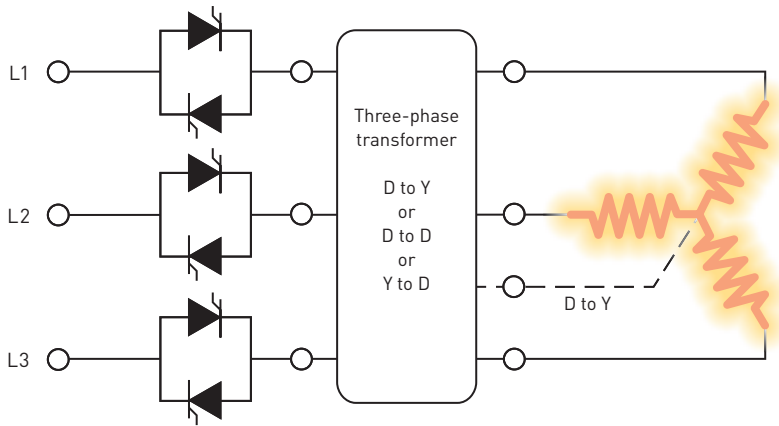
Fig. 2 Single-phase applications with thyristor (SCR) control.



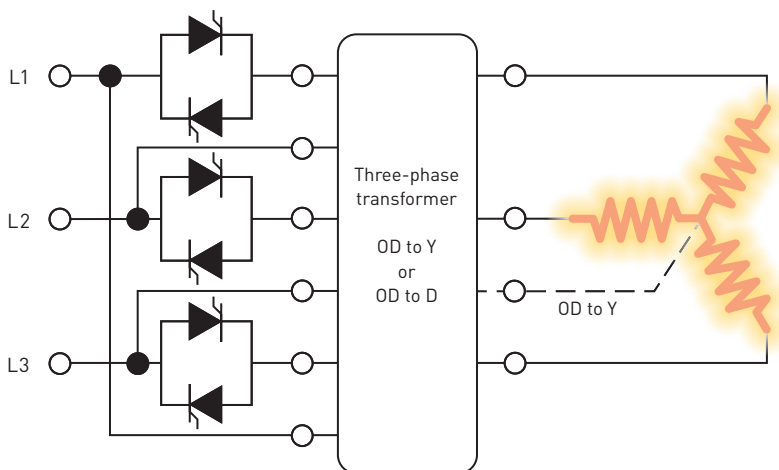
a. Four-wire star.



b. Three-wire open delta.



c. Transformer and star or delta load.



d. Six-wire open delta with transformer and star or delta load.

Fig. 3 Three-phase applications with thyristor (SCR) control.

