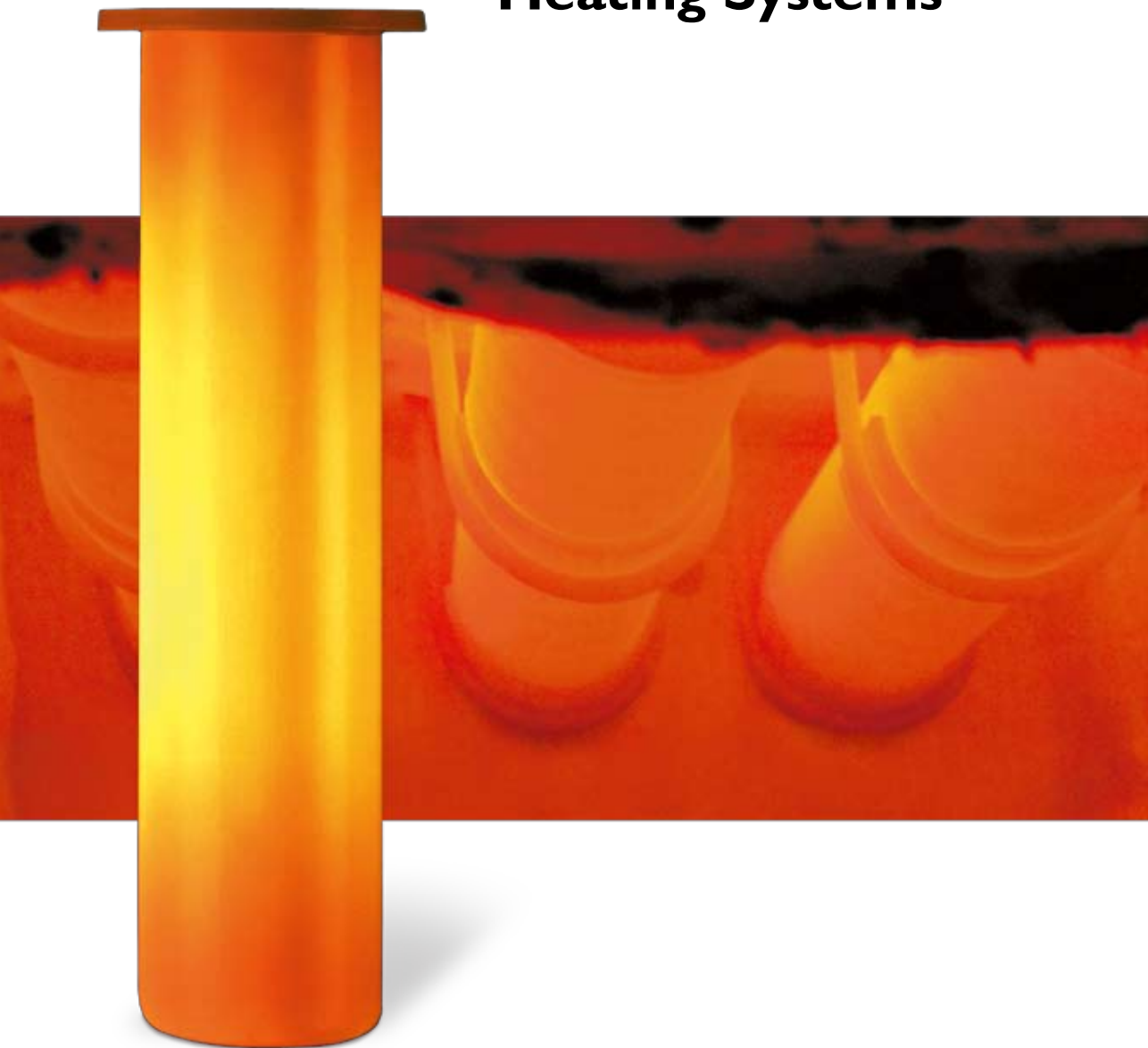


KANTHAL[®] PM Tubes

Radiant Tubes and Heating Systems



KANTHAL

Company Information

Kanthal is a world-renowned name within the field of electric heating. Since the early thirties, Kanthal has developed market leading, electric resistance alloy products and materials.

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

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

Kanthal is a Sandvik Company.



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Kanthal – a Member of the Sandvik Group

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

KANTHAL® PM Tubes

Radiant Tubes and Heating Systems

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More Power, Longer Life and Less Maintenance

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

KANTHAL PM tube range includes APM (Advanced Powder Metallurgy), suitable for most types of processes, and APMT, an alloy with improved hot strength for extra demanding horizontal applications.

KANTHAL PM tubes are suited to both gas and electrically heated furnaces.

Extra High Temperature

Can operate at temperatures up to 1250°C (2280°F).

High Loading Potential

At a furnace temperature of 1000°C (1830°F), the loading can be more than double that of NiCr and FeNiCr tubes. This allows more flexible furnace designs and conversion of existing heating systems to higher furnace power. Fewer tubes are needed for the same power rating.

Long Life

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

No Tube Carburization

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

KANTHAL PM materials withstand coking and metal dusting.

Less Maintenance

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

No Weak Spots

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

Excellent Form Stability

Excellent form stability even at elevated temperatures.

Low Weight

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

Product Summary

Ready to Install

KANTHAL PM tubes are supplied as complete plug-in units for gas or electric furnaces. We can assist you in calculating and choosing the most suitable system

for your particular needs. Tube systems are stocked in standard dimensions to fit most furnaces and to allow fast deliveries.

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KANTHAL PM Material

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

KANTHAL PM materials are based on the well-known Kanthal FeCrAl alloy, the basis of electric elements in many different types of kiln and furnace for over 70 years. The PM materials are both produced by an Advanced Powder Metallurgy process route. The powder metallurgy alloys maintain

all of the benefits of the traditional Kanthal alloys and add many more. The most obvious benefit is the higher mechanical strength achieved by dispersion strengthening.

