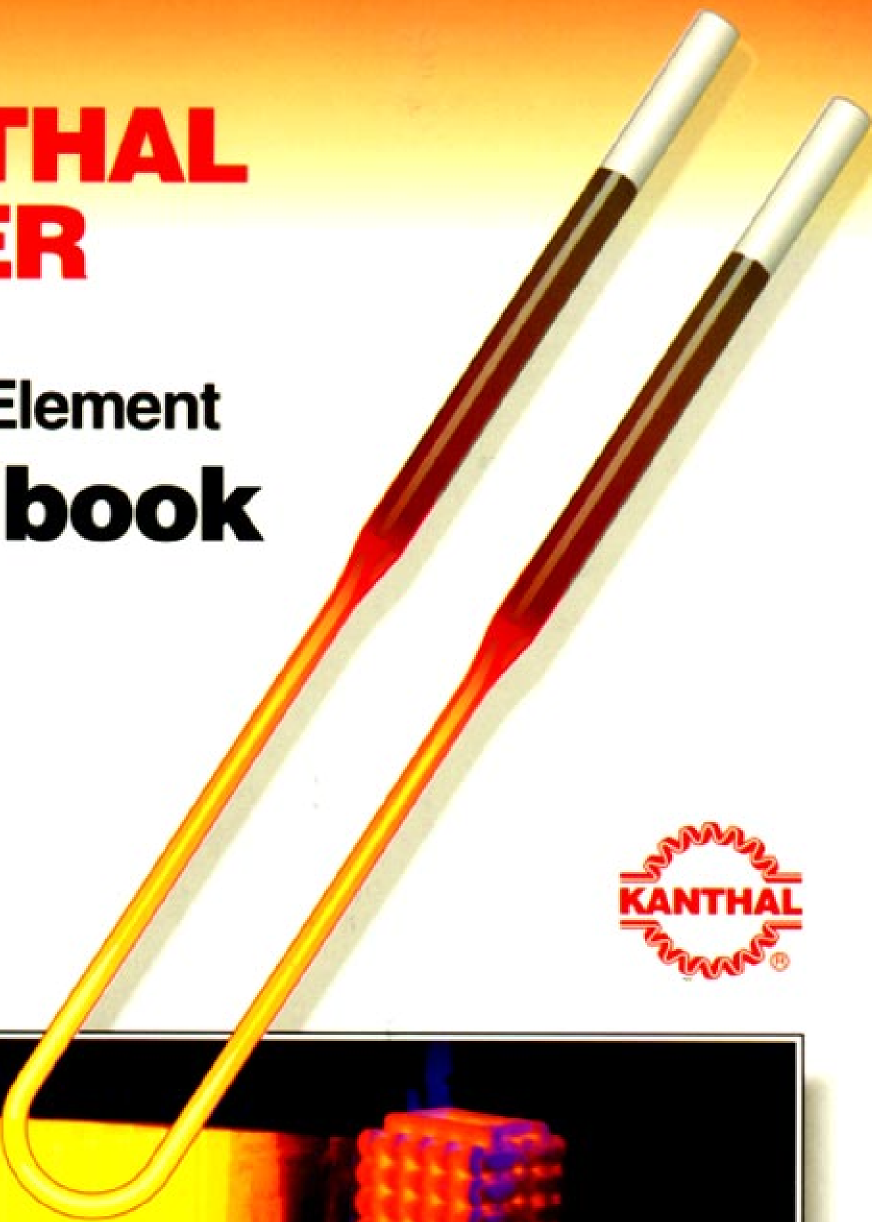
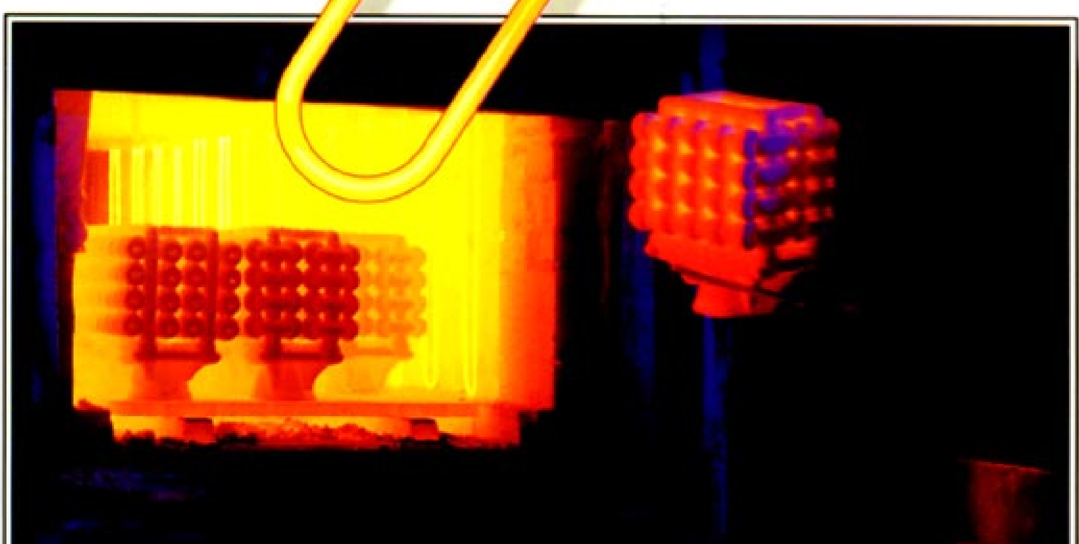
KANTHAL SUPER

Electric Heating Element

Handbook





KANTHAL®

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Electric Heating Element

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KANTHAL

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A Sandvik Company

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KANTHAL is a world-renowned name within the field of electric heating and you will find our handbook an indispensable aid when installing and operating our KANTHAL SUPER resistance elements that are designed for all types of electric heated industrial furnaces.

When we introduced the now world-famous KANTHAL iron-chromium-aluminium electric resistance alloys in the early thirties this represented a considerable rise in the maximum operating temperature of metallic resistance elements.

Again, when KANTHAL SUPER elements were introduced in 1956, this represented a step upwards on the temperature scale for resistance elements.

The aim of our R&D department, however, has always been to improve our materials to enable their use at still higher temperatures.

Through intense research work, we have been able to raise this temperature from 1650 °C (3000 °F) element temperature in 1956, to 1850 °C (3360 °F) today.

New element forms have also been developed and in this handbook you will find information about SUPERTHAL high temperature heating modules.

KANTHAL SUPER elements have proved to be very useful not only at high furnace temperatures, but also at lower temperatures, particularly in the field of heat treatment of metallic products in controlled atmospheres and melting of glass.

The fields of possible applications are unlimited and have yet to be fully investigated. With the increasing interest in electric heating, we can expect many new designs and applications in the future.

In addition to information on the properties of our KANTHAL SUPER material this handbook will also provide data on our standard elements and instructions for element calculation, installation, operation, etc. Further, advice is given on furnace designs, and some examples of actual KANTHAL SUPER element installations are shown in the installation section.

We have tried to give you enough information to enable you to calculate and install KANTHAL SUPER elements and how to operate furnaces. If our advice is followed, you will be assured of an efficient and economical installation for your special heat treatment operations.

If you need any further advice, specialists at our companies, our agents and the skilled staff at our technical service department in Hallstahammar will be pleased to assist you.

Hallstahammar, Sweden 1999
KANTHAL

Fig. 1 Range of KANTHAL SUPER 6/12, 9/18, 12/24 elements and SUPERTHAL heating modules.

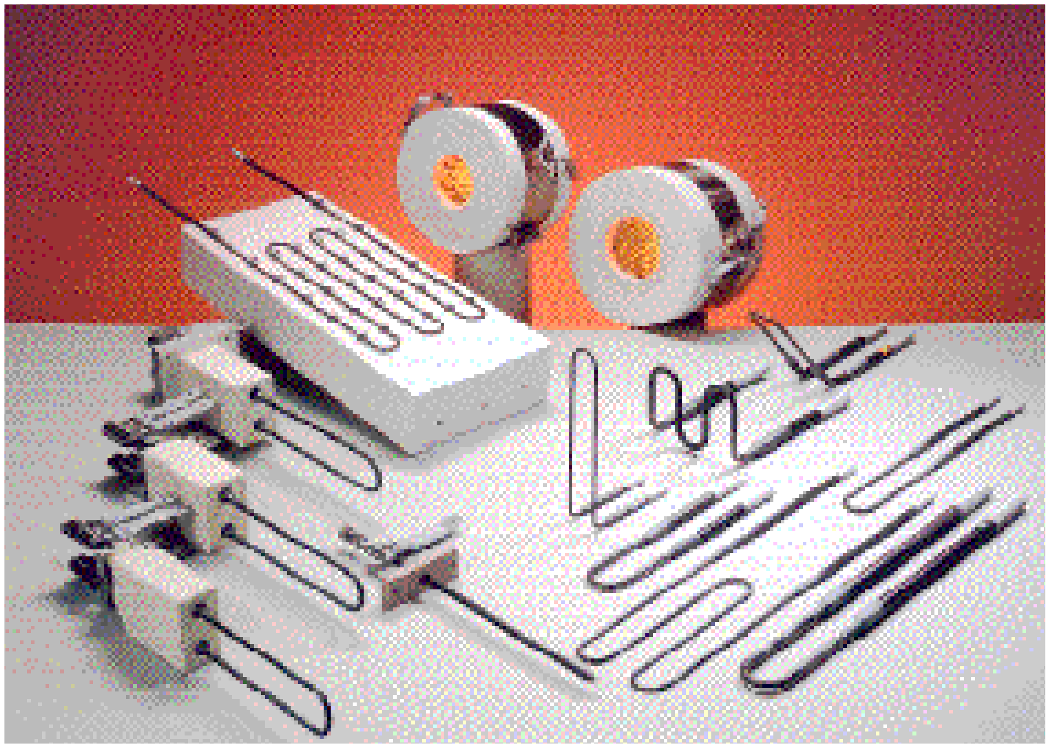
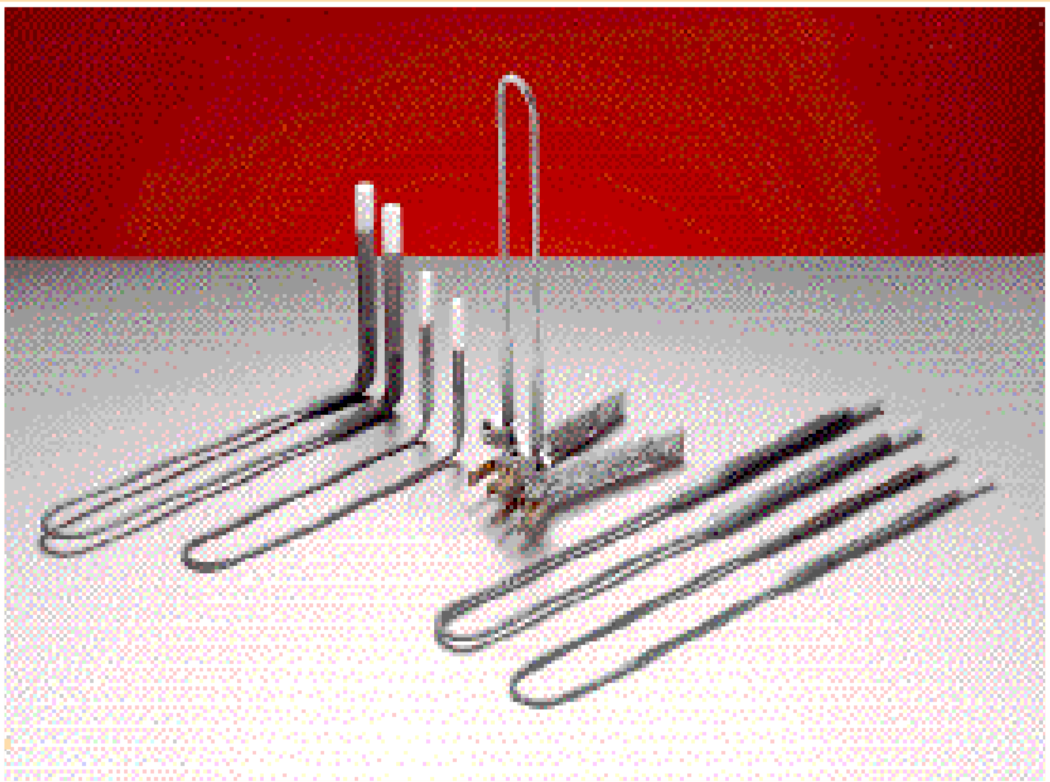


Fig. 2 Range of KANTHAL SUPER 3/6 and 4/9 elements.



1

Introduction

This is KANTHAL SUPER

Composition

KANTHAL SUPER is a dense cermet material consisting of $MoSi_2$ and an oxide component, mainly a glass phase.

KANTHAL SUPER has the ability to withstand 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.

The unique properties

1. The elements may be used in an oxidizing atmosphere up to an element temperature of 1850 °C (3360 °F).
2. Long life combined with ease of replacing failed elements contributes to a high degree of utilization of the furnace and low maintenance costs.
3. New and old elements can be connected in series.
4. High power concentration may be applied.
5. Can be used continuously or intermittently.
6. Fast ramping.

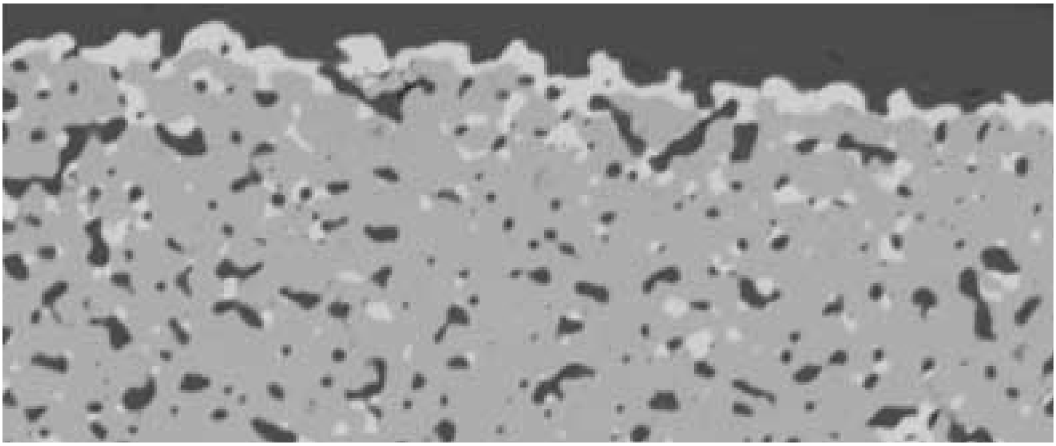


Fig. 3 Microstructure of a KANTHAL SUPER element. Grey= $MoSi_2$. White = Mo_5Si_3, Dark = SiO_2.

1 Quality and product summary

Type of element	Max. element temperature in air	General applications
KANTHAL SUPER 1700	1700 °C (3090 °F)	Most types of industrial furnaces for heat treatment forging, sintering, glass melting and refining and for use in radiant tubes.
KANTHAL SUPER 1800	1800 °C (3270 °F)	Laboratory furnaces, testing equipment and high temperature sintering production furnaces.
KANTHAL SUPER 1900	1850 °C (3360 °F)	Laboratory furnaces, testing equipment and high temperature sintering furnaces.
SUPERTHAL SMU/SHC 	1600 °C (2910 °F) 1650 °C (3000 °F) KANTHAL Super Excel	Laboratory furnaces, testing equipment, tube furnaces, diffusion furnaces and glass feeders.

Properties

Introduction

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 overheating 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 (≈ 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 63, Fig. 26, Resistivity for KANTHAL SUPER 1700, 1800 and 1900.

Mechanical and physical properties

Tensile strength at 1550 °C (2820° F)	100 Mpa± 25%
Bending strength at 20 °C (68° F)	450 Mpa ± 10%
Compression strength at 20 °C (68° F)	1400-1500 Mpa
Fracture Toughness, K_{IC}, at 20 °C (68° F)	3-4 $Mpam^{1/2}$
Hardness, HV, at 20 °C (68° F)	9 Gpa
Density, KS 1700 and KS 1800	5.6 g/cm^3
Density, KS 1900	6.5 g/cm^3
Porosity	< 1 %
Thermal conductivity:	
20 - 600 °C (68 - 1110° F)	30 $W\ m^{-1}\ K^{-1}$
600 - 1200 °C (1110 - 2190° F)	15 $W\ m^{-1}\ K^{-1}$
Coefficient of linear expansion	$7\text{-}8 \cdot 10^{-6}\ K^{-1}$
Specific heat capacity at 20 °C (68° F)	0.42 $kJ\ kg^{-1}\ K^{-1}$
Emissivity	0.70 - 0.80
Resistivity as a Function of Temperature, C_t	See page 63, Fig 26.

Table 1 The mechanical and physical properties of the KANTHAL SUPER electric heating material.

Chemical resistance

Atmospheres

KANTHAL SUPER can be used in most furnace atmospheres. Most favourable are oxidizing atmospheres such as air, carbon dioxide and water vapour, but KANTHAL SUPER elements are also operating successfully in neutral, reducing and carburizing atmospheres.

Table 2 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, M_0O_3 and has normally no detrimental effect on the performance of KANTHAL SUPER elements.

Water vapour and carbon dioxide

Water vapour and carbon dioxide in any amount in the atmosphere have an oxidizing effect. The presence of water vapour 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.

KANTHAL SUPER element	1700		1800		1900	
Atmosphere	**°C**	**° F**	**°C**	**°F**	**°C**	**°F**
Air	1700	3090	1800	3270	1850	3360
Nitrogen	1600	2910	1700	3090	1800	3270
Argon, Helium	1600	2910	1700	3090	1800	3270
Dry hydrogen, dewpoint -80 °C (-112 °F)	1150	2100	1150	2100	1150	2100
Moist hydrogen, dewpoint 20 °C (68 °F)	1450	2640	1450	2640	1450	2640
Endogas (Ex. 40% N_2, 40% H_2, 20% CO)	1400	2550	1450	2640	1450	2640
Cracked and partially burnt ammonia	1400	2550	1400	2550	1400	2550

Table 2 Maximum recommended element temperatures in atmospheres.

Endogas

A typical gas composition is: 20% CO,40% H_2 and balance N_2. Since hydrogen is present in this gas composition, the dewpoint and gas velocity are important for determining the maximum temperature.

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.

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 dewpoint 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 dewpoint 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

2

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.

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 dewpoint the maximum permissible element temperature can be increased (Fig. 4). Installation of the elements in niches can reduce the gas flow around the elements, and this can help to reduce the chemical attacks.

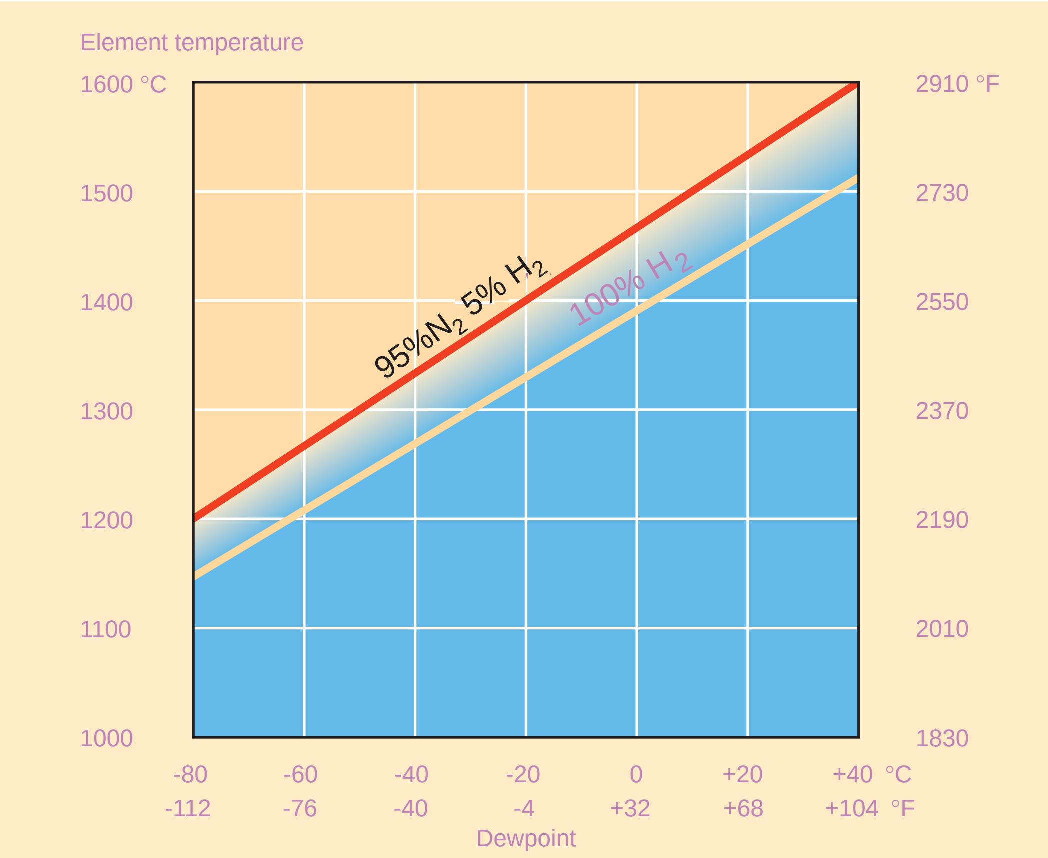


Fig. 4 Maximum element temperature in hydrogen atmospheres (All KANTHAL SUPER qualities).

Nitrogen and hydrogen

This 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 dewpoint of the gas mixture and the gas velocity are always very important (See diagram Fig. 4, page 14). Special heat treatment will improve the performance.

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. Fig. 5 shows the maximum permissible element temperatures at different air pressures.

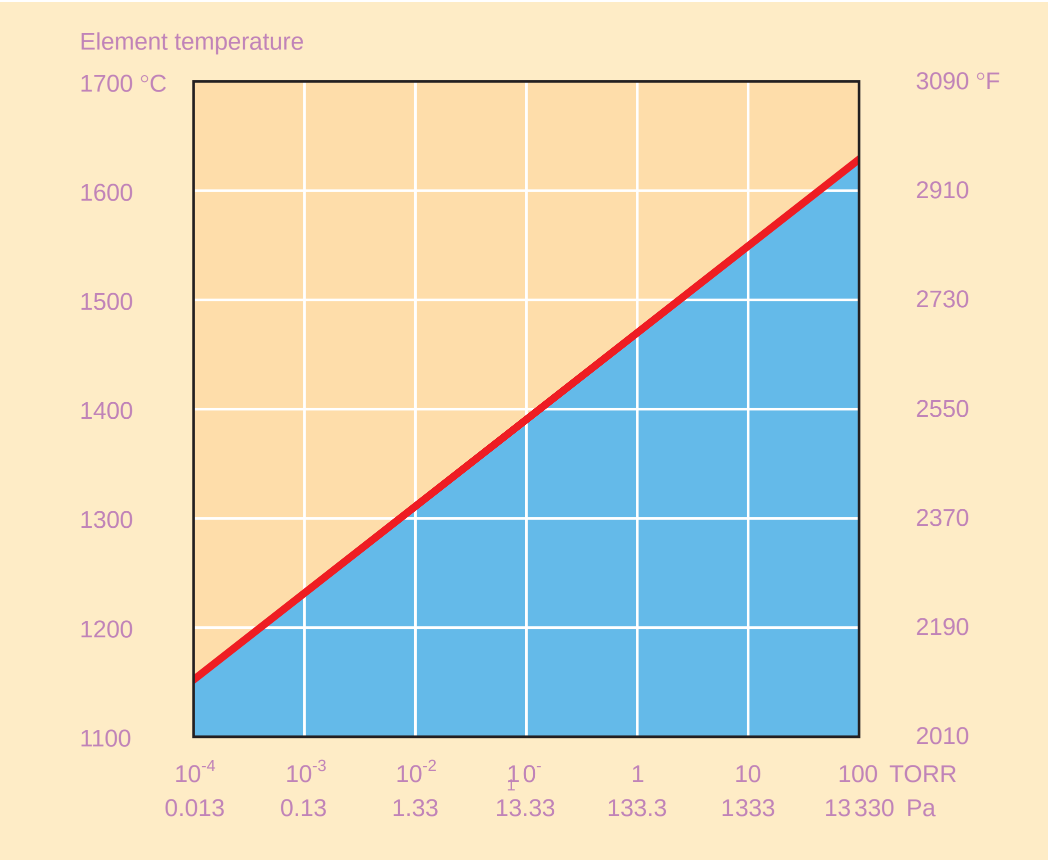


Fig. 5 Maximum element temperatures in vacuum (All KANTHAL SUPER qualities).

Metals

All metals in direct contact with KANTHAL SUPER react with $MoSi_2$, forming silicides. At higher furnace temperatures, vapours 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.

3

Elements and Tubes

The most commonly used design is a two-shank “U”-shaped element (Fig. 6, page 18). 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. 7 - 10, pages 18 - 19).

Four-shank elements are used (Fig. 11) only horizontally. KANTHAL SUPER is also available as a SUPERTHAL heating unit (Pages 25 – 32).

Two-shank elements

Two-shank elements with straight terminals are defined by:

- The quality
- Heating zone diameter, mm
- Terminal diameter, mm
- Terminal length, L_u, mm (in.)
- Heating zone length, L_e, mm (in.)
- Centre distance between shanks, a, mm (in.)

Example: KANTHAL SUPER 1700 9/18 L_u = 450 (17.7 in.)
L_e = 560 (22 in.)
a = 60 (2.36 in.)

The maximum length of the heating zone depends on the element temperature. Fig. 12, page 21 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 L_e longer than 400 mm (15.8 in).*

Qualities			**Standard dimensions**	
1700	**1800**	**1900**	**Heating zone, L_e ø mm**	**Terminal, L_u ø mm**
	X	X	3	6
	X	X	4	9
X	X	X	6	12
X	X	X	9	18
X	X		12	24

Table 3 Range of KANTHAL SUPER two-shank elements.

3

Terminal shapes:

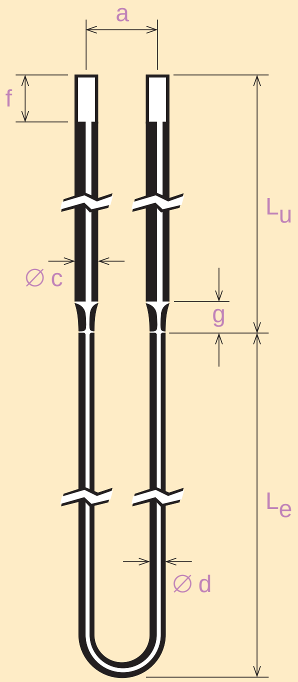


Fig. 6 Straight terminals.

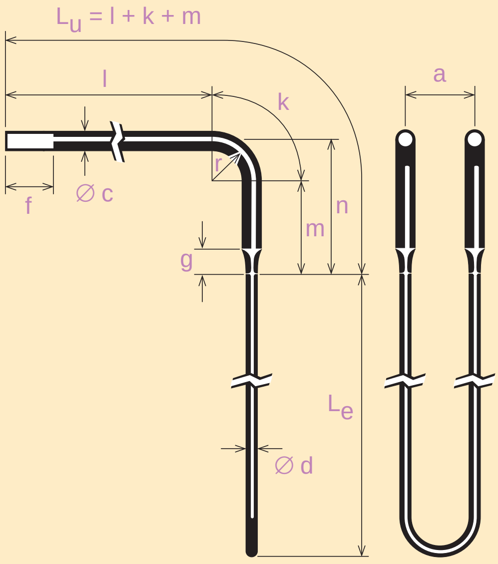


Fig. 7 Element bent 90° at the terminals.

The following parameters are valid for all KANTHAL SUPER elements.

Dimensional tolerances ± 5% (except c and d).

Element size	a mm		c mm	d mm	f mm	g mm	$k_{90°}$ mm	$k_{45°}$ mm	m mm	n mm		r mm	
	Standard	Minimum								Standard	Minimum	Standard	Minimum
3/6	25	20	6	3	25	15	19	9	30	42	37	12	
4/9	25	20	9	4	25	15	19	9	35	47	37	12	
6/12	50	25	12	6	45	25	47	24	60	90	80	30	20
9/18	60	40	18	9	75	30	71	35	90	135	110	45	30
12/24	80	50	24	12	100	40							

Element size	a in.		c in.	d in.	f in.	g in.	$k_{90°}$ in.	$k_{45°}$ in.	m in.	n in.		r in.	
	Standard	Minimum								Standard	Minimum	Standard	Minimum
3/6	1.0	0.79	0.24	0.12	1.0	0.6	0.75	0.35	1.18	1.65	1.44	0.47	
4/9	1.0	0.79	0.35	0.16	1.0	0.6	0.75	0.35	1.38	1.85	1.44	0.47	
6/12	1.97	1.0	0.47	0.24	1.8	1	1.85	0.94	2.36	3.55	3.15	1.18	0.79
9/18	2.36	1.57	0.71	0.35	3.0	1.2	2.8	1.38	3.71	5.31	4.33	1.77	1.18
12/24	3.15	1.97	0.95	0.47	4.0	1.6							

Table 4 Parameters of KANTHAL SUPER Elements.

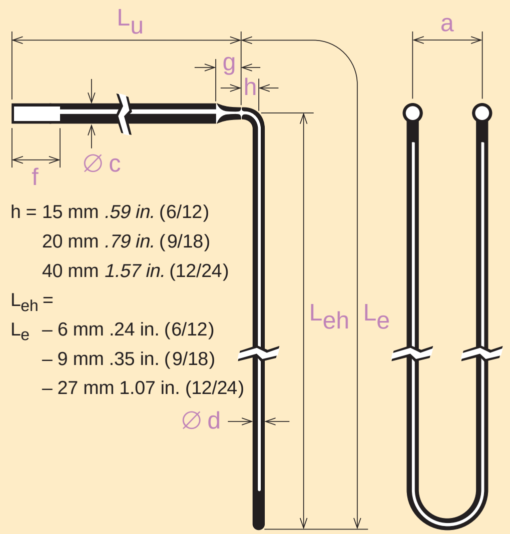


Fig. 8 Element bent 90°.

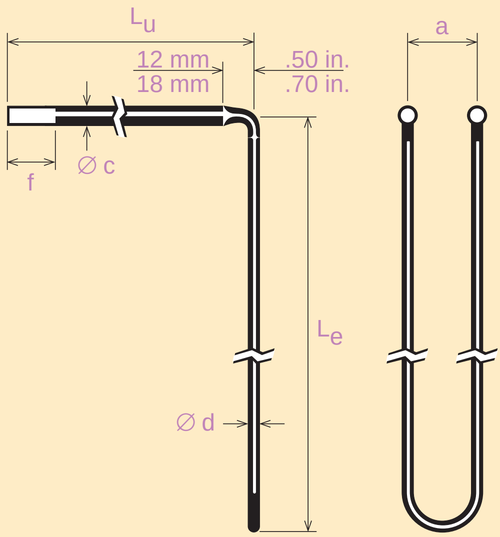


Fig. 9 3/6 and 4/9 element bent 90°.

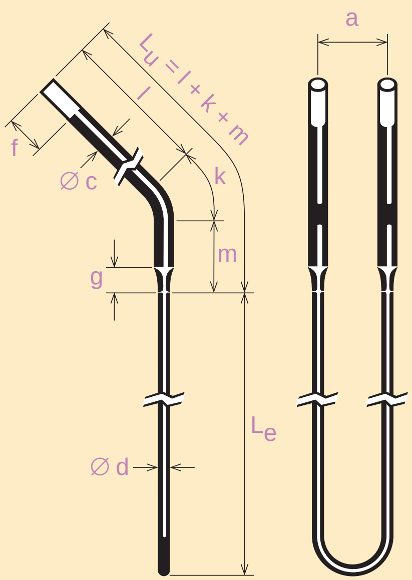


Fig. 10 Element bent 45° at the terminals.

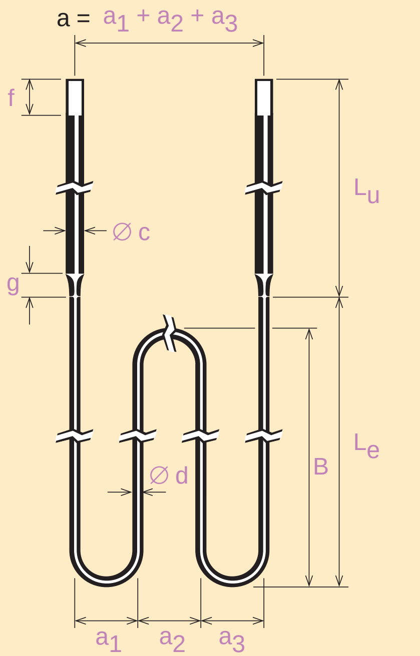


Fig. 11 Four-shank element for horizontal use

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 fibre, which normally limits the maximum temperature to 1600 °C (2910 °F) furnace temperature.

Four-shank 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. 11, page 19) are defined by:

- The quality
- Heating zone diameter, mm
- Terminal diameter, mm
- Terminal length, L_u, mm (in.)
- Heating zone length, L_e, mm (in.)
- Heating zone length, B, mm (in.)
- Centre distances between shanks, a, mm (in.)

Example: KANTHAL SUPER 1700 9/18
L_u = 450 (17.7 in.),
L_e = 450 (17.7 in.),
B = 400 (15.8 in.),
a = 3 x 60 (3 x 2.36 in.)

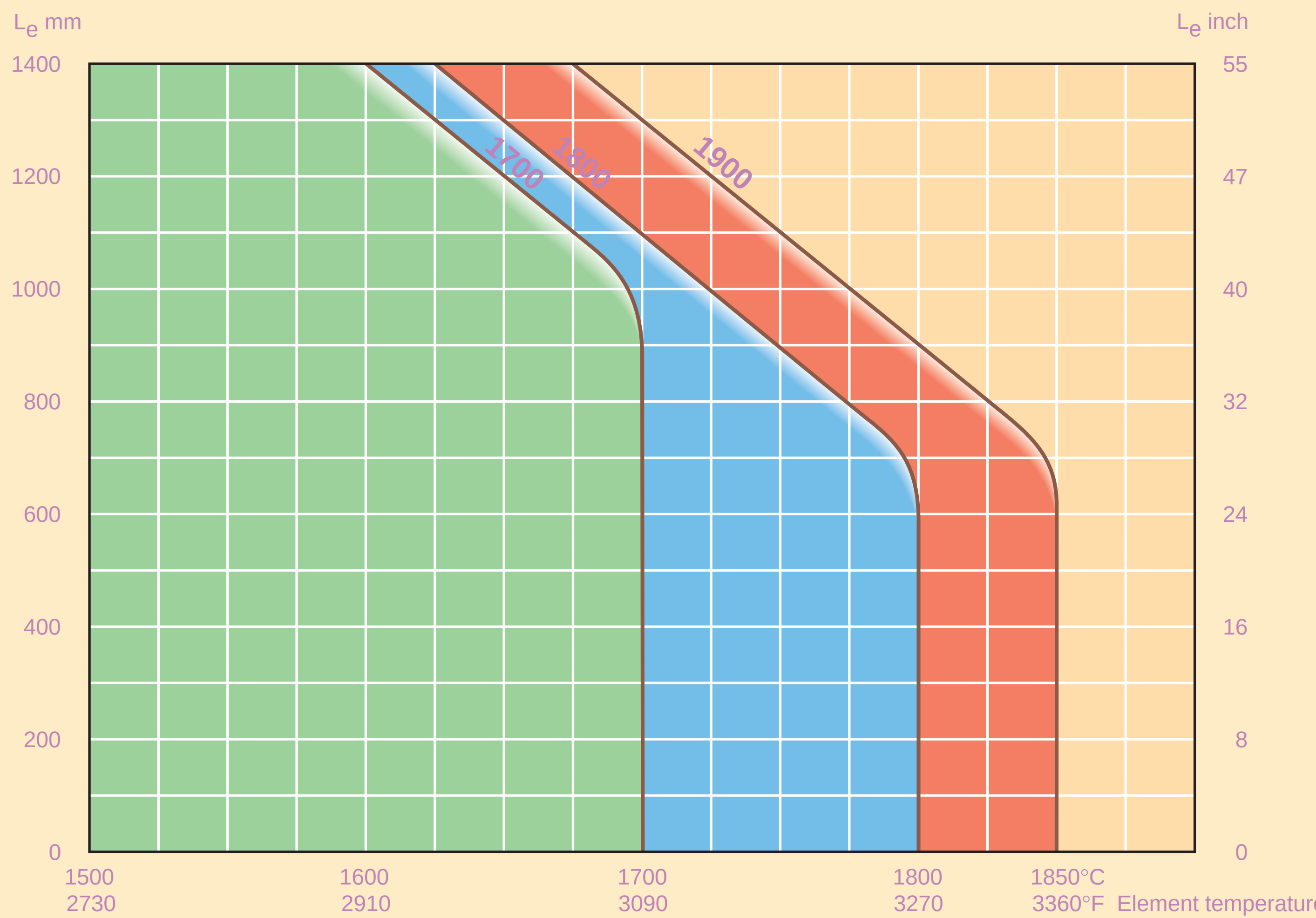


Fig.12 Maximum recommended heating zone lengths for vertically suspended 6/12, 9/18 and 12/24 mm elements.

3

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 5 page 23.

Maximum lengths

- For outer diameter = 7– 25 mm maximum 2000 mm.
- For outer diameter = 32 and 50 mm maximum 1000 mm.

Super bubble tubes

The standard Super bubbler tube has an ID of 3 mm and OD 12 mm – fig 14. Some glass works inquire smaller end holes for generation of smaller air bubbles.
Kanthal can now supply 12/3 tubes with a 5 mm welded endcap, in which we are able to make min 0,7 mm hole by water jet.

Examples of applications for KANTHAL SUPER tubes are:

Fig. 13 Protection tubes for thermocouples.

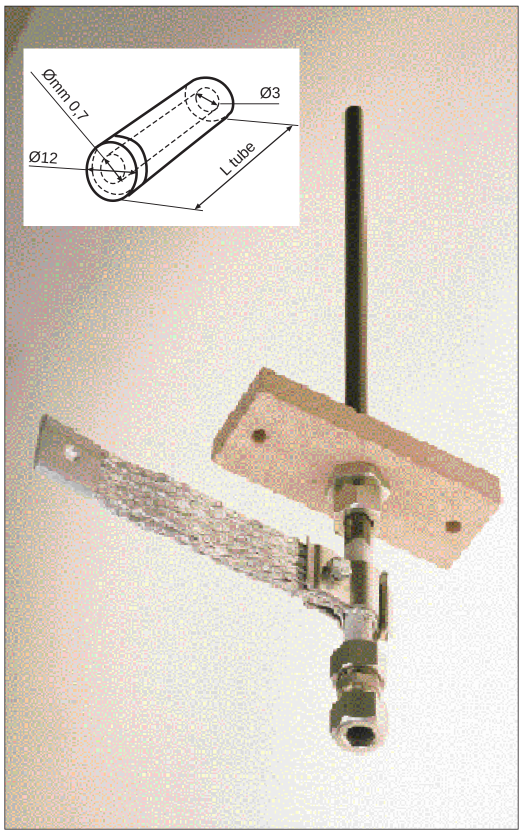


Fig. 14 Bubbler tubes for glass melting.

Standard tube sizes

Outside diameter ± 5%	mm	7	10	12	12	18	22	25	32	50
	in.	*.28*	*.39*	*.47*	*.47*	*.71*	*.87*	*.98*	*1.26*	*1.97*
Inside diameter ± 5%	mm	3	6	3	6	10	13	15	18	28
	in.	*.12*	*.24*	*.12*	*.24*	*.39*	*.51*	*.59*	*.71*	*1.10*

Table 5 KANTHAL SUPER tube diameters.

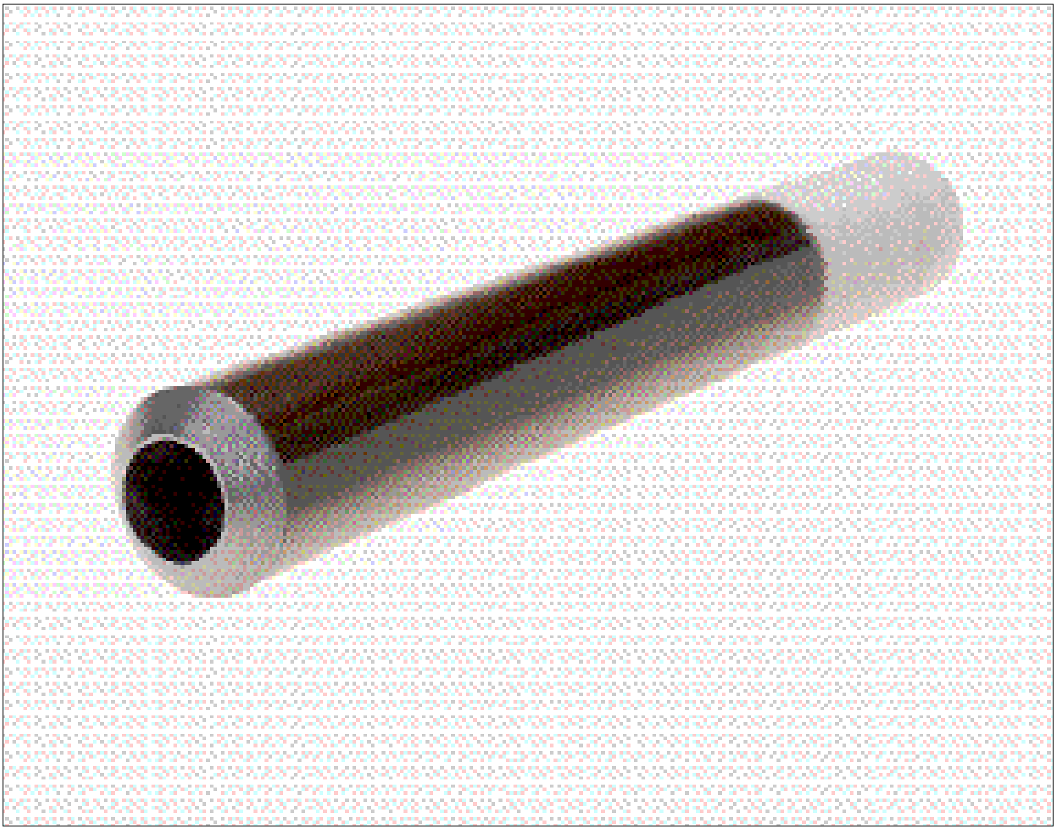
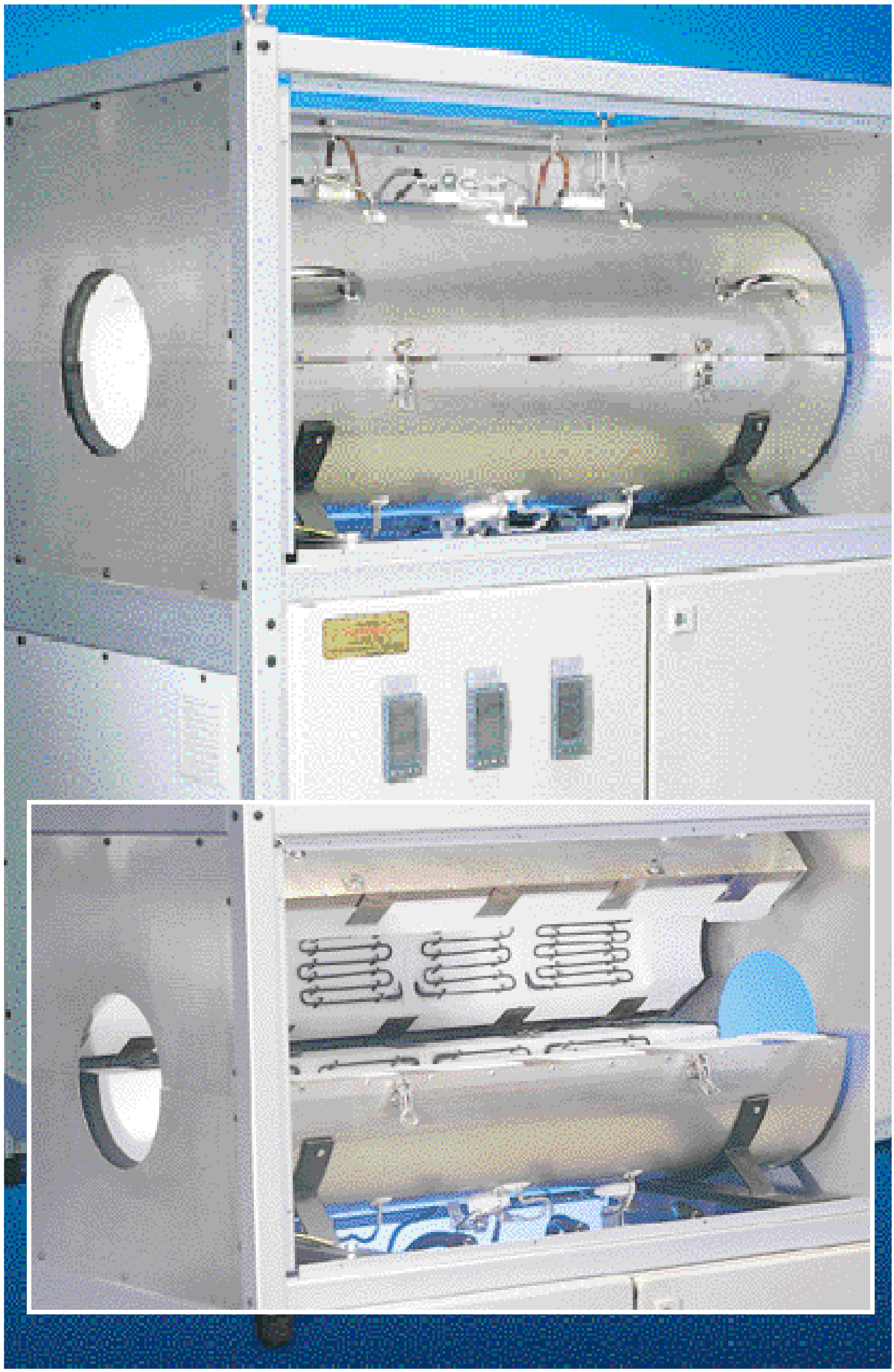


Fig. 15 Tubes for electrodes for glass melting.

Fig. 16 SUPERTHAL multi-zone tube furnace.



SUPERTHAL Heating Modules

The heating modules consist of vacuum formed ceramic fibre shapes, with an integral KANTHAL SUPER heating element.

The standard range includes muffles (SMU) and half cylinders (SHC). These can be readily adapted for use in test equipment and production units where compactness, rapid heating and accurate temperature profiles are needed.

The heating element in the standard modules is made from 3/6 mm KANTHAL SUPER 1800 material. The modules are capable of operating continuously in air up to a maximum of 1600 °C (2910 °F), element temperature.

The SUPERTHAL modules can be delivered as heating packages complete with back-up insulation and stainless steel casing.

The table 6 on page 27 gives basic data for standard modules which are based on an element temperature of 1500 °C (2730 °F) with a ceramic tube (work piece) inside.

When the modules are to be used to operate in their highest temperature range around 1550 °C (2820 °F), a higher voltage may be needed than shown in the tables, in order to achieve a satisfactory heating-up time from room temperature. However it is essential that the element temperature is not allowed to exceed 1600 °C (2910 °F) at any time during the heating cycle.

Naturally the SUPERTHAL modules are used at work-piece temperatures other than 1400 °C (2550 °F), and at different power levels where the element temperature will be lower than 1600 °C (2910 °F). For re-calculating the element data to suit the new requirements, the temperature — loading diagram Fig.17 page 28 is used.

The potential risk of over-heating the elements is even more pronounced when utilizing the SUPERTHAL modules for their high power capability at lower process temperatures, especially in very fast ramping situations, when SUPERTHAL can be considered as a highly powered infrared radiator rather than a conventional furnace heating system.

The IR energy from the KANTHAL SUPER heating element, emitted at a peak wavelength of about 1.5 μm, is absorbed by the ceramic fibre insulation and re-emitted at a longer wavelength.The effective energy transfer to the work piece is highly dependent on its geometry and the absorptive properties of the material, combined with the element (emitter) temperature.

Control of the heating rate is attained by varying the element temperature. Accurate control of the element temperature is critical in radiant heat transfer, as any fluctuation in the element temperature will be amplified in the heating rate by the fourth power function according to the heating equation. See Appendix 2 page 159.

The work-piece temperature also influences the heating rate. Therefore as the temperature of the work piece increases towards the element temperature, the effective heat transfer decreases at a constant element temperature.

Different materials also exhibit different emissivity values at the same temperature. Table 11 on page 159 in Appendix 2, lists some emissivity values of various materials with varying surface conditions.

4

Examples of calculations

Element data: SUPERTHAL SHC 200 H

$P_{e\ tab}$ = 1870 W R_t = 1.06 Ω T_e = 1500°C (2730°F)

$U_{e\ tab}$ = 44.5 V I = 42 A Max. work piece temperature is 1400 °C (2550 °F)

p_{tab} = 8.2 W/cm² (53 W/in.²)

Alt. 1. The maximum power should be calculated.

At 1400°C (2550 °F) according to the temperature - loading diagram Fig.17 on page 28, the maximum surface loading is 18 W/cm² (116 W/in.²) at T_e = 1600 °C (2910 °F).

Maximum power is calculated:

$$P = P_e \times \frac{p}{p_{tab}} = 1870 \times \frac{18}{8.2} = 4105\ W$$

The resistance of KANTHAL SUPER 1800 is proportional to the element temperature according to the formula:

$$R_t = \frac{0.0028 \times T_e - 0.255}{d^2}\ \Omega/m; \quad \left(R_t = \frac{(0.393 \times T_e - 71) \times 10^{-4}}{d^2} \Omega/in.\ (T_e \text{ in } °F,\ d \text{ in mm}) \right)$$

See also page 92.

R_t is calculated at T_e = 1600 °C (2910 °F)

$$R_t = \frac{0.0028 \times 1600 - 0.255}{0.0028 \times 1500 - 0.255} \times 1.06 = 1.14\ \Omega \quad \left(R_t = \frac{0.393 \times 2910 - 71}{0.393 \times 2730 - 71} \times 1.06 = 1.14\ \Omega \right)$$

Voltage is calculated: $U = \sqrt{P \times R_t} = \sqrt{4105 \times 1.14} = 68.4\ V$

Current is calculated: $I = \frac{U}{R_t} = \frac{68.4}{1.14} = 60.0\ A$

Alt. 2. The power needed is 1000 W.

The surface loading is calculated:

$$p = p_{tab} \times \frac{P}{P_{etab}} = 8.2 \times \frac{1000}{1870} = 4.4\ W/cm^2\ (28\ W/in.^2)$$

According to the temperature — loading diagram Fig.17 page 28, the element temperature will be 1455 °C (2650 °F)

R_t is calculated according to the formula above at T_e = 1455 °C (2650 °F)

$$R_t = \frac{0.0028 \times 1455 - 0.255}{0.0028 \times 1500 - 0.255} \times 1.06 = 1.03\ \Omega \quad \left(R_t = \frac{0.393 \times 2650 - 71}{0.393 \times 2730 - 71} \times 1.06 = 1.03\ \Omega \right)$$

Voltage is calculated: $U = \sqrt{P \times R_t} = \sqrt{1000 \times 1.03} = 32.1\ V$

Current is calculated: $I = \frac{U}{R_t} = \frac{32.1}{1.03} = 31.2\ A$

Examples demonstrating SUPERTHAL's high power capabilities and the effect of the emissivity of the work piece

One module type SMU 150 A ($P_{e\ tab}$ = 5050 W) was used to heat a water-cooled iron tube of Ø75 mm (3 in.). A black colored coating was applied to the surface of the tube and the voltage was adjusted to attain an element temperature of 1600 °C (2910 °F).

The voltage, current, and power was measured and recorded as follows:

Voltage: 220 V Current: 69 A Power: 15 200 W

An identical tube was painted with aluminium paint, the voltage was then readjusted to achieve the 1600°C (2910°F) element temperature.

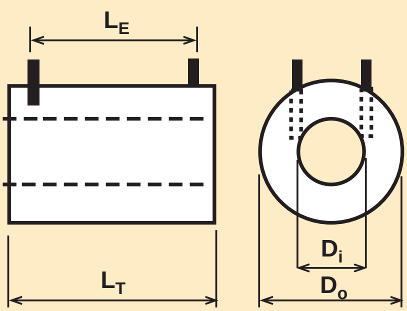
4

SUPERTHAL SMU and SHC 3/6 - standard modules

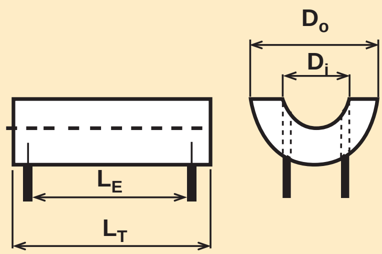
	SMU	SHC
Element length , L_E	209 mm, option A	150 mm
Overall length, L_T	250 mm	200 mm

Data at element temperature	1500 °C (2730 °F)	Surface loading 8.2 W/cm^2 (53 W/in.^{2})
Furnace (work-piece) temperature	1400 °C (2550 °F)	Current 42 A
Max. continuous current 75 A		

Type	Inner dia mm (D_i)	Outer dia mm (D_o)	Resistance Ω	Voltage V	Power W
SMU 40 A	40	240	0.82	34.4	1445
SMU 60 A	60	260	1.19	50.0	2100
SMU 80 A	80	280	1.56	65.6	2760
SMU 100 A	90	300	1.94	81.3	3410
SMU 125 A	115	325	2.40	101	4230
SMU 150 A	140	350	2.86	120	5050
SMU 200 A	190	400	3.80	159	6690
SHC 100 H,V	85	300	0.57	23.9	1000
SHC 150 H,V	135	350	0.85	35.5	1490
SHC 200 H,V	185	400	1.12	47.1	1980
SHC 250 H,V	235	450	1.40	58.6	2460
SHC 300 H,V	285	500	1.67	70.2	2950



SMU



SHC

Table 6.

4

The voltage, current, and power was measured and recorded as follows:

Voltage: 178.5 V Current: 56 A Power: 10 000 W

These tests indicate that the emissivity of the work piece has to be considered in addition to it´s thermal mass.