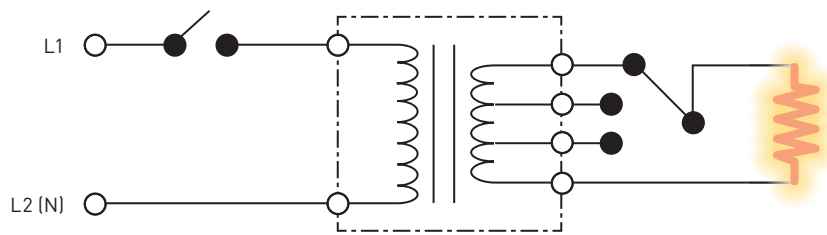
ON/OFF CONTROL

TAPPED TRANSFORMER

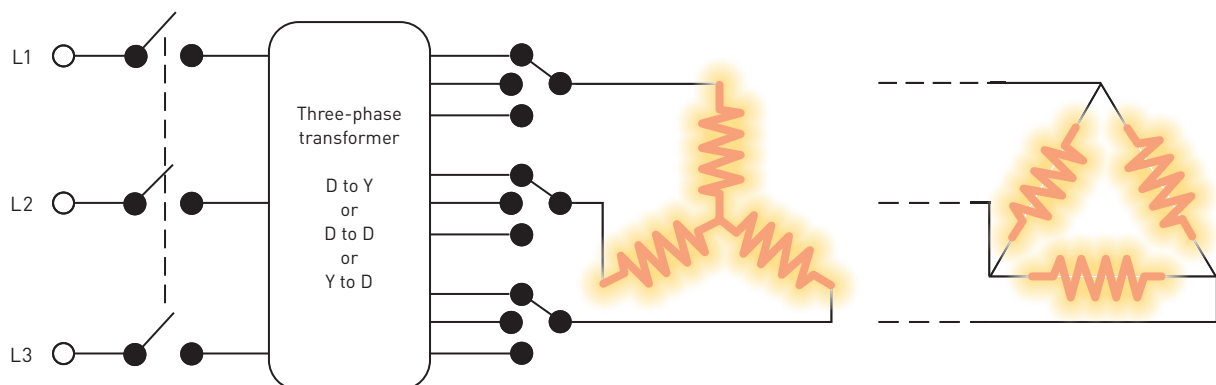
Controlling a furnace with Kanthal® Super elements by a contactor regulated on/off system and a tapped transformer has some disadvantages compared to thyristor control. The main disadvantages are longer on/off periods, which results in less accuracy in temperature control and non-synchronized switching, which means that it creates more transients. There is also mechanical wear on the contactor.

Transformers for stepless voltage regulation are sometimes used to provide accurate control of the energy input in line with the actual requirement.

Fig. 4 below, shows applications with on/off control and tapped transformer.



a. Transformer, single-phase application.



b. Transformer and star or delta load, three-phase application.

Fig. 4 Applications with on/off control.

CONTACTOR SWITCH, CHANGING THE ELEMENT CONNECTION

Fig. 5 on page 54 shows a wiring diagram with the elements star-connected to line voltage. By series-connecting all elements between one phase and neutral, the starting voltage is reduced to 33% of full operating voltage. The intermediate step is to connect the elements in series between two phases, which corresponds to 58% of operating voltage. Finally, the elements are switched to star connection.

Fig. 6 on page 55 shows a wiring diagram with the elements delta-connected to line voltage. By series-connecting all elements between two phases, the starting voltage is reduced to 33% of full operating voltage. The intermediate step is to connect the elements in star, which corresponds to 58% of operating voltage. Finally, the elements are switched to delta connection.

At start-up, all elements can also be series-connected between one phase and neutral and the starting voltage is reduced to 19% of full operating voltage.