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



Chemical Analysis and Physical Properties

Typical chemical composition [wt %]							
	Fe	Cr	Al	Mo	Mn	Si	C
APM	balance	22	5.8	–	≤ 0.4	≤ 0.7	≤ 0.05
APMT	balance	22	5.0	3.0	≤ 0.4	≤ 0.7	≤ 0.05

	APM	APMT
Density [g/cm ³] (lbs/in ³)	7.1 (0.257)	7.2 (0.260)
Emissivity – fully oxidized material	0.7	0.7
Magnetic properties – The material is magnetic up to approx. 600°C (1110°F) (Curie point)		

Coefficient of thermal expansion			
Temperature [°C] (°F)		Thermal expansion [10 ⁻⁶ K ⁻¹]	
		APM	APMT
20–250	(68–480)	13	12
20–500	(68–930)	13	13
20–750	(68–1380)	14	14
20–1000	(68–1830)	15	15
20–1250	(68–2280)	16	15

Thermal conductivity							
Temperature [°C] (°F)	50 (120)	600 (1110)	800 (1470)	1000 (1830)	1200 (2190)	1400 (2550)	
APM [Wm ⁻¹ K ⁻¹] (Win ⁻¹ F ⁻¹)	11 (0.16)	20 (0.28)	22 (0.31)	26 (0.37)	27 (0.38)	35 (0.49)	
APMT [Wm ⁻¹ K ⁻¹] (Win ⁻¹ F ⁻¹)	11 (0.16)	21 (0.30)	23 (0.32)	27 (0.38)	29 (0.41)	32 (0.45)	

Specific heat capacity								
Temperature [°C] (°F)	20 (68)	200 (390)	400 (750)	600 (1110)	800 (1470)	1000 (1830)	1200 (2190)	1400 (2550)
APM [kJkg ⁻¹ K ⁻¹]	0.46	0.56	0.63	0.75	0.71	0.72	0.74	0.80
APMT [kJkg ⁻¹ K ⁻¹]	0.48	0.56	0.64	0.71	0.67	0.69	0.70	0.74

High Temperature Strength

Creep Rupture Strength

KANTHAL PM tubes offer a unique combination of strength and corrosion resistance, which allows them to be used at higher temperatures than NiCr tubes and still exhibit a long working life.

With KANTHAL APMT, tubes have similar strength values as NiCr tubes, but retain much of their strength up to temperatures well above the working temperature of NiCr tubes.

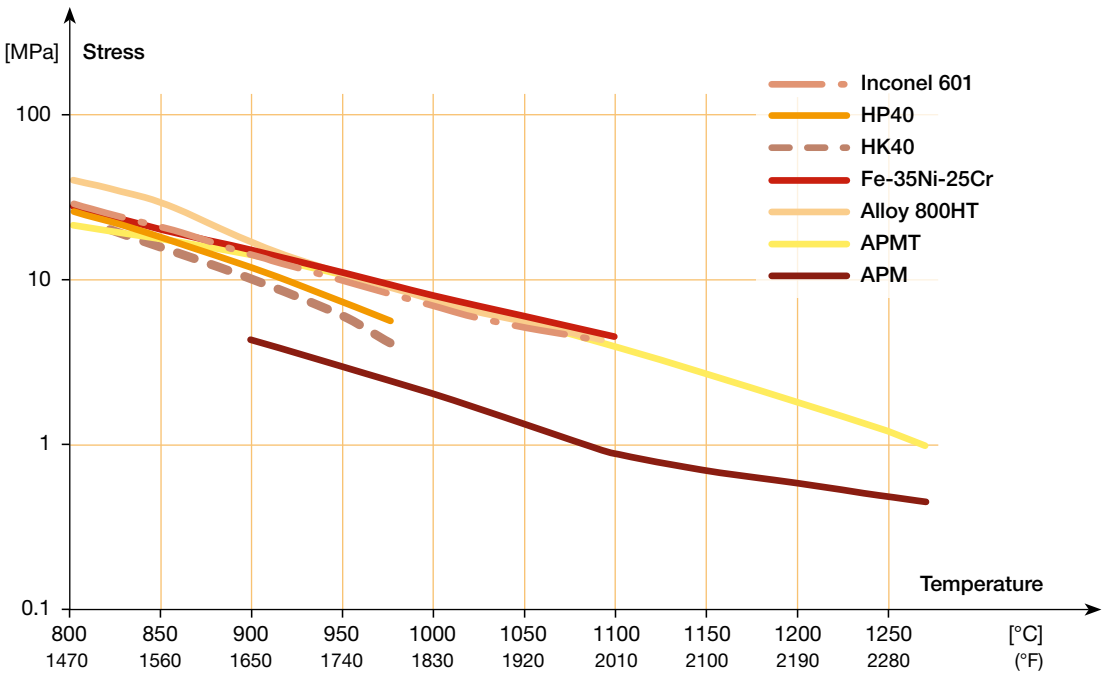


Fig. 1 Creep rupture strength – 10 000 h.

Resistance to Sagging Deformation

Sagging is a form of creep deformation. Most creep data is the result of uniaxial tests of standardised samples. However, it is often very difficult to translate creep data for horizontal and other applications where the stresses are more complex. This difficulty of applying creep data can be illustrated by the following example.

The austenitic steel (Fe, 35Ni, 25Cr) has substantially higher creep resistance than KANTHAL APM and equal to KANTHAL APMT at 1100°C (2010°F). When testing three extruded tubes of exactly the same dimension in a sagging rig, both KANTHAL PM tubes outperformed the FeNiCr-material. There are several reasons for the difference between sagging data

and creep data. In the sagging test, the density of the tube material plays a larger role than in a creep test, where weights are applied independently of the alloy tested. Another factor is the change in deformation behaviour with time. All tubes show initially a higher deformation rate. After the initial sagging, the FeNiCr material follows a fairly linear behaviour with time. In the case of KANTHAL PM the deformation rate continues to decrease with time.

This is often the experience in real applications. Rotating tubes 180° at regular intervals is common practice in furnaces with welded or spun cast NiCr. Normally it is not necessary to turn KANTHAL PM tubes, but if preferred, then only once at the first maintenance stop after installation.

Another factor that often plays a significant role in real applications and is not considered in the standard laboratory test is corrosion. Corrosion will not only change the mechanical strength of the material, but equally importantly, it reduces the load bearing cross-section.



Fig. 2 KANTHAL APMT (left) and Fe-35Ni-25Cr (right) after the sagging test.