Please consult KANTHAL for advice regarding lower temperature processes which may require very high power utilization.

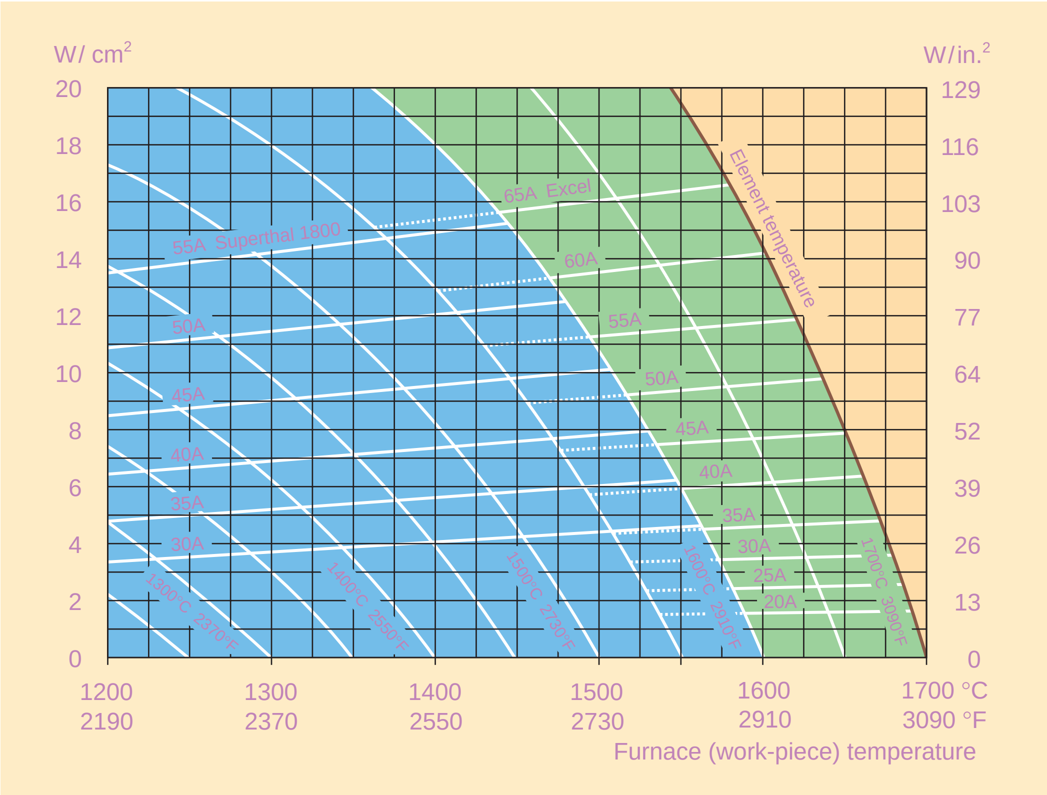


Fig. 17 Temperature — loading diagram for SUPERTHAL.

Fig. 18 SUPERTHAL SMU.

Fig. 19 SUPERTHAL SHC.

Option A is standard.

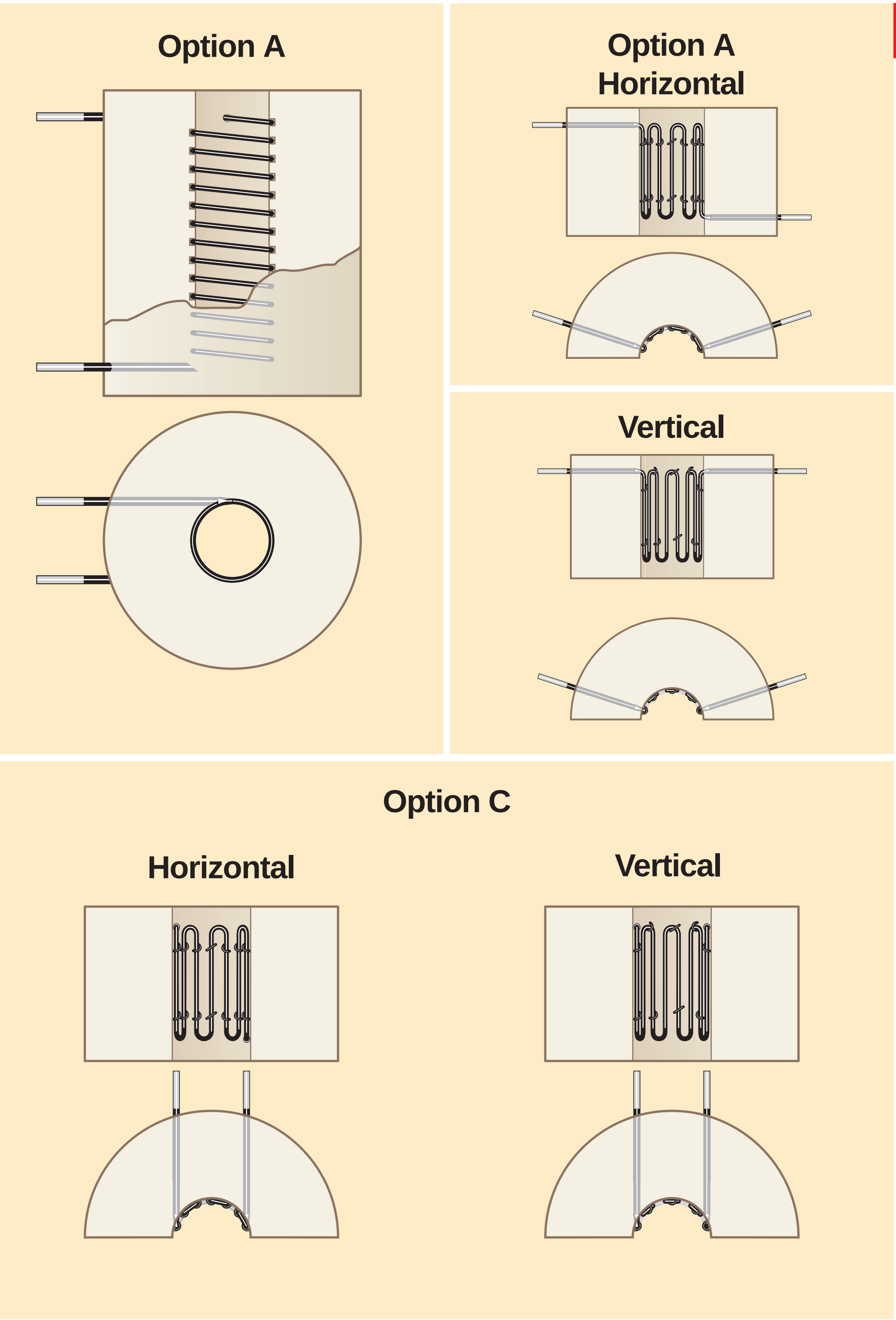


Fig. 20 SUPERTHAL terminal designs.

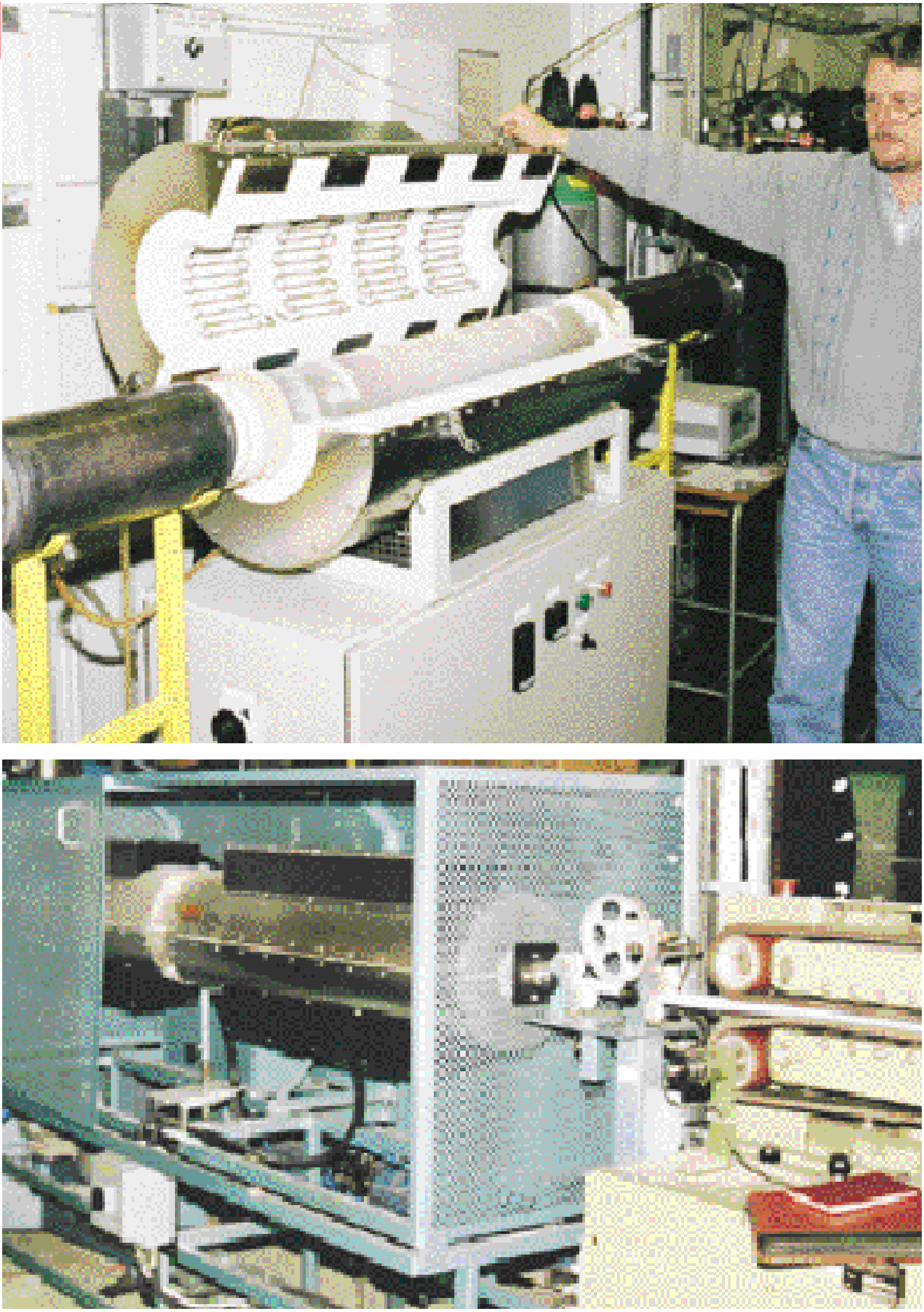


Fig. 21 SUPERTHAL tube furnace for materials testing and as IR-heater at plastic pipe manufacturing

Non standard SUPERTHAL modules

Special elements for muffles, half cylinders, and flat panels with 2, 3, 4, 6, 9, and 12 mm material can also be manufactured.

SUPERTHAL Flat Panels (SFP)

Multi shank elements are fitted to flat ceramic fibre panels for horizontal installation.

They are capable of operating continuously up to a maximum of 1600 °C (2900 °F) element temperature, in air. Typical applications include glass feeders, continuous sintering furnaces and continuous case hardening of steel.

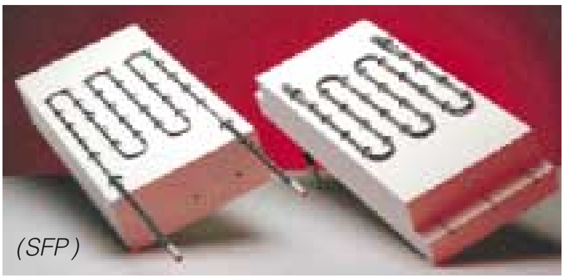
SUPERTHAL Single Wafer Reactors (SWR)

Multi shank and flat coil elements are fitted to circular flat ceramic fibre panels for horizontal or vertical installation. The power is controlled radially, in order to attain even temperature.

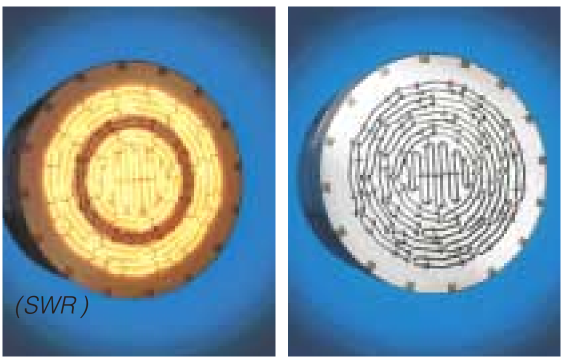
They are capable of operating continuously up to a maximum of 1600 °C (2900 °F) element temperature, in air. Typical application is development of prototypes and processing of Silicon Wafers, where accurate temperature profiles, fast heat-up/cooling cycles, and high temperature capabilities are desirable parameters.

SUPERTHAL Infrared Radiators (SIR)

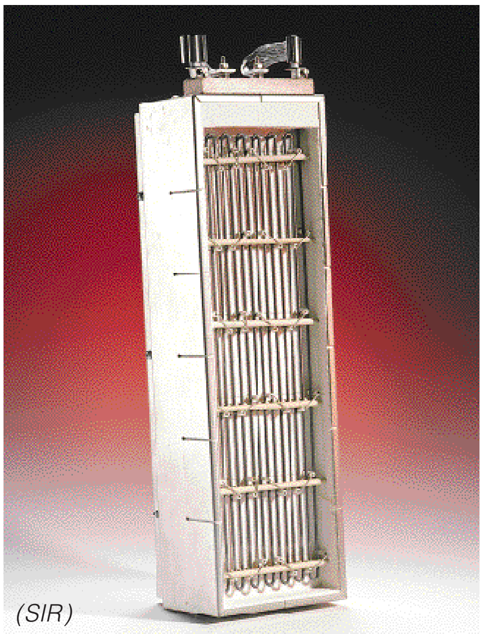
Multi shank elements of 3 or 4 mm KANTHAL SUPER 1800 material mounted in ceramic fibre boxes, freely radiating, are mainly used for drying purposes. The element temperature is in the range of 1550 °C (2820 °F), corresponding to a peak energy wavelength of about 1.5 µm. The inner surface of the ceramic fibre box normally has a temperature of 1100 °C (2010 °F), corresponding to a peak energy wavelength of about 2.2 µm. The maximum power concentration is about 240 kW/m^2.



(SFP)



(SWR)



(SIR)

Fig. 22 SUPERTHAL high temperature material testing furnace.

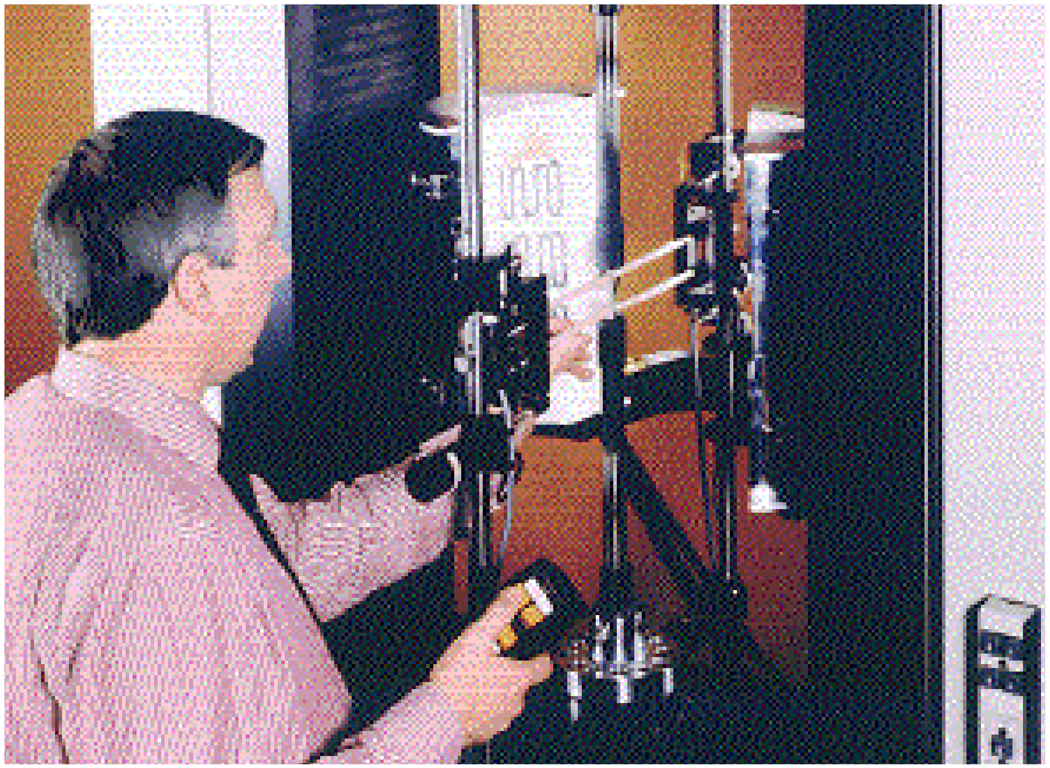
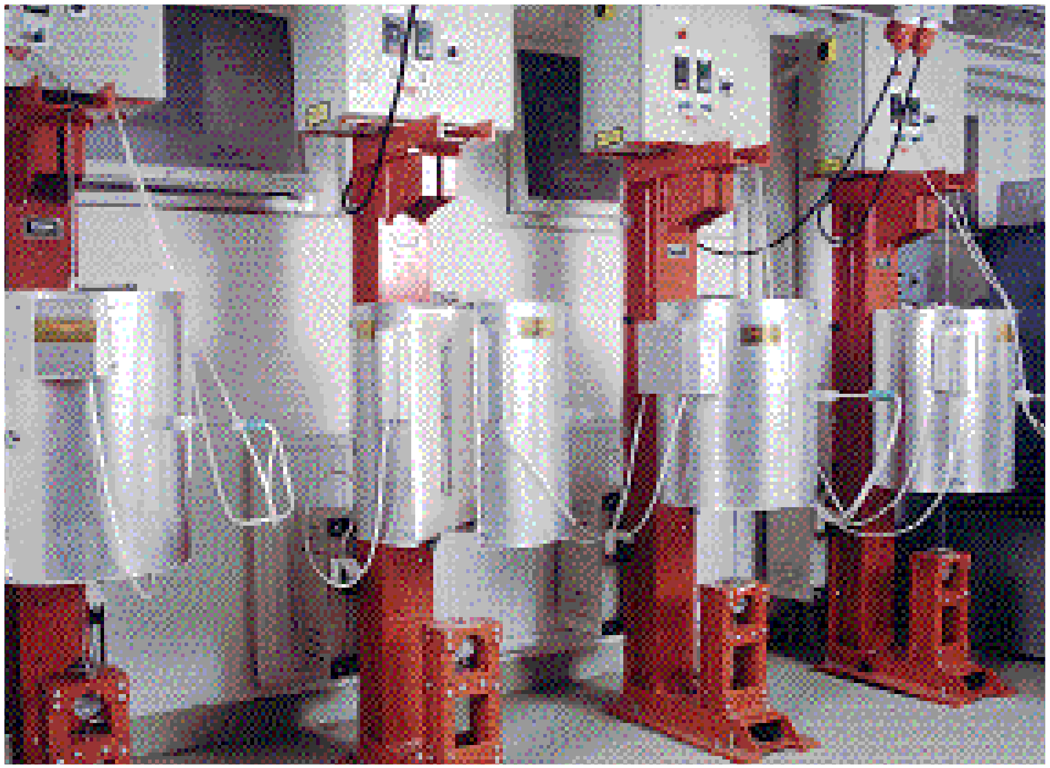


Fig. 23 SUPERTHAL creep testing furnaces.



Electrical data

5

Two-Shank KANTHAL SUPER 1700 6/12

Power W
Resistance Ω
Volt V

Max. element temperature 1700 °C (3090 °F)

Heating zone Ø mm 6
Terminal Ø mm 12
Shank distance mm 50

Furnace temp. °C 1300 (2370° F)
Element temp. °C 1550 (2820° F)

Element current A 166
Surface loading W/cm² 16.6
W/in.² 107

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in. 125	*6.3 in.* 160	*7.1 in.* 180	*7.9 in.* 200	*8.9 in.* 225	*9.8 in.* 250	*11 in.* 280	*12.4 in.* 315	*14 in.* 355	*15.8 in.* 400	*17.7 in.* 450	*19.7 in.* 500	*22 in.* 560	*24.8 in.* 630	*26.4 in.* 670	*28 in.* 710	*31.5 in.* 800	*35.4 in.* 900	*39.4 in.* 1000	*44.1 in.* 1120	*49.2 in.* 1250	*55.1 in.* 1400
4.9 in.	**1020**	**1240**	**1370**	**1490**	**1650**	**1810**	**1990**	**2210**	**2460**	**2740**	**3060**	**3370**	**3740**	**4180**	**4430**	**4680**	**5250**	**5870**	**6500**	**7250**	**8060**	**9000**
125	0.037	0.045	0.050	0.054	0.060	0.066	0.072	0.080	0.089	0.100	0.111	0.122	0.136	0.152	0.161	0.170	0.190	0.213	0.236	0.263	0.292	0.327
	6.2	*7.5*	*8.2*	*9.0*	*9.9*	*10.9*	*12.0*	*13.3*	*14.8*	*16.5*	*18.4*	*20.3*	*22.6*	*25.2*	*26.7*	*28.2*	*31.6*	*35.4*	*39.1*	*43.7*	*48.6*	*54.2*
5.5 in.	**1040**	**1260**	**1380**	**1510**	**1660**	**1820**	**2010**	**2230**	**2480**	**2760**	**3070**	**3380**	**3760**	**4200**	**4450**	**4700**	**5260**	**5880**	**6510**	**7260**	**8070**	**9010**
140	0.038	0.046	0.050	0.055	0.060	0.066	0.073	0.081	0.090	0.100	0.111	0.123	0.136	0.152	0.161	0.170	0.191	0.214	0.236	0.263	0.293	0.327
	6.2	*7.6*	*8.3*	*9.1*	*10.0*	*11.0*	*12.1*	*13.4*	*14.9*	*16.6*	*18.5*	*20.4*	*22.6*	*25.3*	*26.8*	*28.3*	*31.7*	*35.4*	*39.2*	*43.7*	*48.6*	*54.3*
6.3 in.	**1060**	**1270**	**1400**	**1520**	**1680**	**1840**	**2020**	**2240**	**2490**	**2770**	**3090**	**3400**	**3780**	**4210**	**4460**	**4710**	**5280**	**5900**	**6530**	**7280**	**8090**	**9030**
160	0.038	0.046	0.051	0.055	0.061	0.067	0.073	0.081	0.090	0.101	0.112	0.123	0.137	0.153	0.162	0.171	0.191	0.214	0.237	0.264	0.294	0.328
	6.4	*7.7*	*8.4*	*9.2*	*10.1*	*11.1*	*12.2*	*13.5*	*15.0*	*16.7*	*18.6*	*20.5*	*22.7*	*25.4*	*26.9*	*28.4*	*31.8*	*35.6*	*39.3*	*43.8*	*48.7*	*54.4*
7.1 in.	**1070**	**1290**	**1420**	**1540**	**1700**	**1850**	**2040**	**2260**	**2510**	**2790**	**3110**	**3420**	**3790**	**4230**	**4480**	**4730**	**5290**	**5920**	**6540**	**7290**	**8110**	**9050**
180	0.039	0.047	0.051	0.056	0.062	0.067	0.074	0.082	0.091	0.101	0.113	0.124	0.138	0.154	0.163	0.172	0.192	0.215	0.237	0.265	0.294	0.328
	6.5	*7.8*	*8.5*	*9.3*	*10.2*	*11.2*	*12.3*	*13.6*	*15.1*	*16.8*	*18.7*	*20.6*	*22.8*	*25.5*	*27.0*	*28.5*	*31.9*	*35.7*	*39.4*	*43.9*	*48.8*	*54.5*
7.9 in.	**1090**	**1310**	**1430**	**1560**	**1720**	**1870**	**2060**	**2280**	**2530**	**2810**	**3120**	**3440**	**3810**	**4250**	**4500**	**4750**	**5310**	**5940**	**6560**	**7310**	**8130**	**9060**
200	0.040	0.048	0.052	0.057	0.062	0.068	0.075	0.083	0.092	0.102	0.113	0.125	0.138	0.154	0.163	0.172	0.193	0.215	0.238	0.265	0.295	0.329
	6.6	*7.9*	*8.6*	*9.4*	*10.3*	*11.3*	*12.4*	*13.7*	*15.2*	*16.9*	*18.8*	*20.7*	*23.0*	*25.6*	*27.1*	*28.6*	*32.0*	*35.8*	*39.5*	*44.1*	*48.9*	*54.6*
8.9 in.	**1110**	**1330**	**1460**	**1580**	**1740**	**1890**	**2080**	**2300**	**2550**	**2830**	**3140**	**3460**	**3830**	**4270**	**4520**	**4770**	**5330**	**5960**	**6580**	**7330**	**8150**	**9090**
225	0.040	0.048	0.053	0.057	0.063	0.069	0.076	0.083	0.093	0.103	0.114	0.125	0.139	0.155	0.164	0.173	0.194	0.216	0.239	0,266	0.296	0.330
	6.7	*8.0*	*8.8*	*9.5*	*10.5*	*11.4*	*12.5*	*13.9*	*15.4*	*17.1*	*18.9*	*20.8*	*23.1*	*25.7*	*27.2*	*28.7*	*32.1*	*35.9*	*39.7*	*44.2*	*49.1*	*54.7*
9.8 in	**1130**	**1350**	**1480**	**1600**	**1760**	**1920**	**2100**	**2320**	**2570**	**2850**	**3170**	**3480**	**3850**	**4290**	**4540**	**4790**	**5360**	**5980**	**6610**	**7360**	**8170**	**9110**
250	0.041	0.049	0.054	0.058	0.064	0.070	0.076	0.084	0.093	0.104	0.115	0.126	0.140	0.156	0.165	0.174	0.194	0.217	0.240	0.267	0.296	0.331
	6.8	*8.1*	*8.9*	*9.7*	*10.6*	*11.5*	*12.7*	*14.0*	*15.5*	*17.2*	*19.1*	*21.0*	*23.2*	*25.9*	*27.4*	*28.9*	*32.3*	*36.0*	*39.8*	*44.3*	*49.2*	*54.9*
11 in.	**1160**	**1380**	**1500**	**1630**	**1790**	**1940**	**2130**	**2350**	**2600**	**2880**	**3190**	**3510**	**3880**	**4320**	**4570**	**4820**	**5380**	**6010**	**6630**	**7380**	**8200**	**9130**
280	0.042	0.050	0.055	0.059	0.065	0.070	0.077	0.085	0.094	0.105	0.116	0.127	0.141	0.157	0.166	0.175	0.195	0.218	0.241	0.268	0.297	0.331
	7.0	*8.3*	*9.1*	*9.8*	*10.8*	*11.7*	*12.8*	*14.1*	*15.7*	*17.3*	*19.2*	*21.1*	*23.4*	*26.0*	*27.5*	*29.0*	*32.4*	*36.2*	*40.0*	*44.5*	*49.4*	*55.0*
12.4 in.	**1190**	**1410**	**1530**	**1660**	**1820**	**1970**	**2160**	**2380**	**2630**	**2910**	**3220**	**3540**	**3910**	**4350**	**4600**	**4850**	**5410**	**6040**	**6660**	**7410**	**8230**	**9160**
315	0.043	0.051	0.056	0.060	0.066	0.072	0.078	0.086	0.095	0.106	0.117	0.128	0.142	0.158	0.167	0.176	0.196	0.219	0.242	0.269	0.299	0.333
	7.2	*8.5*	*9.2*	*10.0*	*10.9*	*11.9*	*13.0*	*14.3*	*15.8*	*17.5*	*19.4*	*21.3*	*23.6*	*26.2*	*27.7*	*29.2*	*32.6*	*36.4*	*40.1*	*44.7*	*49.6*	*55.2*
14 in.	**1230**	**1450**	**1570**	**1700**	**1850**	**2010**	**2200**	**2410**	**2660**	**2950**	**3260**	**3570**	**3950**	**4380**	**4630**	**4880**	**5450**	**6070**	**6700**	**7450**	**8260**	**9200**
355	0.044	0.052	0.057	0.062	0.067	0.073	0.080	0.088	0.097	0.107	0.118	0.130	0.143	0.159	0.168	0.177	0.198	0.220	0.243	0.270	0.300	0.334
	7.4	*8.7*	*9.5*	*10.2*	*11.2*	*12.1*	*13.2*	*14.5*	*16.1*	*17.7*	*19.6*	*21.5*	*23.8*	*26.4*	*27.9*	*29.4*	*32.8*	*36.6*	*40.4*	*44.9*	*49.8*	*55.4*
15.8 in	**1270**	**1480**	**1610**	**1730**	**1890**	**2050**	**2230**	**2450**	**2700**	**2990**	**3300**	**3610**	**3990**	**4420**	**4670**	**4920**	**5490**	**6110**	**6740**	**7490**	**8300**	**9240**
400	0.046	0.054	0.058	0.063	0.069	0.074	0.081	0.089	0.098	0.108	0.120	0.131	0.145	0.161	0.170	0.179	0.199	0.222	0.245	0.272	0.301	0.335
	7.6	*8.9*	*9.7*	*10.4*	*11.4*	*12.3*	*13.5*	*14.8*	*16.3*	*18.0*	*19.9*	*21.8*	*24.0*	*26.6*	*28.2*	*29.7*	*33.1*	*36.8*	*40.6*	*45.1*	*50.0*	*55.7*
17.7 in.	**1310**	**1530**	**1650**	**1780**	**1930**	**2090**	**2280**	**2500**	**2750**	**3030**	**3340**	**3650**	**4030**	**4470**	**4720**	**4970**	**5530**	**6160**	**6780**	**7530**	**8340**	**9280**
450	0.048	0.055	0.060	0.065	0.070	0.076	0.083	0.091	0.100	0.110	0.121	0.133	0.146	0.162	0.171	0.180	0.201	0.223	0.246	0.273	0.303	0.337
	7.9	*9.2*	*10.0*	*10.7*	*11.7*	*12.6*	*13.7*	*15.0*	*16.6*	*18.2*	*20.1*	*22.0*	*24.3*	*26.9*	*28.4*	*29.9*	*33.3*	*37.1*	*40.9*	*45.4*	*50.3*	*55.9*
19.7 in.	**1350**	**1570**	**1700**	**1820**	**1980**	**2140**	**2320**	**2540**	**2790**	**3070**	**3390**	**3700**	**4070**	**4510**	**4760**	**5010**	**5570**	**6200**	**6830**	**7580**	**8390**	**9330**
500	0.049	0.057	0.062	0.066	0.072	0.077	0.084	0.092	0.101	0.112	0.123	0.134	0.148	0.164	0.173	0.182	0.202	0.225	0.248	0.275	0.304	0.338
	8.2	*9.5*	*10.2*	*11.0*	*11.9*	*12.9*	*14.0*	*15.3*	*16.8*	*18.5*	*20.4*	*22.3*	*24.5*	*27.2*	*28.7*	*30.2*	*33.6*	*37.3*	*41.1*	*45.6*	*50.5*	*56.2*
22 in.	**1410**	**1620**	**1750**	**1880**	**2030**	**2190**	**2380**	**2590**	**2840**	**3130**	**3440**	**3750**	**4130**	**4560**	**4810**	**5060**	**5630**	**6250**	**6880**	**7630**	**8440**	**9380**
560	0.051	0.059	0.064	0.068	0.074	0.079	0.086	0.094	0.103	0.113	0.125	0.136	0.150	0.166	0.175	0.184	0.204	0.227	0.250	0.277	0.306	0.340
	8.5	*9.8*	*10.5*	*11.3*	*12.2*	*13.2*	*14.3*	*15.6*	*17.1*	*18.8*	*20.7*	*22.6*	*24.9*	*27.5*	*29.0*	*30.5*	*33.9*	*37.7*	*41.4*	*46.0*	*50.9*	*56.5*
24.8 in.	**1470**	**1690**	**1810**	**1940**	**2090**	**2250**	**2440**	**2660**	**2910**	**3190**	**3500**	**3810**	**4190**	**4630**	**4880**	**5130**	**5690**	**6310**	**6940**	**7690**	**8500**	**9440**
630	0.053	0.061	0.066	0.070	0.076	0.082	0.088	0.096	0.105	0.116	0.127	0.138	0.152	0.168	0.177	0.186	0.206	0.229	0.252	0.279	0.309	0.343
	8.8	*10.2*	*10.9*	*11.7*	*12.6*	*13.5*	*14.7*	*16.0*	*17.5*	*19.2*	*21.1*	*23.0*	*25.2*	*27.9*	*29.4*	*30.9*	*34.3*	*38.0*	*41.8*	*46.3*	*51.2*	*56.9*
26.4 in.	**1500**	**1720**	**1850**	**1970**	**2130**	**2280**	**2470**	**2690**	**2940**	**3220**	**3540**	**3850**	**4220**	**4660**	**4910**	**5160**	**5720**	**6350**	**6970**	**7720**	**8540**	**9480**
670	0.055	0.062	0.067	0.072	0.077	0.083	0.090	0.098	0.107	0.117	0.128	0.140	0.153	0.169	0.178	0.187	0.208	0.230	0.253	0.280	0.310	0.344
	9.1	*10.4*	*11.1*	*11.9*	*12.8*	*13.8*	*14.9*	*16.2*	*17.7*	*19.4*	*21.3*	*23.2*	*25.4*	*28.1*	*29.6*	*31.1*	*34.5*	*38.2*	*42.0*	*46.5*	*51.4*	*57.1*
28 in.	**1540**	**1760**	**1880**	**2010**	**2160**	**2320**	**2510**	**2730**	**2980**	**3260**	**3570**	**3880**	**4260**	**4700**	**4950**	**5200**	**5760**	**6380**	**7010**	**7760**	**8570**	**9510**
710	0.056	0.064	0.068	0.073	0.078	0.084	0.091	0.099	0.108	0.118	0.130	0.141	0.155	0.170	0.179	0.189	0.209	0.232	0.254	0.282	0.311	0.345
	9.3	*10.6*	*11.3*	*12.1*	*13.0*	*14.0*	*15.1*	*16.4*	*17.9*	*19.6*	*21.5*	*23.4*	*25.7*	*28.3*	*29.8*	*31.3*	*34.7*	*38.5*	*42.2*	*46.7*	*51.6*	*57.3*
31.5 in.	**1620**	**1840**	**1960**	**2090**	**2240**	**2400**	**2590**	**2800**	**3060**	**3340**	**3650**	**3960**	**4340**	**4770**	**5020**	**5280**	**5840**	**6460**	**7090**	**7840**	**8650**	**9590**
800	0.059	0.067	0.071	0.076	0.081	0.087	0.094	0.102	0.111	0.121	0.132	0.144	0.157	0.173	0.182	0.191	0.212	0.235	0.257	0.284	0.314	0.348
	9.7	*11.1*	*11.8*	*12.6*	*13.5*	*14.4*	*15.6*	*16.9*	*18.4*	*20.1*	*22.0*	*23.9*	*26.1*	*28.8*	*30.3*	*31.8*	*35.2*	*38.9*	*42.7*	*47.2*	*52.1*	*57.8*

Four-Shank KANTHAL SUPER 1700 6/12

Power W
Resistance Ω
Volt V

Max. element temperature 1700 °C (3090 °F)

Heating zone Ø mm 6
Terminal Ø mm 12
Shank distance mm 50

Furnace temp. °C 1300 (2370° F)
Element temp. °C 1550 (2820° F)

Element current A 166
Surface loading W/cm^2 16.6
W/in^2 107

Heating zone, L_e mm →

Terminal L_u mm ↓

Terminal L_u mm	*5.5 in.* 140	*7.9 in.* 200	*9.8 in.* 250	*11.4 in.* 290	*12.4 in.* 315	*14 in.* 355	*16.1 in.* 410	*17.7 in.* 450	*19.7 in.* 500	*24.4 in.* 620	*29.5 in.* 750
15.8 in	**2380**	**3130**	**3750**	**4250**	**4560**	**5060**	**5750**	**6250**	**6880**	**8380**	**10010**
400	0.086	0.113	0.136	0.154	0.166	0.184	0.209	0.227	0.250	0.304	0.363
	14.3	*18.8*	*22.6*	*25.6*	*27.5*	*30.5*	*34.7*	*37.7*	*41.4*	*50.5*	*60.3*
17.7 in.	**2420**	**3170**	**3800**	**4300**	**4610**	**5110**	**5800**	**6300**	**6920**	**8420**	**10050**
450	0.088	0.115	0.138	0.156	0.167	0.185	0.210	0.229	0.251	0.306	0.365
	14.6	*19.1*	*22.9*	*25.9*	*27.8*	*30.8*	*34.9*	*37.9*	*41.7*	*50.7*	*60.5*
18.5 in.	**2440**	**3190**	**3810**	**4310**	**4630**	**5130**	**5810**	**6310**	**6940**	**8440**	**10070**
470	0.088	0.116	0.138	0.157	0.168	0.186	0.211	0.229	0.252	0.306	0.365
	14.7	*19.2*	*23.0*	*26.0*	*27.9*	*30.9*	*35.0*	*38.0*	*41.8*	*50.8*	*60.6*
19.7 in.	**2460**	**3210**	**3840**	**4340**	**4650**	**5150**	**5840**	**6340**	**6970**	**8470**	**10090**
500	0.089	0.117	0.139	0.157	0.169	0.187	0.212	0.230	0.253	0.307	0.366
	14.8	*19.4*	*23.1*	*26.1*	*28.0*	*31.0*	*35.2*	*38.2*	*42.0*	*51.0*	*60.8*
20.5 in.	**2480**	**3230**	**3860**	**4360**	**4670**	**5170**	**5860**	**6360**	**6980**	**8480**	**10110**
520	0.090	0.117	0.140	0.158	0.169	0.188	0.213	0.231	0.253	0.308	0.367
	14.9	*19.5*	*23.2*	*26.2*	*28.1*	*31.1*	*35.3*	*38.3*	*42.1*	*51.1*	*60.9*
22 in.	**2520**	**3270**	**3890**	**4390**	**4700**	**5210**	**5890**	**6390**	**7020**	**8520**	**10150**
560	0.091	0.119	0.141	0.159	0.171	0.189	0.214	0.232	0.255	0.309	0.368
	15.2	*19.7*	*23.4*	*26.5*	*28.3*	*31.4*	*35.5*	*38.5*	*42.3*	*51.3*	*61.1*
23.6 in.	**2550**	**3300**	**3930**	**4430**	**4740**	**5240**	**5930**	**6430**	**7050**	**8550**	**10180**
600	0.093	0.120	0.143	0.161	0.172	0.190	0.215	0.233	0.256	0.310	0.369
	15.4	*19.9*	*23.7*	*26.7*	*28.6*	*31.6*	*35.7*	*38.7*	*42.5*	*51.5*	*61.3*
24.8 in.	**2580**	**3330**	**3950**	**4450**	**4770**	**5270**	**5950**	**6450**	**7080**	**8580**	**10210**
630	0.094	0.121	0.143	0.162	0.173	0.191	0.216	0.234	0.257	0.311	0.370
	15.5	*20.0*	*23.8*	*26.8*	*28.7*	*31.7*	*35.9*	*38.9*	*42.7*	*51.7*	*61.5*
28 in.	**2650**	**3400**	**4020**	**4520**	**4840**	**5340**	**6020**	**6520**	**7150**	**8650**	**10280**
710	0.096	0.123	0.146	0.164	0.176	0.194	0.219	0.237	0.259	0.314	0.373
	16.0	*20.5*	*24.2*	*27.3*	*29.1*	*32.1*	*36.3*	*39.3*	*43.1*	*52.1*	*61.9*

Two-Shank KANTHAL SUPER 1700 9/18

Power W
Resistance Ω
Volt V

Max. element temperature 1700 °C (3090 °F)

Heating zone Ø mm 9
Terminal Ø mm 18
Shank distance mm 60

Furnace temp. °C 1300 (2370° F)
Element temp. °C 1550 (2820° F)

Element current A 305
Surface loading W/cm^2 16.6
W/$in.^2$ 107

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in.	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	*15.8 in.*	*17.7 in.*	*19.7 in.*	*22 in.*	*24.8 in.*	*26.4 in.*	*28 in.*	*31.5 in.*	*35.4 in.*	*39.4 in.*	*44.1 in.*	*49.2 in.*	*55.1 in.*
	125	160	180	200	225	250	280	315	355	400	450	500	560	630	670	710	800	900	1000	1120	1250	1400
11 in.	**1750**	**2080**	**2270**	**2460**	**2690**	**2930**	**3210**	**3540**	**3910**	**4330**	**4800**	**5270**	**5840**	**6490**	**6870**	**7240**	**8090**	**9030**	**9960**	**11090**	**12310**	**13720**
280	0.019	0.022	0.024	0.026	0.029	0.031	0.034	0.038	0.042	0.047	0.052	0.057	0.063	0.070	0.074	0.078	0.087	0.097	0.107	0.119	0.132	0.147
	5.7	*6.8*	*7.4*	*8.1*	*8.8*	*9.6*	*10.5*	*11.6*	*12.8*	*14.2*	*15.7*	*17.3*	*19.1*	*21.3*	*22.5*	*23.7*	*26.5*	*29.6*	*32.7*	*36.4*	*40.4*	*45.0*
12.4 in.	**1800**	**2130**	**2320**	**2500**	**2740**	**2970**	**3250**	**3580**	**3960**	**4380**	**4850**	**5320**	**5880**	**6540**	**6910**	**7290**	**8130**	**9070**	**10010**	**11140**	**12360**	**13760**
315	0.019	0.023	0.025	0.027	0.029	0.032	0.035	0.039	0.043	0.047	0.052	0.057	0.063	0.070	0.074	0.078	0.087	0.098	0.108	0.120	0.133	0.148
	5.9	*7.0*	*7.6*	*8.2*	*9.0*	*9.7*	*10.7*	*11.7*	*13.0*	*14.4*	*15.9*	*17.4*	*19.3*	*21.4*	*22.7*	*23.9*	*26.7*	*29.7*	*32.8*	*36.5*	*40.5*	*45.1*
14 in.	**1850**	**2180**	**2370**	**2560**	**2790**	**3030**	**3310**	**3640**	**4010**	**4430**	**4900**	**5370**	**5930**	**6590**	**6970**	**7340**	**8190**	**9120**	**10060**	**11190**	**12410**	**13820**
355	0.020	0.023	0.025	0.027	0.030	0.033	0.036	0.039	0.043	0.048	0.053	0.058	0.064	0.071	0.075	0.079	0.088	0.098	0.108	0.120	0.133	0.149
	6.1	*7.1*	*7.8*	*8.4*	*9.1*	*9.9*	*10.8*	*11.9*	*13.1*	*14.5*	*16.1*	*17.6*	*19.5*	*21.6*	*22.8*	*24.1*	*26.8*	*29.9*	*33.0*	*36.7*	*40.7*	*45.3*
15.8 in	**1910**	**2240**	**2430**	**2620**	**2850**	**3080**	**3370**	**3690**	**4070**	**4490**	**4960**	**5430**	**5990**	**6650**	**7030**	**7400**	**8250**	**9180**	**10120**	**11250**	**12470**	**13870**
400	0.021	0.024	0.026	0.028	0.031	0.033	0.036	0.040	0.044	0.048	0.053	0.058	0.064	0.071	0.076	0.080	0.089	0.099	0.109	0.121	0.134	0.149
	6.3	*7.3*	*8.0*	*8.6*	*9.3*	*10.1*	*11.0*	*12.1*	*13.3*	*14.7*	*16.3*	*17.8*	*19.6*	*21.8*	*23.0*	*24.3*	*27.0*	*30.1*	*33.2*	*36.9*	*40.9*	*45.5*
17.7 in.	**1980**	**2310**	**2490**	**2680**	**2920**	**3150**	**3430**	**3760**	**4140**	**4560**	**5030**	**5500**	**6060**	**6720**	**7090**	**7470**	**8310**	**9250**	**10190**	**11310**	**12530**	**13940**
450	0.021	0.025	0.027	0.029	0.031	0.034	0.037	0.040	0.044	0.049	0.054	0.059	0.065	0.072	0.076	0.080	0.089	0.099	0.110	0.122	0.135	0.150
	6.5	*7.6*	*8.2*	*8.8*	*9.6*	*10.3*	*11.3*	*12.3*	*13.6*	*14.9*	*16.5*	*18.0*	*19.9*	*22.0*	*23.2*	*24.5*	*27.2*	*30.3*	*33.4*	*37.1*	*41.1*	*45.7*
19.7 in.	**2040**	**2370**	**2560**	**2750**	**2980**	**3220**	**3500**	**3830**	**4200**	**4620**	**5090**	**5560**	**6120**	**6780**	**7160**	**7530**	**8380**	**9320**	**10250**	**11380**	**12600**	**14010**
500	0.022	0.025	0.028	0.030	0.032	0.035	0.038	0.041	0.045	0.050	0.055	0.060	0.066	0.073	0.077	0.081	0.090	0.100	0.110	0.122	0.135	0.151
	6.7	*7.8*	*8.4*	*9.0*	*9.8*	*10.5*	*11.5*	*12.5*	*13.8*	*15.2*	*16.7*	*18.2*	*20.1*	*22.2*	*23.5*	*24.7*	*27.5*	*30.5*	*33.6*	*37.3*	*41.3*	*45.9*
22 in.	**2120**	**2450**	**2640**	**2830**	**3060**	**3300**	**3580**	**3910**	**4280**	**4700**	**5170**	**5640**	**6200**	**6860**	**7240**	**7610**	**8460**	**9390**	**10330**	**11460**	**12680**	**14090**
560	0.023	0.026	0.028	0.030	0.033	0.035	0.038	0.042	0.046	0.051	0.056	0.061	0.067	0.074	0.078	0.082	0.091	0.101	0.111	0.123	0.136	0.151
	7.0	*8.0*	*8.7*	*9.3*	*10.0*	*10.8*	*11.7*	*12.8*	*14.0*	*15.4*	*17.0*	*18.5*	*20.3*	*22.5*	*23.7*	*25.0*	*27.7*	*30.8*	*33.9*	*37.6*	*41.6*	*46.2*
24.8 in.	**2210**	**2540**	**2730**	**2920**	**3150**	**3390**	**3670**	**4000**	**4370**	**4790**	**5260**	**5730**	**6300**	**6950**	**7330**	**7700**	**8550**	**9490**	**10420**	**11550**	**12770**	**14180**
630	0.024	0.027	0.029	0.031	0.034	0.036	0.039	0.043	0.047	0.052	0.057	0.062	0.068	0.075	0.079	0.083	0.092	0.102	0.112	0.124	0.137	0.152
	7.3	*8.3*	*9.0*	*9.6*	*10.3*	*11.1*	*12.0*	*13.1*	*14.3*	*15.7*	*17.3*	*18.8*	*20.6*	*22.8*	*24.0*	*25.3*	*28.0*	*31.1*	*34.2*	*37.9*	*41.9*	*46.5*
26.4 in.	**2270**	**2600**	**2780**	**2970**	**3210**	**3440**	**3720**	**4050**	**4430**	**4850**	**5320**	**5790**	**6350**	**7010**	**7380**	**7760**	**8600**	**9540**	**10480**	**11600**	**12820**	**14230**
670	0.024	0.028	0.030	0.032	0.034	0.037	0.040	0.044	0.048	0.052	0.057	0.062	0.068	0.075	0.079	0.083	0.092	0.103	0.113	0.125	0.138	0.153
	7.4	*8.5*	*9.1*	*9.7*	*10.5*	*11.3*	*12.2*	*13.3*	*14.5*	*15.9*	*17.4*	*19.0*	*20.8*	*23.0*	*24.2*	*25.4*	*28.2*	*31.3*	*34.4*	*38.0*	*42.0*	*46.7*
28 in.	**2320**	**2650**	**2840**	**3020**	**3260**	**3490**	**3770**	**4100**	**4480**	**4900**	**5370**	**5840**	**6400**	**7060**	**7430**	**7810**	**8650**	**9590**	**10530**	**11660**	**12880**	**14280**
710	0.025	0.028	0.030	0.033	0.035	0.038	0.041	0.044	0.048	0.053	0.058	0.063	0.069	0.076	0.080	0.084	0.093	0.103	0.113	0.125	0.138	0.154
	7.6	*8.7*	*9.3*	*9.9*	*10.7*	*11.5*	*12.4*	*13.5*	*14.7*	*16.1*	*17.6*	*19.1*	*21.0*	*23.1*	*24.4*	*25.6*	*28.4*	*31.4*	*34.5*	*38.2*	*42.2*	*46.8*
31.5 in.	**2440**	**2770**	**2950**	**3140**	**3380**	**3610**	**3890**	**4220**	**4600**	**5020**	**5490**	**5960**	**6520**	**7180**	**7550**	**7930**	**8770**	**9710**	**10650**	**11770**	**12990**	**14400**
800	0.026	0.030	0.032	0.034	0.036	0.039	0.042	0.045	0.049	0.054	0.059	0.064	0.070	0.077	0.081	0.085	0.094	0.104	0.114	0.127	0.140	0.155
	8.0	*9.1*	*9.7*	*10.3*	*11.1*	*11.8*	*12.8*	*13.8*	*15.1*	*16.5*	*18.0*	*19.5*	*21.4*	*23.5*	*24.8*	*26.0*	*28.8*	*31.8*	*34.9*	*38.6*	*42.6*	*47.2*

Four-Shank KANTHAL SUPER 1700 9/18

Power W
Resistance Ω
Volt V

Max. element temperature 1700 °C (3090 °F)

Heating zone Ø mm 9
Terminal Ø mm 18
Shank distance mm 60

Furnace temp. °C 1300 (2370° F)
Element temp. °C 1550 (2820° F)

Element current A 305
Surface loading W/cm^2 16.6
W/in.^{2} 107

Heating zone, L_e mm →

Terminal L_u mm ↓

	7.1 in.	*8.9 in.*	*10.6 in.*	*12.2 in.*	*13.8 in.*	*15.8 in.*	*17.7 in.*	*20.5 in.*	*23.6 in.*	*26.4 in.*	*28.4 in.*
	180	225	270	310	350	400	450	520	600	670	720
17.7 in.	**4420**	**5260**	**6110**	**6860**	**7610**	**8550**	**9490**	**10800**	**12300**	**13610**	**14550**
450	0.048	0.057	0.066	0.074	0.082	0.092	0.102	0.116	0.132	0.146	0.156
	14.5	*17.3*	*20.0*	*22.5*	*24.9*	*28.0*	*31.1*	*35.4*	*40.3*	*44.6*	*47.7*
19.7 in.	**4480**	**5330**	**6170**	**6920**	**7670**	**8610**	**9550**	**10870**	**12370**	**13680**	**14620**
500	0.048	0.057	0.066	0.074	0.083	0.093	0.103	0.117	0.133	0.147	0.157
	14.7	*17.5*	*20.2*	*22.7*	*25.2*	*28.2*	*31.3*	*35.6*	*40.5*	*44.9*	*47.9*
22 in.	**4560**	**5410**	**6250**	**7000**	**7750**	**8690**	**9630**	**10940**	**12450**	**13760**	**14700**
560	0.049	0.058	0.067	0.075	0.083	0.093	0.104	0.118	0.134	0.148	0.158
	15.0	*17.7*	*20.5*	*23.0*	*25.4*	*28.5*	*31.6*	*35.9*	*40.8*	*45.1*	*48.2*
24 in.	**4630**	**5470**	**6320**	**7070**	**7820**	**8760**	**9700**	**11010**	**12510**	**13820**	**14760**
610	0,050	0,059	0,068	0,076	0,084	0,094	0,104	0,118	0,134	0,149	0,159
	15.2	*17.9*	*20.7*	*23.2*	*25.6*	*28.7*	*31.8*	*36.1*	*41.0*	*45.3*	*48.4*
26.4 in.	**4710**	**5550**	**6400**	**7150**	**7900**	**8840**	**9780**	**11090**	**12590**	**13900**	**14840**
670	0.051	0.060	0.069	0.077	0.085	0.095	0.105	0.119	0.135	0.149	0.160
	15.4	*18.2*	*21.0*	*23.4*	*25.9*	*29.0*	*32.1*	*36.4*	*41.3*	*45.6*	*48.7*
28.5 in.	**4780**	**5630**	**6470**	**7220**	**7970**	**8910**	**9850**	**11160**	**12660**	**13980**	**14910**
725	0.051	0.060	0.070	0.078	0.086	0.096	0.106	0.120	0.136	0.150	0.160
	15.7	*18.4*	*21.2*	*23.7*	*26.1*	*29.2*	*32.3*	*36.6*	*41.5*	*45.8*	*48.9*
30.3 in.	**4840**	**5680**	**6530**	**7280**	**8030**	**8970**	**9910**	**11220**	**12720**	**14040**	**14970**
770	0.052	0.061	0.070	0.078	0.086	0.096	0.106	0.121	0.137	0.151	0.161
	15.9	*18.6*	*21.4*	*23.9*	*26.3*	*29.4*	*32.5*	*36.8*	*41.7*	*46.0*	*49.1*

Four-Shank KANTHAL SUPER 1700 12/24

Power W
Resistance Ω
Volt V

Max. element temperature 1700 °C (3090 °F)

Heating zone Ø mm12
Terminal Ø mm 24
Shank distance mm 60

Furnace temp. °C 1300 (2370° F)
Element temp. °C 1550 (2820° F)