DIRECTLY STAR-CONNECTION TO LINE VOLTAGE

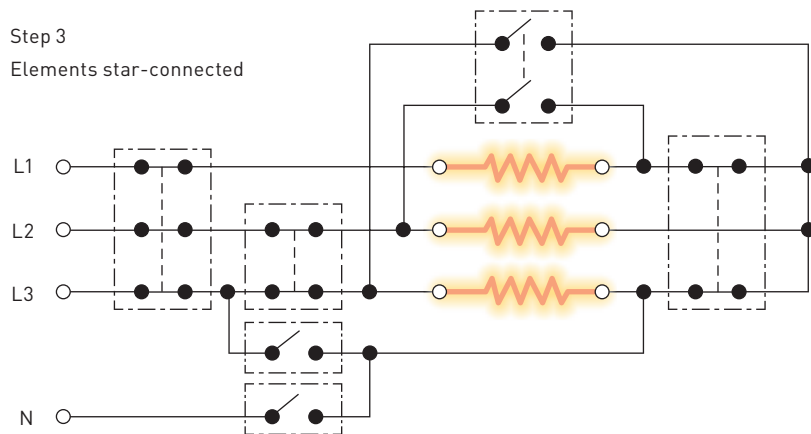
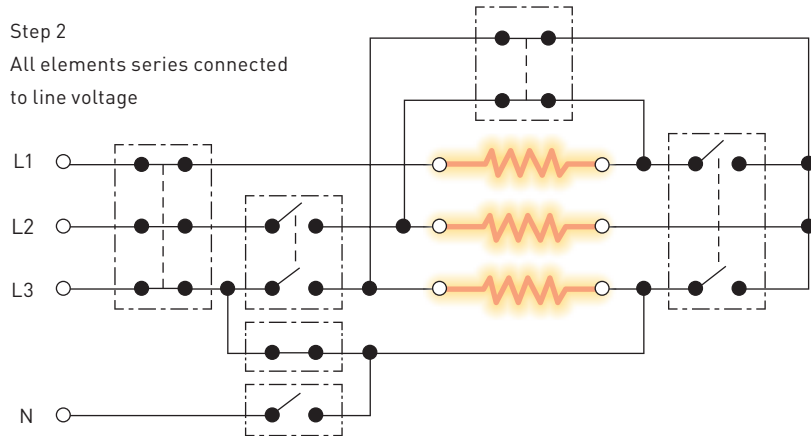
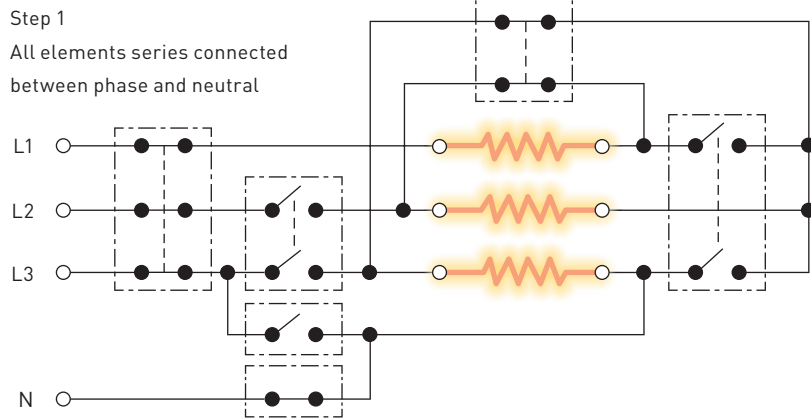
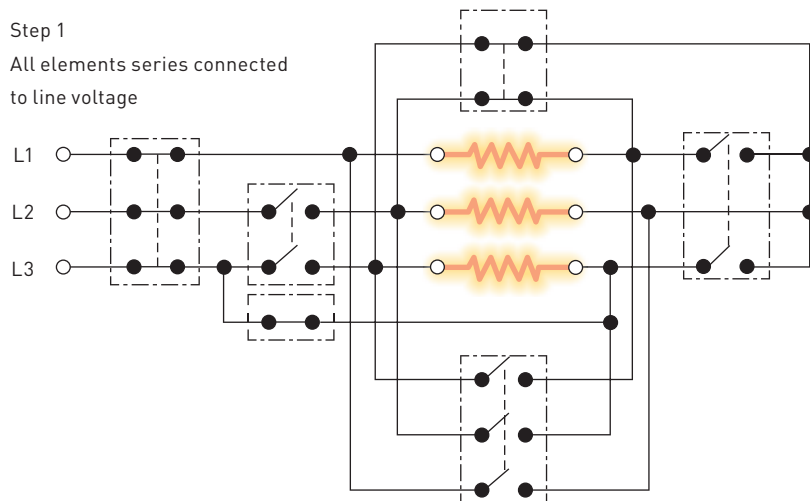


Fig. 5 Wiring diagram for Kanthal® Super elements directly star-connected to line voltage.