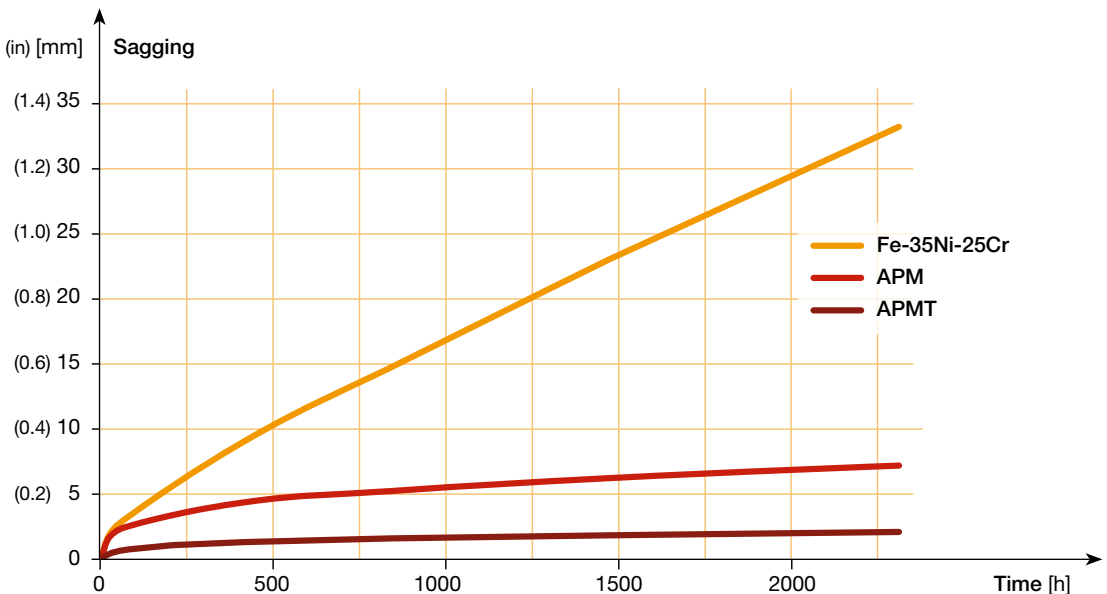


Fig. 3 Comparative sagging test at 1100°C (2010°F).

High Temperature Corrosion Properties

KANTHAL PM alloys exhibit excellent high temperature corrosion properties. The explanation for the excellent corrosion resistance is the formation of a dense, cohesive aluminum oxide layer on the surface protecting the base material from corrosion attack. This aluminum oxide, Al_2O_3 , is formed through selective oxidation of the aluminum in the alloys. There are some criteria that an effective protective oxide must fulfil.

- **Thermodynamically stable** – The oxide should not be reduced or react in any other way with the surrounding atmosphere
- **Adherent** – The oxide must not spall during thermal cycling
- **Low growth rate** – Slow oxide growth is necessary to ensure long life of the product

The aluminum oxide formed on KANTHAL PM alloys fulfils the above criteria better than any other protective oxide formed at high temperatures. NiCr and FeNiCr alloys form a chromium oxide as a protective scale. Chromium oxide is less adherent to the metal i.e. chromium oxide tends to spall or scale much more than the KANTHAL PM materials. Chromium oxide is also volatile in many atmospheres i.e. chromium oxide vaporises from hot metal surfaces and condenses on to colder surrounding surfaces. Spalled and condensed chromium oxide causes contamination and discoloration of products in furnaces and can, in severe cases, cause furnace malfunctions due to short circuiting of resistance heating elements or clogging /leakage of gas valves.

KANTHAL PM alloys have the ability to form a protective surface oxide film even when the oxygen concentrations in the surrounding atmosphere are very low. Practically all industrial atmospheres contain enough oxygen to stabilise aluminum oxide. The oxygen needed for the aluminum oxide growth can come from many sources beside O_2 . Atmospheres containing oxygen in form of H_2O , CO/CO_2 , CH_3OH or SO_2 can be regarded as oxidizing for KANTHAL PM alloys.



Fig. 4 Comparison of APMT Tube vs. Fe-35Ni-25Cr (after 2300 h at 1100°C (2010°F)). The FeNiCr tube is severely contaminated with oxide flakes.

Excellent in High Carbon-Potential Atmospheres

One of the primary benefits of KANTHAL PM tubes, is their excellent resistance to carburization. NiCr and FeNiCr alloys absorb carbon at a much faster rate than KANTHAL PM, and this results not only in a gradual change in the alloy composition, but also in the accumulation of free carbon on the surface of radiant tubes. This carbon can be hard and cohesive with the tube substrate, and is often almost impossible to remove.

Carbon build-up results in poor heat transfer and can cause overheating of tubes and the heating system. This overheating also causes a further increase in the rate at which carburization proceeds, so that carbon build-up tends to accelerate with time.

However, with KANTHAL PM tubes, the protective layer of aluminum oxide formed on the tube surface inhibits reactions between the carbon and the base material. Alumina is highly resistant to carbon. Experience has shown that any carbon, which does accumulate, does not adhere to the tubes and can be easily and periodically brushed off the surface, to prevent any undesirable effects.

This feature is of particular significance in many types of heat treatment furnaces, where a high carbon potential is essential. In these cases, KANTHAL PM

has proved vastly superior to even the best grades of nickel chromium alloys. The graph below shows the comparison between KANTHAL APM and various nickel-chromium alloys, in terms of carburization rate versus temperature. The excellent results speak for themselves.

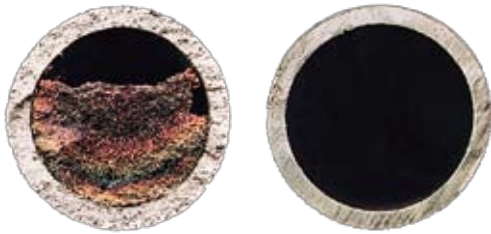


Fig. 5 Comparison of carbon build-up in a strand annealing furnace, NiCr (left) and APM (right).

Experience has shown that APM material works excellently in metal dusting environments. This is a

severe form of localised carbon attack that normally occurs in a temperature interval between 500 and 900°C (930 – 1650°F). Even though this is a lower temperature range than would normally be used for APM/APMT materials, it has proven to resist attack much better than conventional grades.

Resistant to Sulphurous Atmospheres

KANTHAL PM tubes are highly resistant to sulphurous atmospheres, where sulphidation and oxidation are competing reactions. The corrosion resistance is good as long as oxidation is the dominant reaction. Sulphidation usually results in much higher corrosion rates. The relationship between sulphur and oxygen in the atmosphere is important for which reaction will be dominant.

Compared to NiCr tubes, KANTHAL PM tubes are much more resistant to sulphidation, since the alumina surface oxide is much more stable at low oxygen concentrations than chromium oxide.