Element current A 470
Surface loading W/cm^2 16.6
W/in.^{2} 107

Heating zone, L_e mm →

Terminal L_u mm ↓

	7.1 in. 180	*8.9 in.* 225	*10.6 in.* 270	*12.2 in.* 310	*13.8 in.* 350	*15.8 in.* 400	*17.7 in.* 450	*20.5 in.* 520	*23.6 in.* 600	*26.4 in.* 670	*28.4 in.* 720
17.7 in.	**5850**	**6970**	**8100**	**9100**	**10110**	**11360**	**12610**	**14370**	**16370**	**18130**	**19380**
450	0.026	0.032	0.037	0.041	0.046	0.051	0.057	0.065	0.074	0.082	0.088
	12.4	*14.8*	*17.2*	*19.4*	*21.5*	*24.2*	*26.8*	*30.6*	*34.8*	*38.6*	*41.2*
19.7 in.	**5930**	**7060**	**8190**	**9190**	**10200**	**11450**	**12700**	**14460**	**16460**	**18220**	**19470**
500	0.027	0.032	0.037	0.042	0.046	0.052	0.058	0.065	0.075	0.082	0.088
	12.6	*15.0*	*17.4*	*19.6*	*21.7*	*24.4*	*27.0*	*30.8*	*35.0*	*38.8*	*41.4*
22 in.	**6040**	**7170**	**8300**	**9300**	**10300**	**11550**	**12810**	**14560**	**16570**	**18320**	**19580**
560	0.027	0.032	0.038	0.042	0.047	0.052	0.058	0.066	0.075	0.083	0.089
	12.8	*15.2*	*17.6*	*19.8*	*21.9*	*24.6*	*27.2*	*31.0*	*35.2*	*39.0*	*41.6*
24 in.	**6130**	**7260**	**8380**	**9390**	**10390**	**11640**	**12900**	**14650**	**16660**	**18410**	**19660**
610	0.028	0.033	0.038	0.042	0.047	0.053	0.058	0.066	0.075	0.083	0.089
	13.0	*15.4*	*17.8*	*20.0*	*22.1*	*24.8*	*27.4*	*31.2*	*35.4*	*39.2*	*41.8*
26.4 in.	**6230**	**7360**	**8490**	**9490**	**10490**	**11750**	**13000**	**14760**	**16760**	**18520**	**19770**
670	0.028	0.033	0.038	0.043	0.048	0.053	0.059	0.067	0.076	0.084	0.089
	13.3	*15.7*	*18.1*	*20.2*	*22.3*	*25.0*	*27.7*	*31.4*	*35.7*	*39.4*	*42.1*
28.5 in.	**6330**	**7460**	**8590**	**9590**	**10590**	**11840**	**13100**	**14850**	**16860**	**18610**	**19870**
725	0.029	0.034	0.039	0.043	0.048	0.054	0.059	0.067	0.076	0.084	0.090
	13.5	*15.9*	*18.3*	*20.4*	*22.5*	*25.2*	*27.9*	*31.6*	*35.9*	*39.6*	*42.3*
30.3 in.	**6410**	**7540**	**8660**	**9670**	**10670**	**11920**	**13180**	**14930**	**16940**	**18690**	**19940**
770	0.029	0.034	0.039	0.044	0.048	0.054	0.060	0.068	0.077	0.085	0.090
	13.6	*16.0*	*18.4*	*20.6*	*22.7*	*25.4*	*28.0*	*31.8*	*36.0*	*39.8*	*42.4*

Two-Shank KANTHAL SUPER 1700 12/24

Power W
Resistance Ω
Volt V

Max. element temperature 1700 °C (3090 °F)

Heating zone Ø mm 12
Terminal Ø mm 24
Shank distance mm 80

Furnace temp. °C 1300 (2370° F)
Element temp. °C 1550 (2820° F)

Element current A 470
Surface loading W/cm^2 16.6
W/in.^{2} 107

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in.	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	*15.8 in.*	*17.7 in.*	*19.7 in.*	*22 in.*	*24.8 in.*	*26.4 in.*	*28 in.*	*31.5 in.*	*35.4 in.*	*39.4 in.*	*44.1 in.*	*49.2 in.*	*55.1 in.*
	125	160	180	200	225	250	280	315	355	400	450	500	560	630	670	710	800	900	1000	1120	1250	1400
11 in.	**2390**	**2830**	**3080**	**3330**	**3650**	**3960**	**4340**	**4780**	**5280**	**5840**	**6470**	**7090**	**7850**	**8720**	**9230**	**9730**	**10850**	**12110**	**13360**	**14870**	**16490**	**18370**
280	0.011	0.013	0.014	0.015	0.017	0.018	0.020	0.022	0.024	0.026	0.029	0.032	0.036	0.039	0.042	0.044	0.049	0.055	0.060	0.067	0.075	0.083
	5.1	*6.0*	*6.6*	*7.1*	*7.8*	*8.4*	*9.2*	*10.2*	*11.2*	*12.4*	*13.8*	*15.1*	*16.7*	*18.6*	*19.6*	*20.7*	*23.1*	*25.8*	*28.4*	*31.6*	*35.1*	*39.1*
12.4 in.	**2460**	**2900**	**3150**	**3400**	**3710**	**4020**	**4400**	**4840**	**5340**	**5900**	**6530**	**7160**	**7910**	**8790**	**9290**	**9790**	**10920**	**12170**	**13420**	**14930**	**16560**	**18440**
315	0.011	0.013	0.014	0.015	0.017	0.018	0.020	0.022	0.024	0.027	0.030	0.032	0.036	0.040	0.042	0.044	0.049	0.055	0.061	0.068	0.075	0.083
	5.2	*6.2*	*6.7*	*7.2*	*7.9*	*8.6*	*9.4*	*10.3*	*11.4*	*12.6*	*13.9*	*15.2*	*16.8*	*18.7*	*19.8*	*20.8*	*23.2*	*25.9*	*28.6*	*31.8*	*35.2*	*39.2*
14 in.	**2530**	**2970**	**3220**	**3470**	**3780**	**4090**	**4470**	**4910**	**5410**	**5970**	**6600**	**7230**	**7980**	**8860**	**9360**	**9860**	**10990**	**12240**	**13490**	**15000**	**16630**	**18510**
355	0.011	0.013	0.015	0.016	0.017	0.019	0.020	0.022	0.024	0.027	0.030	0.033	0.036	0.040	0.042	0.045	0.050	0.055	0.061	0.068	0.075	0.084
	5.4	*6.3*	*6.8*	*7.4*	*8.0*	*8.7*	*9.5*	*10.4*	*11.5*	*12.7*	*14.0*	*15.4*	*17.0*	*18.8*	*19.9*	*21.0*	*23.4*	*26.0*	*28.7*	*31.9*	*35.4*	*39.4*
15.8 in	**2610**	**3040**	**3300**	**3550**	**3860**	**4170**	**4550**	**4990**	**5490**	**6050**	**6680**	**7310**	**8060**	**8940**	**9440**	**9940**	**11070**	**12320**	**13570**	**15080**	**16710**	**18590**
400	0.012	0.014	0.015	0.016	0.017	0.019	0.021	0.023	0.025	0.027	0.030	0.033	0.036	0.040	0.043	0.045	0.050	0.056	0.061	0.068	0.076	0.084
	5.5	*6.5*	*7.0*	*7.5*	*8.2*	*8.9*	*9.7*	*10.6*	*11.7*	*12.9*	*14.2*	*15.5*	*17.1*	*19.0*	*20.1*	*21.1*	*23.5*	*26.2*	*28.9*	*32.1*	*35.5*	*39.5*
17.7 in.	**2690**	**3130**	**3380**	**3630**	**3950**	**4260**	**4640**	**5080**	**5580**	**6140**	**6770**	**7390**	**8150**	**9020**	**9520**	**10030**	**11150**	**12410**	**13660**	**15160**	**16790**	**18670**
450	0.012	0.014	0.015	0.016	0.018	0.019	0.021	0.023	0.025	0.028	0.031	0.033	0.037	0.041	0.043	0.045	0.050	0.056	0.062	0.069	0.076	0.085
	5.7	*6.7*	*7.2*	*7.7*	*8.4*	*9.1*	*9.9*	*10.8*	*11.9*	*13.1*	*14.4*	*15.7*	*17.3*	*19.2*	*20.3*	*21.3*	*23.7*	*26.4*	*29.1*	*32.3*	*35.7*	*39.7*
19.7 in.	**2780**	**3220**	**3470**	**3720**	**4040**	**4350**	**4720**	**5160**	**5660**	**6230**	**6860**	**7480**	**8230**	**9110**	**9610**	**10110**	**11240**	**12490**	**13750**	**15250**	**16880**	**18760**
500	0.013	0.015	0.016	0.017	0.018	0.020	0.021	0.023	0.026	0.028	0.031	0.034	0.037	0.041	0.044	0.046	0.051	0.057	0.062	0.069	0.076	0.085
	5.9	*6.9*	*7.4*	*7.9*	*8.6*	*9.3*	*10.1*	*11.0*	*12.1*	*13.3*	*14.6*	*15.9*	*17.5*	*19.4*	*20.5*	*21.5*	*23.9*	*26.6*	*29.3*	*32.5*	*35.9*	*39.9*
22 in.	**2890**	**3330**	**3580**	**3830**	**4140**	**4450**	**4830**	**5270**	**5770**	**6330**	**6960**	**7590**	**8340**	**9220**	**9720**	**10220**	**11350**	**12600**	**13850**	**15360**	**16990**	**18870**
560	0.013	0.015	0.016	0.017	0.019	0.020	0.022	0.024	0.026	0.029	0.032	0.034	0.038	0.042	0.044	0.046	0.051	0.057	0.063	0.070	0.077	0.085
	6.1	*7.1*	*7.6*	*8.1*	*8.8*	*9.5*	*10.3*	*11.2*	*12.3*	*13,.5*	*14.8*	*16.1*	*17.7*	*19.6*	*20.7*	*21.7*	*24.1*	*26.8*	*29.5*	*32.7*	*36.1*	*40.1*
24.8 in.	**3010**	**3450**	**3700**	**3950**	**4260**	**4580**	**4950**	**5390**	**5890**	**6460**	**7080**	**7710**	**8460**	**9340**	**9840**	**10340**	**11470**	**12720**	**13980**	**15480**	**17110**	**18990**
630	0.014	0.016	0.017	0.018	0.019	0.021	0.022	0.024	0.027	0.029	0.032	0.035	0.038	0.042	0.045	0.047	0.052	0.058	0.063	0.070	0.077	0.086
	6.4	*7.3*	*7.9*	*8.4*	*9.1*	*9.7*	*10.5*	*11.5*	*12.5*	*13.7*	*15.1*	*16.4*	*18.0*	*19.9*	*20.9*	*22.0*	*24.4*	*27.1*	*29.7*	*32.9*	*36.4*	*40.4*
26.4 in.	**3080**	**3520**	**3770**	**4020**	**4330**	**4650**	**5020**	**5460**	**5960**	**6530**	**7150**	**7780**	**8530**	**9410**	**9910**	**10410**	**11540**	**12790**	**14050**	**15550**	**17180**	**19060**
670	0.014	0.016	0.017	0.018	0.020	0.021	0.023	0.025	0.027	0.030	0.032	0.035	0.039	0.043	0.045	0.047	0.052	0.058	0.064	0.070	0.078	0.086
	6.6	*7.5*	*8.0*	*8.6*	*9.2*	*9.9*	*10.7*	*11.6*	*12.7*	*13.9*	*15.2*	*16.6*	*18.2*	*20.0*	*21.1*	*22.2*	*24.6*	*27.2*	*29.9*	*33.1*	*36.6*	*40.6*
28 in.	**3150**	**3590**	**3840**	**4090**	**4400**	**4720**	**5090**	**5530**	**6030**	**6600**	**7220**	**7850**	**8600**	**9480**	**9980**	**10480**	**11610**	**12860**	**14120**	**15620**	**17250**	**19130**
710	0.014	0.016	0.017	0.019	0.020	0.021	0.023	0.025	0.027	0.030	0.033	0.036	0.039	0.043	0.045	0.047	0.053	0.058	0.064	0.071	0.078	0.087
	6.7	*7.6*	*8.2*	*8.7*	*9.4*	*10.0*	*10.8*	*11.8*	*12.8*	*14.0*	*15.4*	*16.7*	*18.3*	*20.2*	*21.2*	*22.3*	*24.7*	*27.4*	*30.0*	*33.2*	*36.7*	*40.7*
31.5 in.	**3310**	**3750**	**4000**	**4250**	**4560**	**4880**	**5250**	**5690**	**6190**	**6760**	**7380**	**8010**	**8760**	**9640**	**10140**	**10640**	**11770**	**13020**	**14280**	**15780**	**17410**	**19290**
800	0.015	0.017	0.018	0.019	0.021	0.022	0.024	0.026	0.028	0.031	0.033	0.036	0.040	0.044	0.046	0.048	0.053	0.059	0.065	0.071	0.079	0.087
	7.0	*8.0*	*8.5*	*9.0*	*9.7*	*10.4*	*11.2*	*12.1*	*13.2*	*14.4*	*15.7*	*17.0*	*18.6*	*20.5*	*21.6*	*22.6*	*25.0*	*27.7*	*30.4*	*33.6*	*37.0*	*41.0*

Two-Shank KANTHAL SUPER 1800 3/6

Power W
Resistance Ω
Volt V

Max. element temperature 1800 °C (3270 °F)

Heating zone Ø mm 3
Terminal Ø mm 6
Shank distance mm 25

Furnace temp. °C 1600 (2910° F)
Element temp. °C 1700 (3090° F)

Element current A 48
Surface loading W/cm^2 12.0
W/in.^{2} 77

Heating zone, L_e mm →

Terminal L_u mm ↓

	2 in.	*3 in.*	*3.9 in.*	*4.9 in.*	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	*15.8 in.*
	50	75	100	125	160	180	200	225	250	280	315	355	400
2 in.	**166**	**223**	**279**	**336**	**415**	**460**	**505**	**562**	**618**	**686**	**765**	**855**	**957**
50	0.074	0.099	0.124	0.149	0.184	0.204	0.224	0.249	0.274	0.304	0.339	0.379	0.424
	3.5	*4.7*	*5.9*	*7.1*	*8.7*	*9.7*	*10.6*	*11.8*	*13.0*	*14.4*	*16.1*	*18.0*	*20.1*
3 in.	**175**	**232**	**288**	**345**	**424**	**469**	**514**	**571**	**627**	**695**	**774**	**864**	**966**
75	0.078	0.103	0.128	0.153	0.188	0.208	0.228	0.253	0.278	0.308	0.343	0.383	0.428
	3.7	*4.9*	*6.1*	*7.3*	*8.9*	*9.9*	*10.8*	*12.0*	*13.2*	*14.6*	*16.3*	*18.2*	*20.3*
3.9 in.	**184**	**241**	**297**	**354**	**433**	**478**	**523**	**580**	**636**	**704**	**783**	**873**	**975**
100	0.082	0.107	0.132	0.157	0.192	0.212	0.232	0.257	0.282	0.312	0.347	0.387	0.432
	3.9	*5.1*	*6.3*	*7.4*	*9.1*	*10.1*	*11.0*	*12.2*	*13.4*	*14.8*	*16.5*	*18.4*	*20.5*
4.9 in.	**193**	**250**	**306**	**363**	**442**	**487**	**532**	**589**	**645**	**713**	**792**	**882**	**984**
125	0.086	0.111	0.136	0.161	0.196	0.216	0.236	0.261	0.286	0.316	0.351	0.391	0.436
	4.1	*5.3*	*6.4*	*7.6*	*9.3*	*10.3*	*11.2*	*12.4*	*13.6*	*15.0*	*16.7*	*18.6*	*20.7*
5.5 in.	**199**	**255**	**312**	**368**	**447**	**492**	**538**	**594**	**651**	**718**	**797**	**888**	**989**
140	0.088	0.113	0.138	0.163	0.198	0.218	0.238	0.263	0.288	0.318	0.353	0.393	0.438
	4.2	*5.4*	*6.6*	*7.8*	*9.4*	*10.4*	*11.3*	*12.5*	*13.7*	*15.1*	*16.8*	*18.7*	*20.8*
6.3 in.	**206**	**262**	**319**	**375**	**454**	**500**	**545**	**601**	**658**	**726**	**805**	**895**	**997**
160	0.091	0.116	0.141	0.166	0.201	0.221	0.241	0.267	0.292	0.322	0.357	0.397	0.442
	4.3	*5.5*	*6.7*	*7.9*	*9.6*	*10.5*	*11.5*	*12.7*	*13.8*	*15.3*	*16.9*	*18.8*	*21.0*
7.1 in.	**213**	**270**	**326**	**383**	**462**	**507**	**552**	**609**	**665**	**733**	**812**	**902**	**1004**
180	0.095	0.120	0,145	0.170	0.205	0.225	0.245	0.270	0.295	0.325	0.360	0.400	0.445
	4.5	*5.7*	*6.9*	*8.1*	*9.7*	*10.7*	*11.6*	*12.8*	*14.0*	*15.4*	*17.1*	*19.0*	*21.1*
7.9 in.	**220**	**277**	**333**	**390**	**469**	**514**	**559**	**616**	**672**	**740**	**819**	**909**	**1011**
200	0.098	0.123	0.148	0.173	0.208	0.228	0.248	0.273	0.298	0.328	0.363	0.403	0.448
	4.6	*5.8*	*7.0*	*8.2*	*9.9*	*10.8*	*11.8*	*13.0*	*14.2*	*15.6*	*17.2*	*19.1*	*21.3*
8.9 in.	**229**	**286**	**342**	**399**	**478**	**523**	**568**	**625**	**681**	**749**	**828**	**918**	**1020**
225	0.102	0.127	0.152	0.177	0.212	0.232	0.252	0.277	0.302	0.332	0.367	0.407	0.452
	4.8	*6.0*	*7.2*	*8.4*	*10.1*	*11.0*	*12.0*	*13.2*	*14.3*	*15.8*	*17.4*	*19.3*	*21.5*
9.8 in	**239**	**295**	**351**	**408**	**487**	**532**	**577**	**634**	**690**	**758**	**837**	**927**	**1029**
250	0.106	0.131	0.156	0.181	0.216	0.236	0.256	0.281	0.306	0.336	0.371	0.411	0.456
	5.0	*6.2*	*7.4*	*8.6*	*10.3*	*11.2*	*12.2*	*13.3*	*14.5*	*16.0*	*17.6*	*19.5*	*21.7*
11 in.	**249**	**306**	**362**	**419**	**498**	**543**	**588**	**645**	**701**	**769**	**848**	**938**	**1040**
280	0.111	0.136	0.161	0.186	0.221	0.241	0.261	0.286	0.311	0.341	0.376	0.416	0.461
	5.2	*6.4*	*7.6*	*8.8*	*10.5*	*11.4*	*12.4*	*13.6*	*14.8*	*16.2*	*17.9*	*19.8*	*21.9*
12.4 in.	**262**	**318**	**375**	**431**	**510**	**556**	**601**	**657**	**714**	**781**	**861**	**951**	**1053**
315	0.116	0.141	0.166	0.191	0.226	0.246	0.266	0.291	0.316	0.346	0.381	0.421	0.467
	5.5	*6.7*	*7.9*	*9.1*	*10.7*	*11.7*	*12.6*	*13.8*	*15.0*	*16.5*	*18.1*	*20.0*	*22.2*
14 in.	**276**	**333**	**389**	**446**	**525**	**570**	**615**	**672**	**728**	**796**	**875**	**965**	**1067**
355	0.123	0.148	0.173	0.198	0.233	0.253	0.273	0.298	0.323	0.353	0.388	0.428	0.473
	5.8	*7.0*	*8.2*	*9.4*	*11.1*	*12.0*	*13.0*	*14.1*	*15.3*	*16.8*	*18.4*	*20.3*	*22.5*
15.8 in	**293**	**349**	**406**	**462**	**541**	**586**	**631**	**688**	**744**	**812**	**891**	**982**	**1083**
400	0.130	0.155	0.180	0.205	0.240	0.260	0.280	0.305	0.330	0.360	0.395	0.435	0.480
	6.2	*7.4*	*8.5*	*9.7*	*11.4*	*12.3*	*13.3*	*14.5*	*15.7*	*17.1*	*18.8*	*20.7*	*22.8*

Two-Shank KANTHAL SUPER 1800 4/9

Power W
Resistance Ω
Volt V

Max. element temperature 1800 °C (3270 °F)

Heating zone Ø mm 4
Terminal Ø mm 9
Shank distance mm 25

Furnace temp. °C 1600 (2910° F)
Element temp. °C 1700 (2090° F)

Element current A 73
Surface loading W/cm^2 12.0
W/in^2 77

Heating zone, L_e mm →

Terminal L_u mm ↓

	2 in. 50	*3 in.* 75	*3.9 in.* 100	*4.9 in.* 125	*6.3 in.* 160	*7.1 in.* 180	*7.9 in.* 200	*8.9 in.* 225	*9.8 in.* 250	*11 in.* 280	*12.4 in.* 315	*14 in.* 355	*15.8 in.* 400
2 in.	**215**	**291**	**366**	**441**	**547**	**607**	**667**	**743**	**818**	**909**	**1014**	**1135**	**1270**
50	0.040	0.054	0.068	0.082	0.102	0.113	0.125	0.139	0.153	0.170	0.189	0.212	0.237
	2.9	*4.0*	*5.0*	*6.0*	*7.5*	*8.3*	*9.1*	*10.2*	*11.2*	*12.4*	*13.9*	*15.5*	*17.4*
3 in.	**225**	**300**	**376**	**451**	**556**	**617**	**677**	**752**	**828**	**918**	**1024**	**1144**	**1280**
75	0.042	0.056	0.070	0.084	0.104	0.115	0.126	0.141	0.155	0.172	0.191	0.214	0.239
	3.1	*4.1*	*5.1*	*6.2*	*7.6*	*8.4*	*9.3*	*10.3*	*11.3*	*12.5*	*14.0*	*15.6*	*17.5*
3.9 in.	**234**	**310**	**385**	**460**	**566**	**626**	**686**	**762**	**837**	**928**	**1033**	**1154**	**1289**
100	0.044	0.058	0.072	0.086	0.106	0.117	0.128	0.142	0.156	0.173	0.193	0.216	0.241
	3.2	*4.2*	*5.3*	*6.3*	*7.7*	*8.6*	*9.4*	*10.4*	*11.4*	*12.7*	*14.1*	*15.8*	*17.6*
4.9 in.	**244**	**319**	**395**	**470**	**575**	**636**	**696**	**771**	**847**	**937**	**1043**	**1163**	**1299**
125	0.046	0.060	0.074	0.088	0.108	0.119	0.130	0.144	0.158	0.175	0.195	0.217	0.243
	3.3	*4.4*	*5.4*	*6.4*	*7.9*	*8.7*	*9.5*	*10.5*	*11.6*	*12.8*	*14.3*	*15.9*	*17.8*
5.5 in.	**250**	**325**	**400**	**476**	**581**	**641**	**702**	**777**	**852**	**943**	**1048**	**1169**	**1305**
140	0.047	0.061	0.075	0.089	0.109	0.120	0.131	0.145	0.159	0.176	0.196	0.218	0.244
	3.4	*4.4*	*5.5*	*6.5*	*7.9*	*8.8*	*9.6*	*10.6*	*11.7*	*12.9*	*14.3*	*16.0*	*17.8*
6.3 in.	**257**	**333**	**408**	**483**	**589**	**649**	**709**	**785**	**860**	**950**	**1056**	**1176**	**1312**
160	0.048	0.062	0.076	0.090	0.110	0.121	0.133	0.147	0.161	0.178	0.197	0.220	0.245
	3.5	*4.5*	*5.6*	*6.6*	*8.0*	*8.9*	*9.7*	*10.7*	*11.8*	*13.0*	*14.4*	*16.1*	*17.9*
7.1 in.	**265**	**340**	**416**	**491**	**596**	**657**	**717**	**792**	**868**	**958**	**1064**	**1184**	**1320**
180	0.049	0.064	0.078	0.092	0.111	0.123	0.134	0.148	0.162	0.179	0.199	0.221	0.247
	3.6	*4.6*	*5.7*	*6.7*	*8.2*	*9.0*	*9.8*	*10.8*	*11.9*	*13.1*	*14.5*	*16.2*	*18.0*
7.9 in.	**272**	**348**	**423**	**498**	**604**	**664**	**725**	**800**	**875**	**966**	**1071**	**1192**	**1327**
200	0.051	0.065	0.079	0.093	0.113	0.124	0.135	0.149	0.164	0.180	0.200	0.223	0.248
	3.7	*4.8*	*5.8*	*6.8*	*8.3*	*9.1*	*9.9*	*10.9*	*12.0*	*13.2*	*14.6*	*16.3*	*18.1*
8.9 in.	**282**	**357**	**433**	**508**	**614**	**674**	**734**	**809**	**885**	**975**	**1081**	**1201**	**1337**
225	0.053	0.067	0.081	0.095	0.115	0.126	0.137	0.151	0.165	0.182	0.202	0.224	0.250
	3.9	*4.9*	*5.9*	*6.9*	*8.4*	*9.2*	*10.0*	*11.1*	*12.1*	*13.3*	*14.8*	*16.4*	*18.3*
9.8 in	**291**	**367**	**442**	**518**	**623**	**683**	**744**	**819**	**894**	**985**	**1090**	**1211**	**1346**
250	0.054	0.069	0.083	0.097	0.116	0.128	0.139	0.153	0.167	0.184	0.204	0.226	0.252
	4.0	*5.0*	*6.0*	*7.1*	*8.5*	*9.3*	*10.2*	*11.2*	*12.2*	*13.5*	*14.9*	*16.5*	*18.4*
11 in.	**303**	**378**	**454**	**529**	**634**	**695**	**755**	**830**	**906**	**996**	**1102**	**1222**	**1358**
280	0.057	0.071	0.085	0.099	0.119	0.130	0.141	0.155	0.169	0.186	0.206	0.228	0.254
	4.1	*5.2*	*6.2*	*7.2*	*8.7*	*9.5*	*10.3*	*11.3*	*12.4*	*13.6*	*15.1*	*16.7*	*18.6*
12.4 in.	**316**	**392**	**467**	**542**	**648**	**708**	**768**	**844**	**919**	**1009**	**1115**	**1236**	**1371**
315	0.059	0.073	0.087	0.101	0.121	0.132	0.144	0.158	0.172	0.189	0.208	0.231	0.256
	4.3	*5.4*	*6.4*	*7.4*	*8.9*	*9.7*	*10.5*	*11.5*	*12.6*	*13.8*	*15.2*	*16.9*	*18.7*
14 in.	**331**	**407**	**482**	**558**	**663**	**723**	**784**	**859**	**934**	**1025**	**1130**	**1251**	**1386**
355	0.062	0.076	0.090	0.104	0.124	0.135	0.146	0.160	0.175	0.191	0.211	0.234	0.259
	4.5	*5.6*	*6.6*	*7.6*	*9.1*	*9.9*	*10.7*	*11.7*	*12.8*	*14.0*	*15.4*	*17.1*	*18.9*
15.8 in	**349**	**424**	**499**	**575**	**680**	**740**	**801**	**876**	**951**	**1042**	**1147**	**1268**	**1404**
400	0.065	0.079	0.093	0.107	0.127	0.138	0.150	0.164	0.178	0.195	0.214	0.237	0.262
	4.8	*5.8*	*6.8*	*7.9*	*9.3*	*10.1*	*10.9*	*12.0*	*13.0*	*14.2*	*15.7*	*17.3*	*19.2*

Two-Shank KANTHAL SUPER 1800 6/12

Power W
Resistance Ω
Volt V

Max. element temperature 1800 °C (3270 °F)

Heating zone Ø mm 6
Terminal Ø mm 12
Shank distance mm 50

Furnace temp. °C 1600 (2910° F)
Element temp. °C 1700 (2090° F)

Element current A 134
Surface loading W/cm² 12.0
W/in.² 77

Heating zone, L_e mm ⟶

Terminal L_u mm ↓

	4.9 in. 125	*6.3 in.* 160	*7.1 in.* 180	*7.9 in.* 200	*8.9 in.* 225	*9.8 in.* 250	*11 in.* 280	*12.4 in.* 315	*14 in.* 355	*15.8 in.* 400	*17.7 in.* 450	*19.7 in.* 500	*22 in.* 560	*24.8 in.* 630	*26.4 in.* 670	*28 in.* 710	*31.5 in.* 800	*35.4 in.* 900	*39.4 in.* 1000
4.9 in.	**750**	**910**	**1000**	**1090**	**1200**	**1320**	**1450**	**1610**	**1790**	**1990**	**2220**	**2450**	**2720**	**3030**	**3220**	**3400**	**3800**	**4260**	**4710**
125	0.042	0.050	0.055	0.060	0.067	0.073	0.080	0.089	0.099	0.110	0.123	0.135	0.150	0.168	0.178	0.188	0.211	0.236	0.261
	5.6	*6.8*	*7.4*	*8.1*	*9.0*	*9.8*	*10.8*	*12.0*	*13.3*	*14.8*	*16.5*	*18.2*	*20.2*	*22.6*	*23.9*	*25.3*	*28.3*	*31.7*	*35.0*
5.5 in.	**760**	**920**	**1010**	**1100**	**1210**	**1330**	**1460**	**1620**	**1800**	**2010**	**2230**	**2460**	**2730**	**3050**	**3230**	**3410**	**3810**	**4270**	**4720**
140	0.042	0.051	0.056	0.061	0.067	0.073	0.081	0.090	0.100	0.111	0.124	0.136	0.151	0.169	0.179	0.189	0.211	0.236	0.261
	5.7	*6.8*	*7.5*	*8.2*	*9.0*	*9.9*	*10.9*	*12.1*	*13.4*	*14.9*	*16.6*	*18.3*	*20.3*	*22.7*	*24.0*	*25.4*	*28.4*	*31.7*	*35.1*
6.3 in.	**780**	**940**	**1030**	**1120**	**1230**	**1340**	**1480**	**1640**	**1820**	**2020**	**2250**	**2470**	**2740**	**3060**	**3240**	**3420**	**3830**	**4280**	**4730**
160	0.043	0.052	0.057	0.062	0.068	0.074	0.082	0.091	0.101	0.112	0.124	0.137	0.152	0.169	0.179	0.189	0.212	0.237	0.262
	5.8	*7.0*	*7.6*	*8.3*	*9.1*	*10.0*	*11.0*	*12.2*	*13.5*	*15.0*	*16.7*	*18.4*	*20.4*	*22.8*	*24.1*	*25.5*	*28.5*	*31.8*	*35.2*
7.1 in.	**790**	**950**	**1040**	**1130**	**1240**	**1360**	**1490**	**1650**	**1830**	**2030**	**2260**	**2490**	**2760**	**3070**	**3260**	**3440**	**3840**	**4290**	**4750**
180	0.044	0.053	0.058	0.063	0.069	0.075	0.083	0.091	0.101	0.113	0.125	0.138	0.153	0.170	0.180	0.190	0.213	0.238	0.263
	5.9	*7.1*	*7.7*	*8.4*	*9.3*	*10.1*	*11.1*	*12.3*	*13.6*	*15.1*	*16.8*	*18.5*	*20.5*	*22.9*	*24.2*	*25.6*	*28.6*	*32.0*	*35.3*
7.9 in.	**810**	**960**	**1050**	**1140**	**1260**	**1370**	**1510**	**1660**	**1850**	**2050**	**2280**	**2500**	**2770**	**3090**	**3270**	**3450**	**3860**	**4310**	**4760**
200	0.045	0.053	0.058	0.063	0.070	0.076	0.083	0.092	0.102	0.113	0.126	0.138	0.153	0.171	0.181	0.191	0.214	0.239	0.264
	6.0	*7.2*	*7.8*	*8.5*	*9.4*	*10.2*	*11.2*	*12.4*	*13.7*	*15.2*	*16.9*	*18.6*	*20.6*	*23.0*	*24.3*	*25.7*	*28.7*	*32.1*	*35.4*
8.9 in.	**820**	**980**	**1070**	**1160**	**1280**	**1390**	**1520**	**1680**	**1860**	**2070**	**2290**	**2520**	**2790**	**3110**	**3290**	**3470**	**3880**	**4330**	**4780**
225	0.046	0.054	0.059	0.064	0.071	0.077	0.084	0.093	0.103	0.114	0.127	0.139	0.154	0.172	0.182	0.192	0.215	0.240	0.265
	6.1	*7.3*	*8.0*	*8.7*	*9.5*	*10.3*	*11.3*	*12.5*	*13.9*	*15.4*	*17.1*	*18.7*	*20.8*	*23.1*	*24.5*	*25.8*	*28.8*	*32.2*	*35.6*
9.8 in	**840**	**1000**	**1090**	**1180**	**1290**	**1410**	**1540**	**1700**	**1880**	**2090**	**2310**	**2540**	**2810**	**3120**	**3310**	**3490**	**3890**	**4350**	**4800**
250	0.047	0.055	0.060	0.065	0.072	0.078	0.085	0.094	0.104	0.115	0.128	0.140	0.155	0.173	0.183	0.193	0.216	0.241	0.266
	6.3	*7.4*	*8.1*	*8.8*	*9.6*	*10.5*	*11.5*	*12.7*	*14.0*	*15.5*	*17.2*	*18.9*	*20.9*	*23.3*	*24.6*	*25.9*	*29.0*	*32.3*	*35.7*
11 in.	**860**	**1020**	**1110**	**1200**	**1320**	**1430**	**1560**	**1720**	**1900**	**2110**	**2330**	**2560**	**2830**	**3150**	**3330**	**3510**	**3920**	**4370**	**4820**
280	0.048	0.057	0.062	0.067	0.073	0.079	0.087	0.095	0.105	0.117	0.129	0.142	0.157	0.174	0.184	0.194	0.217	0.242	0.267
	6.4	*7.6*	*8.3*	*8.9*	*9.8*	*10.6*	*11.6*	*12.8*	*14.2*	*15.7*	*17.4*	*19.0*	*21.1*	*23.4*	*24.8*	*26.1*	*29.1*	*32.5*	*35.9*
12.4 in.	**890**	**1050**	**1140**	**1230**	**1340**	**1450**	**1590**	**1750**	**1930**	**2130**	**2360**	**2580**	**2860**	**3170**	**3350**	**3530**	**3940**	**4390**	**4840**
315	0.049	0.058	0.063	0.068	0.074	0.080	0.088	0.097	0.107	0.118	0.131	0.143	0.158	0.176	0.186	0.196	0.218	0.243	0.268
	6.6	*7.8*	*8.5*	*9.1*	*10.0*	*10.8*	*11.8*	*13.0*	*14.4*	*15.9*	*17.5*	*19.2*	*21.2*	*23.6*	*24.9*	*26.3*	*29.3*	*32.7*	*36.0*
14 in.	**920**	**1080**	**1170**	**1260**	**1370**	**1480**	**1620**	**1780**	**1960**	**2160**	**2390**	**2610**	**2880**	**3200**	**3380**	**3560**	**3970**	**4420**	**4870**
355	0.051	0.060	0.065	0.070	0.076	0.082	0.090	0.098	0.108	0.120	0.132	0.145	0.160	0.177	0.187	0.197	0.220	0.245	0.270
	6.8	*8.0*	*8.7*	*9.4*	*10.2*	*11.0*	*12.0*	*13.2*	*14.6*	*16.1*	*17.8*	*19.4*	*21.5*	*23.8*	*25.2*	*26.5*	*29.5*	*32.9*	*36.3*
15.8 in	**950**	**1110**	**1200**	**1290**	**1400**	**1520**	**1650**	**1810**	**1990**	**2190**	**2420**	**2650**	**2920**	**3230**	**3410**	**3590**	**4000**	**4450**	**4910**
400	0.053	0.061	0.066	0.071	0.078	0.084	0.091	0.100	0.110	0.121	0.134	0.146	0.161	0.179	0.189	0.199	0.222	0.247	0.272
	7.1	*8.2*	*8.9*	*9.6*	*10.4*	*11.3*	*12.3*	*13.5*	*14.8*	*16.3*	*18.0*	*19.7*	*21.7*	*24.1*	*25.4*	*26.7*	*29.8*	*33.1*	*36.5*
17.7 in.	**990**	**1140**	**1240**	**1330**	**1440**	**1550**	**1690**	**1850**	**2030**	**2230**	**2460**	**2680**	**2950**	**3270**	**3450**	**3630**	**4040**	**4490**	**4940**
450	0.055	0.063	0.068	0.073	0.080	0.086	0.093	0.102	0.112	0.123	0.136	0.148	0.163	0.181	0.191	0.201	0.224	0.249	0.274
	7.3	*8.5*	*9.2*	*9.9*	*10.7*	*11.5*	*12.6*	*13.7*	*15.1*	*16.6*	*18.3*	*20.0*	*22.0*	*24.3*	*25.7*	*27.0*	*30.0*	*33.4*	*36.8*
19.7 in.	**1020**	**1180**	**1270**	**1360**	**1470**	**1590**	**1720**	**1880**	**2060**	**2270**	**2490**	**2720**	**2990**	**3310**	**3490**	**3670**	**4070**	**4530**	**4980**
500	0.057	0.065	0.070	0.075	0.082	0.088	0.095	0.104	0.114	0.125	0.138	0.150	0.165	0.183	0.193	0.203	0.226	0.251	0.276
	7.6	*8.8*	*9.5*	*10.1*	*11.0*	*11.8*	*12.8*	*14.0*	*15.3*	*16.9*	*18.5*	*20.2*	*22.2*	*24.6*	*25.9*	*27.3*	*30.3*	*33.7*	*37.0*
22 in.	**1070**	**1220**	**1310**	**1400**	**1520**	**1630**	**1770**	**1920**	**2110**	**2310**	**2540**	**2760**	**3030**	**3350**	**3530**	**3710**	**4120**	**4570**	**5020**
560	0.059	0.068	0.073	0.078	0.084	0.090	0.098	0.107	0.117	0.128	0.140	0.153	0.168	0.185	0.195	0.205	0.228	0.253	0.278
	7.9	*9.1*	*9.8*	*10.5*	*11.3*	*12.1*	*13.1*	*14.3*	*15.7*	*17.2*	*18.9*	*20.5*	*22.6*	*24.9*	*26.3*	*27.6*	*30.6*	*34.0*	*37.4*
24.8 in.	**1120**	**1270**	**1370**	**1460**	**1570**	**1680**	**1820**	**1980**	**2160**	**2360**	**2590**	**2810**	**3080**	**3400**	**3580**	**3760**	**4170**	**4620**	**5070**
630	0.062	0.071	0.076	0.081	0.087	0.093	0.101	0.109	0.119	0.131	0.143	0.156	0.171	0.188	0.198	0.208	0.231	0.256	0.281
	8.3	*9.5*	*10.2*	*10.8*	*11.7*	*12.5*	*13.5*	*14.7*	*16.0*	*17.6*	*19.2*	*20.9*	*22.9*	*25.3*	*26.6*	*28.0*	*31.0*	*34.4*	*37.7*
26.4 in.	**1150**	**1300**	**1390**	**1480**	**1600**	**1710**	**1850**	**2000**	**2190**	**2390**	**2610**	**2840**	**3110**	**3430**	**3610**	**3790**	**4200**	**4650**	**5100**
670	0.063	0.072	0.077	0.082	0.088	0.095	0.102	0.111	0.121	0.132	0.145	0.157	0.172	0.190	0.200	0.210	0.232	0.257	0.282
	8.5	*9.7*	*10.4*	*11.0*	*11.9*	*12.7*	*13.7*	*14.9*	*16.3*	*17.8*	*19.5*	*21.1*	*23.2*	*25.5*	*26.9*	*28.2*	*31.2*	*34.6*	*38.0*
28 in.	**1170**	**1330**	**1420**	**1510**	**1630**	**1740**	**1880**	**2030**	**2210**	**2420**	**2640**	**2870**	**3140**	**3460**	**3640**	**3820**	**4230**	**4680**	**5130**
710	0.065	0.074	0.079	0.084	0.090	0.096	0.104	0.113	0.123	0.134	0.146	0.159	0.174	0.191	0.201	0.211	0.234	0.259	0.284
	8.7	*9.9*	*10.6*	*11.3*	*12.1*	*12.9*	*14.0*	*15.1*	*16.5*	*18.0*	*19.7*	*21.4*	*23.4*	*25.7*	*27.1*	*28.4*	*31.4*	*34.8*	*38.2*
31.5 in.	**1240**	**1400**	**1490**	**1580**	**1690**	**1800**	**1940**	**2100**	**2280**	**2480**	**2710**	**2930**	**3210**	**3520**	**3700**	**3880**	**4290**	**4740**	**5200**
800	0.069	0.077	0.082	0.087	0.094	0.100	0.107	0.116	0.126	0.137	0.150	0.162	0.177	0.195	0.205	0.215	0.238	0.263	0.288
	9.2	*10.4*	*11.1*	*11.7*	*12.6*	*13.4*	*14.4*	*15.6*	*17.0*	*18.5*	*20.2*	*21.8*	*23.9*	*26.2*	*27.6*	*28.9*	*31.9*	*35.3*	*38.7*

Two-Shank KANTHAL SUPER 1800 9/18

Power W
Resistance Ω
Volt V

Max. element temperature 1800 °C (3270 °F)

Heating zone Ø mm 9
Terminal Ø mm 18
Shank distance mm 60

Furnace temp. °C 1600 (2910° F)
Element temp. °C 1700 (2090° F)

Element current A 247
Surface loading W/cm^2 12.0
W/in^2 77

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in.	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	*15.8 in.*	*17.7 in.*	*19.7 in.*	*22 in.*	*24.8 in.*	*26.4 in.*	*28 in.*	*31.5 in.*	*35.4 in.*	*39.4 in.*
	125	160	180	200	225	250	280	315	355	400	450	500	560	630	670	710	800	900	1000
11 in.	**1310**	**1540**	**1680**	**1810**	**1980**	**2150**	**2360**	**2590**	**2870**	**3170**	**3510**	**3850**	**4260**	**4730**	**5000**	**5280**	**5890**	**6560**	**7240**
280	0.021	0.025	0.028	0.030	0.033	0.035	0.039	0.043	0.047	0.052	0.058	0.063	0.070	0.078	0.082	0.086	0.096	0.108	0.119
	5.3	*6.2*	*6.8*	*7.3*	*8.0*	*8.7*	*9.5*	*10.5*	*11.6*	*12.8*	*14.2*	*15.6*	*17.2*	*19.2*	*20.3*	*21.4*	*23.8*	*26.6*	*29.3*
12.4 in.	**1340**	**1580**	**1720**	**1850**	**2020**	**2190**	**2400**	**2630**	**2900**	**3210**	**3550**	**3890**	**4300**	**4770**	**5040**	**5310**	**5920**	**6600**	**7280**
315	0.022	0.026	0.028	0.030	0.033	0.036	0.039	0.043	0.048	0.053	0.058	0.064	0.070	0.078	0.083	0.087	0.097	0.108	0.119
	5.4	*6.4*	*7.0*	*7.5*	*8.2*	*8.9*	*9.7*	*10.7*	*11.8*	*13.0*	*14.4*	*15.7*	*17.4*	*19.3*	*20.4*	*21.5*	*24.0*	*26.7*	*29.5*
14 in.	**1390**	**1620**	**1760**	**1900**	**2070**	**2240**	**2440**	**2680**	**2950**	**3250**	**3590**	**3930**	**4340**	**4810**	**5090**	**5360**	**5970**	**6650**	**7320**
355	0.023	0.027	0.029	0.031	0.034	0.037	0.040	0.044	0.048	0.053	0.059	0.064	0.071	0.079	0.083	0.088	0.098	0.109	0.120
	5.6	*6.6*	*7.1*	*7.7*	*8.4*	*9.0*	*9.9*	*10.8*	*11.9*	*13.2*	*14.5*	*15.9*	*17.6*	*19.5*	*20.6*	*21.7*	*24.2*	*26.9*	*29.7*
15.8 in	**1440**	**1670**	**1810**	**1940**	**2110**	**2280**	**2490**	**2730**	**3000**	**3300**	**3640**	**3980**	**4390**	**4860**	**5130**	**5410**	**6020**	**6700**	**7370**
400	0.024	0.027	0.030	0.032	0.035	0.037	0.041	0.045	0.049	0.054	0.060	0.065	0.072	0.080	0.084	0.089	0.099	0.110	0.121
	5.8	*6.8*	*7.3*	*7.9*	*8.6*	*9.2*	*10.1*	*11.0*	*12.1*	*13.4*	*14.7*	*16.1*	*17.8*	*19.7*	*20.8*	*21.9*	*24.4*	*27.1*	*29.9*
17.7 in.	**1490**	**1730**	**1860**	**2000**	**2170**	**2340**	**2540**	**2780**	**3050**	**3360**	**3700**	**4030**	**4440**	**4920**	**5190**	**5460**	**6070**	**6750**	**7430**
450	0.024	0.028	0.031	0.033	0.036	0.038	0.042	0.046	0.050	0.055	0.061	0.066	0.073	0.081	0.085	0.089	0.100	0.111	0.122
	6.0	*7.0*	*7.5*	*8.1*	*8.8*	*9.5*	*10.3*	*11.3*	*12.4*	*13.6*	*15.0*	*16.3*	*18.0*	*19.9*	*21.0*	*22.1*	*24.6*	*27.3*	*30.1*
19.7 in.	**1540**	**1780**	**1920**	**2050**	**2220**	**2390**	**2600**	**2830**	**3110**	**3410**	**3750**	**4090**	**4500**	**4970**	**5240**	**5510**	**6120**	**6800**	**7480**
500	0.025	0.029	0.031	0.034	0.036	0.039	0.043	0.046	0.051	0.056	0.061	0.067	0.074	0.081	0.086	0.090	0.100	0.112	0.123
	6.3	*7.2*	*7.8*	*8.3*	*9.0*	*9.7*	*10.5*	*11.5*	*12.6*	*13.8*	*15.2*	*16.6*	*18.2*	*20.1*	*21.2*	*22.3*	*24.8*	*27.5*	*30.3*
22 in.	**1610**	**1850**	**1980**	**2120**	**2290**	**2460**	**2660**	**2900**	**3170**	**3480**	**3810**	**4150**	**4560**	**5040**	**5310**	**5580**	**6190**	**6870**	**7550**
560	0.026	0.030	0.032	0.035	0.038	0.040	0.044	0.048	0.052	0.057	0.063	0.068	0.075	0.083	0.087	0.091	0.101	0.113	0.124
	6.5	*7.5*	*8.0*	*8.6*	*9.3*	*9.9*	*10.8*	*11.7*	*12.8*	*14.1*	*15.4*	*16.8*	*18.5*	*20.4*	*21.5*	*22.6*	*25.1*	*27.8*	*30.6*
24.8 in.	**1690**	**1920**	**2060**	**2190**	**2360**	**2530**	**2740**	**2970**	**3250**	**3550**	**3890**	**4230**	**4640**	**5110**	**5380**	**5660**	**6270**	**6940**	**7620**
630	0.028	0.032	0.034	0.036	0.039	0.042	0.045	0.049	0.053	0.058	0.064	0.069	0.076	0.084	0.088	0.093	0.103	0.114	0.125
	6.8	*7.8*	*8.3*	*8.9*	*9.6*	*10.3*	*11.1*	*12.0*	*13.1*	*14.4*	*15.8*	*17.1*	*18.8*	*20.7*	*21.8*	*22.9*	*25.4*	*28.1*	*30.9*
26.4 in.	**1730**	**1970**	**2100**	**2240**	**2410**	**2580**	**2780**	**3020**	**3290**	**3590**	**3930**	**4270**	**4680**	**5160**	**5430**	**5700**	**6310**	**6990**	**7670**
670	0.028	0.032	0.034	0.037	0.039	0.042	0.046	0.049	0.054	0.059	0.064	0.070	0.077	0.085	0.089	0.093	0.103	0.115	0.126
	7.0	*8.0*	*8.5*	*9.1*	*9.7*	*10.4*	*11.3*	*12.2*	*13.3*	*14.6*	*15.9*	*17.3*	*18.9*	*20.9*	*22.0*	*23.1*	*25.5*	*28.3*	*31.0*
28 in.	**1770**	**2010**	**2150**	**2280**	**2450**	**2620**	**2820**	**3060**	**3330**	**3640**	**3980**	**4320**	**4720**	**5200**	**5470**	**5740**	**6350**	**7030**	**7710**
710	0.029	0.033	0.035	0.037	0.040	0.043	0.046	0.050	0.055	0.060	0.065	0.071	0.077	0.085	0.090	0.094	0.104	0.115	0.126
	7.2	*8.1*	*8.7*	*9.2*	*9.9*	*10.6*	*11.4*	*12.4*	*13.5*	*14.7*	*16.1*	*17.5*	*19.1*	*21.0*	*22.1*	*23.2*	*25.7*	*28.5*	*31.2*
31.5 in.	**1870**	**2110**	**2240**	**2380**	**2550**	**2720**	**2920**	**3160**	**3430**	**3740**	**4080**	**4410**	**4820**	**5300**	**5570**	**5840**	**6450**	**7130**	**7810**
800	0.031	0.035	0.037	0.039	0.042	0.045	0.048	0.052	0.056	0.061	0.067	0.072	0.079	0.087	0.091	0.096	0.106	0.117	0.128
	7.6	*8.5*	*9.1*	*9.6*	*10.3*	*11.0*	*11.8*	*12.8*	*13.9*	*15.1*	*16.5*	*17.9*	*19.5*	*21.4*	*22.5*	*23.6*	*26.1*	*28.9*	*31.6*

Two-Shank KANTHAL SUPER 1800 12/24

Power W
Resistance Ω
Volt V

Max. element temperature 1800 °C (3270 °F)

Heating zone Ø mm 12
Terminal Ø mm 24
Shank distance mm 80

Furnace temp. °C 1600 (2910° F)
Element temp. °C 1700 (2090° F)

Element current A 380
Surface loading W/cm^2 12.0
W/in.^{2} 77

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in.	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	*15.8 in.*	*17.7 in.*	*19.7 in.*	*22 in.*	*24.8 in.*	*26.4 in.*	*28 in.*	*31.5 in.*	*35.4 in.*	*39.4 in.*
	125	160	180	200	225	250	280	315	355	400	450	500	560	630	670	710	800	900	1000
11 in.	**1780**	**2090**	**2270**	**2450**	**2680**	**2910**	**3180**	**3490**	**3850**	**4260**	**4710**	**5160**	**5710**	**6340**	**6700**	**7060**	**7870**	**8780**	**9680**
280	0.012	0.014	0.016	0.017	0.019	0.020	0.022	0.024	0.027	0.030	0.033	0.036	0.040	0.044	0.046	0.049	0.055	0.061	0.067
	4.7	*5.5*	*6.0*	*6.5*	*7.1*	*7.6*	*8.4*	*9.2*	*10.1*	*11.2*	*12.4*	*13.6*	*15.0*	*16.7*	*17.6*	*18.6*	*20.7*	*23.1*	*25.5*
12.4 in.	**1830**	**2140**	**2320**	**2500**	**2730**	**2960**	**3230**	**3540**	**3900**	**4310**	**4760**	**5210**	**5760**	**6390**	**6750**	**7110**	**7930**	**8830**	**9730**
315	0.013	0.015	0.016	0.017	0.019	0.020	0.022	0.025	0.027	0.030	0.033	0.036	0.040	0.044	0.047	0.049	0.055	0.061	0.067
	4.8	*5.6*	*6.1*	*6.6*	*7.2*	*7.8*	*8.5*	*9.3*	*10.3*	*11.3*	*12.5*	*13.7*	*15.1*	*16.8*	*17.8*	*18.7*	*20.9*	*23.2*	*25.6*
14 in.	**1880**	**2200**	**2380**	**2560**	**2790**	**3010**	**3280**	**3600**	**3960**	**4370**	**4820**	**5270**	**5810**	**6450**	**6810**	**7170**	**7980**	**8890**	**9790**
355	0.013	0.015	0.016	0.018	0.019	0.021	0.023	0.025	0.027	0.030	0.033	0.037	0.040	0.045	0.047	0.050	0.055	0.062	0.068
	5.0	*5.8*	*6.3*	*6.7*	*7.3*	*7.9*	*8.6*	*9.5*	*10.4*	*11.5*	*12.7*	*13.9*	*15.3*	*17.0*	*17.9*	*18.9*	*21.0*	*23.4*	*25.8*
15.8 in	**1950**	**2270**	**2450**	**2630**	**2850**	**3080**	**3350**	**3670**	**4030**	**4430**	**4890**	**5340**	**5880**	**6510**	**6870**	**7230**	**8050**	**8950**	**9850**
400	0.013	0.016	0.017	0.018	0.020	0.021	0.023	0.025	0.028	0.031	0.034	0.037	0.041	0.045	0.048	0.050	0.056	0.062	0.068
	5.1	*6.0*	*6.4*	*6.9*	*7.5*	*8.1*	*8.8*	*9.6*	*10.6*	*11.7*	*12.9*	*14.0*	*15.5*	*17.1*	*18.1*	*19.0*	*21.2*	*23.6*	*25.9*
17.7 in.	**2020**	**2340**	**2520**	**2700**	**2930**	**3150**	**3420**	**3740**	**4100**	**4510**	**4960**	**5410**	**5950**	**6580**	**6950**	**7310**	**8120**	**9020**	**9930**
450	0.014	0.016	0.017	0.019	0.020	0.022	0.024	0.026	0.028	0.031	0.034	0.037	0.041	0.046	0.048	0.051	0.056	0.062	0.069
	5.3	*6.2*	*6.6*	*7.1*	*7.7*	*8.3*	*9.0*	*9.8*	*10.8*	*11.9*	*13.0*	*14.2*	*15.7*	*17.3*	*18.3*	*19.2*	*21.4*	*23.7*	*26.1*
19.7 in.	**2090**	**2410**	**2590**	**2770**	**3000**	**3220**	**3490**	**3810**	**4170**	**4580**	**5030**	**5480**	**6020**	**6660**	**7020**	**7380**	**8190**	**9100**	**10000**
500	0.014	0.017	0.018	0.019	0.021	0.022	0.024	0.026	0.029	0.032	0.035	0.038	0.042	0.046	0.049	0.051	0.057	0.063	0.069
	5.5	*6.3*	*6.8*	*7.3*	*7.9*	*8.5*	*9.2*	*10.0*	*11.0*	*12.0*	*13.2*	*14.4*	*15.9*	*17.5*	*18.5*	*19.4*	*21.6*	*23.9*	*26.3*
22 in.	**2180**	**2500**	**2680**	**2860**	**3080**	**3310**	**3580**	**3900**	**4260**	**4670**	**5120**	**5570**	**6110**	**6740**	**7100**	**7470**	**8280**	**9180**	**10090**
560	0.015	0.017	0.019	0.020	0.021	0.023	0.025	0.027	0.029	0.032	0.035	0.039	0.042	0.047	0.049	0.052	0.057	0.064	0.070
	5.7	*6.6*	*7.0*	*7.5*	*8.1*	*8.7*	*9.4*	*10.3*	*11.2*	*12.3*	*13.5*	*14.7*	*16.1*	*17.7*	*18.7*	*19.6*	*21.8*	*24.2*	*26.5*
24.8 in.	**2280**	**2600**	**2780**	**2960**	**3190**	**3410**	**3680**	**4000**	**4360**	**4770**	**5220**	**5670**	**6210**	**6840**	**7210**	**7570**	**8380**	**9280**	**10190**
630	0.016	0.018	0.019	0.020	0.022	0.024	0.025	0.028	0.030	0.033	0.036	0.039	0.043	0.047	0.050	0.052	0.058	0.064	0.071
	6.0	*6.8*	*7.3*	*7.8*	*8.4*	*9.0*	*9.7*	*10.5*	*11.5*	*12.5*	*13.7*	*14.9*	*16.3*	*18.0*	*19.0*	*19.9*	*22.1*	*24.4*	*26.8*
26.4 in.	**2340**	**2660**	**2840**	**3020**	**3240**	**3470**	**3740**	**4060**	**4420**	**4820**	**5280**	**5730**	**6270**	**6900**	**7260**	**7620**	**8440**	**9340**	**10240**
670	0.016	0.018	0.020	0.021	0.022	0.024	0.026	0.028	0.031	0.033	0.037	0.040	0.043	0.048	0.050	0.053	0.058	0.065	0.071
	6.2	*7.0*	*7.5*	*7.9*	*8.5*	*9.1*	*9.8*	*10.7*	*11.6*	*12.7*	*13.9*	*15.1*	*16.5*	*18.2*	*19.1*	*20.1*	*22.2*	*24.6*	*27.0*
28 in.	**2400**	**2710**	**2890**	**3070**	**3300**	**3530**	**3800**	**4110**	**4480**	**4880**	**5330**	**5790**	**6330**	**6960**	**7320**	**7680**	**8500**	**9400**	**10300**
710	0.017	0.019	0.020	0.021	0.023	0.024	0.026	0.028	0.031	0.034	0.037	0.040	0.044	0.048	0.051	0.053	0.059	0.065	0.071
	6.3	*7.1*	*7.6*	*8.1*	*8.7*	*9.3*	*10.0*	*10.8*	*11.8*	*12.8*	*14.0*	*15.2*	*16.7*	*18.3*	*19.3*	*20.2*	*22.4*	*24.7*	*27.1*
31.5 in.	**2530**	**2840**	**3020**	**3200**	**3430**	**3660**	**3930**	**4240**	**4610**	**5010**	**5460**	**5920**	**6460**	**7090**	**7450**	**7810**	**8630**	**9530**	**10430**
800	0.018	0.020	0.021	0.022	0.024	0.025	0.027	0.029	0.032	0.035	0.038	0.041	0.045	0.049	0.052	0.054	0.060	0.066	0.072
	6.7	*7.5*	*8.0*	*8.4*	*9.0*	*9.6*	*10.3*	*11.2*	*12.1*	*13.2*	*14.4*	*15.6*	*17.0*	*18.7*	*19.6*	*20.6*	*22.7*	*25.1*	*27.5*