DIRECTLY DELTA-CONNECTION TO LINE VOLTAGE

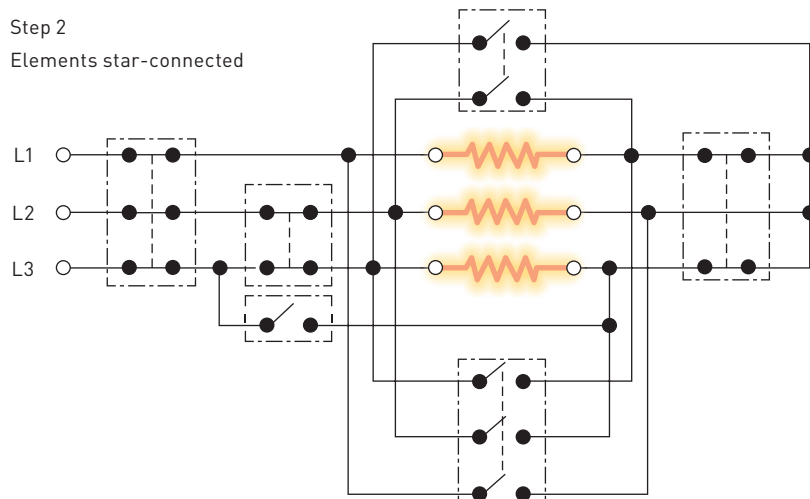
Step 1

All elements series connected to line voltage



Step 2

Elements star-connected



Step 3

Elements delta-connected

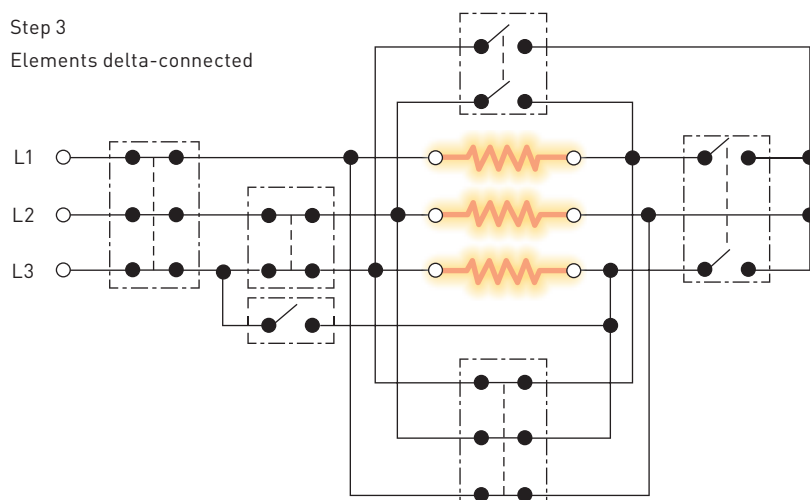


Fig. 6 Wiring diagram for Kanthal® Super elements directly delta-connected to line voltage.

SCOTT-CONNECTED TRANSFORMERS

When the number of elements is such that a symmetrical three-phase load on the secondary side of the transformer is not possible e.g. 4, 8, 10, 14 etc. and yet prefer a symmetrical three-phase load on the primary side a scott-connected transformer should be used.

Note:

Scott-connections with thyristor control require particular attention for successful operation. Consult Kanthal for advice.

When the load is equal on the two secondary windings, the primary side will be symmetrically loaded. The two secondary phases are electrically displaced by 90°.

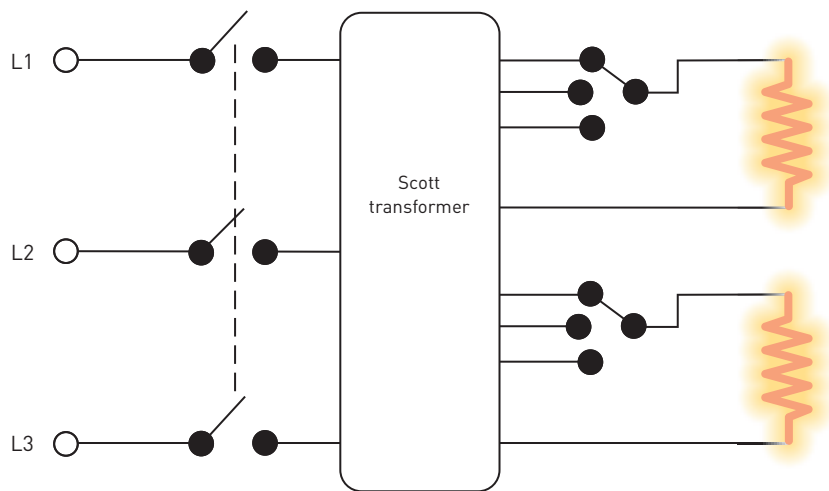


Fig. 7 Application with on/off control and tapped transformer.