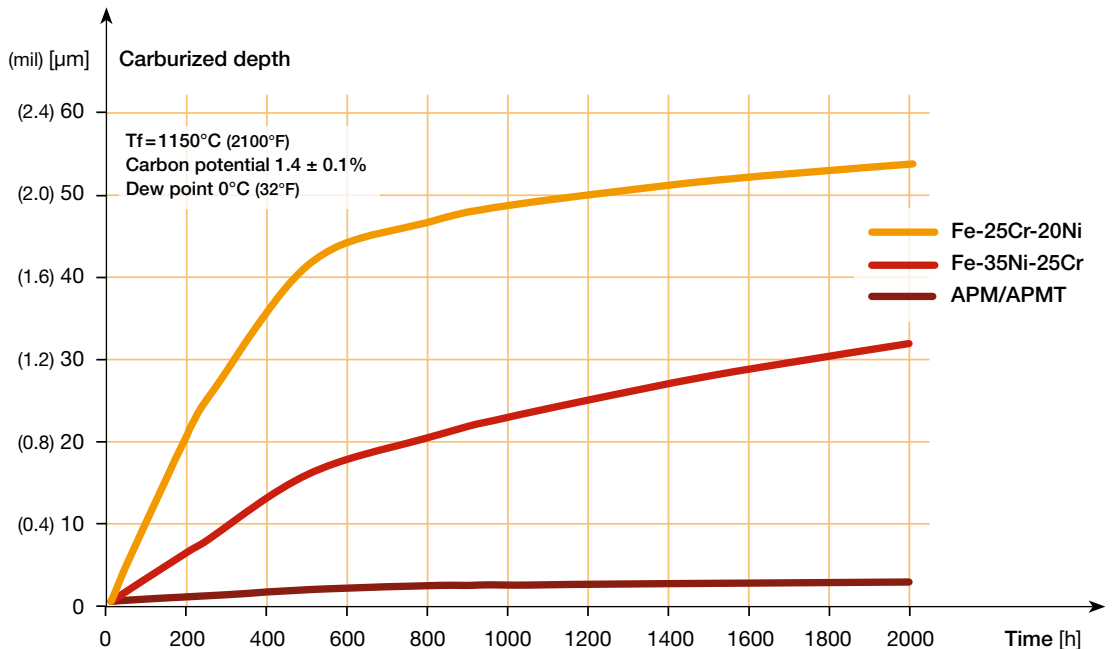
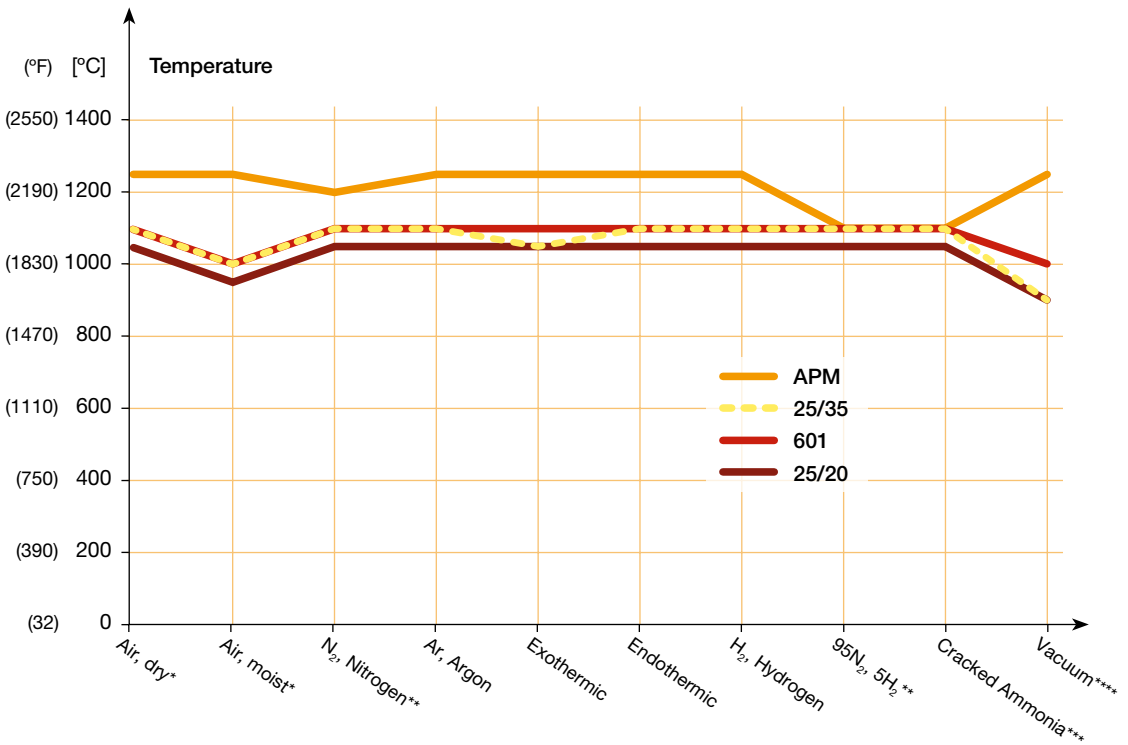


Fig. 6 Carburization resistance.

Maximum Recommended Temperatures

The diagram below shows recommended maximum temperatures for different alloys in various atmospheres. These temperatures are chosen from a practical, industrial point of view, although the material can withstand higher temperatures if needed.

For N_2 and N_2+H_2 atmospheres, at low Dew Point ($< -20^\circ C (-4^\circ F)$), special considerations are needed. Please contact Kanthal for further information.



* Limitation due to mechanical strength. The material can withstand temperatures up to $1425^\circ C (2600^\circ F)$.

** Temperature limitation depending on dew point.

*** An atmosphere created by cracked ammonia, that may contain uncracked ammonia, will lower the max. permissible temperature. Other materials designed for this atmosphere can be provided upon request.

**** To utilize this temperature, APM/APMT alloys should be reoxidized at certain intervals.

Fig. 7 Maximum recommended permissible temperature in various atmospheres.

Limitations of Conventional NiCr Alloys

The majority of radiant tubes are manufactured from nickel-chromium, or iron-nickel-chromium alloys, produced by centrifugal casting, extrusion or fabrication from rolled sheet. The limiting factor for the use of these tubes is in most cases not strength, but poor resistance to high temperatures and/or aggressive atmospheres. The limitations in performance have confined their use to relatively low temperatures and power outputs.

The limitations of NiCr alloys, operating in oxidizing conditions, are due primarily to the formation of chromium oxide on the surface. Although this oxide layer offers some protection against further oxidation, it is not cohesive with the substrate, and tends to spall under thermal cycling, exposing fresh material to attack. As the rate of oxidation

increases with temperature, a practical limitation of about 1100°C (2010°F) is imposed on radiant tubes made from the NiCr family of materials.