Two-Shank KANTHAL SUPER 1900 3/6

Power W
Resistance Ω
Volt V

Max. element temperature 1830 °C (3330 °F)

Heating zone Ø mm 3
Terminal Ø mm 6
Shank distance mm 25

Furnace temp. °C 1750 (3180° F)
Element temp. °C 1800 (3270° F)

Element current A 41
Surface loading W/cm² 9.0
W/in.² 58

Heating zone, L_e mm →

Terminal L_u mm ↓

	2 in.	*3 in.*	*3.9 in.*	*4.9 in.*	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	15.8 in.
	50	75	100	125	160	180	200	225	250	280	315	355	400
2 in.	**125**	**167**	**210**	**252**	**311**	**345**	**379**	**421**	**464**	**514**	**574**	**641**	**717**
50	0.073	0.098	0.122	0.147	0.182	0.201	0.221	0.246	0.270	0.300	0.335	0.374	0.419
	3.0	*4.0*	*5.1*	*6.1*	*7.5*	*8.3*	*9.2*	*10.2*	*11.2*	*12.4*	*13.9*	*15.5*	*17.3*
3 in.	**132**	**174**	**217**	**259**	**318**	**352**	**386**	**428**	**471**	**521**	**581**	**648**	**724**
75	0.077	0.102	0.126	0.151	0.186	0.205	0.225	0.250	0.275	0.304	0.339	0.378	0.423
	3.2	*4.2*	*5.2*	*6.3*	*7.7*	*8.5*	*9.3*	*10.3*	*11.4*	*12.6*	*14.0*	*15.7*	*17.5*
3.9 in.	**139**	**181**	**224**	**266**	**325**	**359**	**393**	**435**	**478**	**528**	**588**	**655**	**731**
100	0.081	0.106	0.131	0.155	0.190	0.209	0.229	0.254	0.279	0.308	0.343	0.382	0.427
	3.4	*4.4*	*5.4*	*6.4*	*7.9*	*8.7*	*9.5*	*10.5*	*11.5*	*12.8*	*14.2*	*15.8*	*17.7*
4.9 in.	**146**	**188**	**231**	**273**	**332**	**366**	**400**	**442**	**485**	**535**	**595**	**662**	**738**
125	0.085	0.110	0.135	0.159	0.194	0.214	0.233	0.258	0.283	0.312	0.347	0.386	0.431
	3.5	*4.6*	*5.6*	*6.6*	*8.0*	*8.8*	*9.7*	*10.7*	*11.7*	*12.9*	*14.4*	*16.0*	*17.8*
5.5 in.	**150**	**193**	**235**	**277**	**336**	**370**	**404**	**446**	**489**	**539**	**599**	**666**	**743**
140	0.088	0.112	0.137	0.162	0.196	0.216	0.236	0.260	0.285	0.315	0.349	0.389	0.433
	3.6	*4.7*	*5.7*	*6.7*	*8.1*	*8.9*	*9.8*	*10.8*	*11.8*	*13.0*	*14.5*	*16.1*	*17.9*
6.3 in.	**156**	**198**	**240**	**283**	**342**	**376**	**410**	**452**	**494**	**545**	**604**	**672**	**748**
160	0.091	0.116	0.140	0.165	0.200	0.219	0.239	0.264	0.288	0.318	0.353	0.392	0.437
	3.8	*4.8*	*5.8*	*6.8*	*8.3*	*9.1*	*9.9*	*10.9*	*11.9*	*13.2*	*14.6*	*16.2*	*18.1*
7.1 in.	**161**	**204**	**246**	**288**	**348**	**381**	**415**	**458**	**500**	**551**	**610**	**678**	**754**
180	0.094	0.119	0.144	0.168	0.203	0.223	0.242	0.267	0.292	0.321	0.356	0.395	0.440
	3.9	*4.9*	*5.9*	*7.0*	*8.4*	*9.2*	*10.0*	*11.1*	*12.1*	*13.3*	*14.7*	*16.4*	*18.2*
7.9 in.	**167**	**209**	**252**	**294**	**353**	**387**	**421**	**463**	**506**	**556**	**616**	**683**	**759**
200	0.097	0.122	0.147	0.172	0.206	0.226	0.246	0.270	0.295	0.325	0.359	0.399	0.443
	4.0	*5.1*	*6.1*	*7.1*	*8.5*	*9.3*	*10.2*	*11.2*	*12.2*	*13.4*	*14.9*	*16.5*	*18.3*
8.9 in.	**174**	**216**	**259**	**301**	**360**	**394**	**428**	**470**	**513**	**563**	**623**	**690**	**766**
225	0.102	0.126	0.151	0.176	0.210	0.230	0.250	0.274	0.299	0.329	0.363	0.403	0.447
	4.2	*5.2*	*6.2*	*7.3*	*8.7*	*9.5*	*10.3*	*11.4*	*12.4*	*13.6*	*15.0*	*16.7*	*18.5*
9.8 in	**181**	**223**	**266**	**308**	**367**	**401**	**435**	**477**	**520**	**570**	**630**	**697**	**773**
250	0.106	0.130	0.155	0.180	0.214	0.234	0.254	0.278	0.303	0.333	0.367	0.407	0.451
	4.4	*5.4*	*6.4*	*7.4*	*8.9*	*9.7*	*10.5*	*11.5*	*12.5*	*13.8*	*15.2*	*16.8*	*18.7*
11 in.	**189**	**232**	**274**	**316**	**376**	**409**	**443**	**486**	**528**	**579**	**638**	**706**	**782**
280	0.111	0.135	0.160	0.185	0.219	0.239	0.259	0.283	0.308	0.338	0.372	0.412	0.456
	4.6	*5.6*	*6.6*	*7.6*	*9.1*	*9.9*	*10.7*	*11.7*	*12.8*	*14.0*	*15.4*	*17.0*	*18.9*
12.4 in.	**199**	**242**	**284**	**326**	**385**	**419**	**453**	**495**	**538**	**589**	**648**	**715**	**792**
315	0.116	0.141	0.166	0.190	0.225	0.245	0.264	0.289	0.314	0.343	0.378	0.417	0.462
	4.8	*5.8*	*6.9*	*7.9*	*9.3*	*10.1*	*10.9*	*12.0*	*13.0*	*14.2*	*15.6*	*17.3*	*19.1*
14 in.	**211**	**253**	**295**	**337**	**397**	**431**	**464**	**507**	**549**	**600**	**659**	**727**	**803**
355	0.123	0.148	0.172	0.197	0.231	0.251	0.271	0.296	0.320	0.350	0.384	0.424	0.468
	5.1	*6.1*	*7.1*	*8.2*	*9.6*	*10.4*	*11.2*	*12.2*	*13.3*	*14.5*	*15.9*	*17.6*	*19.4*
15.8 in	**223**	**265**	**308**	**350**	**409**	**443**	**477**	**519**	**562**	**612**	**672**	**739**	**815**
400	0.130	0.155	0.180	0.204	0.239	0.259	0.278	0.303	0.328	0.357	0.392	0.431	0.476
	5.4	*6.4*	*7.4*	*8.5*	*9.9*	*10.7*	*11.5*	*12.5*	*13.6*	*14.8*	*16.2*	*17.9*	*19.7*

Two-Shank KANTHAL SUPER 1900 4/9

Power W
Resistance Ω
Volt V

Max. element temperature 1850 °C (3450 °F)

Heating zone Ø mm 4
Terminal Ø mm 9
Shank distance mm 25

Furnace temp. °C 1775 (3220° F)
Element temp. °C 1830 (3330° F)

Element current A 69
Surface loading W/cm^2 10.7
W/in^2 69

Heating zone, L_e mm →

Terminal L_u mm ↓

	2 in.	*3 in.*	*3.9 in.*	*4.9 in.*	*6.3 in.*	*7.1 in.*	*7.9 in.*	*8.9 in.*	*9.8 in.*	*11 in.*	*12.4 in.*	*14 in.*	*15.8 in.*
	50	75	100	125	160	180	200	225	250	280	315	355	400
2 in.	**193**	**260**	**327**	**395**	**489**	**543**	**596**	**664**	**731**	**812**	**906**	**1013**	**1135**
50	0.040	0.055	0.069	0.083	0.103	0.114	0.125	0.139	0.154	0.170	0.190	0.213	0.238
	2.8	*3.8*	*4.7*	*5.7*	*7.1*	*7.9*	*8.6*	*9.6*	*10.6*	*11.8*	*13.1*	*14.7*	*16.4*
3 in.	**202**	**269**	**336**	**403**	**498**	**551**	**605**	**672**	**740**	**820**	**915**	**1022**	**1143**
75	0.042	0.056	0.071	0.085	0.105	0.116	0.127	0.141	0.155	0.172	0.192	0.215	0.240
	2.9	*3.9*	*4.9*	*5.8*	*7.2*	*8.0*	*8.8*	*9.7*	*10.7*	*11.9*	*13.3*	*14.8*	*16.6*
3.9 in.	**210**	**278**	**345**	**412**	**506**	**560**	**614**	**681**	**749**	**829**	**923**	**1031**	**1152**
100	0.044	0.058	0.072	0.087	0.106	0.118	0.129	0.143	0.157	0.174	0.194	0.217	0.242
	3.0	*4.0*	*5.0*	*6.0*	*7.3*	*8.1*	*8.9*	*9.9*	*10.8*	*12.0*	*13.4*	*14.9*	*16.7*
4.9 in.	**219**	**286**	**354**	**421**	**515**	**569**	**623**	**690**	**757**	**838**	**932**	**1040**	**1161**
125	0.046	0.060	0.074	0.088	0.108	0.119	0.131	0.145	0.159	0.176	0.196	0.218	0.244
	3.2	*4.2*	*5.1*	*6.1*	*7.5*	*8.2*	*9.0*	*10.0*	*11.0*	*12.1*	*13.5*	*15.1*	*16.8*
5.5 in.	**224**	**292**	**359**	**426**	**520**	**574**	**628**	**695**	**763**	**843**	**937**	**1045**	**1166**
140	0.047	0.061	0.075	0.090	0.109	0.121	0.132	0.146	0.160	0.177	0.197	0.220	0.245
	3.3	*4.2*	*5.2*	*6.2*	*7.5*	*8.3*	*9.1*	*10.1*	*11.1*	*12.2*	*13.6*	*15.1*	*16.9*
6.3 in.	**231**	**299**	**366**	**433**	**527**	**581**	**635**	**702**	**770**	**850**	**944**	**1052**	**1173**
160	0.049	0.063	0.077	0.091	0.111	0.122	0.133	0.148	0.162	0.179	0.198	0.221	0.246
	3.4	*4.3*	*5.3*	*6.3*	*7.6*	*8.4*	*9.2*	*10.2*	*11.2*	*12.3*	*13.7*	*15.2*	*17.0*
7.1 in.	**238**	**306**	**373**	**440**	**534**	**588**	**642**	**709**	**777**	**857**	**952**	**1059**	**1180**
180	0.050	0.064	0.078	0.092	0.112	0.124	0.135	0.149	0.163	0.180	0.200	0.222	0.248
	3.5	*4.4*	*5.4*	*6.4*	*7.7*	*8.5*	*9.3*	*10.3*	*11.3*	*12.4*	*13.8*	*15.3*	*17.1*
7.9 in.	**245**	**313**	**380**	**447**	**541**	**595**	**649**	**716**	**784**	**864**	**959**	**1066**	**1187**
200	0.052	0.066	0.080	0.094	0.114	0.125	0.136	0.150	0.165	0.182	0.201	0.224	0.249
	3.6	*4.5*	*5.5*	*6.5*	*7.8*	*8.6*	*9.4*	*10.4*	*11.4*	*12.5*	*13.9*	*15.5*	*17.2*
8.9 in.	**254**	**322**	**389**	**456**	**550**	**604**	**658**	**725**	**792**	**873**	**967**	**1075**	**1196**
225	0.053	0.068	0.082	0.096	0.116	0.127	0.138	0.152	0.166	0.183	0.203	0.226	0.251
	3.7	*4.7*	*5.6*	*6.6*	*8.0*	*8.8*	*9.5*	*10.5*	*11.5*	*12.7*	*14.0*	*15.6*	*17.3*
9.8 in	**263**	**330**	**398**	**465**	**559**	**613**	**667**	**734**	**801**	**882**	**976**	**1084**	**1205**
250	0.055	0.069	0.084	0.098	0.117	0.129	0.140	0.154	0.168	0.185	0.205	0.228	0.253
	3.8	*4.8*	*5.8*	*6.7*	*8.1*	*8.9*	*9.7*	*10.6*	*11.6*	*12.8*	*14.1*	*15.7*	*17.5*
11 in.	**274**	**341**	**408**	**475**	**570**	**623**	**677**	**744**	**812**	**892**	**987**	**1094**	**1215**
280	0.057	0.072	0.086	0.100	0.120	0.131	0.142	0.156	0.170	0.187	0.207	0.230	0.255
	4.0	*4.9*	*5.9*	*6.9*	*8.3*	*9.0*	*9.8*	*10.8*	*11.8*	*12.9*	*14.3*	*15.9*	*17.6*
12.4 in.	**286**	**353**	**420**	**488**	**582**	**636**	**689**	**757**	**824**	**905**	**999**	**1107**	**1228**
315	0.060	0.074	0.088	0.102	0.122	0.134	0.145	0.159	0.173	0.190	0.210	0.232	0.258
	4.1	*5.1*	*6.1*	*7.1*	*8.4*	*9.2*	*10.0*	*11.0*	*11.9*	*13.1*	*14.5*	*16.0*	*17.8*
14 in.	**300**	**367**	**434**	**502**	**596**	**650**	**704**	**771**	**838**	**919**	**1013**	**1121**	**1242**
355	0.063	0.077	0.091	0.105	0.125	0.136	0.148	0.162	0.176	0.193	0.213	0.235	0.261
	4.3	*5.3*	*6.3*	*7.3*	*8.6*	*9.4*	*10.2*	*11.2*	*12.1*	*13.3*	*14.7*	*16.2*	*18.0*
15.8 in	**316**	**383**	**450**	**518**	**612**	**666**	**719**	**787**	**854**	**935**	**1029**	**1136**	**1257**
400	0.066	0.080	0.095	0.109	0.128	0.140	0.151	0.165	0.179	0.196	0.216	0.239	0.264
	4.6	*5.6*	*6.5*	*7.5*	*8.9*	*9.6*	*10.4*	*11.4*	*12.4*	*13.5*	*14.9*	*16.5*	*18.2*

Two-Shank KANTHAL SUPER 1900 6/12

Power W
Resistance Ω
Volt V

Max. element temperature 1850 °C (3360 °F)

Heating zone Ø mm 6
Terminal Ø mm 12
Shank distance mm 50

Furnace temp. °C 1800 (3270° F)
Element temp. °C 1850 (3360° F)

Element current A 125
Surface loading W/cm^2 10.5
W/in^2 68

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in. 125	*6.3 in.* 160	*7.1 in.* 180	*7.9 in.* 200	*8.9 in.* 225	*9.8 in.* 250	*11 in.* 280	*12.4 in.* 315	*14 in.* 355	*15.8 in.* 400	*17.7 in.* 450	*19.7 in.* 500	*22 in.* 560	*24.8 in.* 630	*26.4 in.* 670	*28 in.* 710
5.5 in.	**680**	**810**	**890**	**970**	**1070**	**1170**	**1290**	**1430**	**1590**	**1770**	**1970**	**2160**	**2400**	**2680**	**2840**	**3000**
140	0.043	0.052	0.057	0.062	0.069	0.075	0.083	0.092	0.102	0.113	0.126	0.139	0.154	0.172	0.182	0.192
	5.4	*6.5*	*7.2*	*7.8*	*8.6*	*9.4*	*10.3*	*11.4*	*12.7*	*14.1*	*15.7*	*17.3*	*19.2*	*21.4*	*22.7*	*24.0*
6.3 in.	**690**	**830**	**910**	**990**	**1090**	**1190**	**1300**	**1440**	**1600**	**1780**	**1980**	**2180**	**2420**	**2690**	**2850**	**3010**
160	0.044	0.053	0.058	0.063	0.070	0.076	0.083	0.092	0.103	0.114	0.127	0.139	0.155	0.172	0.183	0.193
	5.5	*6.6*	*7.3*	*7.9*	*8.7*	*9.5*	*10.4*	*11.5*	*12.8*	*14.2*	*15.8*	*17.4*	*19.3*	*21.6*	*22.8*	*24.1*
7.1 in.	**700**	**840**	**920**	**1000**	**1100**	**1200**	**1320**	**1460**	**1620**	**1790**	**1990**	**2190**	**2430**	**2710**	**2870**	**3030**
180	0.045	0.054	0.059	0.064	0.070	0.077	0.084	0.093	0.103	0.115	0.128	0.140	0.155	0.173	0.183	0.194
	5.6	*6.7*	*7.4*	*8.0*	*8.8*	*9.6*	*10.5*	*11.7*	*12.9*	*14.4*	*15.9*	*17.5*	*19.4*	*21.7*	*22.9*	*24.2*
7.9 in.	**720**	**860**	**930**	**1010**	**1110**	**1210**	**1330**	**1470**	**1630**	**1810**	**2010**	**2210**	**2440**	**2720**	**2880**	**3040**
200	0.046	0.055	0.060	0.065	0.071	0.078	0.085	0.094	0.104	0.116	0.128	0.141	0.156	0.174	0.184	0.194
	5.7	*6.8*	*7.5*	*8.1*	*8.9*	*9.7*	*10.7*	*11.8*	*13.0*	*14.5*	*16.1*	*17.6*	*19.5*	*21.8*	*23.0*	*24.3*
8.9 in.	**730**	**870**	**950**	**1030**	**1130**	**1230**	**1350**	**1490**	**1650**	**1820**	**2020**	**2220**	**2460**	**2740**	**2900**	**3060**
225	0.047	0.056	0.061	0.066	0.072	0.079	0.086	0.095	0.105	0.117	0.130	0.142	0.157	0.175	0.185	0.196
	5.9	*7.0*	*7.6*	*8.2*	*9.0*	*9.8*	*10.8*	*11.9*	*13.2*	*14.6*	*16.2*	*17.8*	*19.7*	*21.9*	*23.2*	*24.4*
9.8 in	**750**	**890**	**970**	**1050**	**1150**	**1250**	**1370**	**1500**	**1660**	**1840**	**2040**	**2240**	**2480**	**2760**	**2910**	**3070**
250	0.048	0.057	0.062	0.067	0.073	0.080	0.087	0.096	0.106	0.118	0.131	0.143	0.159	0.176	0.186	0.197
	6.0	*7.1*	*7.7*	*8.4*	*9.2*	*10.0*	*10.9*	*12.0*	*13.3*	*14.7*	*16.3*	*17.9*	*19.8*	*22.0*	*23.3*	*24.6*
11 in.	**770**	**910**	**990**	**1070**	**1170**	**1270**	**1390**	**1520**	**1680**	**1860**	**2060**	**2260**	**2500**	**2780**	**2930**	**3090**
280	0.049	0.058	0.063	0.068	0.075	0.081	0.089	0.098	0.108	0.119	0.132	0.145	0.160	0.178	0.188	0.198
	6.2	*7.3*	*7.9*	*8.5*	*9.3*	*10.1*	*11.1*	*12.2*	*13.5*	*14.9*	*16.5*	*18.1*	*20.0*	*22.2*	*23.5*	*24.7*
12.4 in.	**790**	**930**	**1010**	**1090**	**1190**	**1290**	**1410**	**1550**	**1710**	**1890**	**2080**	**2280**	**2520**	**2800**	**2960**	**3120**
315	0.051	0.060	0.065	0.070	0.076	0.083	0.090	0.099	0.109	0.121	0.133	0.146	0.161	0.179	0.189	0.199
	6.4	*7.5*	*8.1*	*8.7*	*9.5*	*10.3*	*11.3*	*12.4*	*13.7*	*15.1*	*16.7*	*18.3*	*20.2*	*22.4*	*23.7*	*24.9*
14 in.	**820**	**960**	**1040**	**1120**	**1220**	**1320**	**1440**	**1580**	**1730**	**1910**	**2110**	**2310**	**2550**	**2830**	**2990**	**3140**
355	0.053	0.061	0.067	0.072	0.078	0.084	0.092	0.101	0.111	0.122	0.135	0.148	0.163	0.181	0.191	0.201
	6.6	*7.7*	*8.3*	*9.0*	*9.7*	*10.5*	*11.5*	*12.6*	*13.9*	*15.3*	*16.9*	*18.5*	*20.4*	*22.6*	*23.9*	*25.2*
15.8 in	**850**	**990**	**1070**	**1150**	**1250**	**1350**	**1470**	**1610**	**1760**	**1940**	**2140**	**2340**	**2580**	**2860**	**3020**	**3170**
400	0.055	0.063	0.068	0.074	0.080	0.086	0.094	0.103	0.113	0.124	0.137	0.150	0.165	0.183	0.193	0.203
	6.8	*7.9*	*8.6*	*9.2*	*10.0*	*10.8*	*11.7*	*12.8*	*14.1*	*15.5*	*17.1*	*18.7*	*20.6*	*22.9*	*24.1*	*25.4*
14 in.	**890**	**1020**	**1100**	**1180**	**1280**	**1380**	**1500**	**1640**	**1800**	**1980**	**2180**	**2370**	**2610**	**2890**	**3050**	**3210**
450	0.057	0.066	0.071	0.076	0.082	0.088	0.096	0.105	0.115	0.127	0.139	0.152	0.167	0.185	0.195	0.205
	7.1	*8.2*	*8.8*	*9.5*	*10.3*	*11.1*	*12.0*	*13.1*	*14.4*	*15.8*	*17.4*	*19.0*	*20.9*	*23.1*	*24.4*	*25.7*
15.8 in	**920**	**1060**	**1140**	**1220**	**1320**	**1420**	**1540**	**1670**	**1830**	**2010**	**2210**	**2410**	**2650**	**2920**	**3080**	**3240**
500	0.059	0.068	0.073	0.078	0.084	0.091	0.098	0.107	0.117	0.129	0.141	0.154	0.169	0.187	0.197	0.207
	7.4	*8.5*	*9.1*	*9.7*	*10.5*	*11.3*	*12.3*	*13.4*	*14.7*	*16.1*	*17.7*	*19.3*	*21.2*	*23.4*	*24.7*	*25.9*

Two-Shank KANTHAL SUPER 1900 9/18

Power W
Resistance Ω
Volt V

Max. element temperature 1850 °C (3360 °F)

Heating zone Ø mm 9
Intermediate piece Ø mm 12
Intermediate piece length mm 70
Terminal Ø mm 18
Shank distance (a) mm 60

Furnace temp. °C 1800 (3270° F)
Element temp. °C 1850 (3450° F)

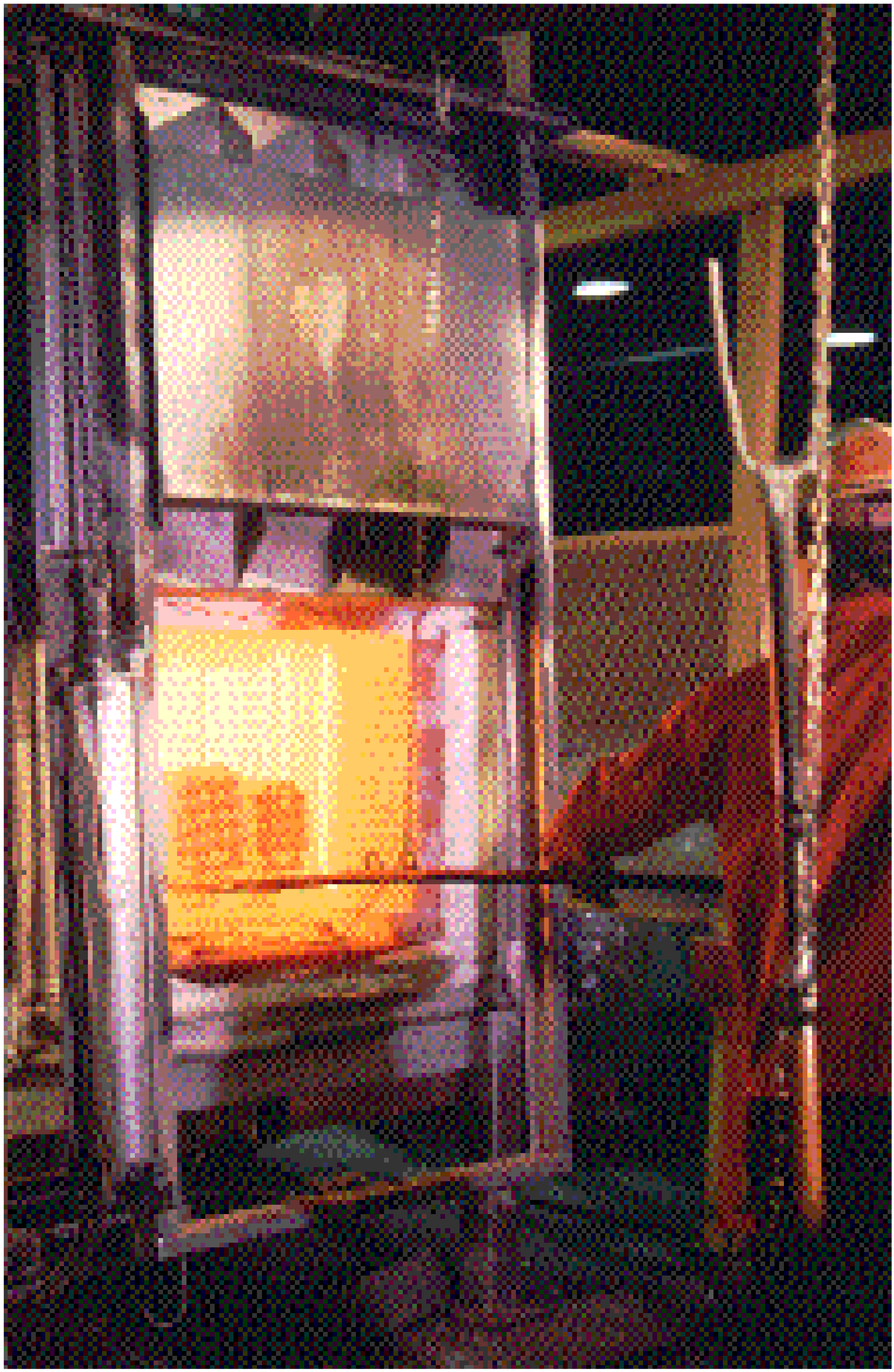
Element current A 229
Surface loading W/cm^2 10.5
W/in.^{2} 68

Heating zone, L_e mm →

Terminal L_u mm ↓

	4.9 in. 125	*6.3 in.* 160	*7.1 in.* 180	*7.9 in.* 200	*8.9 in.* 225	*9.8 in.* 250	*11 in.* 280	*12.4 in.* 315	*14 in.* 355	*15.8 in.* 400	*17.7 in.* 450	*19.7 in.* 500	*22 in.* 560	*24.8 in.* 630	*26.4 in.* 670	*28 in.* 710
9.8 in 250	**1280**	**1490**	**1610**	**1730**	**1870**	**2020**	**2200**	**2410**	**2640**	**2910**	**3210**	**3500**	**3860**	**4270**	**4510**	**4750**
	0.024	0.028	0.031	0.033	0.036	0.039	0.042	0.046	0.050	0.056	0.061	0.067	0.074	0.081	0.086	0.091
	5.6	*6.5*	*7.0*	*7.5*	*8.2*	*8.8*	*9.6*	*10.5*	*11.5*	*12.7*	*14.0*	*15.3*	*16.9*	*18.7*	*19.7*	*20.7*
11 in. 280	**1310**	**1520**	**1640**	**1760**	**1910**	**2050**	**2230**	**2440**	**2680**	**2940**	**3240**	**3530**	**3890**	**4300**	**4540**	**4780**
	0.025	0.029	0.031	0.034	0.036	0.039	0.043	0.046	0.051	0.056	0.062	0.067	0.074	0.082	0.087	0.091
	5.7	*6.6*	*7.2*	*7.7*	*8.3*	*9.0*	*9.7*	*10.6*	*11.7*	*12.8*	*14.1*	*15.4*	*17.0*	*18.8*	*19.8*	*20.9*
12.4 in. 315	**1350**	**1560**	**1670**	**1790**	**1940**	**2090**	**2270**	**2470**	**2710**	**2980**	**3270**	**3570**	**3920**	**4340**	**4580**	**4810**
	0.026	0.030	0.032	0.034	0.037	0.040	0.043	0.047	0.052	0.057	0.062	0.068	0.075	0.083	0.087	0.092
	5.9	*6.8*	*7.3*	*7.8*	*8.5*	*9.1*	*9.9*	*10.8*	*11.8*	*13.0*	*14.3*	*15.6*	*17.1*	*18.9*	*20.0*	*21.0*
14 in. 355	**1390**	**1600**	**1710**	**1830**	**1980**	**2130**	**2310**	**2510**	**2750**	**3020**	**3310**	**3610**	**3960**	**4380**	**4620**	**4850**
	0.026	0.030	0.033	0.035	0.038	0.041	0.044	0.048	0.052	0.058	0.063	0.069	0.076	0.084	0.088	0.093
	6.1	*7.0*	*7.5*	*8.0*	*8.7*	*9.3*	*10.1*	*11.0*	*12.0*	*13.2*	*14.5*	*15.8*	*17.3*	*19.1*	*20.2*	*21.2*
15.8 in 400	**1430**	**1640**	**1760**	**1880**	**2030**	**2170**	**2350**	**2560**	**2800**	**3060**	**3360**	**3660**	**4010**	**4430**	**4660**	**4900**
	0.027	0.031	0.034	0.036	0.039	0.041	0.045	0.049	0.053	0.058	0.064	0.070	0.076	0.084	0.089	0.093
	6.3	*7.2*	*7.7*	*8.2*	*8.8*	*9.5*	*10.3*	*11.2*	*12.2*	*13.4*	*14.7*	*16.0*	*17.5*	*19.3*	*20.4*	*21.4*
17.7 in. 450	**1490**	**1690**	**1810**	**1930**	**2080**	**2230**	**2400**	**2610**	**2850**	**3110**	**3410**	**3710**	**4060**	**4480**	**4710**	**4950**
	0.028	0.032	0.035	0.037	0.040	0.042	0.046	0.050	0.054	0.059	0.065	0.071	0.077	0.085	0.090	0.094
	6.5	*7.4*	*7.9*	*8.4*	*9.1*	*9.7*	*10.5*	*11.4*	*12.4*	*13.6*	*14.9*	*16.2*	*17.7*	*19.5*	*20.6*	*21.6*
19.7 in. 500	**1540**	**1740**	**1860**	**1980**	**2130**	**2280**	**2450**	**2660**	**2900**	**3160**	**3460**	**3760**	**4110**	**4530**	**4760**	**5000**
	0.029	0.033	0.035	0.038	0.041	0.043	0.047	0.051	0.055	0.060	0.066	0.072	0.078	0.086	0.091	0.095
	6.7	*7.6*	*8.1*	*8.6*	*9.3*	*9.9*	*10.7*	*11.6*	*12.7*	*13.8*	*15.1*	*16.4*	*18.0*	*19.8*	*20.8*	*21.8*
22 in. 560	**1600**	**1800**	**1920**	**2040**	**2190**	**2340**	**2510**	**2720**	**2960**	**3220**	**3520**	**3820**	**4170**	**4590**	**4820**	**5060**
	0.030	0.034	0.037	0.039	0.042	0.045	0.048	0.052	0.056	0.061	0.067	0.073	0.080	0.087	0.092	0.097
	7.0	*7.9*	*8.4*	*8.9*	*9.6*	*10.2*	*11.0*	*11.9*	*12.9*	*14.1*	*15.4*	*16.7*	*18.2*	*20.0*	*21.1*	*22.1*
24.8 in. 630	**1670**	**1870**	**1990**	**2110**	**2260**	**2410**	**2580**	**2790**	**3030**	**3300**	**3590**	**3890**	**4240**	**4660**	**4890**	**5130**
	0.032	0.036	0.038	0.040	0.043	0.046	0.049	0.053	0.058	0.063	0.068	0.074	0.081	0.089	0.093	0.098
	7.3	*8.2*	*8.7*	*9.2*	*9.9*	*10.5*	*11.3*	*12.2*	*13.2*	*14.4*	*15.7*	*17.0*	*18.5*	*20.3*	*21.4*	*22.4*
26.4 in. 670	**1710**	**1910**	**2030**	**2150**	**2300**	**2450**	**2630**	**2830**	**3070**	**3340**	**3630**	**3930**	**4280**	**4700**	**4940**	**5170**
	0.033	0.037	0.039	0.041	0.044	0.047	0.050	0.054	0.059	0.064	0.069	0.075	0.082	0.090	0.094	0.099
	7.5	*8.4*	*8.9*	*9.4*	*10.0*	*10.7*	*11.5*	*12.4*	*13.4*	*14.6*	*15.9*	*17.2*	*18.7*	*20.5*	*21.6*	*22.6*
28 in. 710	**1750**	**1960**	**2070**	**2190**	**2340**	**2490**	**2670**	**2870**	**3110**	**3380**	**3670**	**3970**	**4320**	**4740**	**4980**	**5210**
	0.033	0.037	0.040	0.042	0.045	0.047	0.051	0.055	0.059	0.064	0.070	0.076	0.082	0.090	0.095	0.099
	7.6	*8.5*	*9.1*	*9.6*	*10.2*	*10.9*	*11.6*	*12.5*	*13.6*	*14.7*	*16.0*	*17.3*	*18.9*	*20.7*	*21.7*	*22.8*

Fig. 25   Pusher furnace for melting and burn-out of moulds.



6

Performance

Temperature Dependence of Resistivity

The diagram in Fig. 26, page 63, shows that the resistivity of KANTHAL SUPER increases sharply with temperature.

Element Surface Load

The curves shown in Figs. 27 and 28 in the pages 64-65, 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/q.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 Ø and 286 A for 9 mm Ø.

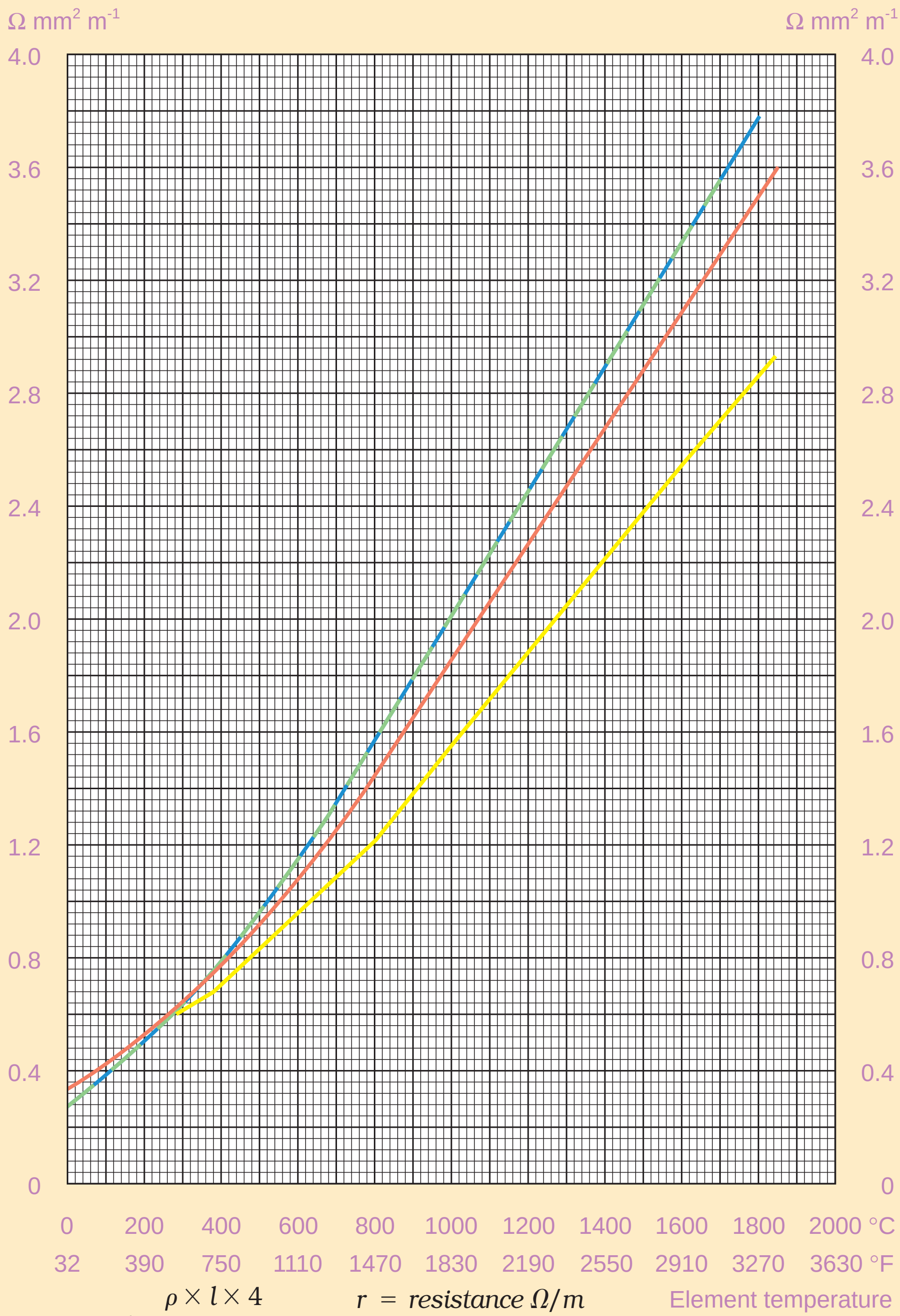
Wall Loading

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.

Fig. 29, page 66 shows maximum recommended wall loading as a function of the furnace temperature for different element diameters and mode of installation.

6



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

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

Fig. 26 Resistivity of KANTHAL SUPER 1700 (green), 1800 (blue), 1900 (red) and Excel (yellow).

6

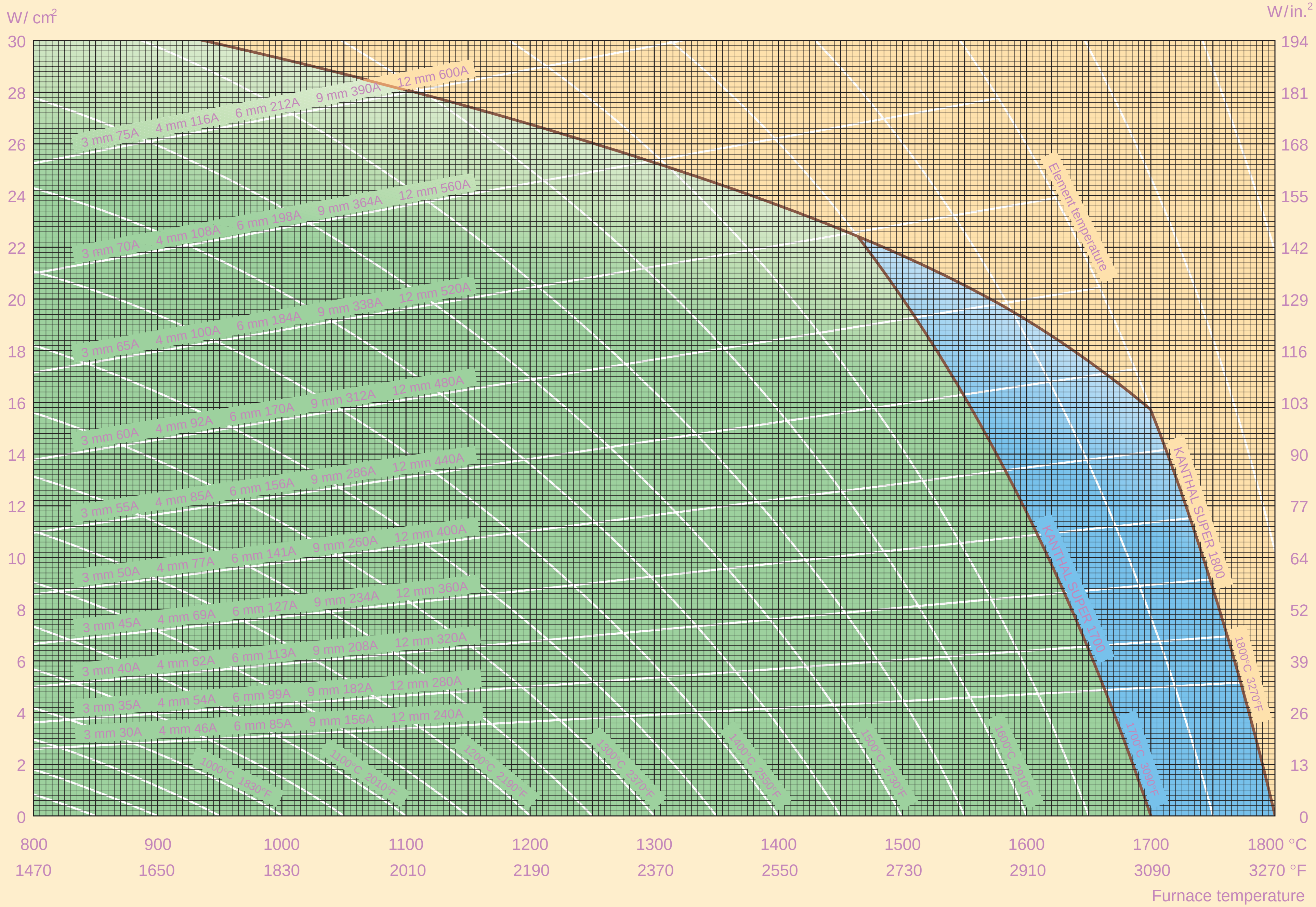


Fig. 27 Temperature — loading diagram for KANTHAL Super 1700 (green) and 1800 (blue).

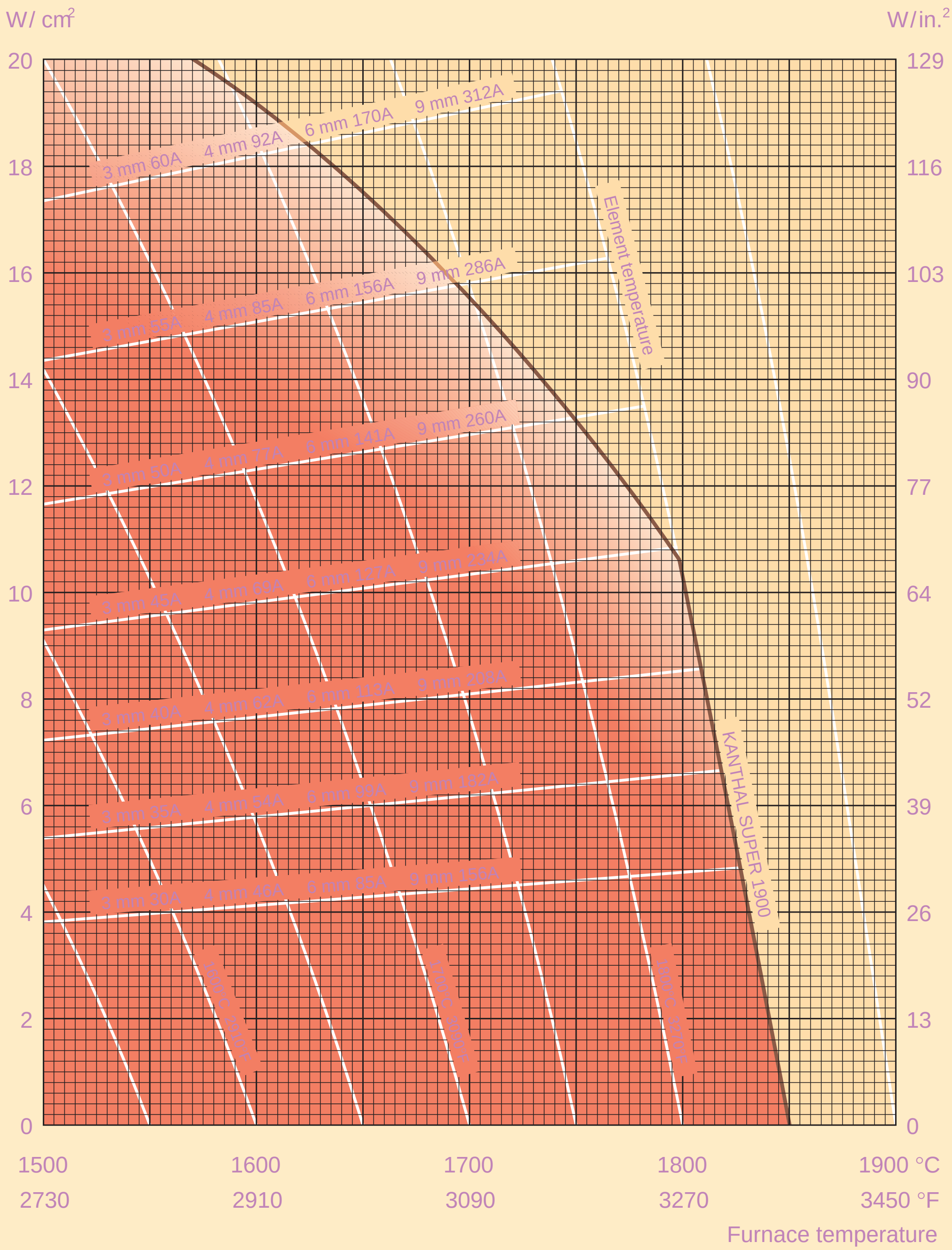
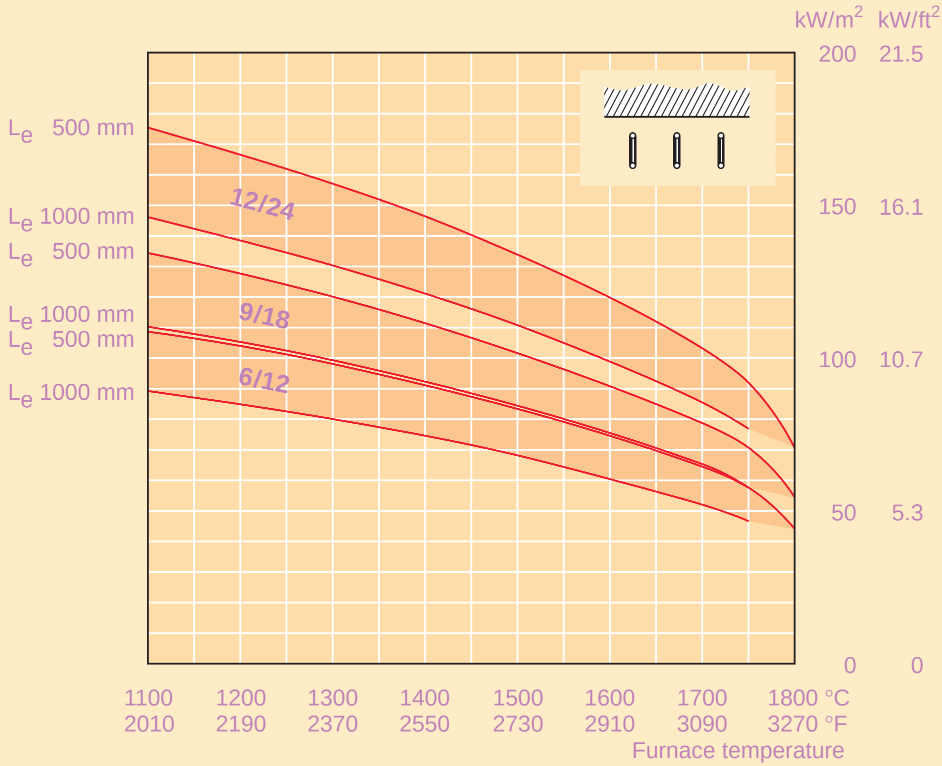


Fig. 28 Temperature — loading diagram for KANTHAL Super 1900.

6



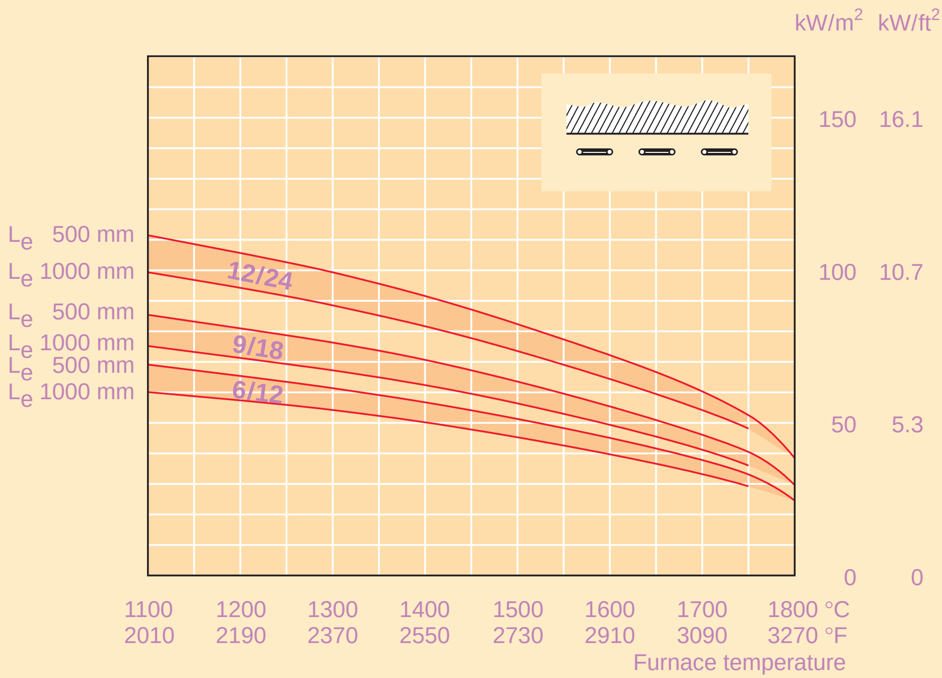


Fig. 29 Maximum recommended wall loading as a function of the furnace temperature for different element diameters and mode of installation.

Installation

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. 31, page 56). 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 (Fig. 30, page 55).

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 (Figs. 32 – 34, pages 57 - 58).

Horizontally mounted elements

In some types of furnaces where the roof height is low, horizontally installed KANTHAL SUPER elements may be economical and efficient.

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

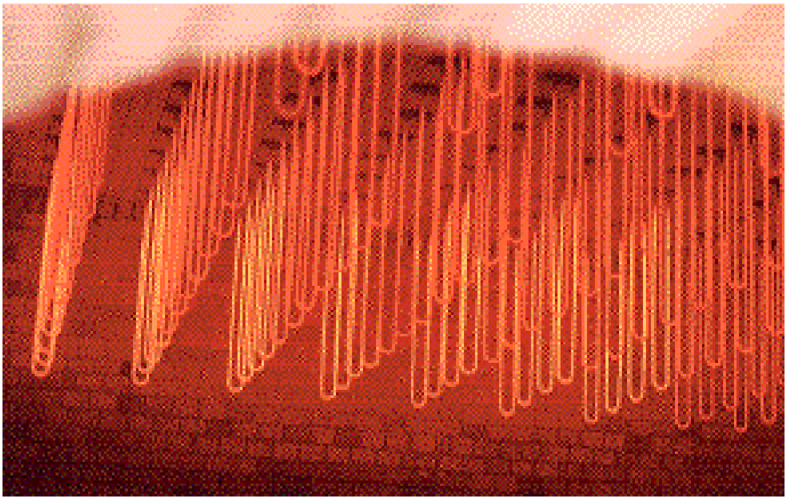


Fig. 30 Two-shank KANTHAL SUPER elements installed across the width of the furnace.

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/.12 in.) can be used on the supporting surface where applicable.

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 (Figs. 31 and 32, page 57). 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.