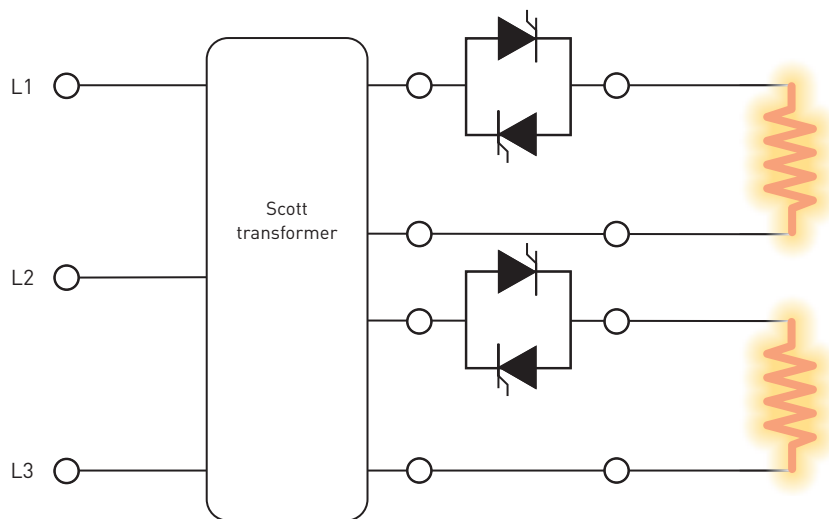


Fig. 8 Application with thyristor control.

CALCULATION OF TRANSFORMERS

THYRISTOR CONTROL

When a transformer is used in combination with thyristor control, it must be designed for working with thyristors. The main difference is that larger iron cores are needed than when using on-off control. The reason for this is to obtain a lower magnetic flux density through the core.

Typical values of flux density are for:

On/off controlled transformers: 1.6 T (Tesla)

Transformer with phase-angle fired thyristors: < 1.4 T

Transformers for on/off control can be used for phase-angle firing to 80% of their power rating.

The rating of the transformer for thyristor control is calculated in the following way:

1. The furnace power needed is determined.
2. The size of thyristor is decided.
3. The size of transformer is based on the maximum power that the thyristor needs to control. Generally the transformer is rated 10–20% higher than the furnace power.

ON/OFF CONTROL

When a transformer is used in combination with on/off control, it must be designed for the maximum continuous loading.

Generally it is accurate enough to calculate the power at full operating element voltage and the maximum current permitted for the actual element dimension. Maximum continuous element current for different element dimensions is:

ELEMENT SIZE:	3/6	4/9	6/12	9/18	12/24
CURRENT, A	75	115	200	365	560

When heating a furnace from room temperature the starting voltage is normally 1/3 or 1/4 of operating voltage to avoid overloading of the electrical equipment. Transformers provided with steps for 1/3, 2/3, or 1/4, 1/2, 3/4, and full operating voltage is utilized.

WIRING TO COUNTERACT ELECTROMAGNETIC FORCES

Current passing through two parallel conductors produces an electromagnetic force between them. If the current flows in the same direction in the two conductors, there is an attracting force and if it flows in the opposite direction there is a repelling force.

Hence, in a two-shank Kanthal® Super element, a repelling force is set up between the two shanks, which leads to an increase in the distance, *a*, between the shanks of the heating zone.

The result of the repelling force and gravitation on the heating zone of a vertically mounted Kanthal® Super element means that a state of equilibrium tends to be reached.

The degree of deformation depends on the amperage *I*, the length of the heating zone *L_e*, and the distance between the shanks *a*.

The diagram "Deformation of Kanthal® Super", page 15 in Part I: Products and accessories, shows how to calculate the distances necessary to counteract the effect of electro-magnetic force on Kanthal® Super elements.

The effect of the repelling force is reduced if the distance between the shanks is increased. It has been found from practical experience that to avoid excessive deformation, the minimum value of, *a*, should not be below the following:

ELEMENT SIZE	MINIMUM A	NORMAL A
12/24	50 mm (2 in)	80 mm (3.1 in)
9/18	40 mm (1.5 in)	60 mm (2.4 in)
6/12	25 mm (1 in)	50 mm (2 in)
4/9	20 mm (0.8 in)	25 mm (1 in)
3/6	20 mm (0.8 in)	25 mm (1 in)

If two or more elements are installed together, it is important that they are connected in such a way that the current flows in the opposite direction in two adjacent shanks that are placed close together. Theoretically, if

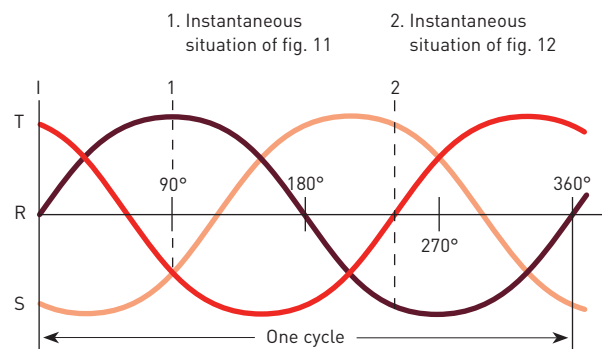


Fig. 9 Sine curve variations in a three-phase system.