Other drawbacks of these alloys include rapid carburization in heat treatment furnaces with a high carbon potential, and the formation of NiS in sulphurous atmospheres. As the Cr₂O₃ oxide spalls, there can also be problems with contamination of the products being fired.

When NiCr tubes are used as protective tubes for electrical heating elements, the oxide spallation is a common reason for premature element failure, since loose oxides from the tube short-circuit the element.

KANTHAL APM™ or APMT?

KANTHAL APM has been used successfully for more than a decade in various tube applications and in resistance heating elements. However, there are applications where a higher mechanical strength is desired. KANTHAL APMT is a new alloy specially developed for these applications.

The composition of KANTHAL APMT is slightly modified compared to KANTHAL APM. The base

is still Fe-Cr-Al, but APMT also contains 3 wt % molybdenum and the aluminum content is slightly lower. These small modifications in composition have not affected the oxidation resistance, as seen in Fig. 8 below. APMT forms a protective aluminum oxide, just like APM, and tests show that the behaviour in Carburizing and sulphidising atmospheres is practically identical for the two alloys.

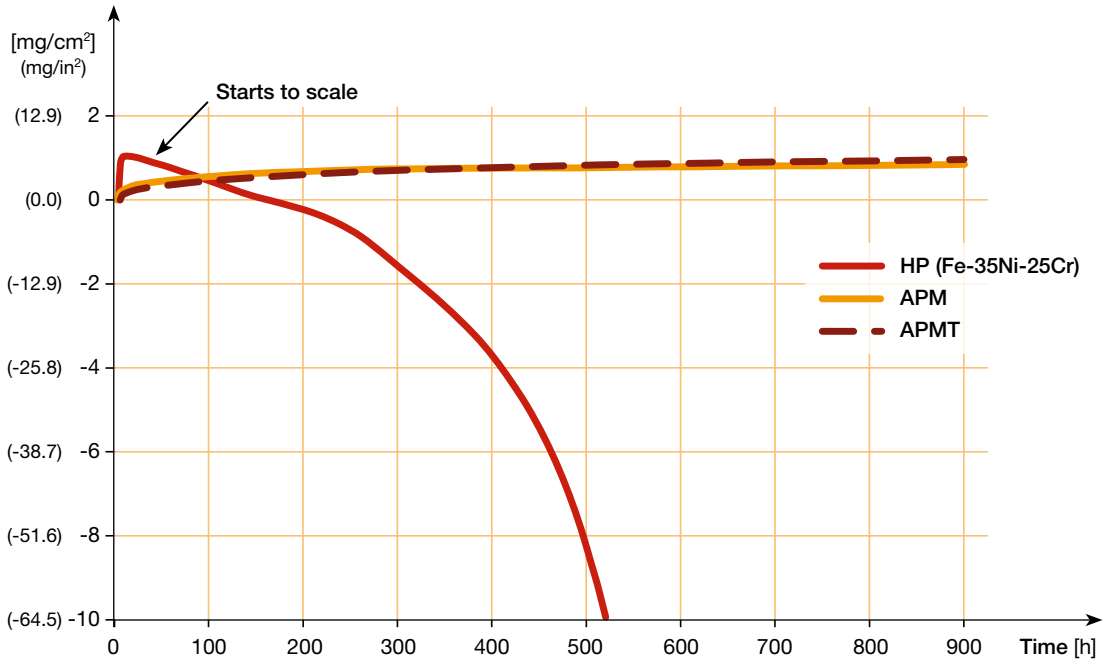


Fig. 8 Sample weight gain – 1100°C (2010°F).

KANTHAL APMT tubes are considered a complement to KANTHAL APM tubes in applications where higher form stability is needed. In some instances, sagging deformation can be a problem for long, horizontal APM tubes containing electric resistance heating elements like SiC GLOBAR® or TUBOTHAL®. KANTHAL APMT tubes can also solve deformation problems of metallic inner tubes or sagging of the outer tube in SER assemblies.

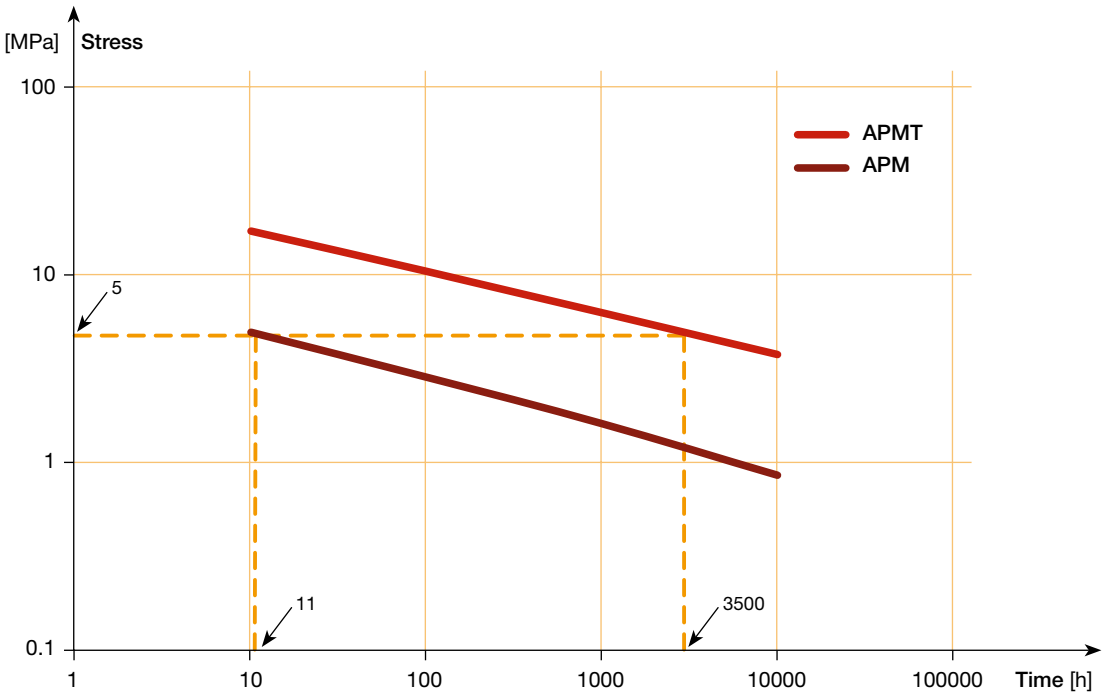


Fig. 9 Creep rupture time at 1100°C (2010°F).