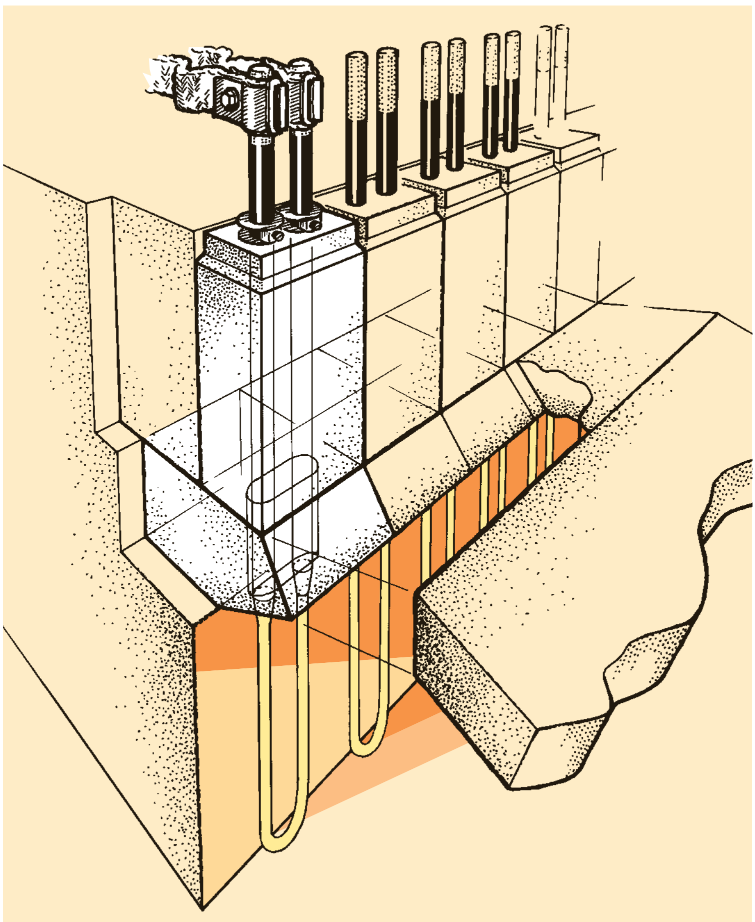


Fig. 31 KANTHAL SUPER element installation with standard passage bricks in a brick lined furnace.

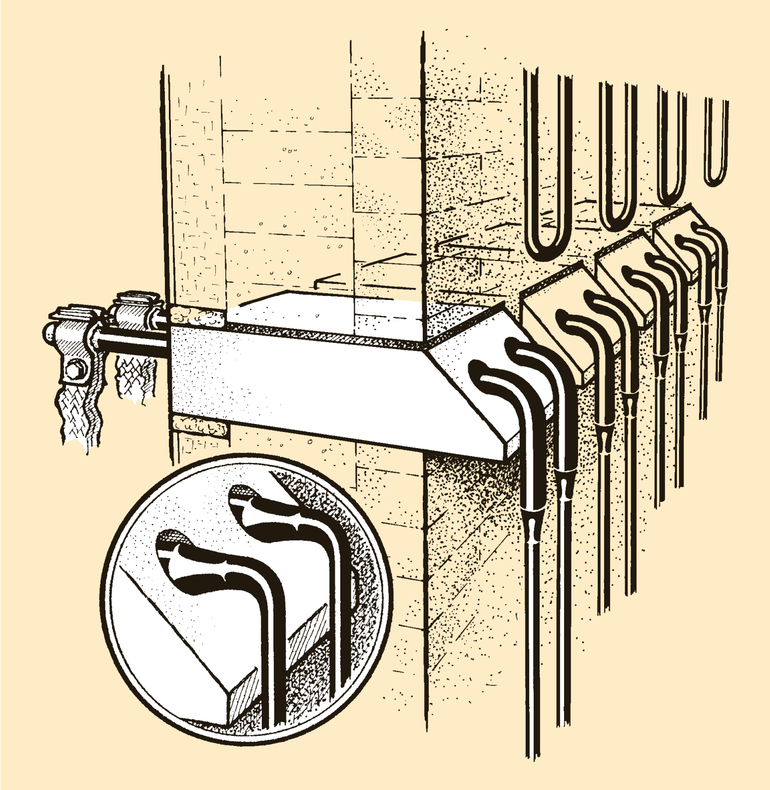


Fig. 32 KANTHAL SUPER elements, with terminals bent 90°, installed in a brick lined furnace.

Ceramic fibre lined furnaces

In fibre lined industrial furnaces, e.g. forging furnaces, if passage plugs of fibre or refractory bricks are used, then the complete element assembly also needs to be supported by the furnace roof or side walls. Figs. 33 – 36, pages 58 – 59.

In small fibre 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 fibre (Fig. 37, page 60).

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 fibre (Fig. 38, page 61) or a passage plug supported by the cold side of the roof (Fig. 39, page 61).

7

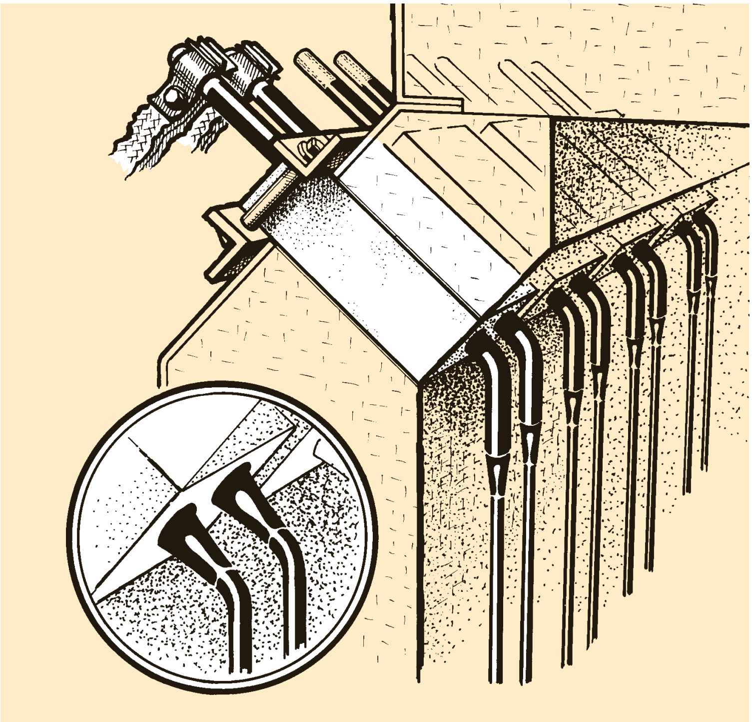


Fig. 33 KANTHAL SUPER elements, with terminals bent 45°, installed in ceramic fibre insulated furnace.

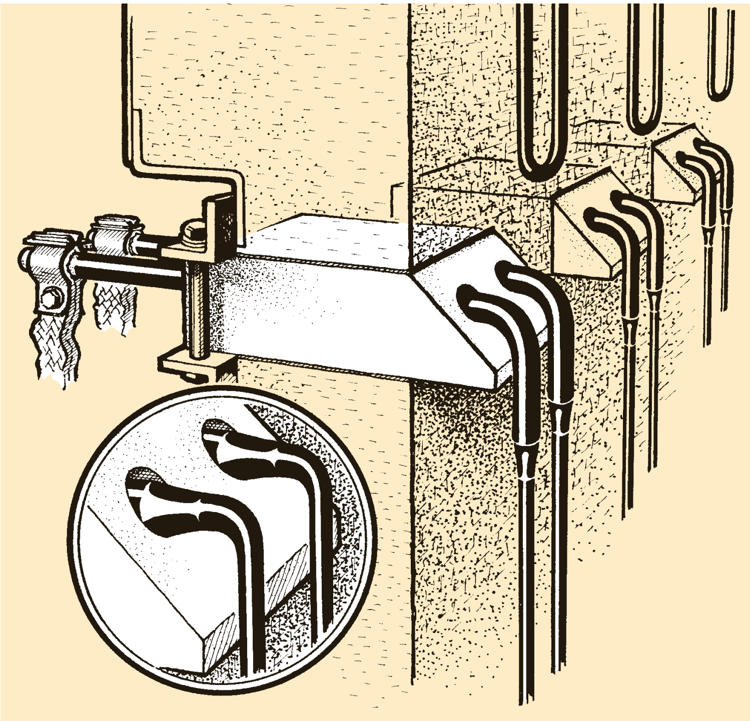


Fig. 34 KANTHAL SUPER elements, with terminals bent 90°, installed through a furnace wall in a fibre lined furnace.

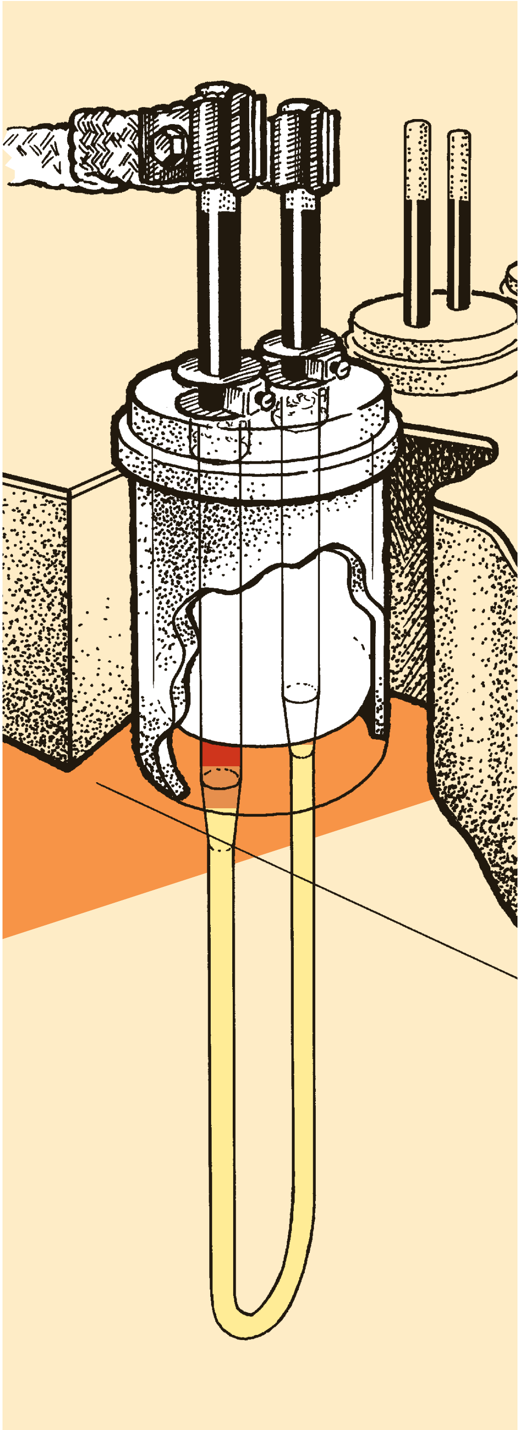


Fig. 35 KANTHAL SUPER elements in ceramic fibre lined furnaces. The passage plugs with a flange are made of ceramic fibre and fitted into ceramic fibre sleeves.

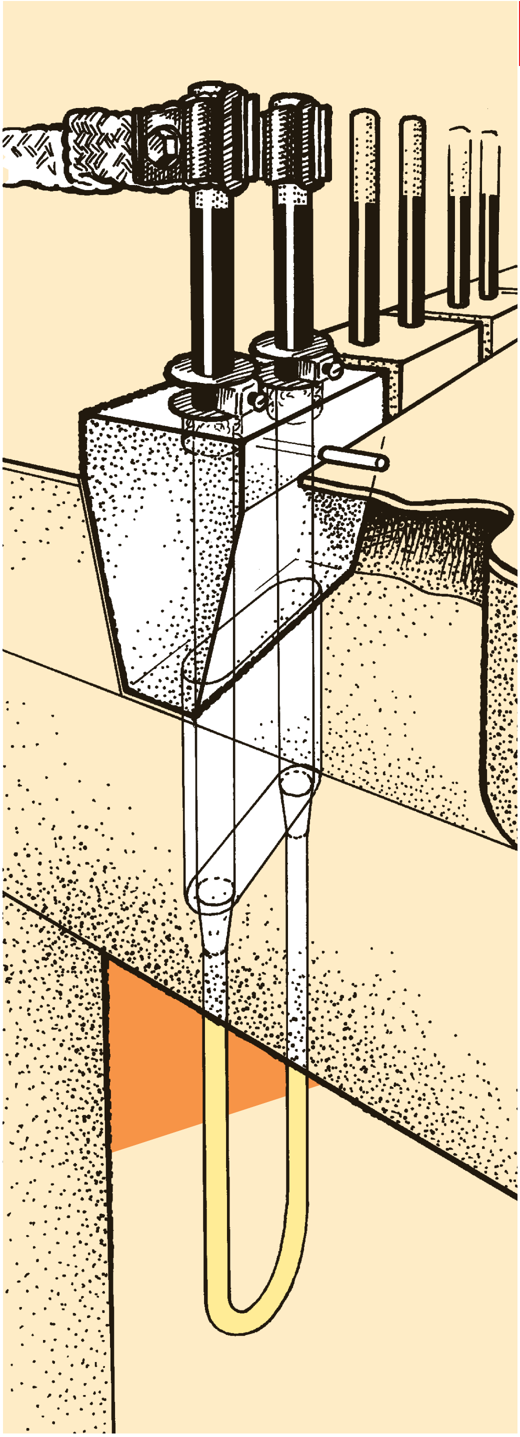


Fig. 36 KANTHAL SUPER elements in ceramic fibre lined furnaces. The passage plugs made of a heavy duty insulating firebrick are suspended by the cold side of the roof.

7

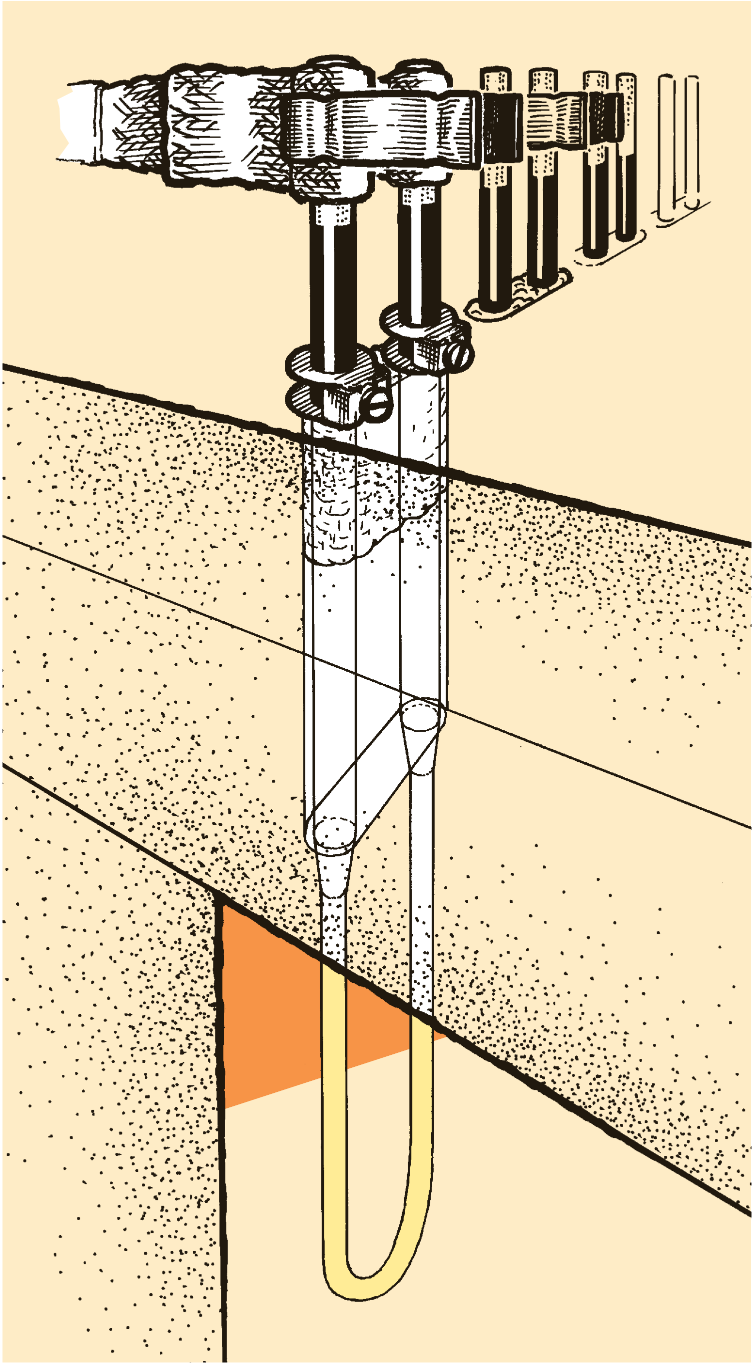


Fig. 37 KANTHAL SUPER elements in ceramic fibre lined furnaces installed through oval slots in the roof.

7

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

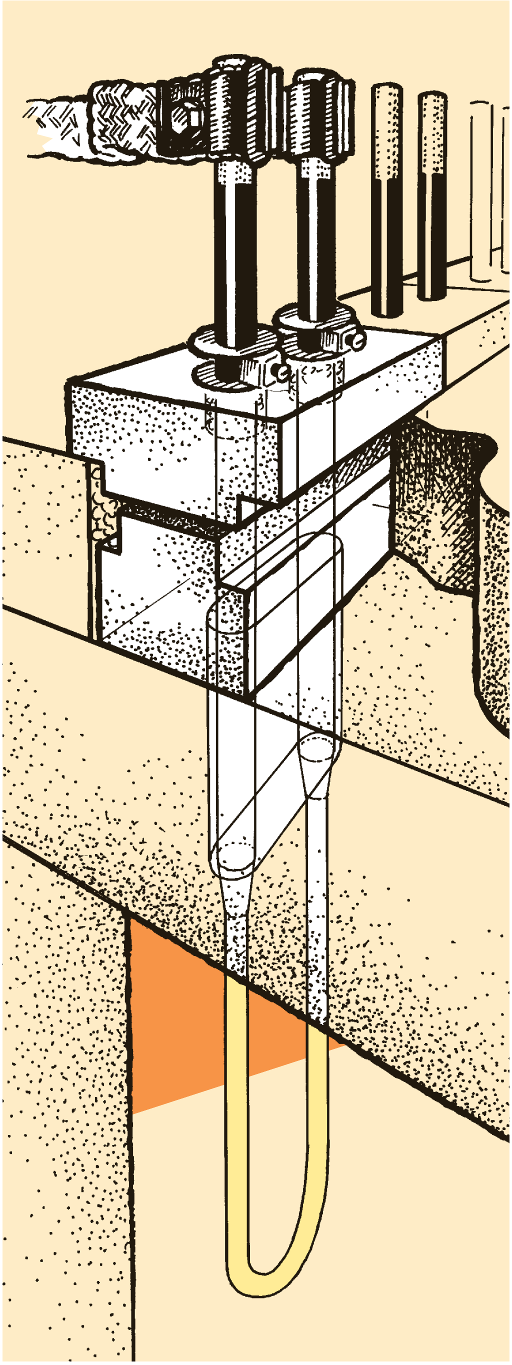


Fig. 38 KANTHAL SUPER elements in ceramic fibre lined furnaces. The passage plugs are divided in two pieces.

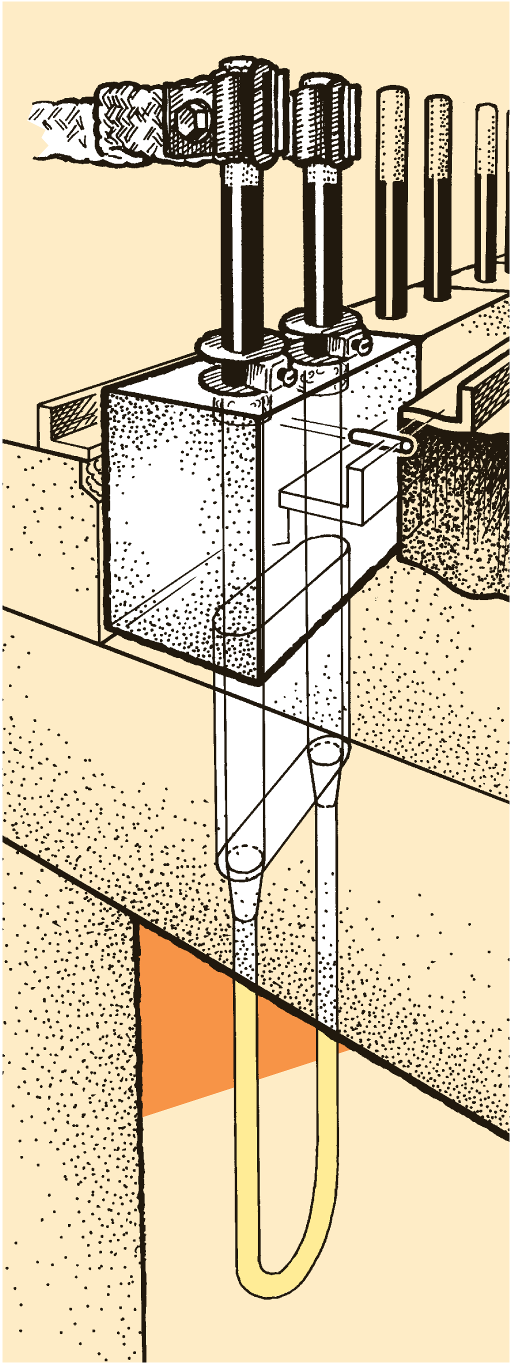


Fig. 39 KANTHAL SUPER elements in ceramic fibre lined furnaces. The passage plugs and elements are supported by the cold side of the roof.

7

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.

Two-shank holders

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

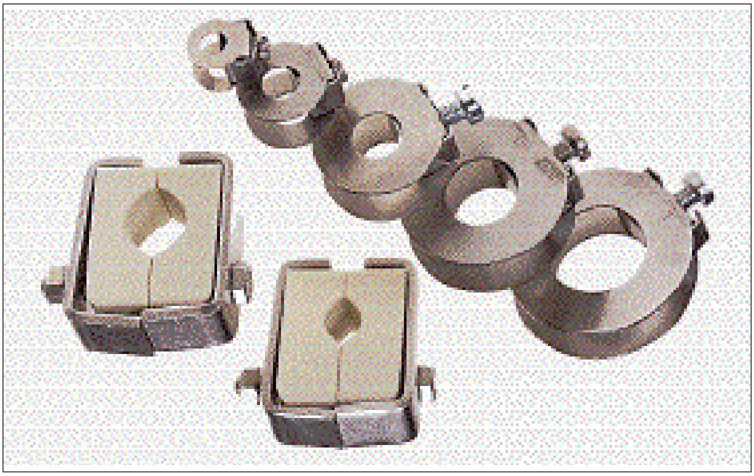


Fig. 40 Single-shank holders.

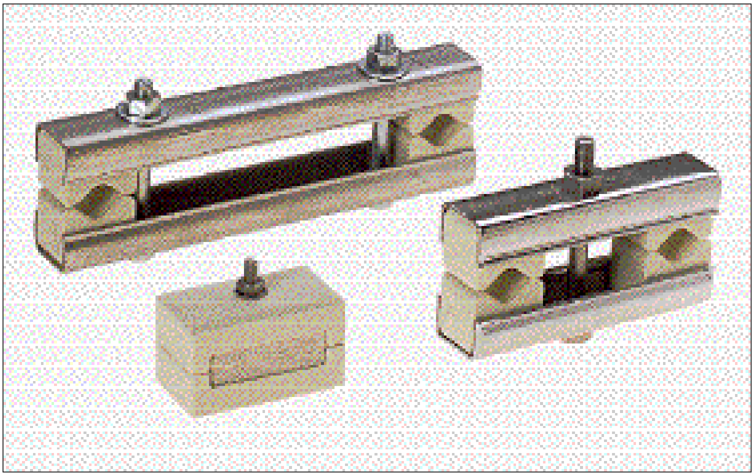


Fig. 41 Two-shank holders.

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.

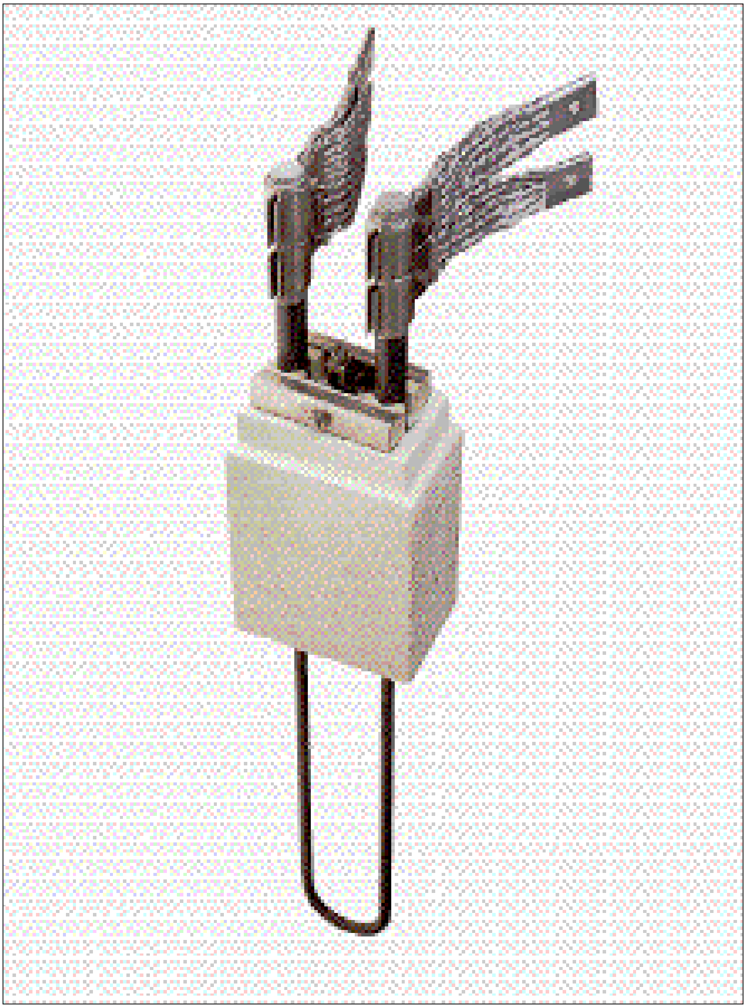


Fig. 42 Element holder and anchor system — Standard design.

7

"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 litres/minute for each element.

Fig. 43 Element holder and anchor system — Air cooled design.

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.

Fig. 44 Element holder and anchor system — Sealed design.

7

Contacts

Each contact consists of a double-folded aluminium 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 aluminium sleeve. The standard sizes and types available are shown on pages 111 – 118, Appendix 1.

It is essential that **no mechanical stresses should be transmitted to the elements through the aluminium 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 photo below.

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

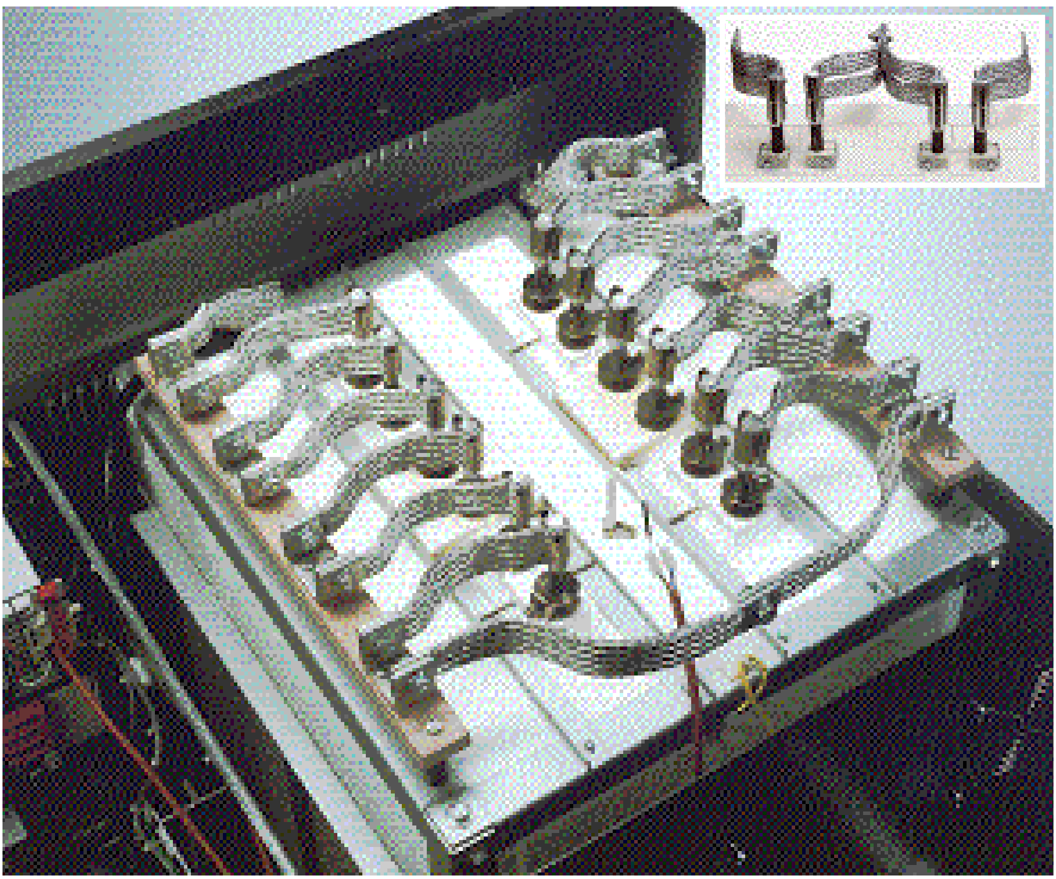


Fig. 45 KANTHAL SUPER elements connected to busbars.

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. Aluminium oxidizes easily, and the alumina layer built up on the surface is a good insulator. Furthermore, the creep strength of aluminium 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 90.

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 fibre. 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.

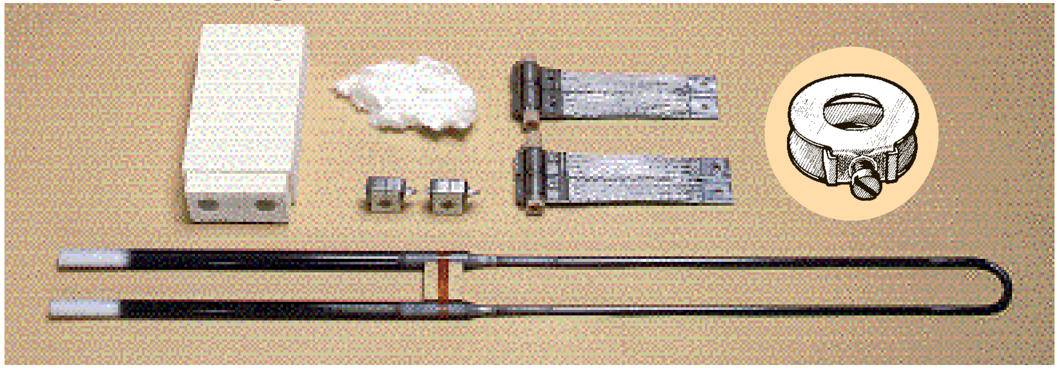
Fixed contacts Kanthal Super

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.

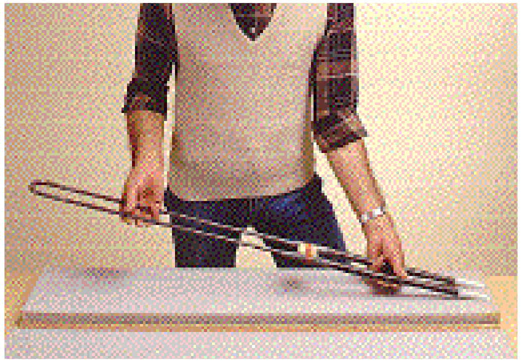
The fixed contact design, for terminal dimensions 4-24 mm, consists of a metallic sleeve soldered to the terminal end. The other end is squeezed around the aluminum braid, which has a cable clip at the other end.

This contact design can withstand 400°C on the sleeve.

Assembling of KANTHAL SUPER element



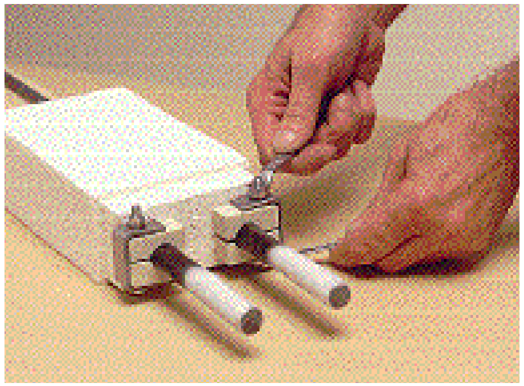
1. KANTHAL SUPER elements should not be unpacked until the furnace and the busbars are ready. Pages 80 - 81show the practice employed when assembling vertically suspended KANTHAL SUPER elements with passage bricks.



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.

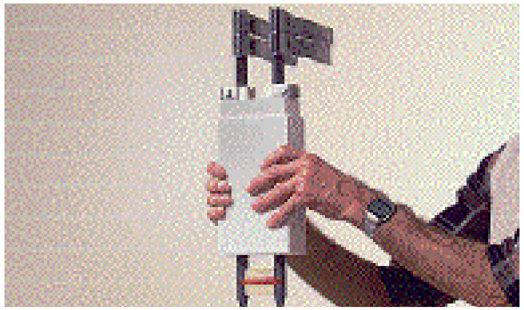
4. After packing heavy-duty ceramic fibre loosely into the recesses of the terminal holes



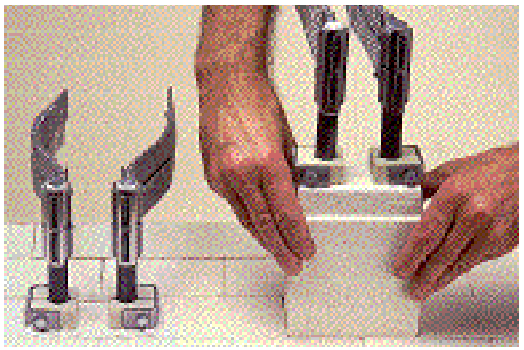
5. …single- or two-shank element holders should be fixed to the terminals.

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 (10) (g Fig. 47, page 70). If not, there is a risk that the part of the heating zone which is inside the lining may become overheated.

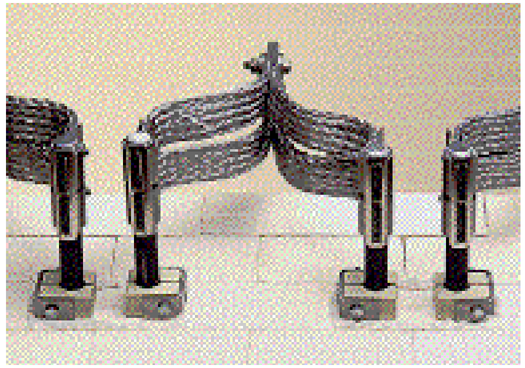
When connecting the installed elements, the aluminium braids should first be bolted to the elements and then to the busbars.



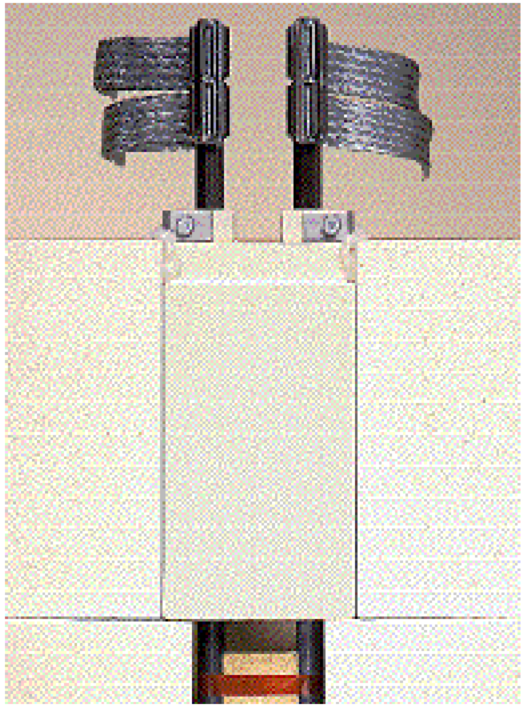
7 Before inserting the element assembly …



8. …it is necessary to check the size of the corresponding holes in the roof.



9. When fastening the contact bolts the elements must not be bent or twisted.



*10. **Finally, check that the installed elements can move freely !***

7

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 Fig. 47, page 83.

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 = min.*15 *mm* (0.6 *in.*)
For L_e > 1000 *mm* (39.4 *in.*); *e = min.* 50 *mm* (1.97 *in.*)

When installed **perpendicular to the wall**, the deformation due to the electro-magnetic 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 (Fig. 49), 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:

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

Distance between elements

Minimum distances, *b*, between adjacent elements are given in fig. 48, page 83.

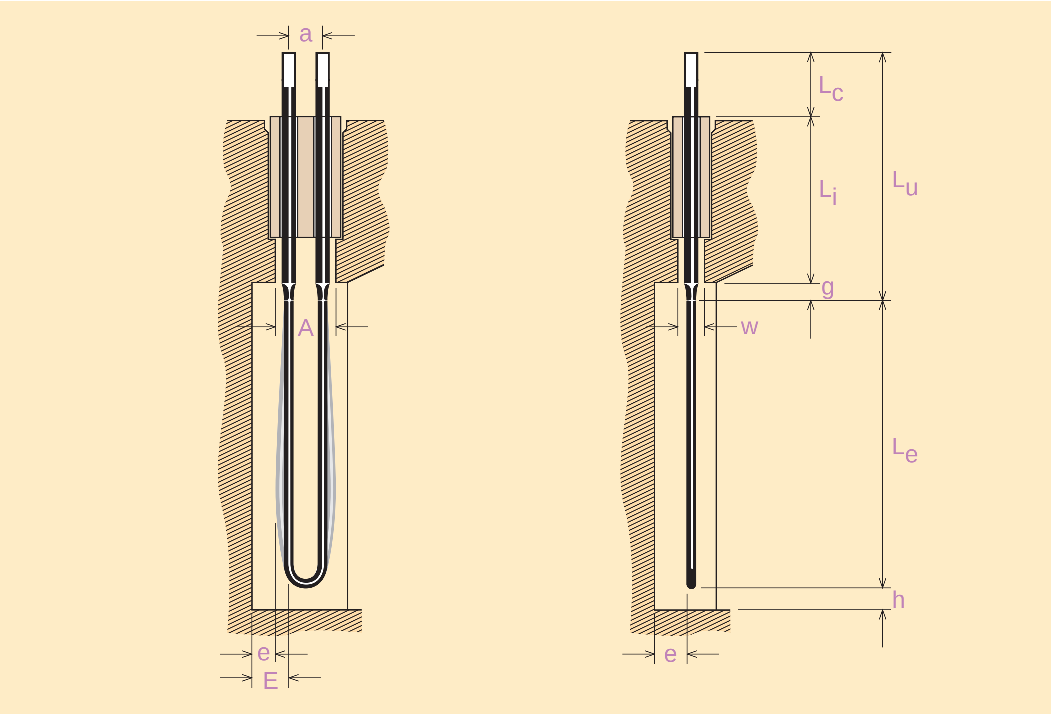


Fig. 47 Installation parameters.

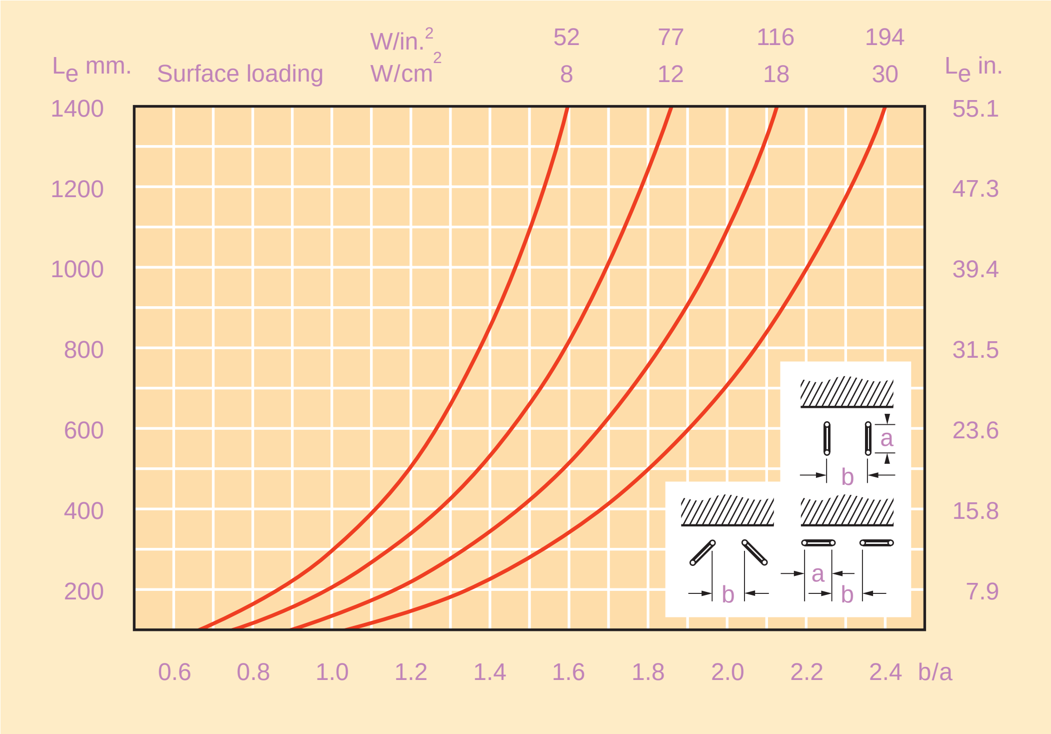


Fig. 48 Necessary distances, b, to counteract the effect of the electro-magnetic force on KANTHAL SUPER elements.

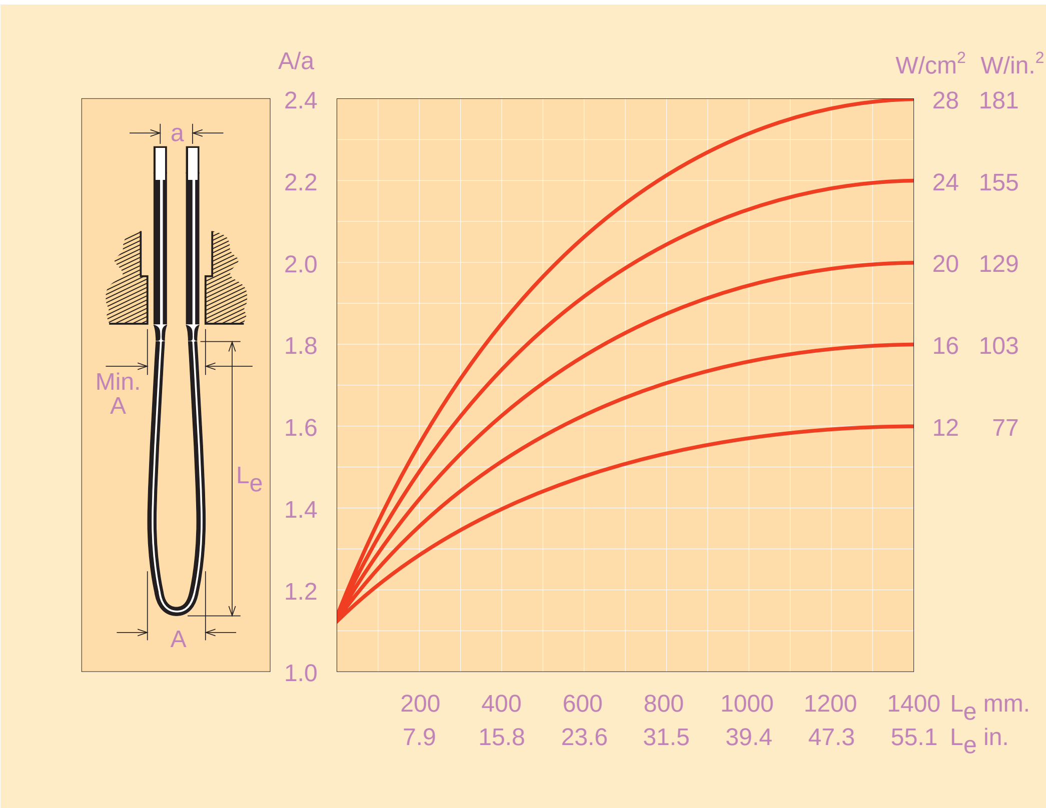
7

Element size:	3/6	4/9	6/12	9/18	12/24
Hole dia. of pass. brick	9 mm 0.35 in.	12 0.5	15 0.6	23 0.9	30 1.2
Recomm-ended min. width of opening in skew brick, w	15 mm 0.6 in.	20 0.8	25 1	30 1.2	40 1.6

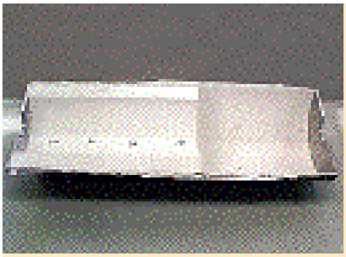
Table 7 Important Installation parameters for passage brick and skew brick.

The minimum length of opening A is calculated according to the diagram in Fig. 49.

Fig. 49 Deformation of KANTHAL SUPER elements due to electro-magnetic forces. Valid for all sizes – 3/6, 4/9, 6/12, 9/18 and 12/24.

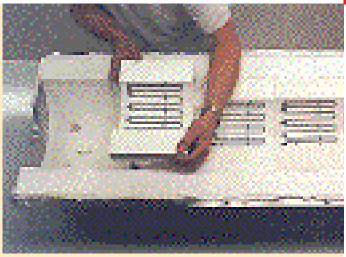


Assembling of SUPERTHAL furnaces.

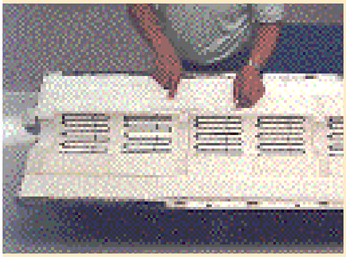


1. Place the steel casing on a table and apply a fibre felt onto the inside of the casing. Adjust the back-up insulation if needed and put it in place. Mark carefully the location of the element terminals and drill the holes to 20 – 23 mm through the fibre and casing.

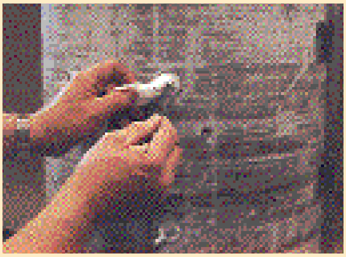
2. With multizone vertical furnaces intermediate supports are recommended, which could be secured to the back-up insulation with ceramic tubes.



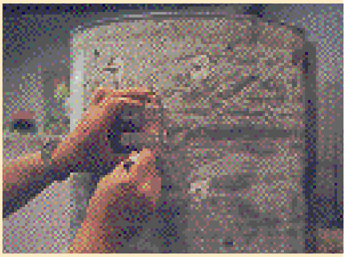
3. When the element modules are installed the casing is put on supports with room for the protruding terminals. ***Be very careful during assembling to avoid mechanical stress on the terminals.***



4. Before the two half-shells are put together apply insulating ceramic fibre felt onto the module ends to improve the insulation.



5. After the two half-shells are bolted together, raise the furnace to an erect position. Seal around the terminals with ceramic fibre wool. Do not pack too tight. Be careful not to create stress in the terminals.



6. Mark the location for the terminal blocks. Drill and bolt them to the casing.

7. Before connecting the braids they have to be preformed to eliminate any stress on the terminals. Very important — When the spring clips are applied hold the terminal with the other hand ***to avoid any bending force on the terminal.***

8. The furnace is wired for three zones. Note the slack in the braids.

Fig. 50 Assembling and installation of a SUPERTHAL furnace.

7

Elements in radiant tubes

Although KANTHAL SUPER elements can operate directly in most atmospheres, it is sometimes advantageous to insert them in radiant tubes. These protect the elements when maintenance is performed inside the furnace.

Element replacement is simplified as no special precautions have to be taken with the furnace atmosphere when an element needs to be replaced.

Complete tube system

The development of KANTHAL Extruded APM tubes enables us to offer a complete heating system, element assembly and radiant tube. KANTHAL Extruded APM tubes have an excellent form stability up to a furnace temperature of 1250 °C (2280 °F), and a non-flaking alumina oxide layer. They are available in various standard dimensions. For KANTHAL SUPER 9/18 and 12/24 elements suitable dimensions are:

For horizontal mounting
OD/ID 146/134 mm
(5.8/5.3 in.)
and 154/142 mm
(6.1/5.6 in.).

For vertical mounting
OD/ID 154/142 mm
(6.1/5.6 in.)
and 164/152 mm
(6.5/6.0 in.).

Example:
2 pcs KANTHAL SUPER 1700 12/24 elements in a vertical APM tube with dimension 198/180 mm (7.8/7.1 in.).
At furnace temperature 900 °C (1650 °F) a power of 40 kW/m (12 kW/ft.) heating zone length is possible.
At 1200 °C (2190 °F) furnace temperature the maximum power is 25 kW/m. (7.6 kW/ft.).

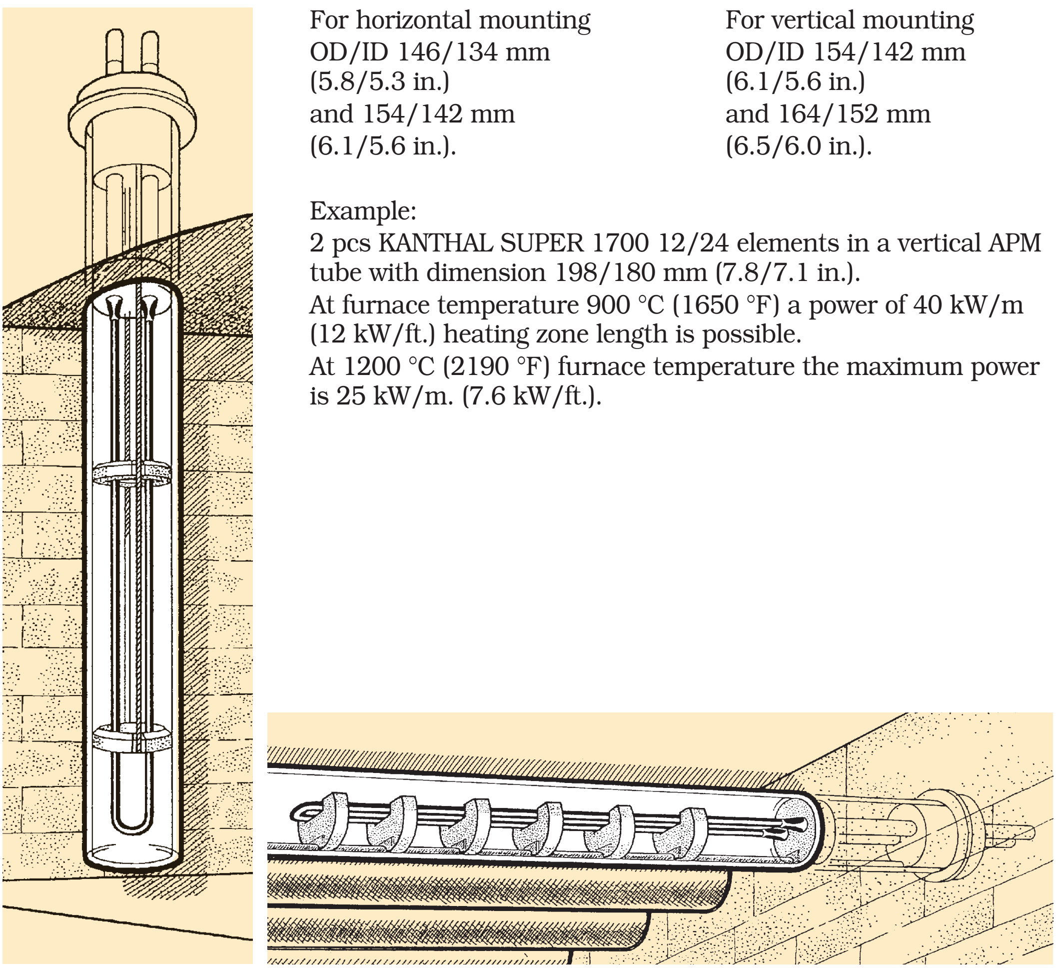


Fig. 51 KANTHAL SUPER elements in horizontally and vertically mounted radiant tubes.

Calculations

8

Symbols

The following symbols are used:

L_u = Terminal length, mm; in.

L_e = Heating zone length, mm; in.

a = Distance between shanks, mm; in.

B = Intermediate heating zone length, mm; in.

d = Heating zone diameter, mm

D = Terminal diameter, mm

L_H = Total rod length of heating zone, m; in.

L_T = Total rod length of terminals, m; in.

P = Total power, kW

P_e = Power per element, W

$P_{e\ tab}$ = Power per element from table, W (See pages 34-48)

U = Connecting voltage per group, V

U_e = Voltage per element, V

I = Current, A

R_t = Hot resistance per element, Ω

r_e = Heating zone resistance, Ω/m; Ω/in.

r_u = Terminal resistance, Ω/m; Ω/in.

T_e = Temperature of the heating zone,°C; °F

T_f = Furnace temperature, °C; °F

p = Surface load on the heating zone, W/cm^2; W/in.^{2}

p_{tab} = Table value of surface load on the heating zone, W/cm^2; W/in.^{2} (See pages 34 - 48)

n = Number of elements

S = Number of shanks

( ) = Imperial Units

8

Furnace power

The design and size of the furnace needed are generally determined by the charge. The power of the furnace can be calculated in two basic ways:

1. According to diagram (Fig. 52)
2. According to the actual charge and heat losses.

The most accurate method is according to the actual charge and heat losses. The power needed according to the actual charge is determined as follows:

$$P_c = G \times C \qquad \textbf{...1}$$

P_c = Power needed for charge, kW
G = Weight of charge, kg
C = Heat storage of charge at temperature, kWh/kg

Example: G = 60 kg, C = 2.5 kWh/kg: $P_c = 60 \times 2.5 = 150kW$

The efficiency of electric furnaces varies normally between 0.6 and 0.9. Generally it is sufficient to make an allowance of 70 - 80 % for losses and control intermittence in order to obtain a fully adequate installed power.