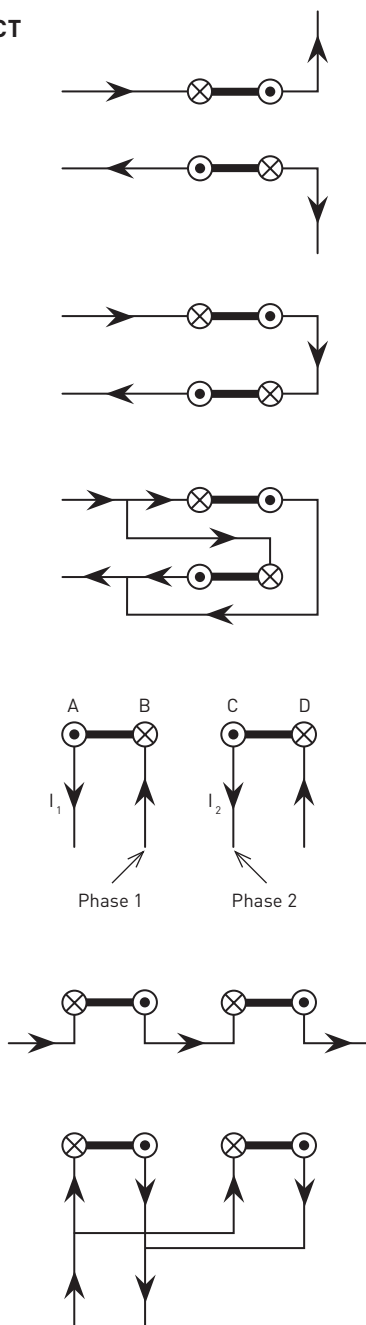
all the repelling effects are of the same magnitude, they balance each other and do not increase the distance between the element shanks. Normally, the distance between adjacent elements is greater than, a , and consequently the repelling effect between the two shanks of an element will dominate. The result is an increase in, a .

In the case of element groups connected to a three-phase supply, the connecting points should be combined in such a way that the currents in the adjacent shanks of two Kanthal® Super elements have a phase

displacement of 120°. Regardless of the phase displacement, it is always a repelling force which occurs between the two shanks of a Kanthal® Super element, and which varies between zero and maximum, see fig. 9.

In fig. 10 "Correct" below, the electromagnetic force between shank "B" (through which a current " I_1 " flows) and shank "C" (through which a current " I_2 " flows) produces a repelling effect due to the angular displacement between the two phases to which the elements are connected.

CORRECT



INCORRECT

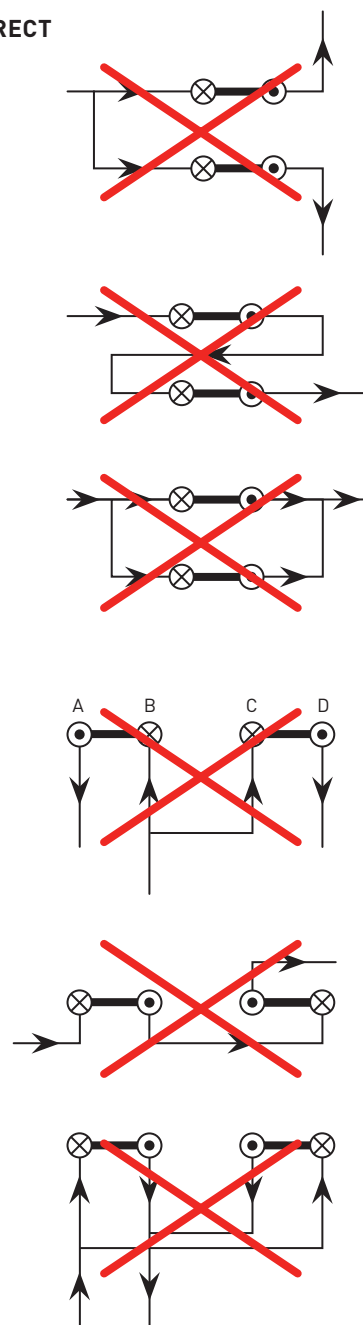


Fig. 10 Examples of correct and incorrect connections.