Gas Fired Systems

Straight Through Tubes

In its simplest form, a radiant tube consists of a straight tube, with the burner fitted at one end and the exhaust at the other. These straight through tubes, although simple and relatively inexpensive, are inherently inefficient, as the temperature of the exhaust gases is significantly higher than the furnace temperature, and the majority of the energy of combustion is lost to the atmosphere. The use of KANTHAL PM tubes, however, allows higher temperature and power output and longer life than NiCr tubes.

Recuperative Radiant Tubes – SER Systems

The majority of tubes in use today are of a single ended design, where the burner and exhaust are situated on the same side of the furnace. With these designs, the exhaust gases can be used to pre-heat the air required for combustion. This results in a major improvement in system efficiency, by exhausting only low temperature gases into the atmosphere. Common designs are

U, W, and P shaped tubes, but these are gradually being replaced by less expensive and lighter single-ended recuperative burners, SER. With this design, the recuperator is integrated with the tube. Recovery of heat from the exhaust gases takes place within the furnace wall, minimising heat loss in the process.

Modern, high efficiency SER systems offer efficiencies in excess of 80% and are highly cost effective compared with direct fire systems and straight through tube designs of radiant tube. The inherent reliability and temperature capability of KANTHAL PM tubes makes them an ideal partner for the modern low NO_x , high efficiency burners available, and they are rapidly becoming the preferred choice for the most demanding of radiant tube applications.

With SER burners, the limiting factor in the design is normally the inner or re-circulation tube, which operates at a significantly higher temperature than the outer tube. Even in low temperature applications,

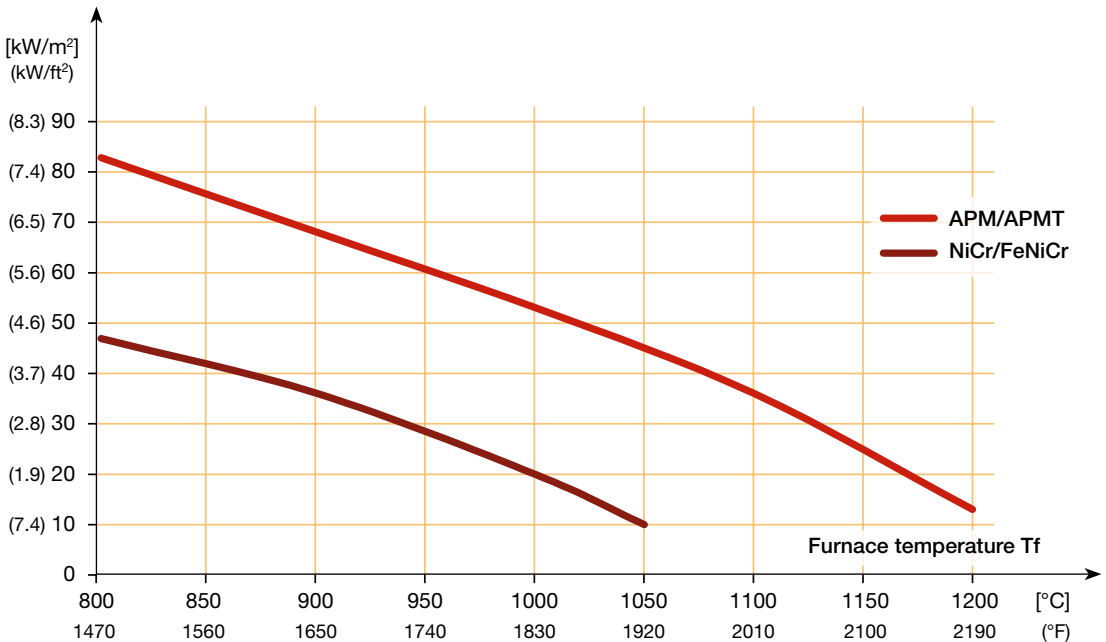


Fig. 10 Power output SER-burner systems.

the inner tube temperature can exceed the practical maximum for Ni-Cr materials, especially when the burner output is high. This has imposed severe limitations on the output of radiant tube designs.

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

Silicon Carbide Inner Tubes

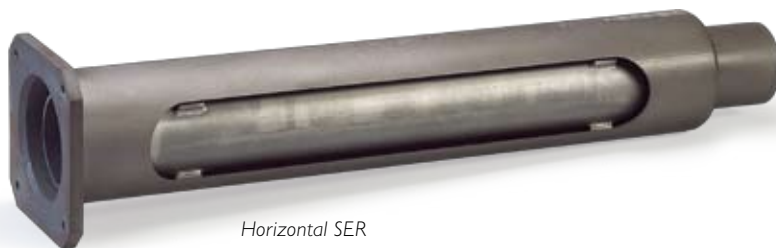
Silicon carbide can be combined with KANTHAL PM tubes in gas applications, where the temperature is higher or the power loading is higher than metallic tubes can endure. SER systems that work at very high temperature or high loading can be designed with a ceramic flame tube (inner). The flame tube is the part in the system that works at the highest temperature, often 100–200°C (210 – 390°F) warmer than the outer tube. As outer tubes, KANTHAL PM tubes can work under tougher conditions than other metallic tubes

and have better resistance to mechanical shock than ceramic tubes. Flanges, end caps and support systems are much cheaper and easier to install for metallic systems compared to ceramic.



Vertical SER

Straight through



Horizontal SER

ECOTHAL® SER-Burner, the Most Efficient Gas Solution on the Market

ECOTHAL SER-burner (Single-Ended Recuperative) is designed for high efficiency, reliability and low emissions. It is possible to raise the degree of efficiency to about 80 %, in other words 10 % more than conventional recuperative systems.

ECOTHAL SER-burner is developed by using established methods optimized by applying the latest simulation technology regarding gas/air and exhaust-flow. A robust design, with all metallic parts, ensures reliable and virtually maintenance free operation. The metallic design also means easy handling with little risk of damage.

Thanks to the complex simulation and calculations we can offer an optimal heating solution which increases your productivity and improves the quality of the final product.

In certain cases, our heating solutions have increased productivity by almost 100 %.

Customer Perceived Value

ECOTHAL SER-burner is the most efficient gas solution on the market; it reduces both gas consumption and emissions. This is the ultimate solution for cost and environmentally conscious companies.

With ECOTHAL you can increase your productivity or maintain the productivity at a lower cost, meaning less number of burners – and thus lower fuel consumption – for the same productivity. The high efficiency of the burners reduces the overall fuel costs up to 25 %.