The furnace power P, is then determined:

$$P = \frac{P_c}{\eta} \qquad \textbf{...2}$$

η= efficiency and allowance for losses and control intermittence

$$\eta = 0.75 \times 0.8 = 0.6$$

Example: $P = \frac{150}{0.6} = 250kW$

When calculating a laboratory furnace or some other multi-purpose furnace, when the charge is not entirely known, the power should be calculated according to the diagram or based on experience.

In order to check the feasibility of:

Installed power
Accessible area for element installation
Element dimension
Element location

recommendations shown in Fig. 52, page 76 should be followed.

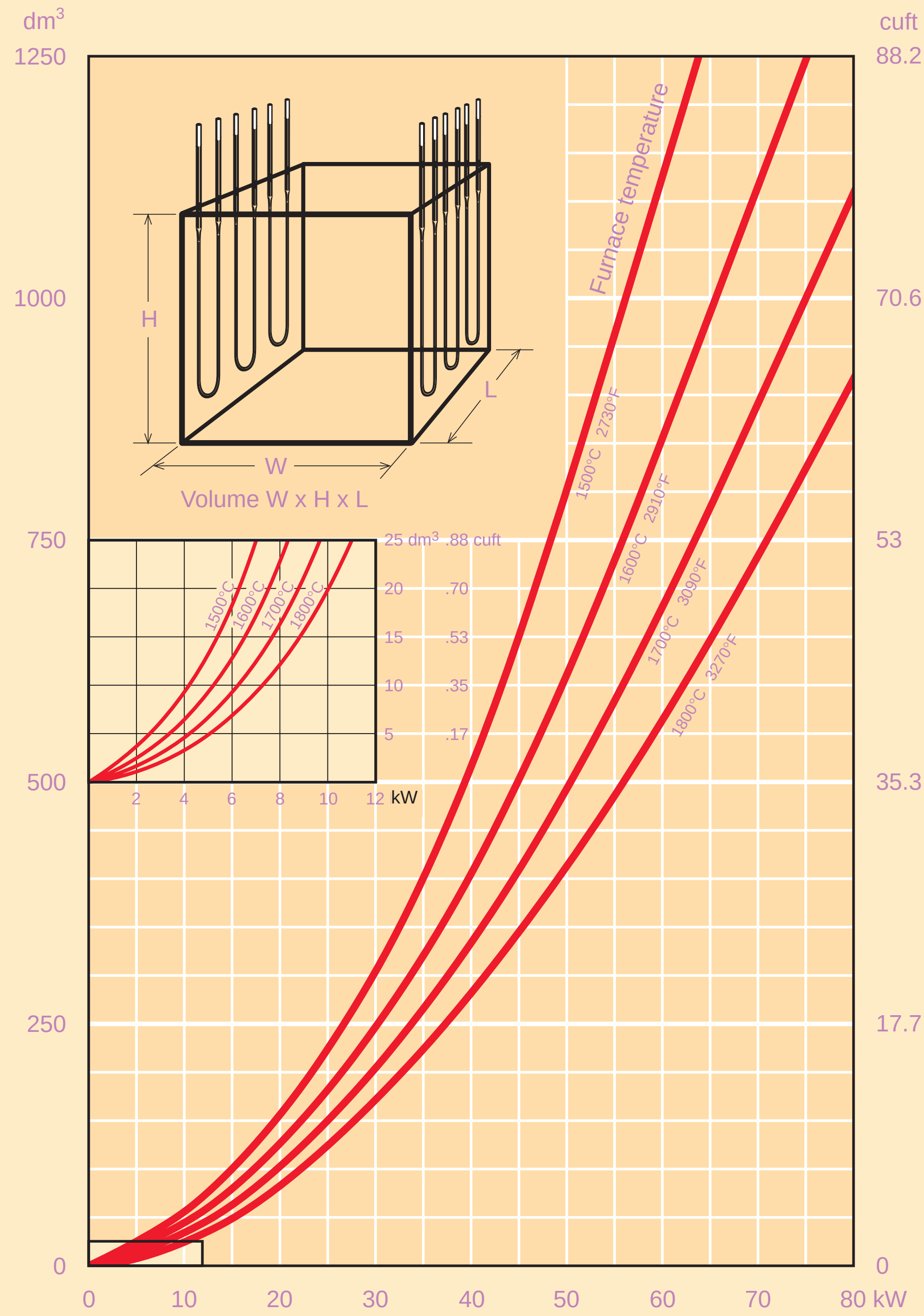


Fig. 52 The approximate power at a given chamber volume for a ceramic fibre lined furnace. For a brick lined furnace the power is normally about 25 % higher.

8

Element selection

Element quality and dimensions have to be selected and calculation of the number of elements has to be made.

The furnace data provided are:

- Size (W x H x L)
- Type of insulation and thickness
- Operating temperature
- Total power
- Element location
- Line voltage
- Control and power supply

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 as indicated in Fig. 47, page 70.

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

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 g	15	0.6	15	0.6	25	1.0	30	1.2	40	1.6
$L_{c\,min.}$*	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.).*

The total minimum terminal length is calculated according to the formula:

$$L_{u\,min.} = L_i + L_{c\,min.} + g \qquad \textbf{...3}$$

Heating zone length

The following must be taken into consideration:

The internal height of the furnace where the elements are located, H.

The length of the tapered part, g.

A safety distance, h, beneath the bend to bottom of the furnace. This distance, h, is recommended to be at least $L_e/20$, min. 10 mm, (0.4 in.).

This gives the formula:

$$L_{e\,max.} = H \times 0.95 - g \text{ mm for } L_e \geq 200 \text{ mm (7.9 in.)} \qquad \textbf{...4}$$

$$L_{e\,max.} = H - 10 - g \text{ mm } (H - 0.4 - g \text{ in.) for } L_e < 200 \text{ mm (7.9 in.)}$$

Distance between elements

A minimum distance between elements must be applied to prevent the elements from coming in contact with each other due to electromagnetic forces and deformation. The minimum centre distance, *b*, between the shanks in two adjacent elements is calculated according to Fig. 48, page 70.

Element data

The element data is calculated as follows:

Power per element, P_e

Total power is divided by the number of elements.

$$P_e = \frac{P}{n} \qquad \text{...5}$$

Example: $P_e = \frac{250}{18} = 13.89\ kW$

Surface loading, p

Check with table value for element power and estimate new surface loading.

$$p = \frac{P_e}{P_{e\ tab}} \times p_{\ tab}; \qquad \text{...6}$$

$p_{\ tab}$ and $P_{e\ tab}$ from tables on pages 34 - 48.

Example: KANTHAL SUPER 1700 9/18, See table page 36.

L_u = 500 mm (19.7 in.)
L_e = 1120 mm (44 in.)
a = 60 mm (2.36 in.)

$P_{e\ tab}$ = 11 380 W
$p_{\ tab}$ = 16.6 W/cm^2 (107 W/in.^{2})

$$p = \frac{13\ 890}{11\ 380} \times 16.6 = 20.3\ W/cm^2$$

$$(\ )\quad p = \frac{13\ 890}{11\ 380} \times 107 = 131\ W/\ in.^2$$

Element temperature, T_e

Estimate element temperature from the temperature - loading diagram in Fig. 27, page 52.

Example: At p = 20.3 W/cm^2 (131 W/in.^{2}) and T_f =1150°C (2100°F), T_e ≈1520°C (2770°F).

8

Hot resistance, R_t

Calculate total rod length of the heating zone, L_H and of terminals, L_T.

For two-shank elements

$$L_H = \frac{2\ L_e + 20 + 0.57a - d}{1000} \quad m \qquad \textbf{...7a}$$

$$(\ )\quad L_H = 2\ L_e + 0.8 + 0.57a - \frac{d}{25.4} \ in. \quad \text{(d in mm)}$$

For multi-shank elements

$$L_H = \frac{2\ L_e + 20 + B(S-2) + (S-1)\ (0.57a - d)}{1000} \quad m \qquad \textbf{...7b}$$

$$(\ )\quad L_H = 2\ L_e + 0.8 + B(S-2) + (S-1)\ (0.57a - \frac{d}{25.4})\ in. \quad \text{(d in mm)}$$

$$L_T = \frac{2\ L_u}{1000}\ m \qquad \textbf{...8}$$

$$(\ )\quad L_T = 2\ L_u\ in.$$

Calculate resistance in Ω/m for KANTHAL SUPER 1700 and 1800.
See also diagram in Fig. 26, page 63.

Resistance is calculated at actual element temperature, T_e.

$$r_e = \frac{(0.0028 \times T_e - 0.255)}{d^2} \quad for\ T_e > 600\ °C \qquad \textbf{...9}$$

$$r_u = \frac{(0.00196\ x\ T_f - 0.255)}{D^2} \qquad \textbf{...10}$$

Calculate resistance in Ω/in. for KANTHAL SUPER 1700 and 1800

$$(\ )\quad r_e = \frac{(0.393 \times T_e - 71) \times 10^{-4}}{d^2} \quad for\ T_e > 1000\ °F \quad \text{(d in mm)} \qquad \textbf{...9}$$

$$(\ )\quad r_u = \frac{(0.275 \times T_f - 71) \times 10-4}{D^2} \quad \text{(D in mm)} \qquad \textbf{...10}$$

Calculate resistance in Ω/m for KANTHAL SUPER 1900
See also diagram in Fig. 26, page 51.

$$r_e = \frac{(0.00261 \times T_e - 0.255)}{d^2} \quad for\ T_e > 900\ °C \qquad ...11$$

$$r_u = \frac{(0.00183 \times T_f - 0.255)}{D^2} \qquad ...12$$

Calculate resistance in Ω/in. for KANTHAL SUPER 1900

$$(\ )\quad r_e = \frac{(0.391 \times T_e - 78) \times 10^{-4}}{d^2} \quad for\ T_e > 1650\ °F \quad (d\ in\ mm) \qquad ...11$$

$$(\ )\quad r_u = \frac{(0.274 \times T_f - 78) \times 10^{-4}}{D^2} \quad (\text{D in mm}) \qquad ...12$$

Total resistance, R_t is calculated:

$$R_t = (r_e \times L_H) + (r_u \times L_T) \qquad ...13$$

Example: KANTHAL SUPER 1700 9/18.

L_u = 500 mm (19.7 in.)
L_e = 1120 mm (44.1 in.)
a = 60 (2.36 in.)
T_f = 1150 °C (2100 °F)
T_e = 1520 °C (2770 °F)

$$R_t = \frac{0.0028 \times 1520 - 0.255}{9^2} \times \frac{2 \times 1120 + 20 + 0.57 \times 60 - 9}{1000} +$$

$$\frac{0.00196 \times 1150 - 0.255}{18^2} \times \frac{2 \times 500}{1000} = (0.0494 \times 2.285) + (0.0062 \times 1) =$$

$$0.113 + 0.006 = 0.119\Omega$$

$$(\ )\ R_t = \frac{(0.393 \times 2770 - 71)}{9^2} \times 10^{-4} \times \left(2 \times 44.1 + 0.8 + 0.57 \times 2.36 - \frac{9}{25.4}\right)$$

$$+ \frac{(0.275 \times 2100 - 71)}{18^2} \times 10^{-4} \times 2 \times 19.7 = (0.00126 \times 90) + (0.000156 \times 39.4) =$$

$$0.113 + 0.006 = 0.119\Omega$$

8

Element voltage, U_e

$$U_e = \sqrt{P_e \times R_t} \qquad \text{...14}$$

Example: $U_e = \sqrt{13\,890 \times 0.119} = 40.65\ V$

Current, I

$$I = \frac{U_e}{R_t} \qquad \text{...15}$$

Example: $I = \frac{40.65}{0.119} = 342A$

Element power, P_e

$$P_e = R_t \times I^2 \qquad \text{...16}$$

Example: $P_e = 0.119 \times 342^2 \approx 13\,900\ W$

Examples of element calculations

Example 1

Laboratory furnace, T_f max. 1700 °C (3090 °F)

Inside dimensions:

Width	180 mm	7.1 in.	Line voltage	400/230 V
Height	210 mm	8.3 in.	Control	Thyristor, phase-angle fired
Depth	255 mm	10 in.	Elements	KANTHAL SUPER 1800 3/6 or 4/9
Roof insulation, L_i	90 mm	3.5 in.		

The chamber volume is calculated: $V = 1.8 \times 2.1 \times 2.55 \approx 10\ dm^3$
$(V = 7.1 \times 8.3 \times 10 \approx 589\ in.^3 \approx 0.34\ ft^3)$

Since it is a laboratory furnace the charge is not known.
According to the diagram Fig. 52, page 76 the power needed is 6 kW

Terminal length, L_u ...3

$L_{u\ min} = 90 + 50 + 15 = 155\ mm\ \ (3.5 + 2 + 0.6 = 6.1\ in.)$

Closest standard length 160 mm (6.3 in.) for 3/6 and 4/9 elements.

Heating zone length, L_e

...4

$L_{e\,max}$ = 210 × 0.95 – 15 = 185 *mm* ((8.3 – 0.6) × 0.95 = 7.3 *in.*)

Closest standard length 180 *mm* (7.1 *in.*)

Number of elements, n

Check power per element according to tables in pages 39 – 40

For 3/6 element P_e = 500 W, and 4/9 element P_e = 649 W at 12 W/cm^2 (77 W/in.^{2})
T_f = 1600 °C (2910 °F) and T_e = 1700 °C (3090 °F).

According to the temperature - loading diagram on page 64, 12 W/cm^2 (77 W/in.^{2}) is within the recommendations also at T_f = 1700 °C (3090 °F).

Number of 3/6 elements will be $\frac{6\,000}{500} = 12$

Number of 4/9 elements will be $\frac{6\,000}{649}$ = 9.2, say 10pcs.

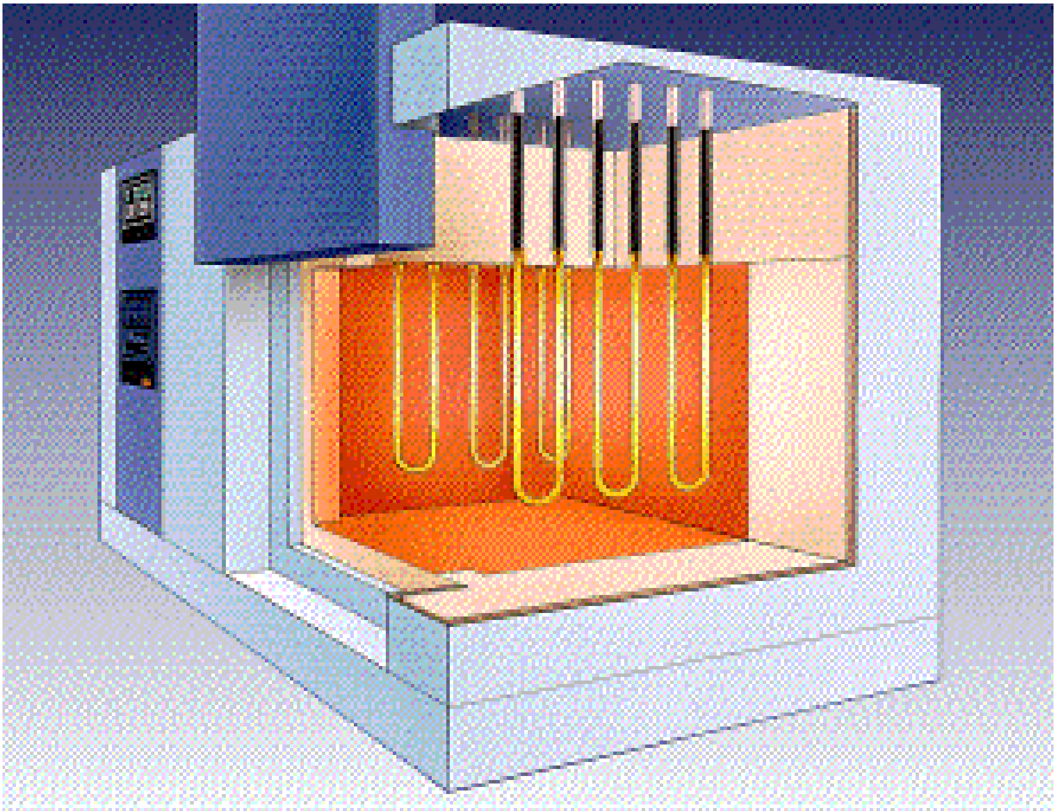


Fig.53 High temperature laboratory furnace.

8

Distance between elements

Wall length is 255 mm.
Using 3/6 elements, the centre distance between elements will be

$$\frac{255}{6} = 42.5\ mm \qquad \left(\frac{10}{6} = 1.7\ in.\right)$$

Using 4/9 elements, the centre distance between elements will be

$$\frac{255}{5} = 51\ mm \qquad \left(\frac{10}{5} = 2\ in.\right)$$

According to diagram in Fig. 48, page 83 b/a = 0.95 for L_e = 180 mm (7.1 in.) at a surface loading of 12 W/cm^2 (77 W/in.^{2}).

Minimum centre distance between elements when mounted:
a) parallel to the wall;

$$a + b = 25 + 0.95 \times 25 = 49\ mm\ (1 + 0.95 \times 1 = 1.95\ in.).$$

and,

b) perpendicular to the wall;

$$b = 0.95 \times 25 = 24\ mm \quad (0.95 \times 1 = 0.95\ in.)$$

It is preferred that the elements are mounted parallel to the walls therefore ten pcs 4/9 elements are selected.

Power per element, P_e ...5

$$P_e = \frac{6000}{10} = 600\ W$$

Surface loading, p ...6

Nominal power according to table on page 41 is 649 W at a surface loading of 12 W/cm^2 (77 W/in.^{2})

$$p = \frac{600 \times 12}{649} \approx 11.1\ W/cm^2 \qquad (72\ W/in.^2)$$

According to the loading diagram on page 64 the element temperature will be ≈ 1770 °C (3220 °F).

Hot Resistance, R_t ...13

$$R_t = \frac{0.0028 \times 1770 - 0.255}{4^2} \times \frac{2 \times 180 + 20 + 0.57 \times 25 - 4}{1000} +$$

$$\frac{0.00196 \times 1700 - 0.255}{9^2} \times 2 \times \frac{160}{1000} = (0.294 \times 0.39) + (0.0380 \times 0.32) =$$

$$0.115 + 0.012 = 0.127\ \Omega$$

( ) $$R_t = \frac{0.393 \times 3220 - 71}{4^2} \times 10^{-4} \times \left(2 \times 7.1 + 0.8 + 0.57 \times 1 - \frac{4}{25.4} \right) +$$

$$\frac{0.275 \times 3090 - 71}{9^2} \times 10^{-4} \times 2 \times 6.3 = (0.00747 \times 15.4) + (0.0010 \times 12.6) =$$

$$0.117 + 0.012 = 0.127\ \Omega$$

Element voltage, U_e ...14

$$U_e = \sqrt{600 \times 0.127} = 8.7\ V$$

Current, I ...15

$$I = \frac{8.7}{0.127} = 68.5\ A$$

Final element data: 10 pcs KANTHAL SUPER 1800 4/9

L_u = 160 (6.3 in.)	P_e = 600 W	T_e = 1770 °C (3220 °F)
L_e = 180 (6.3 in.)	U_e = 8.7 V	
a = 25 (1 in.)	I = 68.5 A	
	R_t = 0.127 Ω	
	p = 11.1 W/cm² (72 W/in.²)	

Electrical equipment.

The elements could be connected all in series to a single phase transformer since this is a relatively small furnace.

Secondary voltage of the transformer is $U_e \times n = 8.7 \times 10 = 87\ V$.

Since the resistance of cold elements is low the voltage must be controlled in such a way that the maximum continuous element current does not exceed 115 A (see page 79).

The maximum potential power of the furnace during operation is $U_{tot} \times I_{max} = 87 \times 115 = 10\,000\ W$ and the power supply should be rated at no less than this.

The supply to which the furnace is being connected consists of two lines of a 400 V, three-phase system.

The maximum primary current will be $VA_{max}/U_{supply} = 10\,000/400 = 25\ A$.

For power control, a single phase, phase-angle fired thyristor unit rated at 400 V should be connected to the primary side of the transformer with current limit set to 25 A (R.M.S.) incorporating a soft start (transformer inrush protection).

8

Example 2

Sealed quench furnace with endogas atmosphere, T_f max. 1100 °C (2010 °F).
Inside dimensions:

Width	1300 mm (51 in.)	Roof insulation L_i (including plate).	280 mm (11 in.)
Height	1300 mm (51 in.)	Line voltage	400/230 V
Depth	1300 mm (51 in.)	Control	Thyristor

This is an existing furnace and is presently equipped with twelve pcs 102 mm 4" gas heated radiant tubes with an installed power of 227 000 kcal/h. This is to be rebuilt to electric heating.

Total power, P ...2

$$227\,000\ kcal/h = 227\,000 \times 1.163 \times 10^{-3} = 264\ kW$$

The system efficiency of this furnace is estimated to be 40%.
The efficient power is then 264 × 0.4 = 106 kW
The efficiency of this furnace retrofitted to electric is estimated at 80%

The installed power should be $\dfrac{106}{0.8} = 132\ kW$

Number of elements, n

Since there are twelve pieces radiant tubes installed in the furnace, it is suitable to replace them with the same number of KANTHAL SUPER elements.

Terminal Length, L_u ...3

$L_{c\ min} = 140\ mm$ (5.5 *in.*). See page 90.
$L_{u\ min} = 280 + 140 + 30 = 450\ mm$ (11 + 5.5 + 1.2 *in.* = 17.7 *in.*), which is a standard length.

Heating zone length, L_e ...4

$L_{e\ max} = 1300 \times 0.95 - 30 \approx 1205\ mm$ ($51 \times 0.95 - 1.2 \approx 47.3$ *in.*).
The closest standard length 1120 mm (44.1 in.).

Power per element, P_e ...5

$$P_e = \frac{132}{12} = 11\,000\ W$$

For an element KANTHAL SUPER 1700 9/18, L_u = 450 (17.7 in.), L_e = 1120 (44.1 in.), a = 60 (2.36 in.), the nominal power according to table on page 38 is 11 310 W at a surface loading of 16.6 W/cm^2 (107 W/in.^{2}).

Surface loading in our case will be $p \approx \dfrac{11\,000}{11\,310} \times 16.6 \approx 16.1\ W/cm^2$ ($104\ W/in^2$)

According to the loading diagram in Fig. 27, page 52, the $T_e \approx$ 1435 °C (2615 °F) at T_f = 1100 °C (2010 °F).

Hot Resistance, R_t

...13

8

$$R_t = \frac{0.0028 \times 1435 - 0.255}{9^2} \times \frac{2 \times 1120 + 20 + 0.57 \times 60 - 9}{1000} +$$

$$\frac{0.00196 \times 1100 - 0.255}{18^2} \times 2 \times \frac{450}{1000} = (0.0465 \times 2.285) + (0.0059 \times 0.9) =$$

$$0.106 + 0.005 = 0.111\Omega$$

( )
$$R_t = \frac{0.393 \times 2615 - 71}{9^2} \times 10^{-4} \times \left(2 \times 44.1 + 0.8 + 0.57 \times 2.36 - \frac{9}{25.4}\right) +$$

$$\frac{0.275 \times 2010 - 71}{18^2} \times 10^{-4} \times 2 \times 17.7 = (0.00118 \times 90) + (0.00015 \times 35.4) =$$

$$0.106 + 0.005 = 0.111\Omega$$

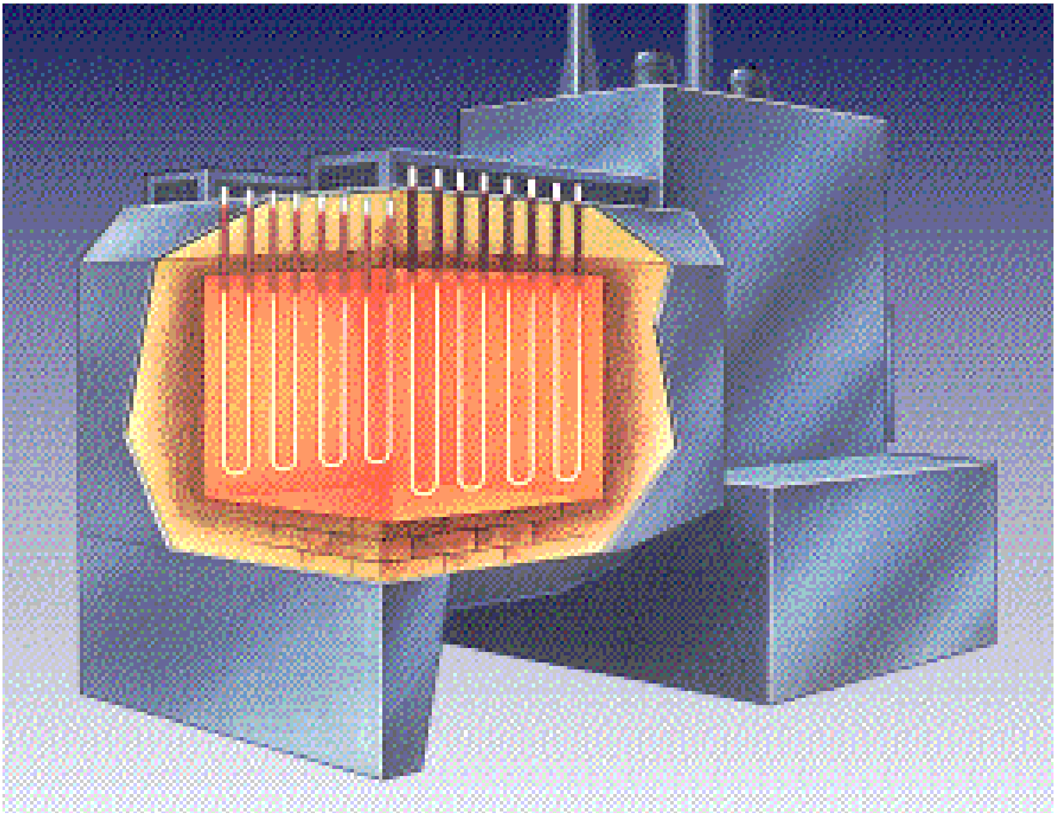


Fig. 54 Sealed quench furnace.

8

Element voltage, U_e ...14

$$U_e = \sqrt{11\ 000 \times 0.111}\ \text{V} = 34.9\ \text{V}$$

Current, I ...15

$$I = \frac{34.9}{0.111} = 315\ A$$

Final element data: 12 pcs KANTHAL SUPER 1700 9/18

L_u = 450 (17.7 in.)	P_e = 11 000 W	T_e = 1435 °C (2615 °F)
L_e = 1120 (44.1 in.)	U_e = 34.9 V	
a = 60 (2.36 in.)	I = 315 A	
	R_t = 0.111 Ω	
	p = 16.1 W/cm² (104 W/in.²)	

Electrical equipment.

It is advised that the elements are delta connected to a three-phase transformer as shown in Fig. 59 c, page110 (thyristor control), or Fig. 60 b, page 99 (on/off control).
Secondary voltage of the transformer is $\boldsymbol{U_e} \times \boldsymbol{n} = 34.9 \times 4 \approx 140\ V$.
Maximum element current for 9/18 elements is 365 A (see page 67).
The maximum potential power of the furnace during operation is

$$\frac{\boldsymbol{U_{tot}} \times \boldsymbol{I_{max}} \times \mathbf{3}}{\mathbf{1000}} = \frac{140 \times 365 \times 3}{1000} \approx 153\ kW$$

The power supply should be rated at no less than 153 kVA.
At supply voltage of 400 V the maximum line current is

$$\frac{\boldsymbol{P_{tot}}}{\boldsymbol{U_{supply}} \times \sqrt{\mathbf{3}}} = \frac{153\ 000}{400 \times \sqrt{3}} \approx 221\ A$$

In this case thyristor control is selected. The nearest standard size of three-phase thyristor is 250 A 440 V.

Example 3

Rotary hearth furnace, T_f max. 1300 °C (2370 °F), nitrogen atmosphere.

Inside dimensions:

Diameter, outer wall	4700 mm (185 in.)	Width of door opening	1800 mm (71 in.)
Diameter, inner wall	1650 mm (65 in.)	Line voltage	400/230 V
Height	1525 mm (60 in.)	Control	Thyristor
Roof insulation L_i	300 mm (12 in.)	Weight of steel billets	1500 kg/hour

The heating capacity for iron at 1300 °C (2370 °F) is 0.245 kWh/kg according to Appendix 2, Fig. 75 on page 135.

The power needed according to the actual charge is determined as follows:

$$P_c = 0.245 \times 1500 = 368\ kW \quad \text{...1}$$

Total power, P ...2

$$P = \frac{P_c}{\eta} \quad \eta = 0.6 \text{ (see page 88)} \qquad P = \frac{368}{0.6} = 613\ kW$$

The elements should be installed vertically along both outer and inner walls.

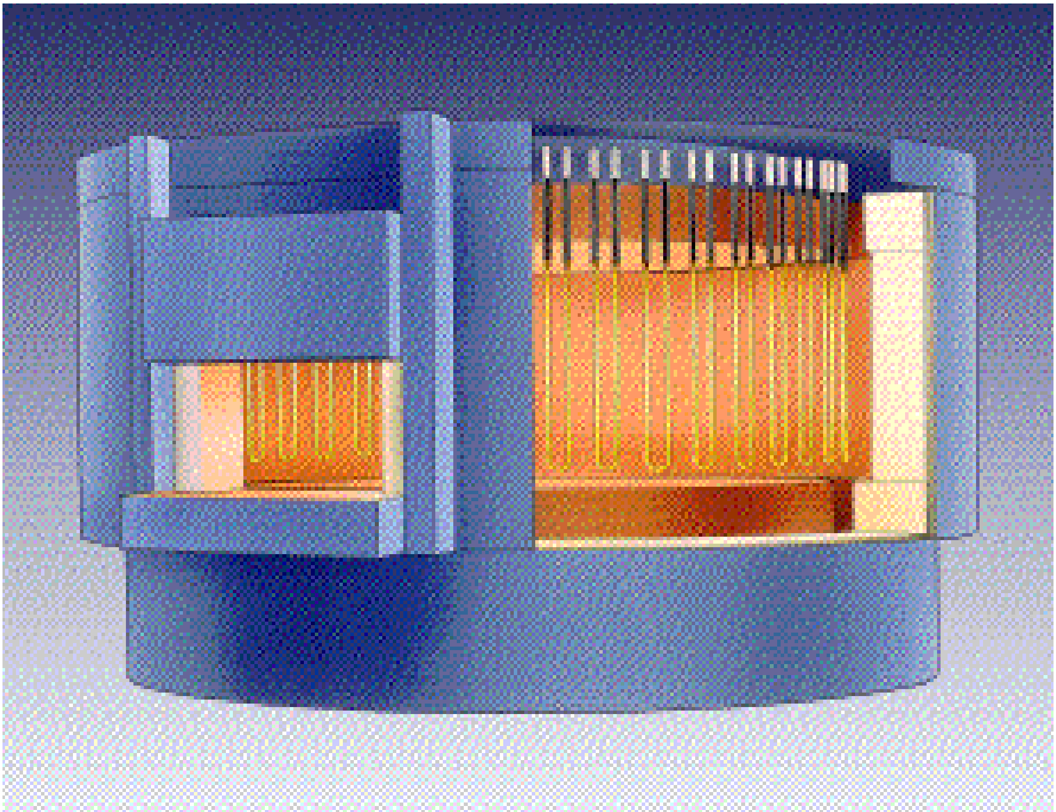


Fig. 55 Rotary hearth furnace.

8

Heated area is calculated: $A = ((\pi \times 4.7 - 1.8) + \pi \times 1.65) \times 1.525 = 27.7\ m^2$

$$( )\ A = ((\pi \times 185 - 71) + \pi \times 65) \times \frac{60}{144} = 298\ ft^2$$

Wall loading is calculated: $\frac{P}{A} = \frac{613}{27.7} = 22.1\ kW/m^2 \quad \left(\frac{613}{298} = 2.1\ kW/ft^2\right)$

According to diagrams in Fig. 29, page 54, KANTHAL SUPER 9/18 elements installed parallel to the wall are preferred.

Terminal length, L_u ...3

$L_{c\ min} = 125\ mm\ (5.5\ in.)$. See page 77.

$L_{u\ min} = 300 + 125 + 30 = 455\ mm\ (12 + 5 + 1.2 = 18.2\ in.)$

Closest standard length 500 mm (19.7 in.)

Heating zone length, L_e ...4

$L_{e\ max} = 1525 \times 0.95 - 30 \approx 1420\ mm\ (60 \times 0.95 - 1.2 \approx 55.8\ in.)$

The maximum standard L_e in table on page 38 is 1400 mm
$L_e = 1400\ mm\ (55\ in.)$ is O.K. for T_e max. 1600 °C (2910 °F). See Fig. 12, page 21.

An element temperature above 1500 °C (2730 °F) is prefered in nitrogen atmosphere (see page 13).

Element data for KANTHAL SUPER 1700 9/18. See page 36.

L_u = 500 (19.7 in.)	P_e = 14 010 W	T_e = 1550 °C (2820 °F)
L_e = 1400 (44.1 in.)	U_e = 45.9 V	
a = 60 (2.36 in.)	I = 305 A	
	R_t = 0,151 Ω	
	p = 16.6 W/cm^2 (107 W/in.^{2})	

Number of Elements

$$n = \frac{613}{14.01} = 44, \text{ say 45 to achieve a symmetrical three phase load.}$$

Electrical equipment.

The power can be divided into three star connected regulation groups, which are connected directly to supply voltage. See Fig. 59 a page 96.
Five elements are connected in series to 230 V. This gives 230/5 = 46 V per element which is close to the table value 45.9 V.
Maximum element current for 9/18 elelements is 365 A (see page 67).
The maximum potential power of the furnace during operation is

$$\frac{\boldsymbol{U_{tot} \times I_{max} \times 9}}{\mathbf{1000}} = \frac{230 \times 365 \times 9}{1000} \approx 755\ kW.$$

The power supply should be rated at no less than 755 kVA.
The nearest standard size of three phase thyristor is 400 A 440 V.

An alternative is the three-phase open delta connection. See Fig. 59 b page 96.
Eight elements are connected in series to 400 V. This gives 400/8 = 50 V per element.
The total number of elements will be 48 pcs instead of 45.
The maximum potential power of furnace during operation is now

$$\frac{400 \times 365 \times 6}{1000} = 876\ kW.$$

The power supply should be rated at no less than 876 kVA.
The nearest standard size of three-phase thyristor is 400 A 440 V.

Example 4

Melting furnace for lead crystal glass, semi-closed pot.
Furnace temperature max. 1450 °C (2640 °F). Melting capacity 600 kg.
Melting is performed during approximately 8 of every 24 hours.
The energy consumption during the melting period at 1450 °C (2640 °F) is estimated to be about four times higher than when working at 1150 °C (2100 °F).
The lining consists of a combination of brick and ceramic fibre.

Inside dimensions:

Diameter wall	1600 mm (63 in.)	Line voltage	400/230 V
Height	1050 mm (41.3 in.)	Control	Thyristor
Roof insulation L_i	400 mm (15.7 in.)		

In this kind of furnace a normal power consumption for melting is 3 kWh/kg produced glass over a 24 hour cycle.
Using this value the total energy, E, consumption during 24 hours can be calculated:

$$E = 600 \times 3 = 1800\ kWh$$

8 h melting needs full power.
16 h when working needs 25 % of full power

Then the necessary power input can be calculated:

$$E = 8\ h \times P + (16\ h \times 0.25P) \qquad P = \frac{1800}{(8 \times 1) + (16 \times 0.25)} = 150\ kW$$

Terminal length, L_u ...3

For 9/18 elements with air cooled holders:

$L_{c\ min} = 140\ mm$ (5.5 *in.*). See page 77.

$L_{u\ min} = 400 + 140 + 30 = 570\ mm$ $(16.7 + 5.5 + 1.2 = 23.4\ in.)$

Closest standard length 630 mm (24.8 in.)

Heating zone length, L_e ...4

$L_{e\ max} = 1050 \times 0.95 - 30 \approx 968\ mm$ $(41.3 \times 0.95 - 1.2 \approx 38\ in.)$

Closest standard length 900 mm (35.4 in.)

Number of elements, n

According to table page 36, $P_{e\ tab} = 9490$ W.

$$n = \frac{150}{9.49} \approx 15.8\ pcs$$, say 18 to achieve a symmetrical three-phase load.

Power per element, P_e ...5

$$P_e = \frac{150}{18} = 8333W$$

Surface loading, p ...6

Check with table value and estimate surface loading.

$$p = \frac{8333}{9490} \times 16.6 = 14.6\ W/cm^2 \qquad (\ )\quad p = \frac{9333}{9490} \times 107 = 94\ W/in.^2$$

Centre distance between the elements.

The elements are calculated to be installed at a diameter of 1400 mm (55.1 in.) 100 mm (4 in.) from the wall.
The circumferential length of the circle is $\pi \times 1400 \approx 4400\ mm$ $(\pi \times 55.1 \approx 173\ in.)$
The door opening is ≈1000 mm (39.4 in.), where no elements can be placed.
The elements are then installed over a length of 4400 − 1000 ≈ 3400 mm (173 - 39.4 ≈ 134 in.) Calculate the centre distance between the elements:

$$\frac{3400}{18} \approx 189\ mm \qquad (\ )\quad \frac{134}{18} \approx 7.4\ in.$$

According to diagram Fig. 48, page 70, b/a ≈ 1.75 for L_e = 900 mm at surface loading 14.6 W/cm^2 (94 W/in.^{2}).

Minimum centre distance between elements when installed parallel to the wall:
$a + b = 1.75 \times 60 + 60 = 165$ mm $(1.75 \times 2.36 + 2.36 = 6.5\ in.)$.
When installed perpendicular to the wall:
$b = 1.75 \times 60 = 105$ mm $(1.75 \times 2.36 = 4.1\ in.)$
The elements can either be mounted perpendicular or parallel to the wall.

Element temperature, T_e

Estimate element temperature from the temperature - loading diagram Fig. 27, page 52. At p = 14.6 W/cm^2 (94 W/in.^{2}) and T_f = 1450 °C (2640 °F), $T_e \approx$ 1620 °C (2950 °F)

Hot Resistance, R_t ...13

$$R_t = \frac{0.0028 \times 1620 - 0.255}{9^2} \times \frac{2 \times 900 + 20 + 0.57 \times 60 - 9}{1000} +$$

$$\frac{0.00196 \times 1450 - 0.255}{18^2} \times 2 \times \frac{630}{1000} = (0.0529 \times 1.845) + (0.0080 \times 1.26) =$$

$$0.0975 + 0.01 = 0.108\Omega$$

$$(\,)\quad R_t = \frac{0.393 \times 2950 - 71}{9^2} \times 10^{-4} \times \left(2 \times 35.4 + 0.8 + 0.57 \times 2.36 - \frac{9}{25.4}\right) +$$

$$\frac{0.275 \times 2640 - 71}{18^2} \times 10^{-4} \times 2 \times 24.8 = (0.00134 \times 72.6) + (0.00020 \times 49.6) =$$

$$0.0975 + 0.01 = 0.108\,\Omega$$

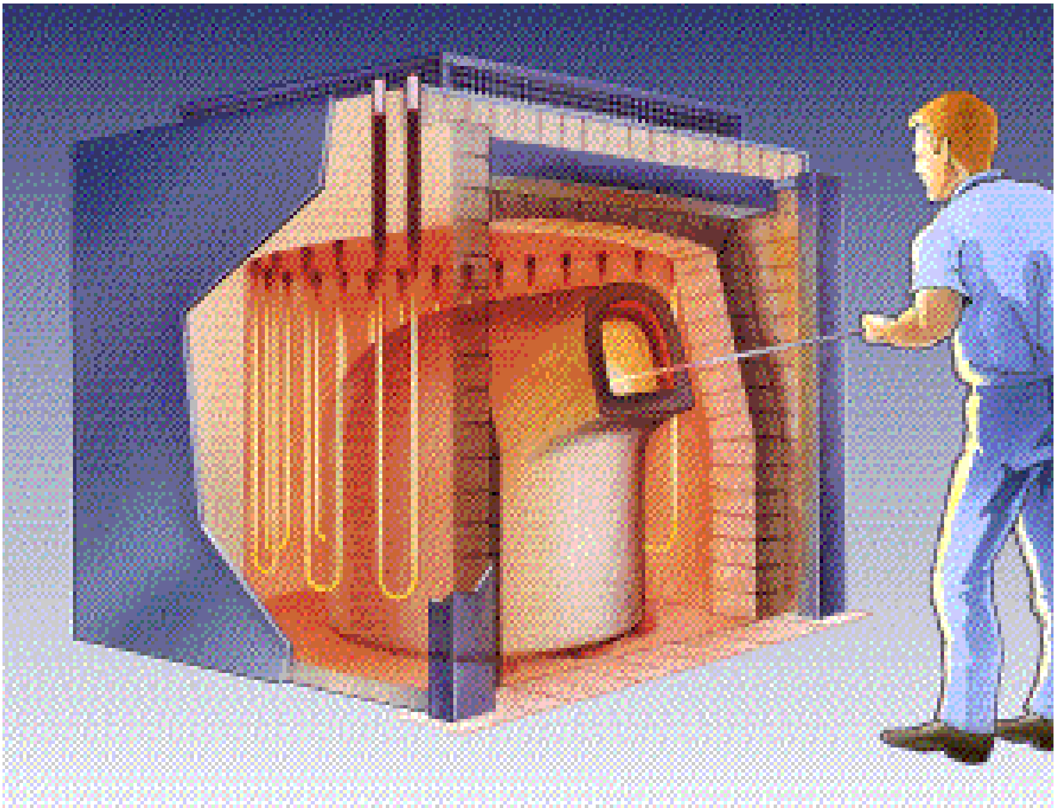


Fig. 56 Pot melting furnace.

8

Element voltage, U_e ...14

$$U_e = \sqrt{8333 \times 0.108} = 30\ V$$

Current, I ...15

$$I = \frac{30}{0.108} = 278\ A$$

Final element data: 18 pcs KANTHAL SUPER 1700 9/18

L_u = 630 (24.8 in.)	P_e = 8333 W	T_e = 1620 °C (2950 °F)
L_e = 900 (35.4 in.)	U_e = 30 V	
a = 60 (2.36 in.)	I = 278 A	
	R_t = 0.108 Ω	
	p = 14.6 W/cm^2 (94 W/in.^{2})	

Electrical equipment.

It is advised that the elements are delta connected to a three-phase transformer as shown in Fig. 59 c, page 97.
Secondary voltage of the transformer is $U_e \times n = 30 \times 6 = 180\ V$.
Maximum element current for 9/18 elements is 365 A (see page 79).
The maximum potential power of the furnace during operation is:

$$\frac{U_{tot} \times I_{max} \times 3}{1000} = \frac{180 \times 365 \times 3}{1000} \approx 197 kW$$

The power supply should be rated at no less than 197 kVA.
At supply voltage of 400 V the maximum line current is

$$\frac{P_{tot}}{U_{supply} \times \sqrt{3}} = \frac{197\ 000}{400 \times \sqrt{3}} \approx 284\ A$$

The nearest standard size of three-phase thyristor is 300 A 440 V.

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 Fig. 26, page 51). 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 KANTHAL SUPER´s rapid heat-up capability.

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

9

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. 57 a). 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 electronical equipment.

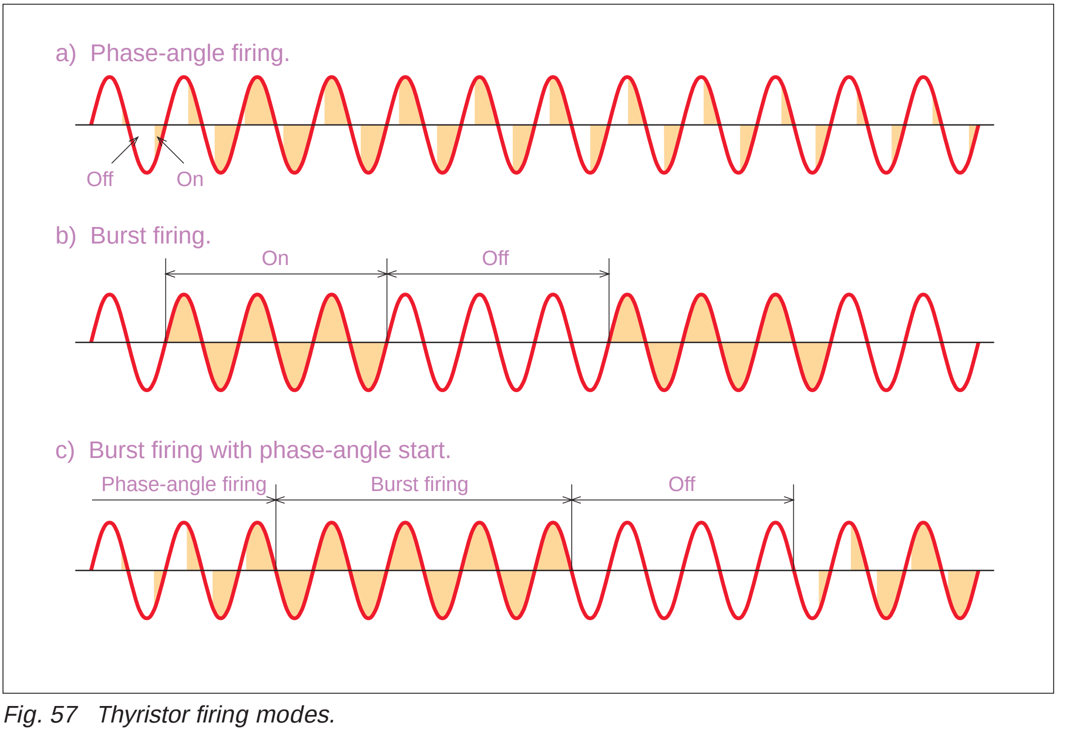


Fig. 57 Thyristor firing modes.

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. 57 b).

A burst fired thyristor switches on and off when the instantaneous current is zero and therefore creates less transients than non-synchronised 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. 57c). 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.

Figs. 58 and 59 on pages 96 - 97 show applications with thyristor control.

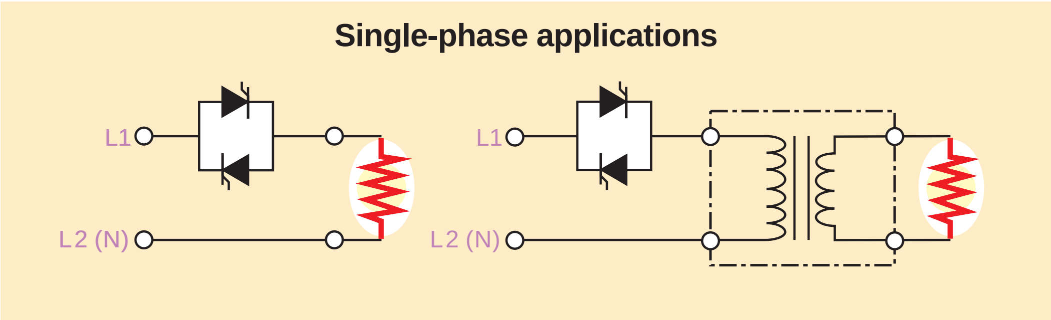


Fig. 58 Applications with thyristor (SCR) control.

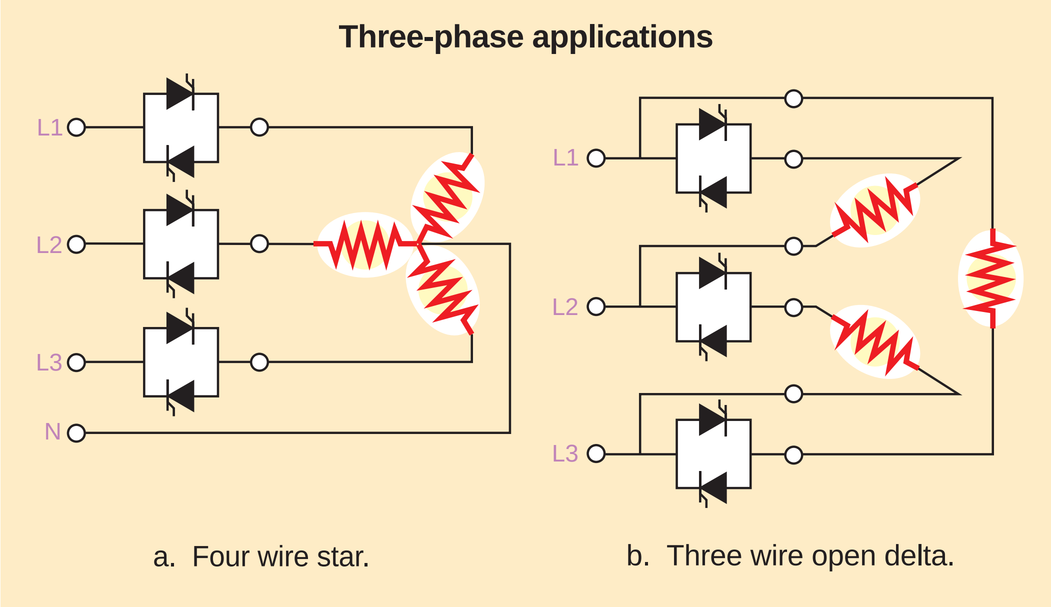
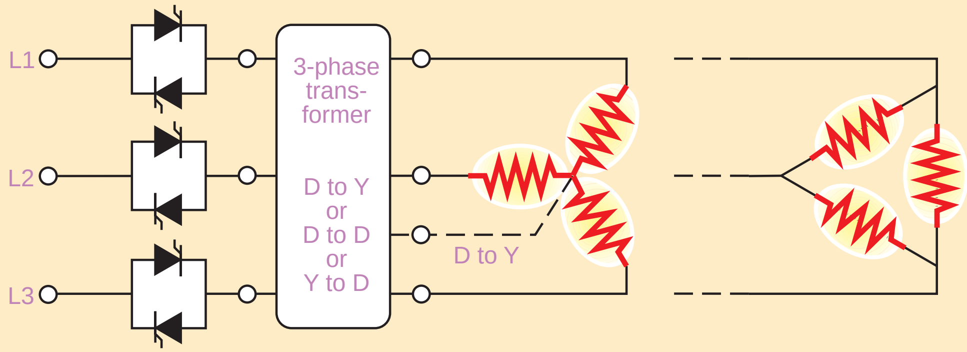
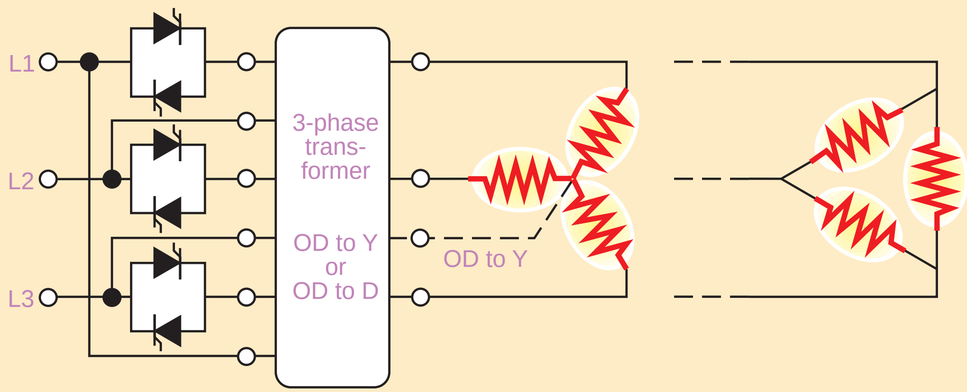


Fig. 59 Applications with thyristor (SCR) control.

Three-phase applications



c. Transformer and star or delta load.



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

Fig. 59 Applications with thyristor (SCR) control.

On/off Control

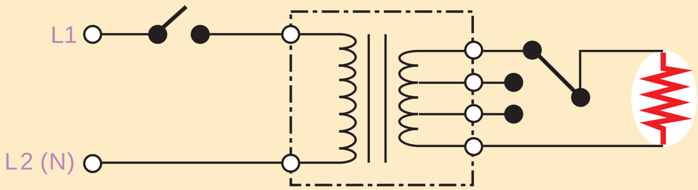
Tapped transformer

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-synchronised 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.

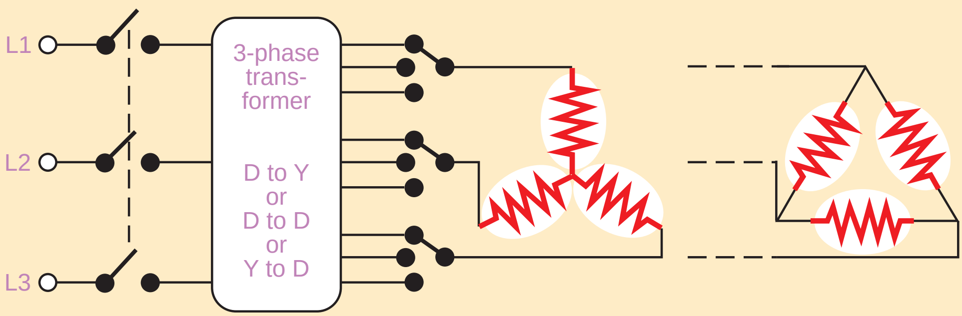
Fig. 60 on page 98 shows applications with on/off control and tapped transformer.

Single-phase application



a. Transformer.

Three-phase applications



b. Transformer and star or delta load.

Fig. 60 Applications with on/off control.

Contactor switch, changing the element connection

Fig. 61 on page 99 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. 62 on page 100 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.