In three-phase systems the connecting points should be combined in such a way that the currents in the adjacent shanks of two Kanthal® Super elements have a phase displacement of 120°. Any other connection should be avoided, since the magnetic force will then have a predominantly attracting effect. This intensifies the effect of the repelling forces acting on the two elements, which can lead to severe deformation.

In order to facilitate the correct connection of Kanthal® Super elements to a three-phase supply, bearing in mind that the phases are 120° apart, the current flow directions should be regarded as in fig. 11 and 12 below, as follows:

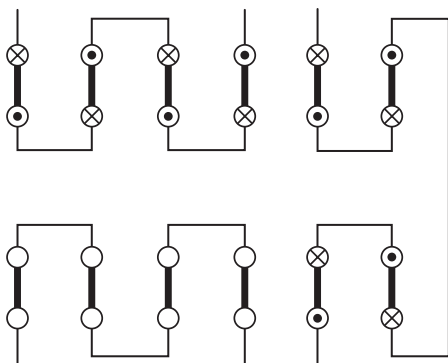


Fig. 11 Delta-connected arrangement.

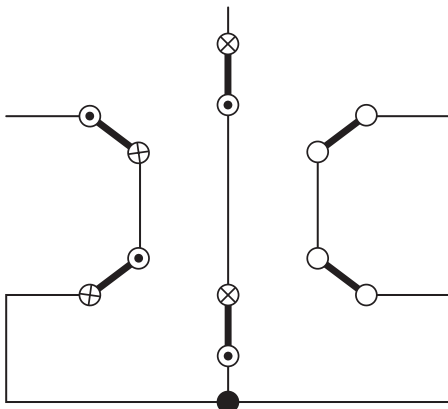


Fig. 12 Star-connected arrangement.

1. The current in two phases flow in opposite directions

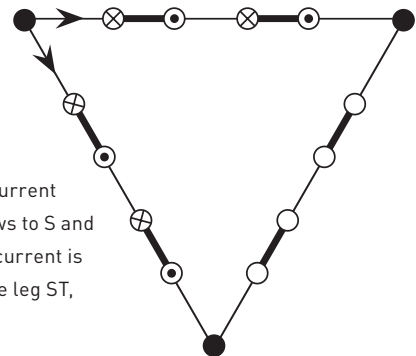
During part of the cycle the currents will flow in the same direction. The maximum attracting effect is obtained when the currents have half the value of the momentary maximum current. The average action, however, is repelling.

2. Two currents from the neutral point flow in opposite directions

The same as under 1. above.

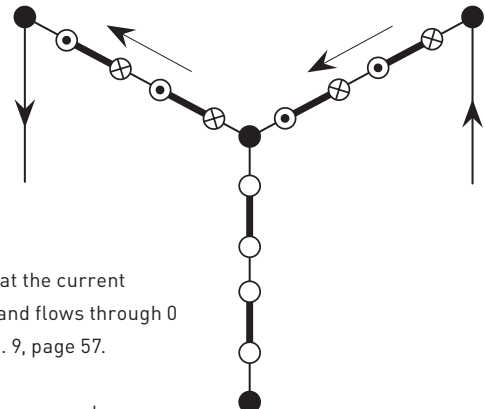
3. Two currents which come from a common phase connecting point flow in the same direction

Remember that two currents from a common phase connection always flow in the same direction. Adjacent elements must never be connected in parallel to the same phase.



Consider that the current enters in R and flows to S and T. Momentarily no current is passing through the leg ST, see fig. 9, page 57.

Then the same procedure starting from S and then T is followed.



Consider that the current enters in S and flows through 0 to R, see fig. 9, page 57.

Then the same procedure starting from T and then R is followed.