Environment Friendly

ECOTHAL SER-burner is the cleanest recuperative radiant heater on the market. The high efficiency also reduces emissions of carbon dioxide per energy unit produced. This give you less pollution and greenhouse effect, less costs and a lot of goodwill!

A well-defined combustion is important when maximizing efficiency and reducing pollution. Too much air reduces heat output and increases the amount of harmful nitrogen oxides (NO_x) in the exhaust gases.

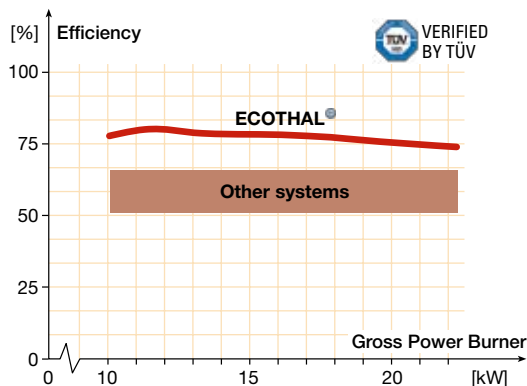


Fig. 11 Comparison of efficiency

Too little air results in incomplete combustion, which causes unburned residues in form of carbon monoxide (CO) and hydrocarbons (C_xH_y). The burner design results in no added need of regulation system.

ECOTHAL is designed to meet these ever tougher environmental goals, by enabling you as a user to reduce your emission levels to meet environmental standards – today’s and tomorrows.

ECOTHAL SER-Burner Fulfills All Market Applicable Standards Regarding Emissions and is Approved by TÜV

- Reference in Natural gas;
- Carbon dioxide 75 g/MJ
- Carbon monoxide ≈ 0 ppm
- Nitrous oxide <50 ppm (3% O₂)
- Nitrous oxide 20 mg/MJ

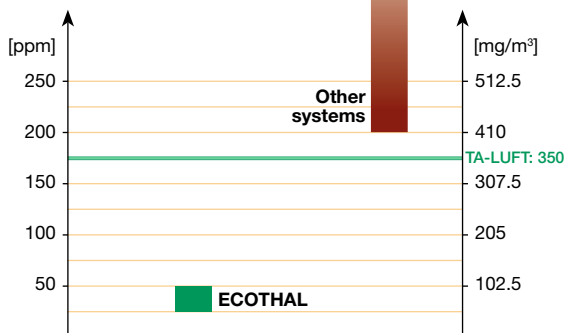


Fig. 12 Typical NO_x-levels



ECOTHAL Portfolio

ECOTHAL principle gives you a possibility to upgrade your system, from basic solution to a complete solution with surveillance, feed-back and the ability to monitor and report malfunctions. You can go directly from model one to model three if you wish.

All three models share the same high efficiency and low emission.

ECOTHAL in Three Different Models

Model one – ECOTHAL glow plug: An indirect surveillance by glow plug in the exhaust outlet, offers a secure and controlled combustion with verified low NOx outlet and high efficiency.

Model two – ECOTHAL ignition: An upgrade by adding ignition transformer and rod which render easier start ups of the burner. The fuel economy and outlet levels will be maintained; hence the burner has the same good combustion economy as before. This is an indirect surveillance system.

Model three – ECOTHAL UV: The ultimate model to monitor and report malfunctions. This is a sophisticated steering and regulating system using ultra violet flame detection together with ignition, often demanded by larger industries. In most cases this upgrade requires a redesign of the electrical and gas supply system.

ECOTHAL, the Ultimate SER-Solution in Combination with APM/APMT Tubes

ECOTHAL SER-burner is designed in special consideration of high efficiency and low emissions and are therefore highly cost effective compared with direct fire systems, straight through designs of radiant tubes and conventional recuperative systems:

- Raise productivity – efficiency in excess of 80 %.
- Reduces overall fuel costs up to 25 %.
- Environmental friendly – fulfils all applicable standards regarding emissions.

ECOTHAL SER-burner diminishes the need for maintenance, due to the robust design and easy handling of equipment, and is easily adaptable to existing system because of the standardized and systemized designed components. When used together with KANTHAL PM-tubes the system is more or less maintenance free.



Kanthal TUBOTHAL® – the Most Powerful Metallic Element System



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

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

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

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

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

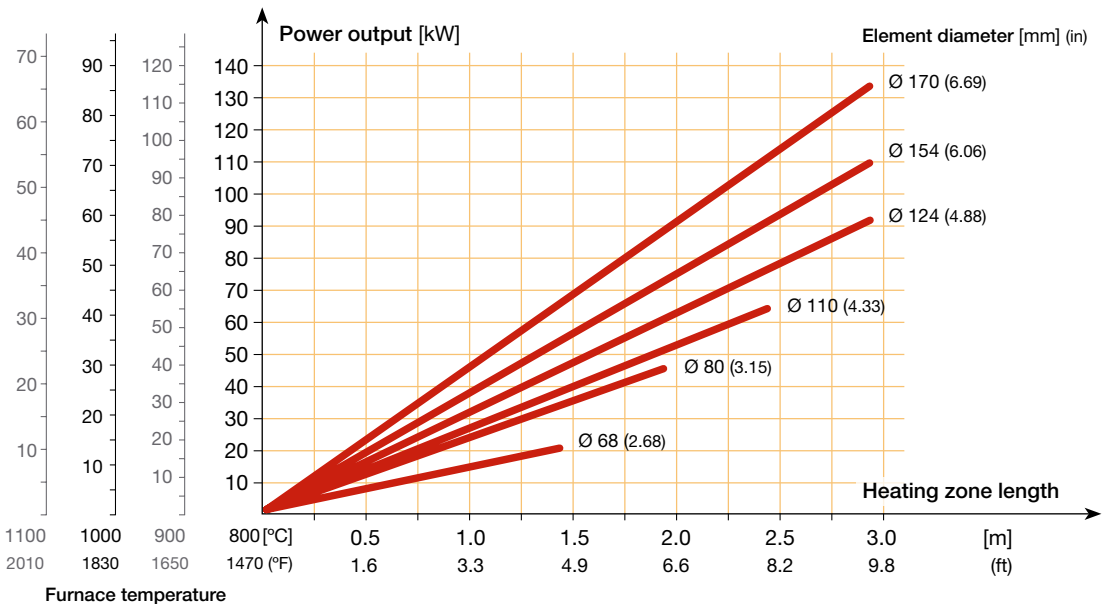


Fig. 13 Maximum design power outputs for all standard element diameters at different furnace temperatures.