9

Step 1

All elements series connected between phase and neutral

Step 2

All elements series connected to line voltage

Step 3

Elements star-connected

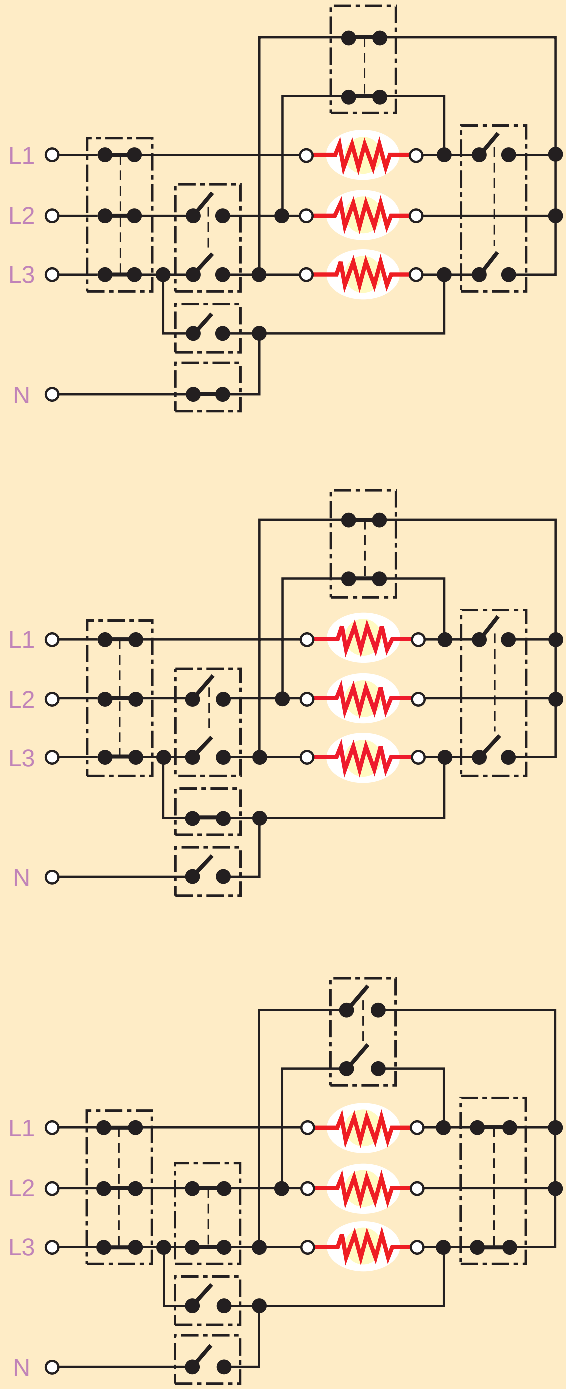
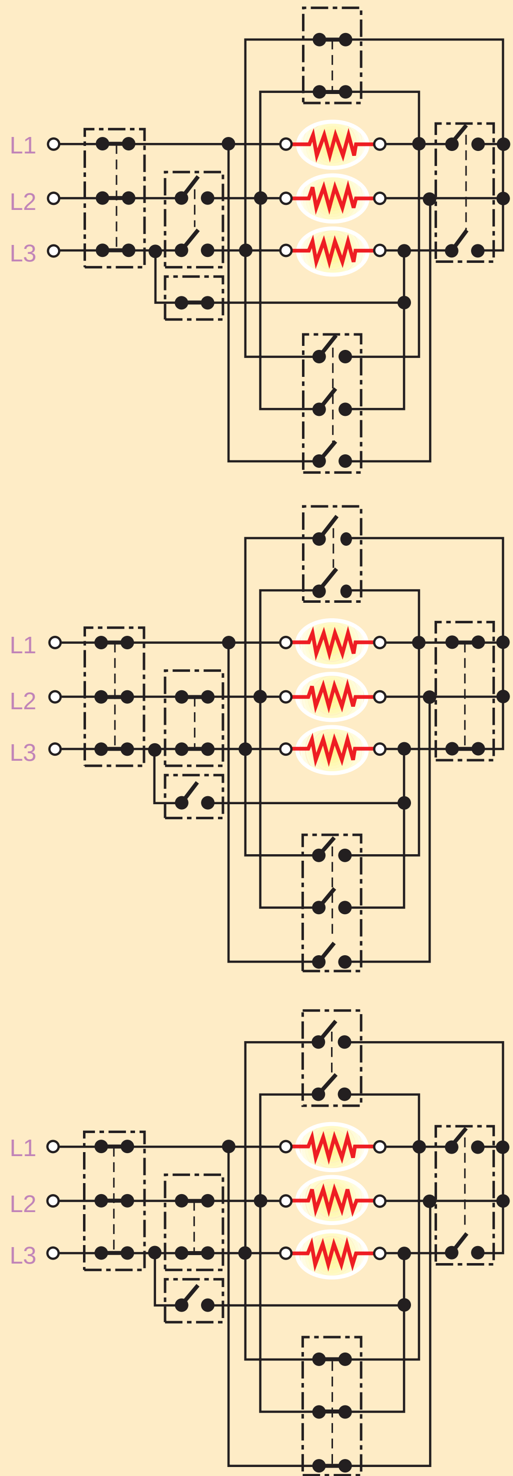


Fig. 61 Wiring diagram for KANTHAL SUPER elements directly star-connected to line voltage.



Step 1

All elements series connected to line voltage

Step 2

Elements star-connected

Step 3

Elements delta-connected

Fig. 62 Wiring diagram for KANTHAL SUPER elements directly delta-connected to line voltage.

9

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.

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

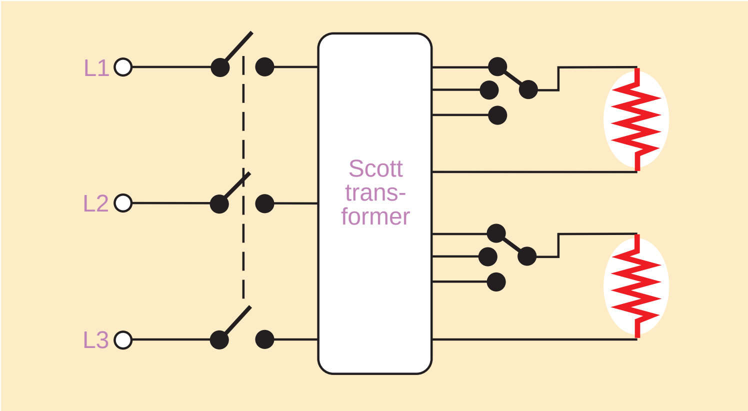
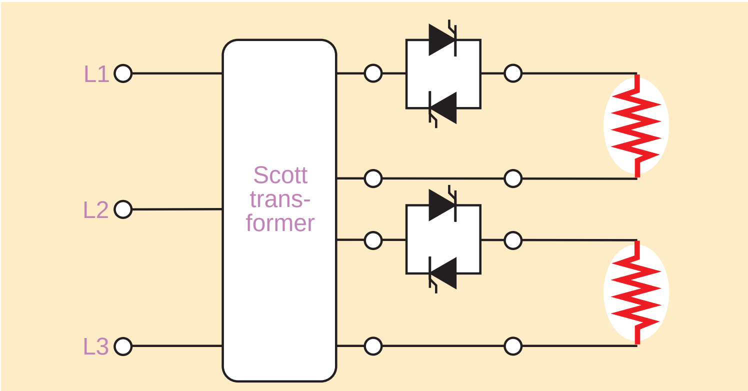


Fig. 63 Application with on/off control and tapped transformer.



NOTE: Scott-connections with thyristor control require particular attention for successful operation. Consult KANTHAL for advice.

Fig. 64 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 continous 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 are 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 2-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 in Fig. 49, page 84 shows how to calculate the distances necessary to counteract the effect of electromagnetic 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 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. 65.

In Fig. 66 “Correct” page 117, 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.

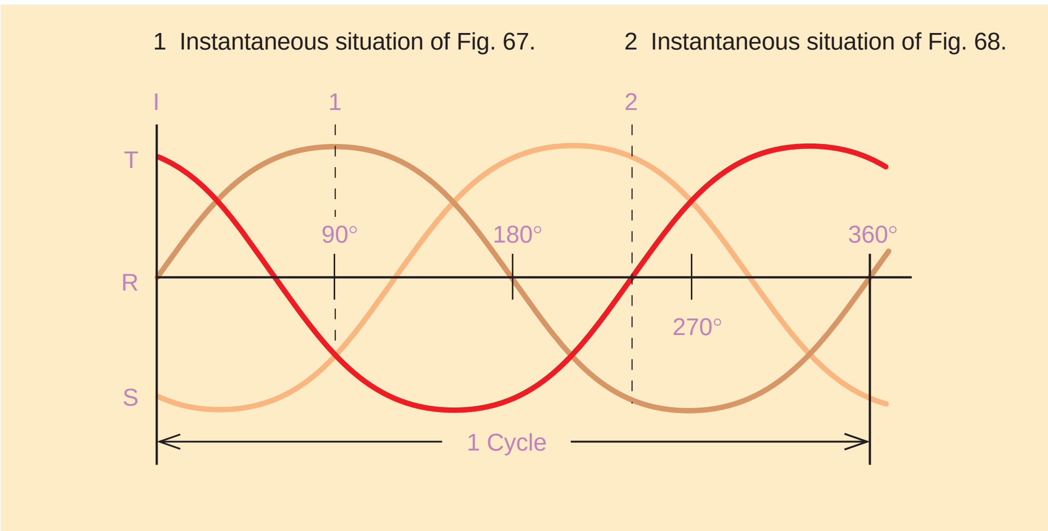


Fig. 65 Sine curve variations in a three-phase system.

Correct	Incorrect

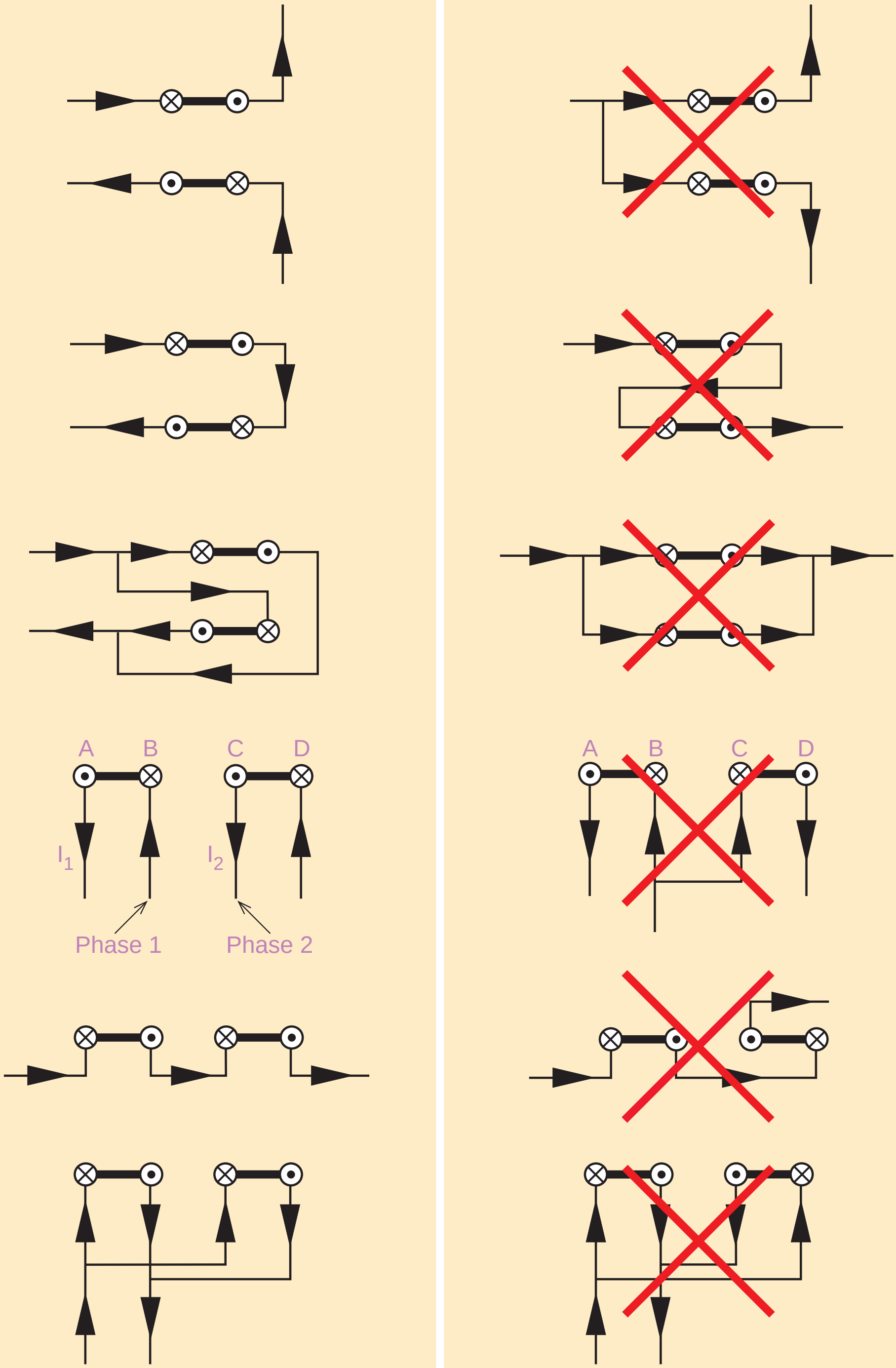
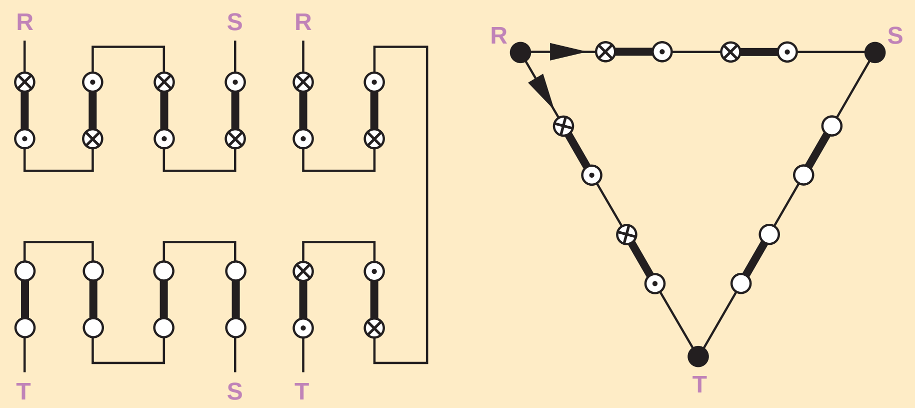


Fig. 66 Examples of correct and incorrect connections.

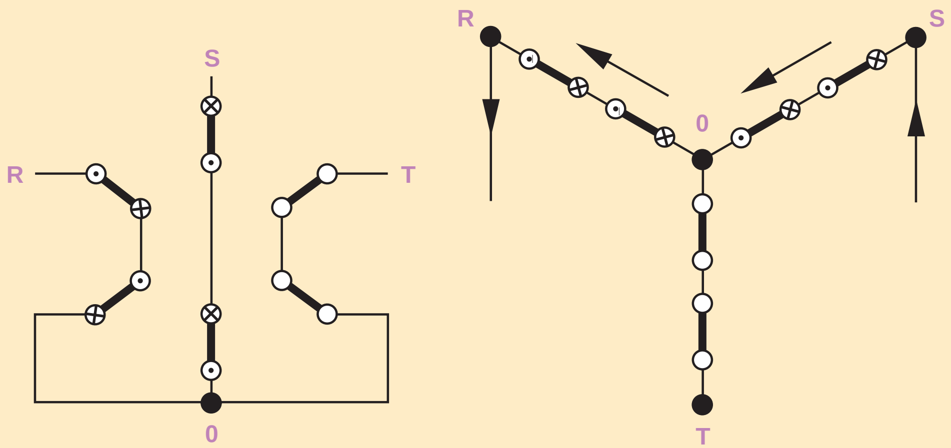


Consider that the current enters in R and flows to S and T.

Momentarily no current is passing through the leg ST. See Fig. 65 page 116.

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

Fig. 67 Delta-connected arrangement.



Consider that the current enters in S and flows through 0 to R.See Fig. 65, page 116.

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

Fig. 68 Star-connected arrangement.

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. 67 and 68, page 105 as follows:

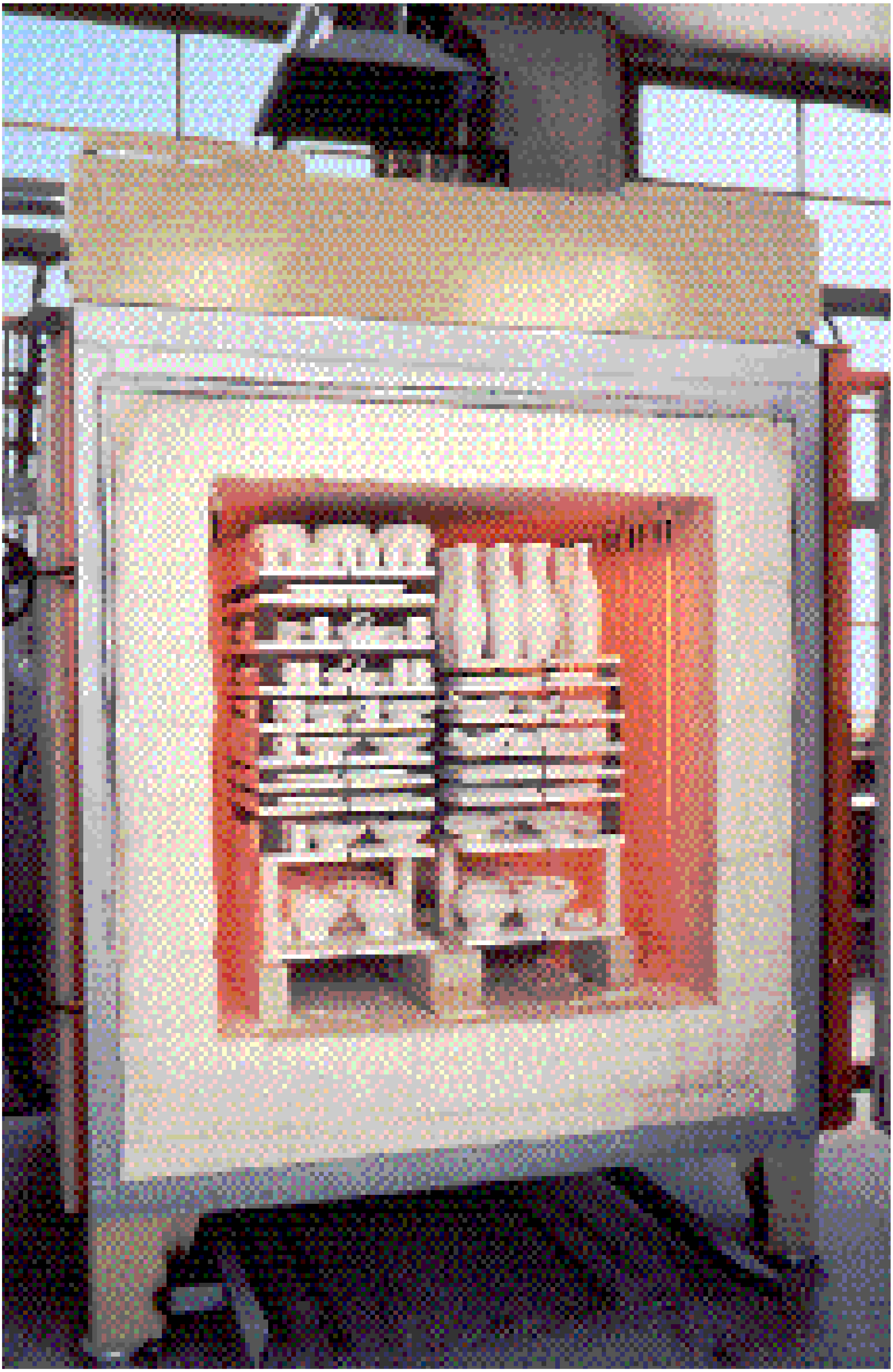
1. **The current in two phases flow in opposite directions**
   During part of the cycle the currents will flow in the same direction. The maximum attracting effect is obtained when the currents have half the value of the momentary maximum current. The average action, however, is repelling.

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.

Fig. 69   Multi purpose controlled atmosphere kiln.



10

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 preadjusted 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 neccesary 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 fibre 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 above1750 °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.

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

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.

Fig. 70 KANTHAL SUPER furnace for ingot heating.

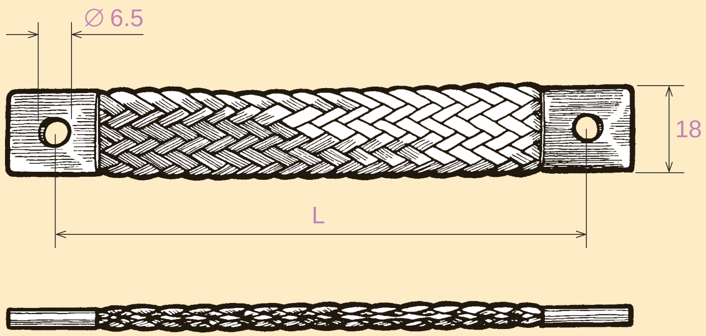
Accessories

11

Element size 3/6 mm and 4/9 mm

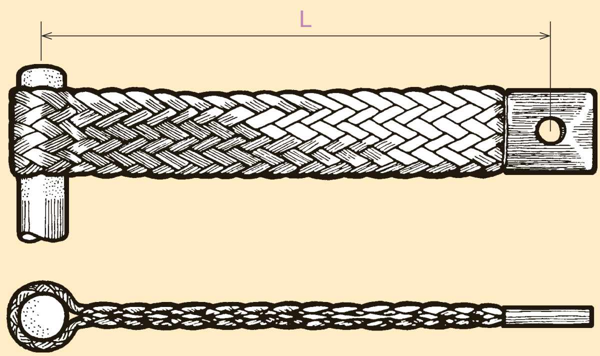
(All dimensions in mm)

Contact straps



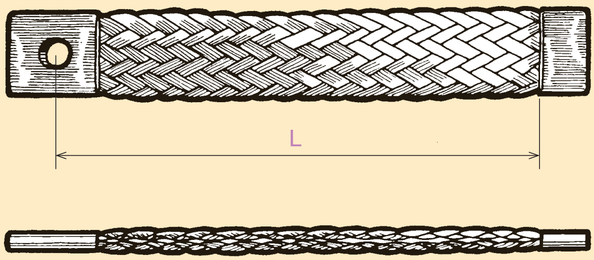
Type 5826

Lengths (L):
100, 150, 200



Type 5827

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



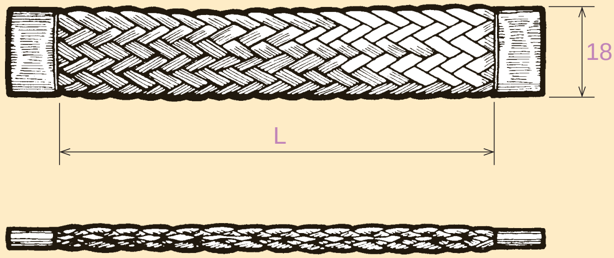
Type 5828

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

11

Type 5829

Lengths (L):
75, 100, 150, 200
Spring clips to be
used at both ends.



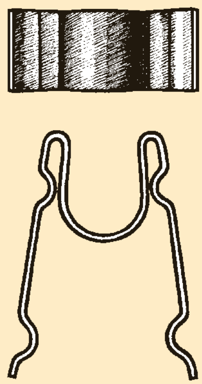
Type 10434

for element
size 3/6 mm

Type 10435

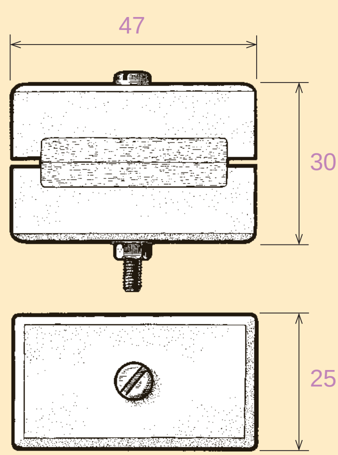
for element
size 4/9 mm

Spring clips



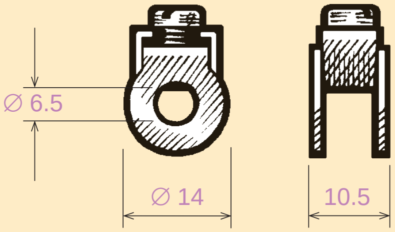
Type 5830

Element holder



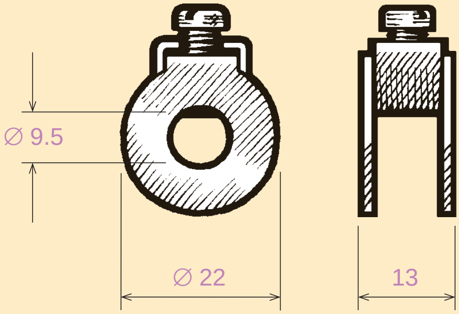
11

Single-shank holders



Type 10421

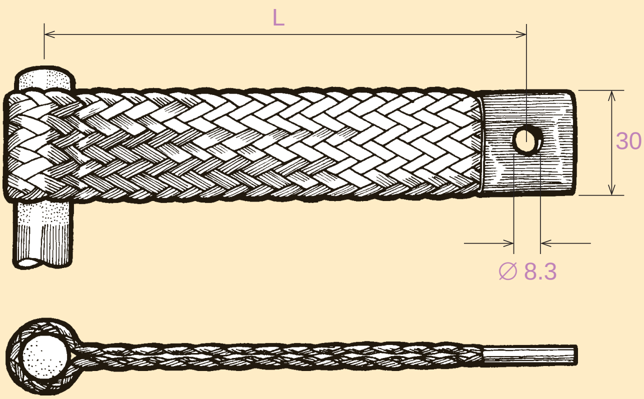
for element
size 3/6 mm



Type 10424

for element
size 4/9 mm

Element size 6/12 mm
Contact straps

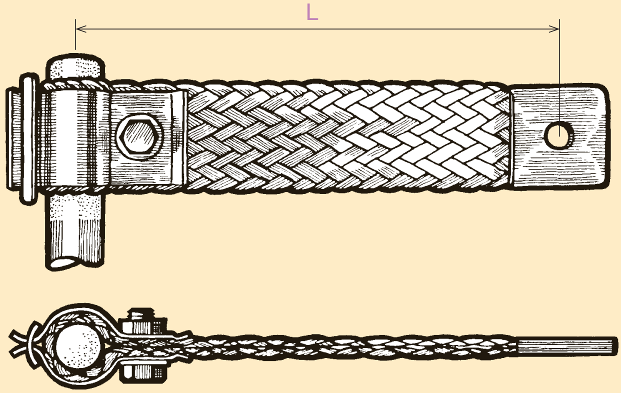


Type 5766

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

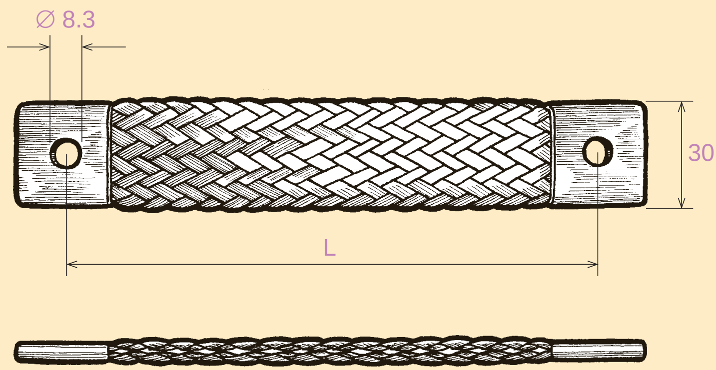
Type 3579

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



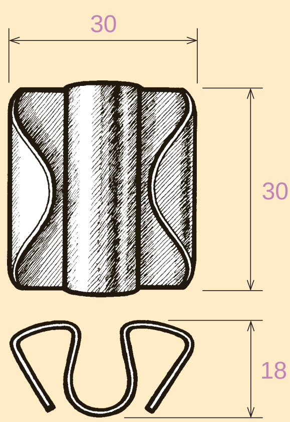
Type 5768

Lengths (L): 150
200, 250, 300
Note: two pcs per
shank for 9/18



Type 5758

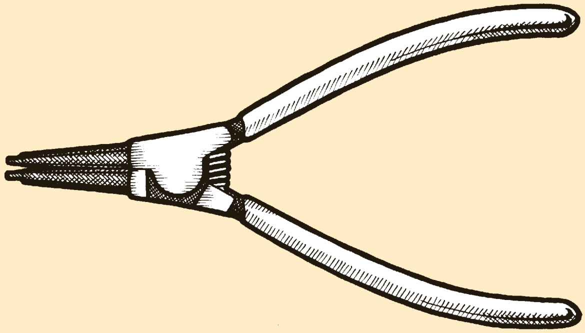
Contact clamp



11

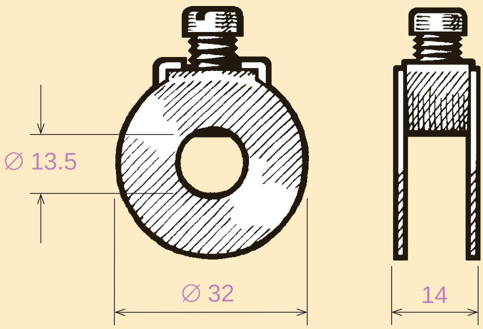
Expansion tool for clamps

Type 21690

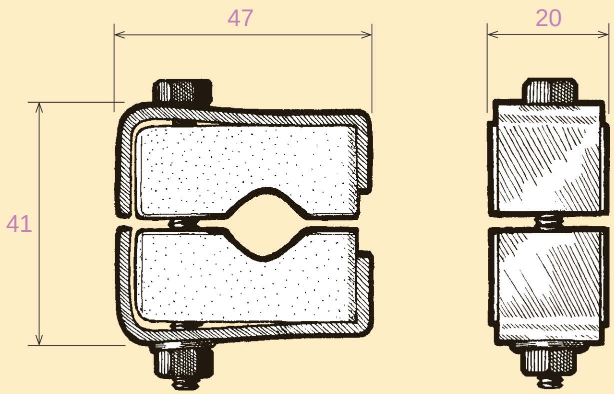


Single-shank holders

Type 6248



Type 5778

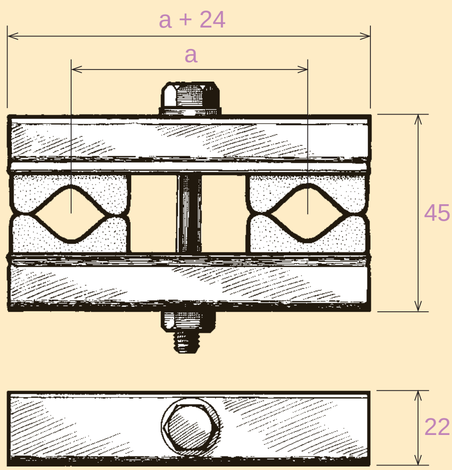


11

Type 5776

a = 40, 45, 50, 55, 60

Two-shank holder

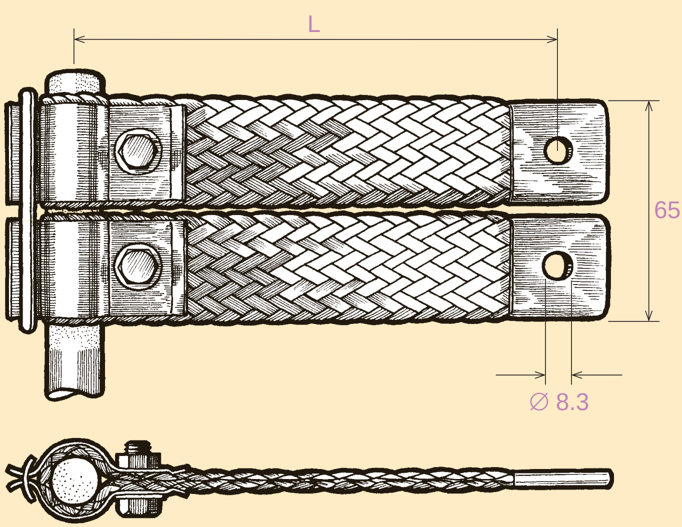


Element size 9/18 mm

Contact straps

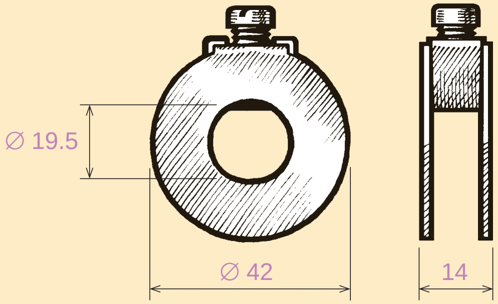
Type 3801

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

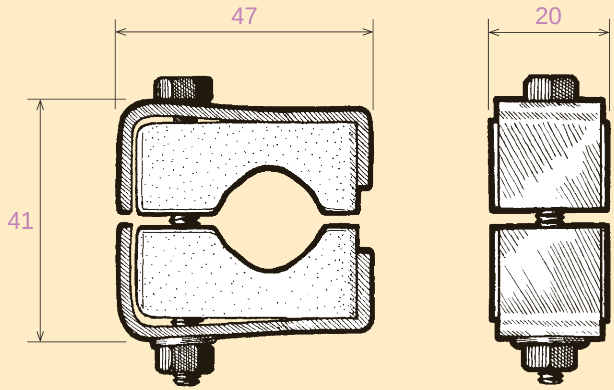


Single-shank holders

Type 6249



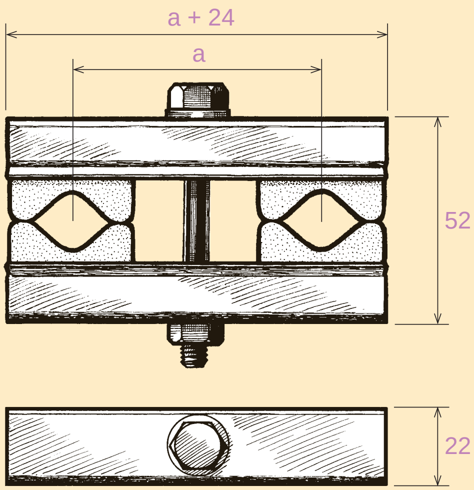
Type 5779



Two-shank holders

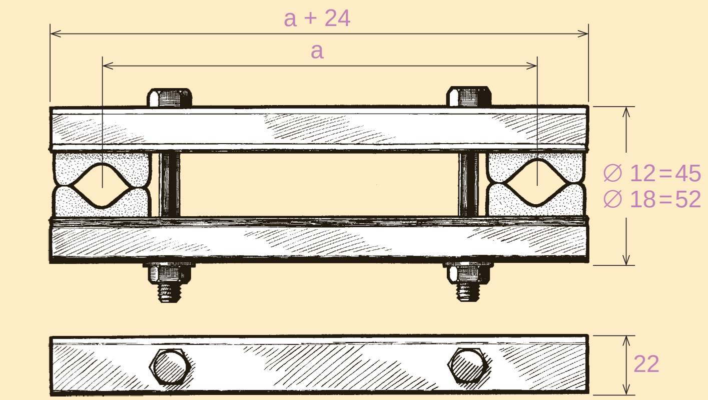
Type 5776

a = 40, 45, 50, 55, 60



Type 5777

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

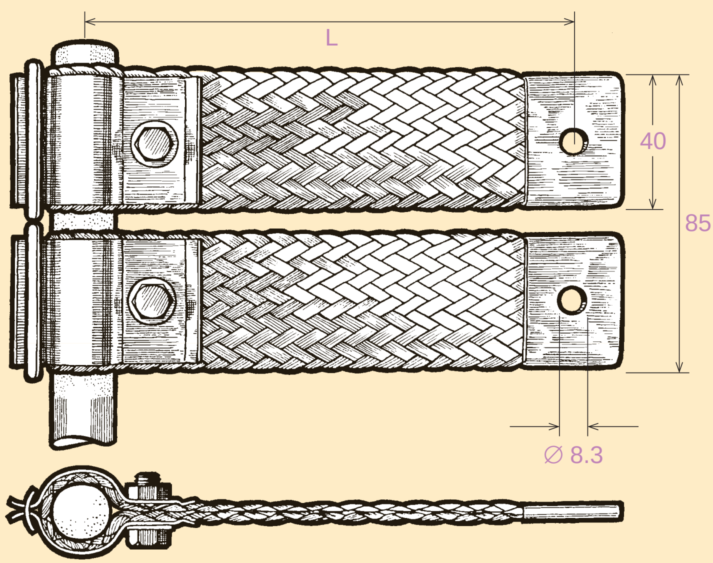


Element size 12/24mm

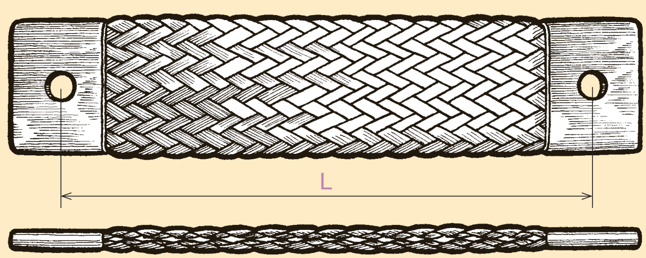
Contact straps

Type 10432

Lengths (L):
150, 200, 250, 300
Note: Two per
shank



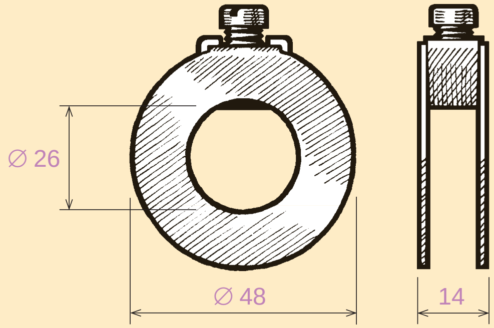
Type 10439



11

Single-shank holder

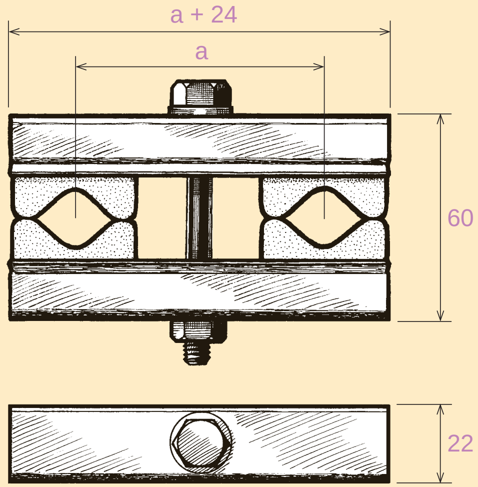
Type 10433



Two-shank holders

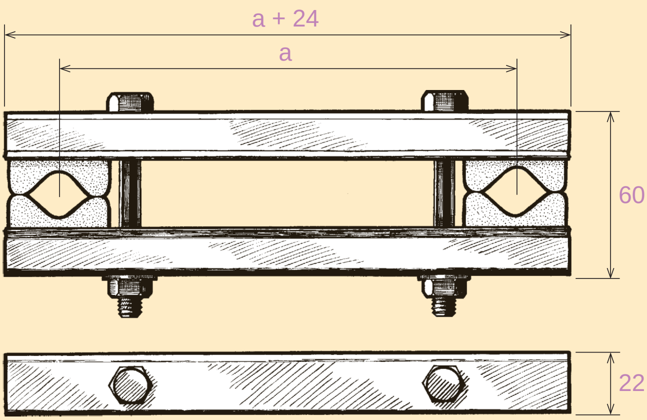
Type 10437

a = 60



Type 10438

a = 80



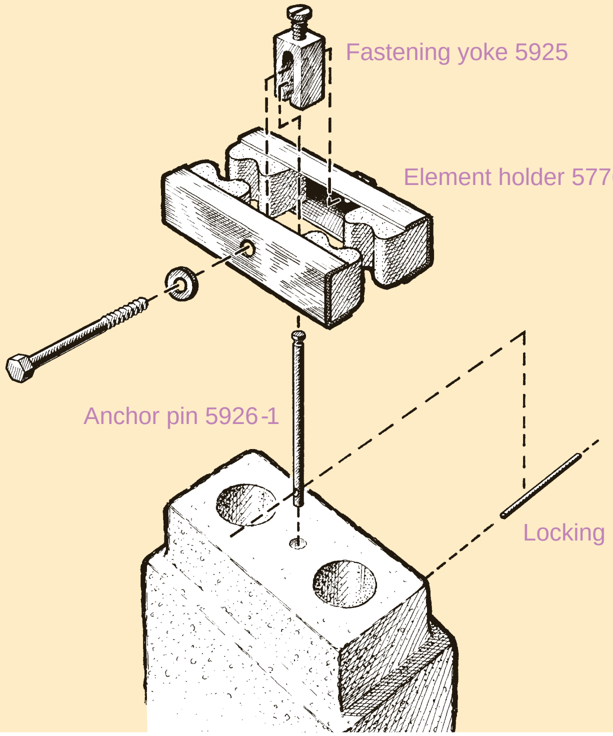
11

Anchor systems

Standard anchor system

Type 5987

Element holder
Standard design



Air cooled anchor system

Type 5927

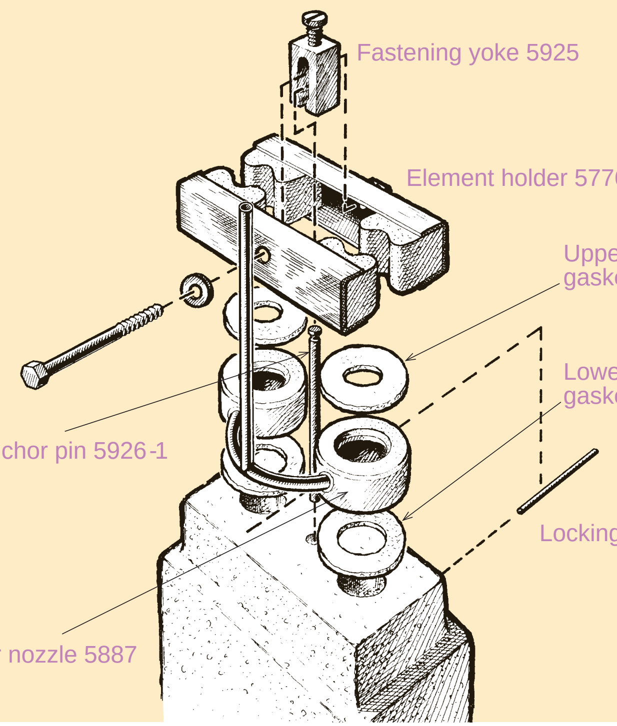
Element holder
with air nozzle for
KANTHAL SUPER
9/18 mm a = 60

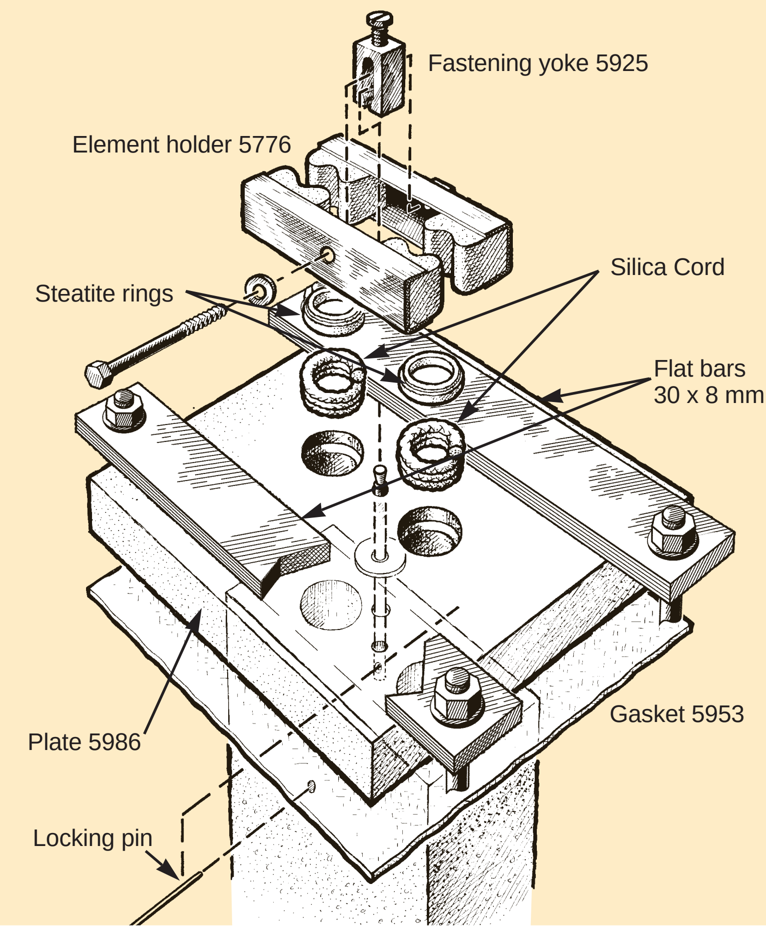
Type 6031

Element holder for
KANTHAL SUPER
6/12 mm a = 50

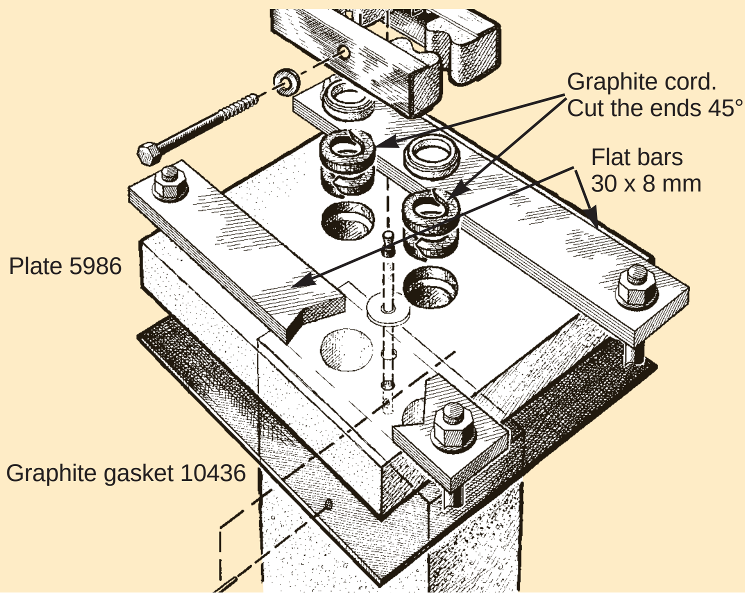
Type 6033

Element holder for
KANTHAL SUPER
6/12 mm a = 40





Graphite alternative



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

11

For anchor systems. Sealed design.

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.

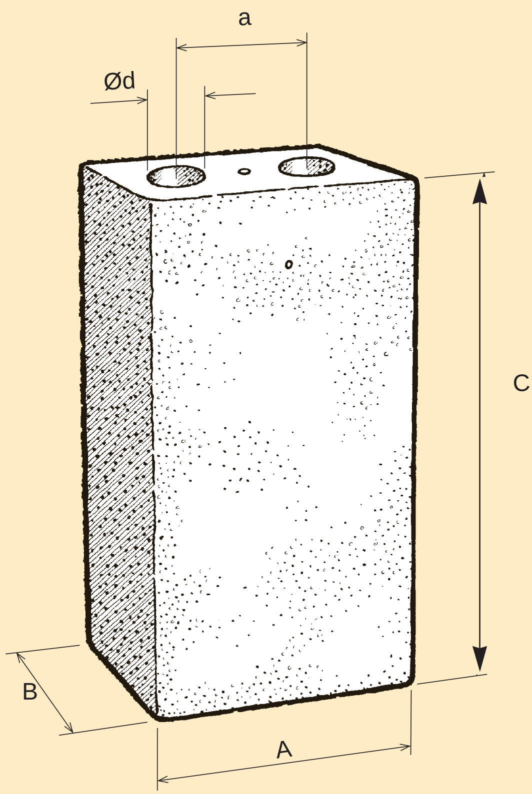
Type No.	Grade	A	B	C	a	d	Element size
6038-1	28	115	64	229	50	15	6/12
5984-1 5984-2 5984-3		115 115 152	64 76 76	229 229 305	60 60 60	23 23 23	9/18

Type 6038

for 6/12 mm

Type 5984

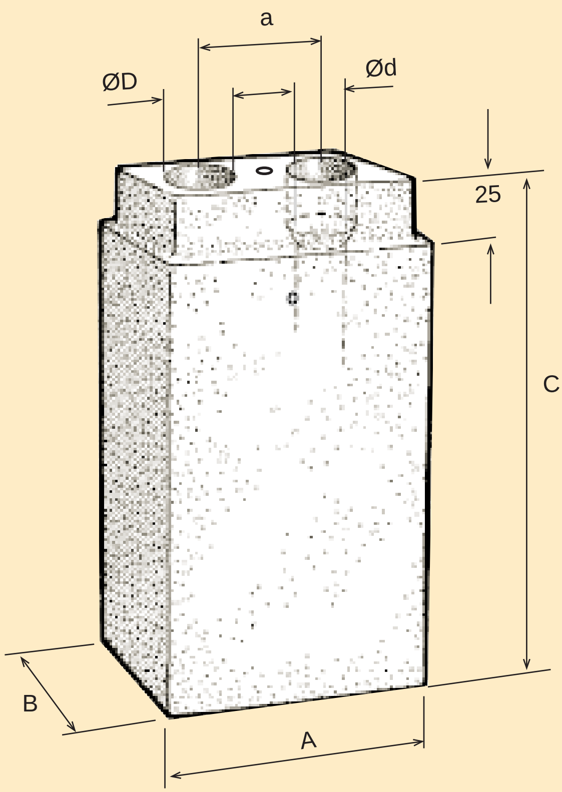
for 9/18 mm



11

For anchor systems. Standard design.

Type No.	Grade	A	B	C	a	d	D	Element size
6036-1,-3,-6 6036-9,-4,-8 6036-2,-5,-7	G28,30,33	115 115 115	64 64 64	229 229 229	40 45 50	15 15 15	25 25 25	6/12
5985-1,-4,-8 5985-2,-5,-10 5985-3,-6,-11	G28,30,33	115 115 152	64 76 76	229 229 305	60 60 60	23 23 23	35 35 35	9/18
10943-1,-4,-7 10943-2,-5,-8 10943-3,-6,-9	G28,30,33	115 115 152	64 76 76	229 229 305	60 60 80	30 30 30	40 40 40	12/24



Type 6036
for 6/12 mm

Type 5985
for 9/18 mm

Type 10943
for 12/24

11

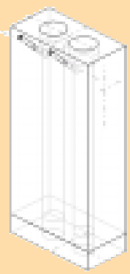
For anchor systems. Air cooled design.

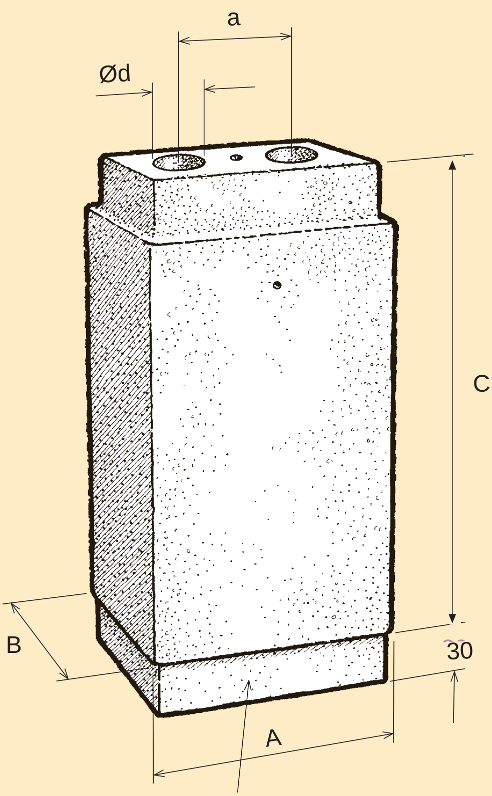
Type No.	Grade	A	B	C	a	d	D	Element size
6035-1,-3,-6 6035- ,-4,-7 6035-2,-5,-8	G28,30,33	115 115 115	64 64 64	229 229 229	40 45 50	15 15 15	25 25 25	6/12
5930-1,-4,-7 5930-2,-5,-8 5930-3,-6,-9	G28,30,33	115 115 152	64 76 76	229 229 305	60 60 60	23 23 23	35 35 35	9/18

Type 6035
for 6/12 mm

Type 5930
for 9/18 mm

for 12/24 mm



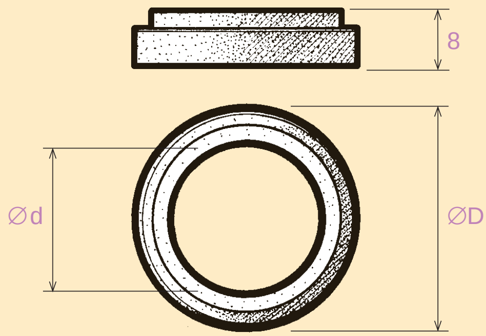


Bottom plate: ALFRAX coated grade 33

Other Accessories

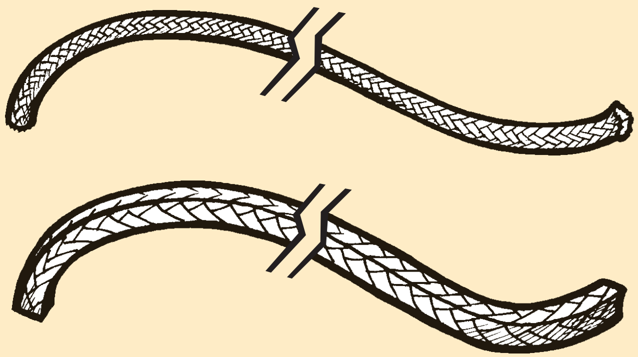
Steatite rings

Element size	6/12	9/18
D d	20 13	27 19



Silica cord and graphite cord

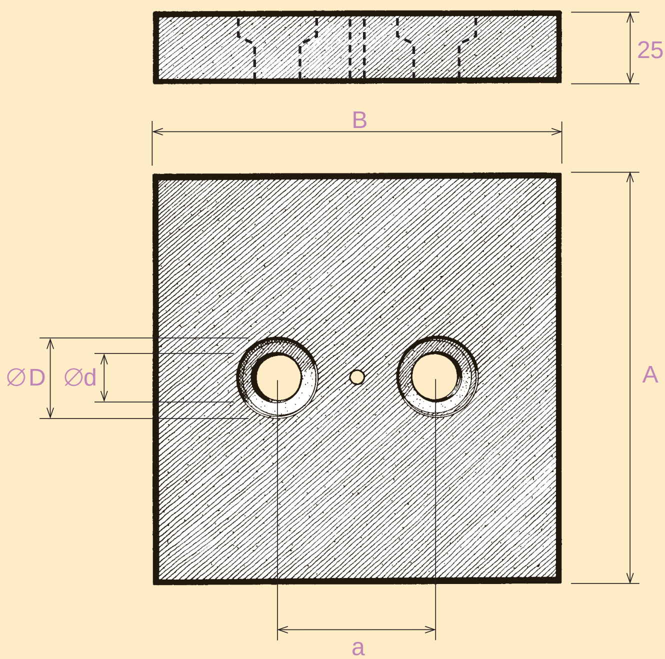
Element size	6/12	9/18
Length of silica cord	2 x 180	2 x 230
Length of graphite cord	4 x 60	4 x 80



11

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

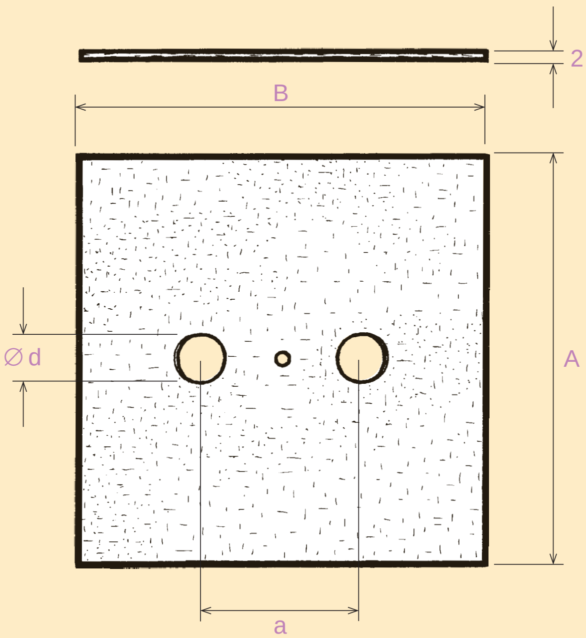


11

Gasket for plates

Graphite	Ceramic fibre	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

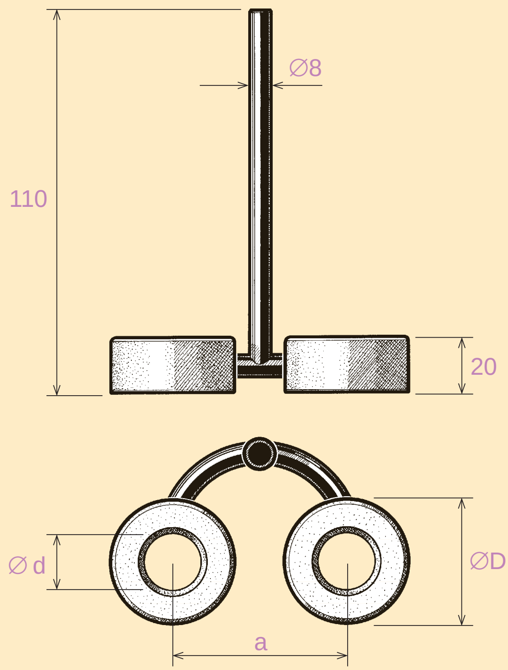
10436-1-5 d = 30 mm
10436-10 d = 24 mm



11

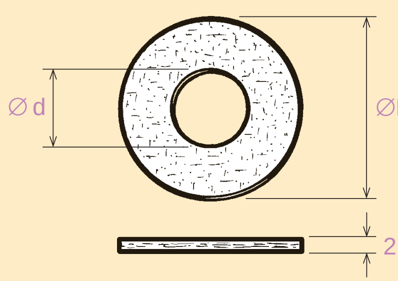
Air nozzles

Type	Element size	a	D	d
5887-A 5887-B 5887-C	6/12 6/12 9/18	40 50 60	36 36 42	13.5 13.5 19.5



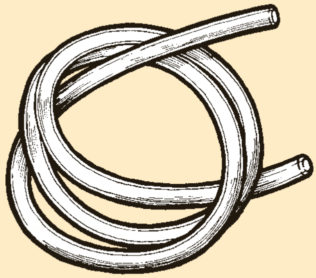
Gaskets for air nozzles

Element size	6/12 d	6/12 D	9/18 d	9/18 D
Upper gasket Lower gasket	11 16	32 36	17 22	38 42

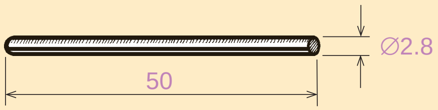


Silicon rubber hose

For connection to air nozzles



Locking pin

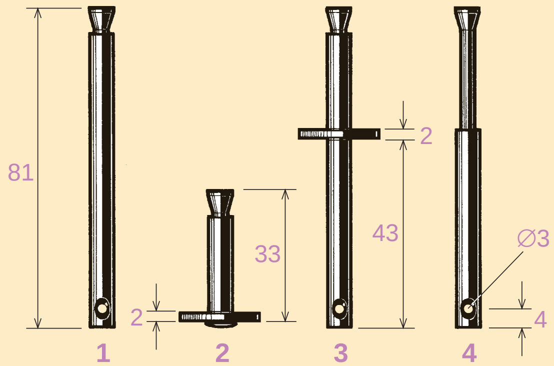


Anchor pins

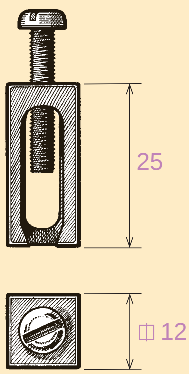
1) Without locking pin.

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

Type	Anchor system
5926-1	Standard and air cooled
5926-2	Sealed 1)
5926-3	Sealed
5926-4	Air cooled 2)



Fastening yoke Type 5925



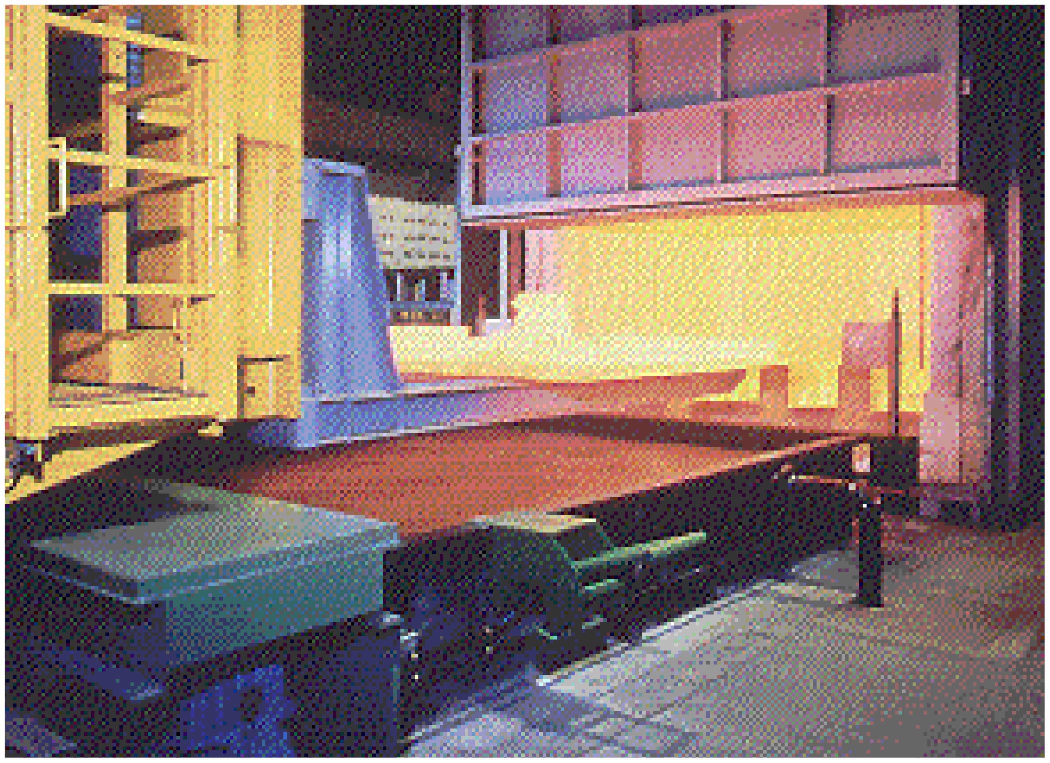
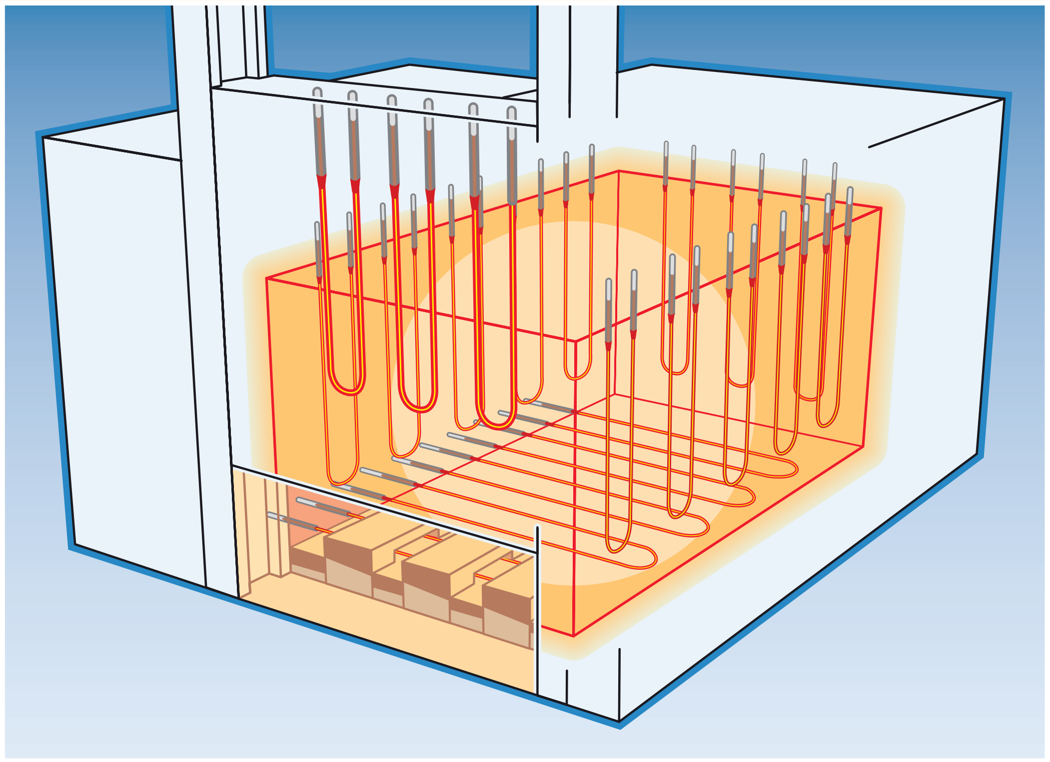


Fig. 71 Automatic hardening line heated with KANTHAL SUPER elements located in the floor, in the door and along the three walls.



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 electro-magnetic 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 chapter 2.

Overheated elements

- When the element temperature exceeds the limit for each of the three qualities, the silica in the material starts to boil. The $MoSi_2$ 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 fibre 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.

12

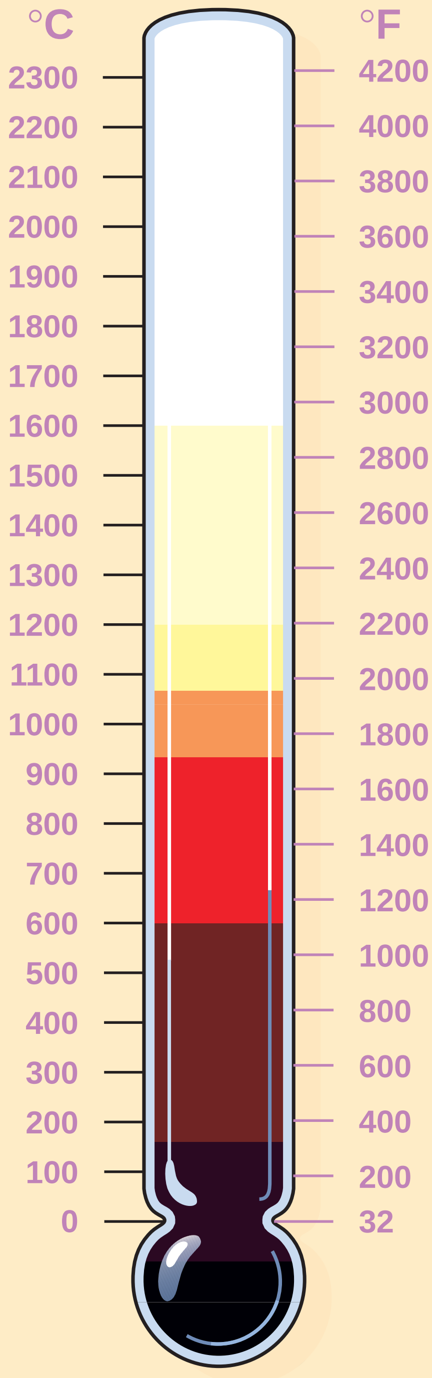


Fig. 72 Element temperature.

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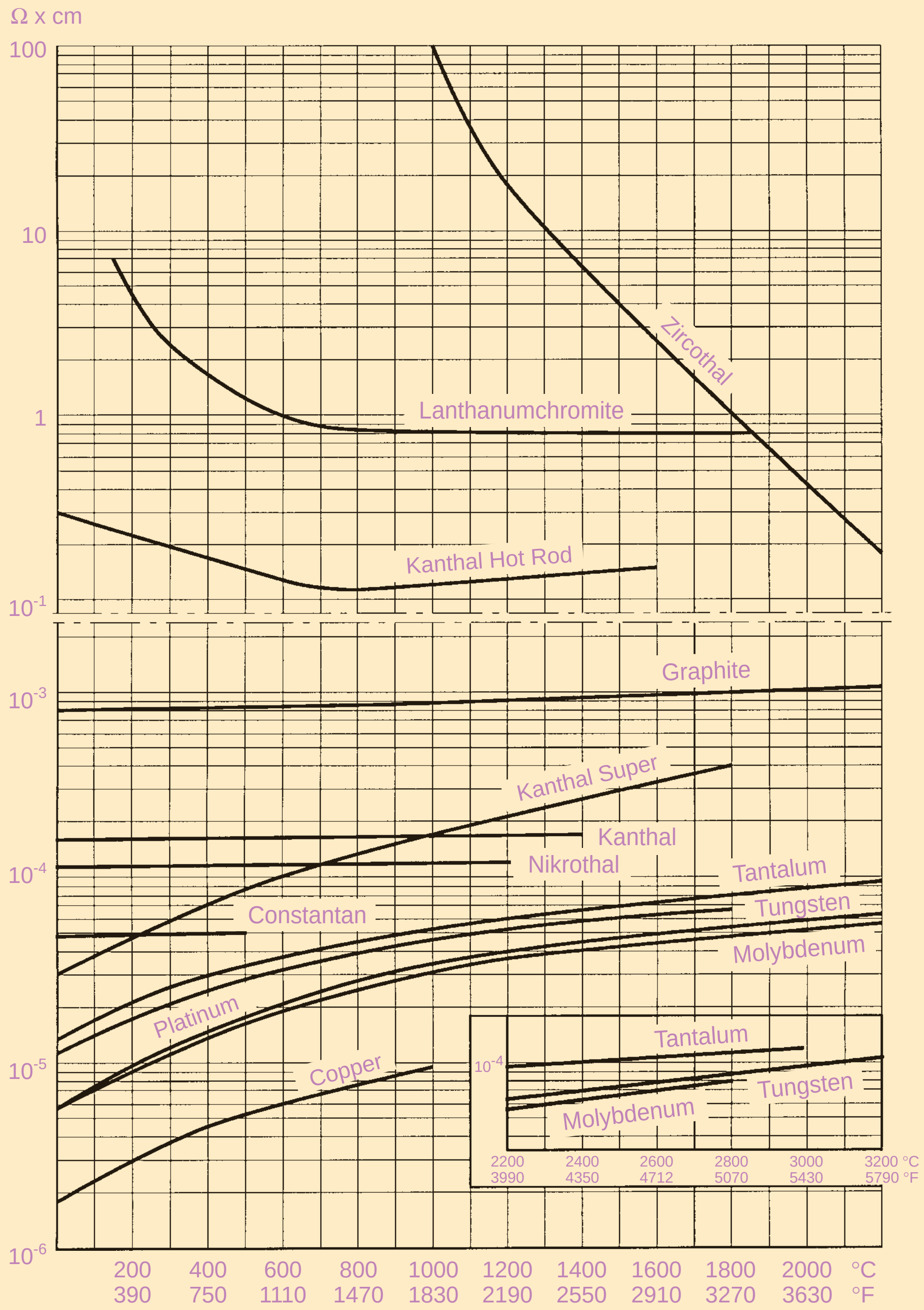

Fig. 73 Resistivity (Ω x cm) as a function of temperature for some resistor materials and for copper.

Gases	Chemical formula	Molecular weight	Liquid state			Gaseous state		
			Density at 20 °C kg/l	Boiling point (1013 bar) °C	Heat of evaporation kJ/kg	Density (15°C, 1 bar) kg/m^3	Specific heat cp kJ/kg x°C	Thermal conductivity µW/cm · °C
Ammonium	NH_3	17.03	0.591	–34.4	1370.8	0.72	2.12 (25°C)	215 (0°C)
Argon	Ar	39.95	—	–185.9	163.8	1.67	0.52 (15°C)	162 (0°C)
n-Butane	C_4H_{10}	58.12	0.579	–0.5	384.8	2.51	1.68 (15°C)	135 (0°C)
Helium	He	4.00	—	–268.9	20.3	0.17	5.19 (15°C	1484 (0°C)
Hydrogen	H_2	2.02	—	–252.8	446.0	0.084	14.26 (15°C)	1682 (0°C)
Carbon dioxide	CO_2	44.01	0.775	–78.4	348.3	1.85	0.85 (15°C)	162 (25°C)
Carbon monoxide	CO	28.01	—	–191.5	215.7	1.17	1.04 (15°C)	248 {25°C)
Air		28.96	—	—	—	1.21	1.01	255
Methane	CH_4	16.04	—	–161.5	510.0	0.671	219 (15°C)	305 (0°C)
Methanol	CH_3OH	32.04	0.739	65	1109	1.34	1.34 (0°C)	140 {0°C)
Nitrogen	N_2	28.01	—	–195.8	198.9	1.17	1.04 (15°C)	241 (0°C)
Propane	C_3H_8	44.10	0.501	–42.1	425.6	1.88	1.65 (15°C)	146 {0°C)
Propene	C_3H_6	42.08	0.505	–47.7	438.0	1.78	1.50 (15°C)	199 {25°C)

Table 8 Physical data — Gases.

Dew point °C	Percentage by volume	g/Nm^3	Dew point °C	Percentage by volume	g/Nm^3	Dew point °C	Percentage by volume	g/Nm^3
–100	0.00000139	0.0000111	–20	0.102	0.816	+1	0.649	5.21
–90	0.00000955	0.0000767	–19	0.112	0.899	+2	0.696	5.59
–80	0.0000540	0.000343	–18	0.123	0.989	+3	0.750	6.02
–70	0.000258	0.00207	–17	0.135	1.09	+4	0.803	6.45
–60	0.00107	0.00857	–16	0.148	1.19	+5	0.861	6.91
–55	0.00207	0.0166	-15	0.163	1.31	+6	0.922	7.41
–50	0.00388	0.0312	–14	0.179	1.43	+7	0.922	7.41
–48	0.00496	0.0399	–13	0.196	1.57	+8	1.06	8.51
–46	0.00631	0.0507	–12	0.214	1.72	+9	1.13	9.10
–44	0.00800	0.0642	–11	0.234	1.88	+10	1.21	9.74
–42	0.0102	0.0816	–10	0.256	2.06	+11	1.29	10.4
–40	0.0127	0.102	–9	0.280	2.25	+12	1.38	11.1
–38	0.0159	0.127	–8	0.305	2.45	+13	1.48	11.9
–36	0.0198	0.159	–7	0.333	2.68	+14	1.58	11.9
–34	0.0246	0.197	–6	0.363	2.92	+15	1.68	13.5
–32	0.0304	0.244	–5	0.396	3.18	+16	1.79	14.4
–30	0.0375	0.301	–4	0.431	3.456	+17	1.91	15.4
–28	0.0461	0.371	–3	0.469	3.77	+18	2.0	16.4
–26	0.0565	0.454	–2	0.510	4.10	+19	2.17	17.4
–24	0.0690	0.554	–1	0.555	4.46	+20	2.31	18.5
–22	0.0840	0.675	0	0.602	4.84			

Table 9 Content of water — Gases.

Fig.74 Average theoretical heat storage in kWh per metric tonne for some common metals.

Element	Symbol	Molecular weight	Specific gravity g/cm^3	Melting point °C	Boiling point 760 Torr °C	Heat of fusion		Specific heat capacity at 20 °C		Thermal conductivity at 20 °C			Coefficient of linear expansion $10^6 \cdot 1/°C$	Specific electrical resistance $R_a \cdot 10^2$ at 20 °C $\Omega\ mm^2\ m$
						kcal/kg	kWh/$kg \cdot 10^3$	cal/$g \cdot °C$	Wh/$g \cdot °C \cdot 10^3$	cal/$cm \cdot s \cdot °C$	kcal/$m \cdot h \cdot °C$	W/$cm \cdot °C$		
Aluminium	Al	26.97	2.70	660.1	2500	85	98.82	0.214	0.2488	0.55	198.0	2.3117	23.1	2.86
Antimony	Sb	121.75	6.69	630.5	1635	38.9	45.23	0.0496	0.0577	0.55	198.00	2.3117	10.8	38.6
Bismuth	Bi	208.90	9.8	271.3	1560	14.1	16.393	0.0295	0.0343	0.02	7.2	0.0837	12.1	125
Cadmium	Cd	112.4	8.64	320.9	765	12.9	14.997	0.0552	0.0642	0.23	82.8	0.9625	31	7.7
Caesium	Cs	132.9	1.87	28.5	690	—	—	—	—	—	—	—	97	19
Calcium	Ca	40.08	1.54	850.0	1439	78	90.683	0.155	0.1802	—	—	—	22	4.3
Chromium	Cr	52.0	7.1	1920	2327	70	81.382	0.105	0.1221	0.165	59.4	0.8605	8.5	15
Cobalt	Co	58.93	8.8	1492	3185	64	74.406	0.093	0.1080	0.17	61.2	0.7115	11	5.06
Copper	Cu	63.54	8.93	1083	2595	51	59.293	0.093	0.1080	0.94	338.4	3.9339	16.5	1.75
Gallium	Ga	69.72	5.9	29.78	2064	19.1	22.206	0.080	0.093	—	—	—	18	39.5
Germanium*	Ge	72.59	5.32	958.5	2700	—	—	0.0727	0.0845	—	—	—	6	$8.9 \cdot 10^4$
Gold	Au	196.97	19.29	1063	2960	15.9	18.485	0.0307	0.0357	0.75	270	3.1387	14.2	2.2
Hafnium	Hf	178.49	13.3	2230	>3200	—	—	0.033	0.0384	—	—	—	—	30
Indium	In	114.82	7.25	156.7	>1450	—	—	0.056	0.0651	—	—	—	5.6	8.2
Iridium	Ir	192.2	22.4	2442	4800	28	32.553	0.032	0.0372	0.14	50.4	0.5859	6.58	4.58
Iron	Fe	55.85	7.876	1535	2730	49.4	57.432	0.108	0.1256	0.21	75.6	0.8788	11.5	8.7
Lead	Pb	207.19	11.34	327.4	1750	5.7	6.63	0.0309	0.0359	0.084	30.24	0.3515	31.3	20.7
Lanthanum	La	138.91	6.15	885	1800	—	—	0.044	0.0512	—	—	—	—	—
Lithium	Li	6.94	0.534	186	1370	32.8	38.123	1.0	1.1626	0.16	57.6	0.6696	58	8.55
Magnesium	Mg	24.31	1.74	650	1107	46.5	54.061	0.243	0.2825	0.41	147.6	1.7158	26	4.18
Manganese	Mn	54.94	7.3	1247	2095	63.7	74.06	0.114	0.1325	0.12	43.2	0.5022	23	10.0
Mercury	Hg	200.59	13.65	–38.87	356.58	2.7	3.149	0.0333	0.0387	0.02	7.2	0.0837	—	94.07
Molybdenum	Mo	95.94	10.2	2610	4800	69.4	80.69	0.065	0.0756	0.34	122.4	1.4229	5.1	5.4
Nickel	Ni	58.71	8.9	1453	3177	73	84.870	0.1065	0.1238	0.21	75.6	0.8788	12.5	9.5
Niobium	Nb	92.06	8.57	1950	2900	—	—	0.0645	0.0750	—	—	—	7.1	13.0
Osmium	Os	190.20	22.5	2700	>5300	35	40.691	0.0310	0.0350	—	—	—	7.0	9.66
Palladium	Pd	106.4	11.97	1552	2800	36.3	42.202	0.058	0.0674	0.17	61.2	0.7115	10.6	10.88
Potassium	K	39.10	0.862	63.5	776	15.7	18.253	0.177	0.2058	0.23	82.8	0.9625	84	6.38
Platinum	Pt	195.1	21.45	1769	4300	27.2	31.623	0.032	0.0372	0.17	61.2	0.7115	8.94	9.8
Radium	Ra	226.05	5.0	700	1140	—	—	—	—	—	—	—	—	—
Rhodium	Rh	102.9	12.4	1960	>2500	52	60.452	0.0592	0.0688	0.21	75.6	0.877	9.0	4.3
Selenium*	Se	78.96	4.8	170	688	15.4	17.904	0.079	0.0918	—	—	—	37	12
Silver	Ag	107.87	10.5	960.5	1950	25	29.065	0.0559	0.0650	0.974	350.6	4.0762	18.7	1.5
Silicon*	Si	28.09	2.33	1440	2630	33.8	39.296	0.168	0.1953	—	—	—	7	10^5
Sodium	Na	22.997	0.971	97.8	883	27.5	31.972	0.288	0.3348	0.33	118.8	1.3811	71	4.34
Tantalum	Ta	180.95	16.6	3000	4100	41.5	48.248	0.033	0.0384	0.13	46.8	0.5441	6.58	12.4
Tellurium	Te	127.61	6.24	452	1390	—	—	0.048	0.0558	—	—	—	17.2	$6 \cdot 10^4$
Thorium	Th	232.04	11.2	1845	3530	—	—	0.03	0.0349	—	—	—	11.1	12.0
Tin	Sn	118.69	7.28	231.9	2430	14.2	16.509	0.053	0.0616	0.15	54.0	0.6278	12.8	11.4
Titanium	Ti	47.9	4.35	1727	3200	—	—	0.146	0.1697	—	—	—	—	43.5
Tungsten	W	183.85	19.3	3380	6000	60	69.756	0.33	0.3837	0.31	111.6	1.2973	4.5	5.48
Uranium	U	238.03	18.7	1130	—	—	—	0.03	0.0349	—	—	—	—	30.6
Vanadium	V	50.94	6.0	1726	3000	—	—	0.12	0.1395	—	—	—	8.84	19
Zinc	Zn	65.37	7.13	419.5	906	26	30.228	0.092	0.1070	0.27	97.2	1.13	14.1	6.0
Zirconium	Zr	91.22	6.53	1860	2900	—	—	0.06	0.0697	—	—	—	14.3	41

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Temperature Conversion Table

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

°C		°F	°C		°F	°C		°F	°C		°F
–17.8	0	32	16.1	61	141.8	154	310	590	488	910	1670
–17.2	1	33.8	16.7	62	143.6	160	320	608	493	920	1688
–16.7	2	35.6	17.2	63	145.4	166	330	626	499	930	1706
–16.1	3	37.4	17.8	64	147.2	171	340	644	504	940	1724
–15.6	4	39.2	18.3	65	149.0	177	350	662	510	950	1742
–15.0	5	41.0	18.9	66	150.8	182	360	680	516	960	1760
–14.4	6	42.8	19.4	67	152.6	188	370	698	521	970	1778
–13.9	7	44.6	20.0	68	154.4	193	380	716	527	980	1796
–13.3	8	46.4	20.6	69	156.2	199	390	734	532	990	1814
–12.8	9	48.2	21.1	70	158.0	204	400	752	538	1000	1832
–12.2	10	50.0	21.7	71	159.8	210	410	770	543	1010	1850
–11.7	11	51.8	22.2	72	161.1	216	420	788	549	1020	1868
–11.1	12	53.6	22.8	73	163.4	221	430	806	554	1030	1886
–10.6	13	55.4	23.3	74	165.2	227	440	824	560	1040	1904
–10.0	14	57.2	23.9	75	167.0	232	450	842	566	1050	1922
–9.44	15	59.0	24.4	76	168.8	238	460	860	571	1060	1940
–8.89	16	60.8	25.0	77	170.6	243	470	878	577	1070	1958
–8.33	17	62.6	25.6	78	172.4	249	480	896	582	1080	1976
–7.78	18	64.4	26.1	79	174.2	254	490	914	588	1090	1994
–7.22	19	66.2	26.7	80	176.0	260	500	932	593	1100	2012
–6.67	20	68.0	27.2	81	177.8	266	510	950	599	1110	2030
–6.11	21	69.8	27.8	82	179.6	271	520	968	604	1120	2048
–5.56	22	71.6	28.3	83	181.4	277	530	986	610	1130	2066
–5.00	23	73.4	28.9	84	183.2	282	540	1004	616	1140	2084
–4.44	24	75.2	29.4	85	185.0	288	550	1022	621	1150	2102
–3.89	25	77.0	30.0	86	186.8	293	560	1040	627	1160	2120
–3.33	26	78.8	30.6	87	188.6	299	570	1058	632	1170	2138
–2.78	27	80.6	31.1	88	190.4	304	580	1076	638	1180	2156
–2.22	28	82.4	31.7	89	192.2	310	590	1094	643	1190	2174
–1.67	29	84.2	32.2	90	194.0	316	600	1112	649	1200	2192
–1.11	30	86.0	32.8	91	195.8	321	610	1130	654	1210	2210
–0.56	31	87.8	33.3	92	197.6	327	620	1148	660	1220	2228
–0	32	89.6	33.9	93	199.4	332	630	1166	666	1230	2246
0.56	33	91.4	34.4	94	201.2	366	690	1274	671	1240	2264
1.11	34	93.2	35.0	95	203.0	338	640	1184	677	1250	2282
1.67	35	95.0	35.6	96	204.8	343	650	1202	682	1260	2300
2.22	36	96.8	36.1	97	206.6	349	660	1220	688	1270	2318
2.78	37	98.6	36.7	98	208.4	354	670	1238	693	1280	2336
3.33	38	100.4	37.2	99	210.2	360	680	1256	699	1290	2354
3.89	39	102.2	38	100	212	366	690	1274	704	1300	2372
4.44	40	104.0	43	110	230	371	700	1292	710	1310	2390
5.00	41	105.8	49	120	248	377	710	1310	716	1320	2408
5.56	42	107.6	54	130	266	382	720	1328	721	1330	2426
6.11	43	109.4	60	140	284	388	730	1346	727	1340	2444
6.67	44	111.2	66	150	302	393	740	1364	732	1350	2462
7.22	45	113.0	71	160	320	399	750	1382	738	1360	2480
7.78	46	114.8	77	170	338	404	760	1400	743	1370	2498
8.33	47	116.6	82	180	356	410	770	1418	749	1380	2516
8.89	48	118.4	88	190	374	416	780	1436	754	1390	2534
9.44	49	120.2	93	200	392	421	790	1454	760	1400	2552
10.0	50	122.0	99	210	410	427	800	1472	766	1410	2570
10.6	51	123.8	100	212	413	432	810	1490	771	1420	2588
11.1	52	125.6	104	220	428	348	820	1508	777	1430	2606
11.7	53	127.4	110	230	446	443	830	1526	782	1440	2624
12.2	54	129.2	116	240	464	449	840	1544	788	1450	2642
12.8	55	131.0	121	250	482	454	850	1562	793	1460	2660
13.3	56	132.8	127	260	500	460	860	1580	799	1470	2678
13.9	57	134.6	132	270	518	468	870	1598	804	1480	2696
14.4	58	136.4	138	280	536	471	880	1616	810	1490	2714
15.0	59	138.2	143	290	554	477	890	1634	816	1500	2732
15.6	60	140.0	149	300	572	482	900	1652	821	1510	2750

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°C		°F	°C		°F	°C		°F
827	1520	2768	1221	2230	4046	1621	2950	5342
832	1530	2786	1227	2240	4064	1627	2960	5360
838	1540	2804	1232	2250	4082	1632	2970	5376
843	1550	2822	1238	2260	4100	1638	2980	5396
849	1560	2840	1243	2270	4118	1643	2990	5414
860	1580	2876	1249	2280	4138	1649	3000	5432
866	1590	2894	1254	2290	4154			
871	1600	2912	1260	2300	4172			
877	1610	2930	1266	2310	4190			
882	1620	2948	1271	2320	4208			
888	1630	2966	1277	2330	4226			
893	1640	2984	1282	2340	4244			
899	1650	3002	1288	2350	4262			
904	1660	3020	1293	2360	4280			
910	1670	3038	1299	2370	4298			
916	1680	3058	1304	2380	4316			
921	1690	3074	1310	2390	4334			
927	1700	3092	1316	2400	4352			
932	1710	3110	1321	2410	4370			
938	1720	3128	1327	2420	4388			
943	1730	3146	1332	2430	4406			
949	1740	3164	1338	2440	4424			
954	1750	3182	1343	2450	4442			
960	1760	3200	1349	2460	4460			
966	1770	3218	1354	2470	4478			
971	1780	3236	1360	2480	4496			
977	1790	3254	1366	2490	4514			
982	1800	3272	1371	2500	4532			
988	1810	3290	1377	2510	5450			
993	1820	3308	1382	2520	4568			
999	1830	3326	1388	2530	4586			
1004	1840	3344	1393	2540	4604			
1010	1850	3362	1399	2550	4622			
1016	1860	3380	1404	2560	4640			
1021	1870	3398	1410	2570	4658			
1027	1880	3416	1416	2580	4676			
1032	1890	3434	1421	2590	4694			
1038	1890	3452	1427	2600	4712			
1043	1910	3470	1432	2610	4730			
1049	1920	3488	1438	2620	4748			
1054	1930	3506	1443	2630	4766			
1060	1940	3524	1449	2640	4784			
1066	1950	3542	1454	2650	4802			
1071	1960	3560	1460	2660	4820			
1077	1970	3578	1466	2670	4838			
1504	2740	4964	1471	2680	4856			
1082	1980	3596	1477	2690	4874			
1088	1990	3614	1482	2700	4892			
1093	2000	3632	1488	2710	4910			
1099	2010	3650	1493	2720	4928			
1104	2020	3668	1499	2730	4946			
1110	2030	3686	1510	2750	4982			
1116	2040	3704	1516	2760	5000			
1121	2050	3722	1521	2770	5018			
1127	2060	3740	1527	2780	5036			
1132	2070	3758	1532	2790	5054			
1138	2080	3776	1538	2800	5072			
1143	2090	3794	1543	2810	5090			
1149	2100	3812	1549	2820	5108			
1154	2110	3830	1554	2830	5126			
1160	2120	3848	1560	2840	5144			
1166	2130	3866	1566	2850	5162			
1171	2140	3884	1571	2860	5180			
1177	2150	3902	1577	2870	5198			
1182	2160	3920	1582	2880	5216			
1188	2170	3938	1588	2890	5234			
1193	2180	3956	1593	2900	5252			
1199	2190	3974	1599	2910	5270			
1204	2200	3992	1604	2920	5288			
1210	2210	4010	1610	2930	5306			
1216	2220	4028	1616	2940	5324			

INTERPOLATION TABLE

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

°F = 1.8 x °C + 32
°C = (°F – 32) x 5/9

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Miscellaneous Conversion Factors

Imperial units			Metric units	
Weights				
1 grain	(=1/7000 lb)	= 0.0648g	1 gram	=15.4 grains
1 dram (dr)		= 1.77 g	1 kilogr (1000 gr)	=2.204 lb
1 ounce (oz)	= 16 dr	= 28.35 g	1 metric ton	= 19.68 cwt
1 pound (lb)	= 16 oz	= 454 g		=2204 lb
1 stone (st)	= 14 lb	= 6.35 kg		= 1000 kg
1 quarter (qr)	= 2 st	= 12.7 kg		
1 central	= 100 lb	= 45.4 kg		
1 hundredweight (cwt)	= 112 lb	= 50.8 kg		
1 quntal		= 100 kg		
1 short ton = 20 centr	= 2000 lb	= 908 kg		
1 long ton = 20 cwt	= 2240 lb			
Linear measures				
1 inch (")		= 25.4 mm	1 mm	= 0.039 inch
1 foot (ft)	= 12 inches	= 30.48 cm	1 cm	= 0.394 inch
1 yard	= 3 ft	= 91.44 cm	1 dm	= 3.937 inches
1 rod, pole or perch	= 5.5 yds	= 5.03 m	1 m	= 39.37 inches
1 chain	= 4 pls	= 20.12 m	1 km	= 0.621 mile
1 furlong	= 10 chs	= 201.2 m		
1 mile	= 8 fri	= 1609 m		
1 sea mile		= 1852 m		
Square measures				
1 sq inch		= 6.45 cm^2	1 cm^2	= 0.155 sq inch
1 sq foot	= 144 sq inches	= 9.29 dm^2	1 dm^2	= 15.5 sq inches
1 sq yard	= 9 sq ft	= 0.836 m^2	1 m^2	= 1.196 sq yard
1 sq pole	= 30.2509 sq yd	= 25.29 m^2	1 are	= 119.6 sq yard
1 rood	= 40 sq pls	= 10.1 acre	1 hectare	= 2.471 acres
1 acre	= 4 roods	= 0.4047 ha	1 km^2	= 247 acres
1 sq mile	= 640 acres	= 259 ha		

Imperial units			Metric units	

Cubic measures

1 cu inch		= 16.39 cm^3	1 cm^3	= 0.061 cu inch
1 cu foot	= 1728 cu inch	= 28.32 dm^3	1 dm^3	= 61.02 cu inches
1 cu yard	= 27 cu ft	= 0.765 m^3	1 m^3	= 1.308 cu yds
1 gill	= 8.655 cu inches	= 142 cm^3	1 centliter	= 0.07 gill
1 pint	= 4 gills	= 0.568 dm^3	1 deciliter	= 0.176 pint
1 quart	= 2 pints	= 1.136 dm^3	1 liter	= 1.759 pint
1 gallon	= 4 quarts	= 4.546 dm^3	1 hectoliter	= 22 gallons
1 peck	= 2 gallons	= 9.092 dm^3	or	= 2.75 bushels
1 bushel	= 4 pecks	= 36.37 dm^3		
1 quarter	= 8 bushels	= 2.909 hl		
1 barrel	= 31.5 gallons	= 1.432 hl		
1 hogshead	= 2 barrels	= 2.864 hl		

Density

1 lb/cu inch	= 27.7 g/cm^3	1 g/cm^3	= 0.0361 lb/cu inch
1 lb/cu ft	= 16.0 kg/m^3	1 kg/m^3	= 0.0624 lb/cu ft

Force

1 lbf (pound-force)	= 4.45 N	1 N	= 0.225 lbf

Pressure

1 lbf/sq inch	= $6.89 \cdot 10^3$ N/m^2	1 N/m^3	= $0.145 \cdot 10^{-3}$ lbf/sq inch
1 ton/sq inch	= 15.444 N/mm^2	1 N/mm^2	= 145.04 lbf/sq inch
		1 N/mm^2	= 0.0647 49 ton-force/sq inch
		1 Pa	= 1 N/m^2

Energy

1 Btu (British thermal unit)	= 1055 J	1 J	= $0.948 \cdot 10^{-3}$ Btu
	= $0.293 \cdot 10^{-3}$ kWh	1 kWh	= 3412 Btu
	= 1055 Nm	1 Nm	= $0.948 \cdot 10^{-3}$ Btu
		1 kcal	= 3.97 Btu

Thermal conductivity

1 Btu/ft h °F	= 1.73 W/mK	1 W/mK	= 0.578 Btu/ft h °F
1 Btu inch/ft^2 h °F	= 0.143 W/m°K		= 6.93 Btu inch/ft^2 h °F

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Thermocouples

Thermocouples	Maximum service		Atmosphere temperature °C	Reference Junction compensation
	Continuous	Intermittent		
Type S Pt–10Rh v Pt	1400	1650	Oxidising Neutral Vacuum	Compensating leads, see B.S. 1843
Type R Pt–13Rh v Pt	1400	1650	Oxidising Neutral Vacuum Reducing	Compensating leads, see B.S. 1843
Type B Pt–30Rh v Pt–6Rh	1500	1800	Oxidising Neutral Vacuum	Not normally necessary
Pt–40Rh v Pt–20Rh	1600	1800	Oxidising Neutral Vacuum	Not normally necessary
Ir–40Rh v Ir	2000	2100	Neutral Vacuum Oxidising	Copper v Aluminium
W v W–26Re	2300	2600	Neutral Vacuum Reducing	Use reference junction correction table

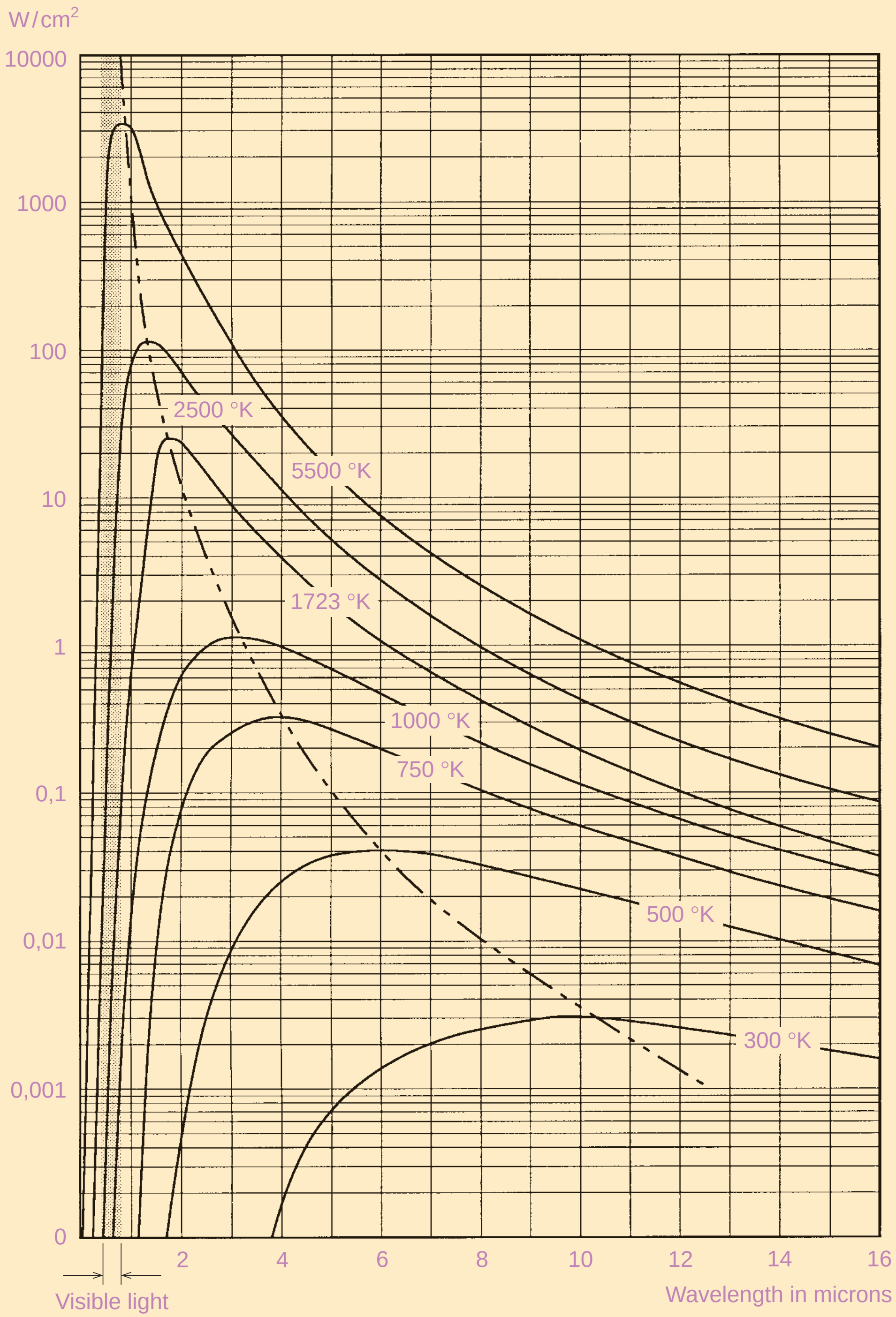
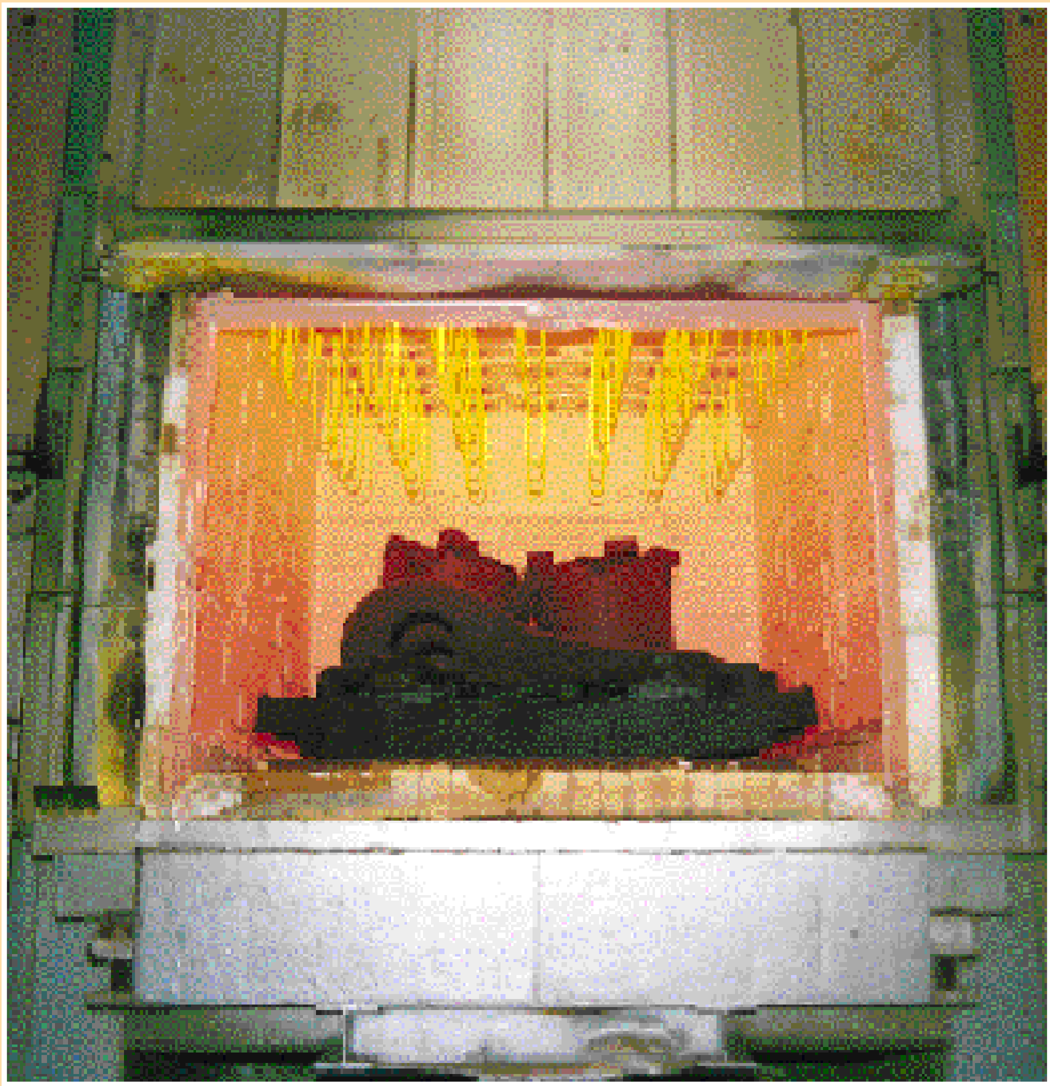


Fig. 75 Intensity of black body radiation.

Fig. 76 Car bottom furnace for forging and annealing.



Heat transfer by radiation

For radiation from an ideal black solid the following so called thesis of Stefan-Boltzmann holds:

$Q_s = C_s \times \left(\frac{T}{100}\right)^4 \; W/m^2$ C_s = Coefficient of radiation for a black body = 5.67 $W/m^2 K^4$.

For radiation from one solid to another solid with equal surfaces, through a transparent non-absorbing medium, the following holds:

$$Q_s = C_r \times A \times \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$$

$$C_r = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} - \frac{1}{5.67}}$$

C_1 and C_2 = Coefficient of radiation for the two surfaces
T_1 = Surface temperature of the radiating body in °K
T_2 = Surface temperature of the work piece in °K

The coefficient of radiation for the two surfaces are:
$C_1 = \epsilon_1 \times C_s$ $C_2 = \epsilon_2 \times C_s$ ϵ_1 and ϵ_2 from table below

If the area A_2 is surrounding the area A_1 completely:

$$C_r = \frac{1}{\frac{1}{C_1} + \frac{A_1}{A_2}\left(\frac{1}{C_2} - \frac{1}{5.67}\right)}$$

In furnace practice, the surface of the furnace interior is usually four or more times the projected area of the charge. The surface of the KANTHAL SUPER elements is about 10% of the surface of the furnace interior. Considering the heating equation above, this means that only about 20% of the power is transferred directly from the heating elements to the charge. The remaining 80% is transferred indirectly by the furnace interior.

Emissivity ϵ, guiding values

Material		Temp °C	Temp °F	ϵ
Aluminium	bright	500	930	0.06
	oxidized	600	1110	0.18
Brass	bright	100	210	0.04
	oxidized	600	1110	0.60
Copper	bright	100	210	0.02
	oxidized	1000	1830	0.60
Iron	bright	100	210	0.30
	oxidized	1200	2190	0.85
Nickel	bright	1000	1830	0.20
	oxidized	1200	2190	0.85
Platinum	bright	1500	2730	0.20
Steel	bright	100	210	0.10
	oxidized	600	1110	0.80
Firebrick		1000	1830	0.80
Zirconia		1400	2550	0.40
KANTHAL SUPER		1400	2550	0.70
Aluminium paint				0.55
Sooted surface				0.97
Black body				1.00

Table 11.

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Calculation of furnace insulation

Flat furnace wall

The heat flow Q Watts through a flat furnace wall with the area A m^2 and with one or more layers of insulation can be calculated according to the formula:

$$Q = k\,A\,(T_f - T_a)\ W$$

k = Thermal conductivity, W/(m^2 °C)
T_f = Furnace temperature, °C
T_a = Temperature of the ambient air, °C
α = Coefficient of heat transfer, W/(m^2 °C)
s = Thickness of layer, m
λ = Thermal conductivity, W/(m °C)

In high temperature furnaces α_1 = 100 W/(m^2 °C)
Non-metallic surfaces, e. g. cement and metal surfaces that have been painted. α_2 = 10.0 W/(m^2 °C)
Galvanized or planished steel; finishes in the nature of metallic paints. α_2 = 8.0 W/(m^2 °C)
Bright metallic surfaces, e. g. polished aluminium. α_2 = 5.7 W/(m^2 °C)

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{s_1}{\lambda_1} + \frac{s_2}{\lambda_2} + \frac{s_3}{\lambda_3} + \frac{1}{\alpha_2}} \text{ (for three layers)}$$

The temperatures between the different layers of insulation are calculated as follows:

$$T_b = T_f - \frac{1}{\alpha_1} \times k\,(T_f - T_a)$$

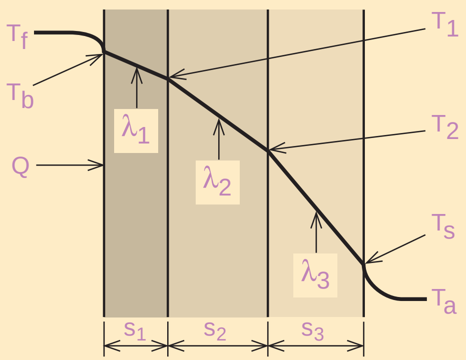
$$T_1 = T_b - \frac{s_1}{\lambda_1} \times k\,(T_f - T_a)$$

$$T_2 = T_1 - \frac{s_2}{\lambda_2} \times k\,(T_f - T_a)$$

$$T_s = T_2 - \frac{s_3}{\lambda_3} \times k\,(T_f - T_a)$$

T_b = Hot face temperature, °C

T_s = Cold face temperature, °C



Tubular furnace wall

The heat flow Q Watts through a tubular furnace wall with the length L m and with one or more layers of insulation can be calculated according to the formula:

$$Q = k_r\, L\, (T_f - T_a)\ W$$

$$k_r = \frac{\pi}{\dfrac{1}{\alpha_1 d_1} + \dfrac{0.5}{\lambda_1}\ln\left(\dfrac{d_2}{d_1}\right) + \dfrac{0.5}{\lambda_2}\ln\left(\dfrac{d_3}{d_2}\right) + \dfrac{0.5}{\lambda_3}\ln\left(\dfrac{d_4}{d_3}\right) + \dfrac{1}{\alpha_2 d_4}} \quad \text{(for three layers)}$$

k_r = Thermal conductivity, W/(m°C).
ln = natural logarithm.
d = diameter, m.

The temperatures between the different layers of insulation are calculated as follows:

$$T_b = T_f - \frac{1}{\pi\alpha_1 d_1} \times k_r (T_f - T_a)$$

$$T_1 = T_b - \frac{0.5}{\pi\lambda_1} \times k_r (T_f - T_a) \times \ln\left(\frac{d_2}{d_1}\right)$$

$$T_2 = T_1 - \frac{0.5}{\pi\lambda_2} \times k_r (T_f - T_a) \times \ln\left(\frac{d_3}{d_2}\right)$$

$$T_s = T_2 - \frac{0.5}{\pi\lambda_3} \times k_r (T_f - T_a) \times \ln\left(\frac{d_4}{d_3}\right)$$