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

Higher Power Output

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

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

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

The power output for standard TUBOTHAL elements is a function of the element diameter, the effective heating length and the operating temperature of the furnace. Fig. 11, illustrates maximum suggested design power outputs for all standard element diameters, at furnace temperatures between 800°C and 1100°C (1430 – 2010°F).

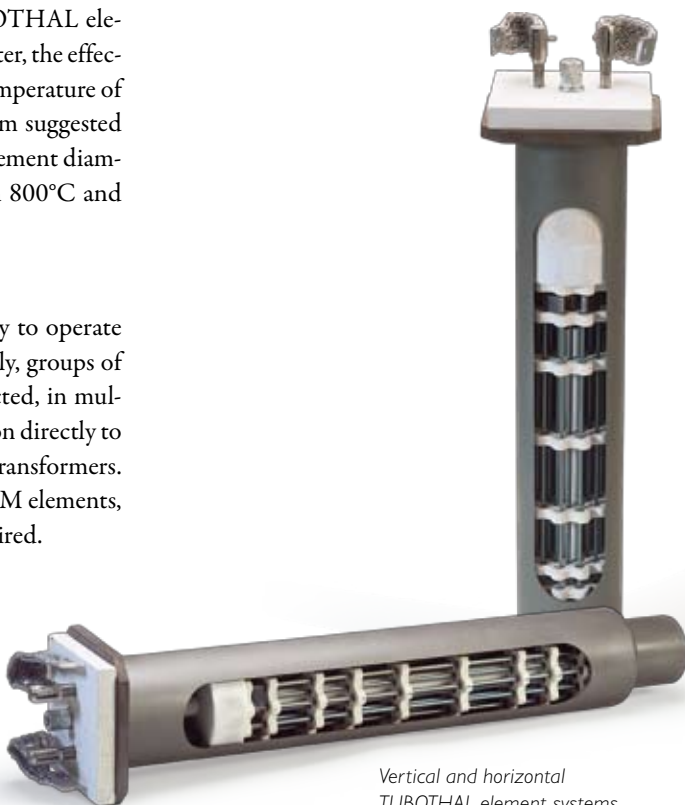
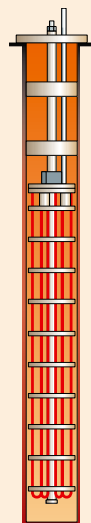
Power Supply

Although individual elements are likely to operate at a voltage lower than that of the supply, groups of elements can be generally series-connected, in multiple element installations, for connection directly to the main voltage, without the need for transformers. There is no significant ageing of the APM elements, so a variable voltage supply is not required.

On/off control can be used, but three-term control, using fast or slow, cycle fired thyristors, will ensure a stable element temperature and a longer element life, as well as offering better control of the furnace temperature.

Kanthal TUBOTHAL Benefits

- Very high power levels
- Long life
- “Maintenance free”, longer service intervals
- Low ageing
- Low element weight
- Low thermal mass
- Standardized product for fast delivery and reliability
- Design flexibility
- Most KANTHAL PM tube sizes for TUBOTHAL can also be used for gas heated solutions giving flexibility for changes depending on energy prices



Vertical and horizontal TUBOTHAL element systems.

Kanthal GLOBAL® Heating Systems – Versatility and Reliability

As Kanthal GLOBAL silicon carbide elements remain rigid at all operating temperatures, they do not require any form of support and will operate successfully in most process atmospheres. Normally, they are installed directly in the furnace, without the need for protection with radiant tubes.

Despite this, there are some cases where the elements will benefit from being fitted inside tubes:

- Where elements are being broken because of mechanical damage
- Where elements are chemically attacked by process volatiles
- Where elements may be affected by carbon deposition, either in the furnace or on the elements, leading to short circuiting
- Where it is difficult to seal the furnace atmosphere
- In conversions from other types of radiant tube system

Typical GLOBAL – APM and APMT Applications

Typical applications include aluminum reverberatory furnaces, low pressure and gravity die-casting machinery, batch and continuous heat treatment furnaces, continuous steel industry furnaces and industrial waste incinerators. In all of these cases, GLOBAL elements can operate successfully without tubes, although where element life is compromised by particular furnace conditions, KANTHAL PM radiant tubes are an ideal solution for overcoming problems.

For example, in continuous annealing and galvanising of steel strip, the use of PM radiant tubes protects the elements from mechanical damage in the event of strip breakage, simplifies both the sealing of the

furnace and element replacement, and allows an element life of over 10 years to be achieved. GLOBAL elements are beneficial to tube life also, imparting no mechanical load on the tubes and minimising creep. In addition, the low mass of the heating system allows faster temperature response and also a reduction in the cost of the furnace structure, compared with heavier heating elements.

The use of PM tubes is of particular benefit in controlled atmosphere furnaces, simplifying sealing of the element terminal ends and allowing the element connections to operate in freely ventilated conditions. This is also a benefit when element replacement is required, as it can be carried out while the furnace is still in operation, without any risk of air entering the furnace and diluting the protective atmosphere.

Wide Range of GLOBAL – APM Tube Combinations

Kanthal GLOBAL elements are available in a wide range of product forms, with options of single or double-ended connections. In general, the double ended connection is far more economical in terms of cost per kW installed, as extremely high power densities can be achieved, usually limited only by the surface loading capabilities of the protection tubes. Elements can be loaded up to 15 W/cm^2 (96.8 W/in^2), but are operated normally at between $6\text{--}10 \text{ W/cm}^2$ ($38.7\text{--}64.5 \text{ W/in}^2$) in most industrial applications.

KANTHAL PM are the best metallic radiant tube materials available for the high power outputs that GLOBAL elements can provide. Their resistance to chemical attack, high operating temperature capability and cohesive oxide coating make them the ideal partner for cost effective and low mass electric radiant tube systems.

GLOBAR SD Element in Double-Ended APM Tubes

GLOBAR SD elements can be fitted in either horizontal or vertical radiant tubes. The elements are simply located by ceramic or fiber sleeves at each end of the tubes. Support slots can be provided, so that the elements can be suspended from the top.

The use of small diameter, double-ended tubes, combined with GLOBAR SD elements, offer a very low cost per kilowatt, compared with other systems.



Fig. 14 Kanthal GLOBAR SD element fitted in a KANTHAL PM radiant tube.

GLOBAR SDU Element in Single-Ended APM Tubes

GLOBAR SDU elements can be fitted in either horizontal or vertical radiant tubes. Elements are centralized by ceramic or fiber location blocks at the terminal end of the tubes. A ceramic support is required under the bridge of horizontally mounted elements, but no supports are required under the hot zone.

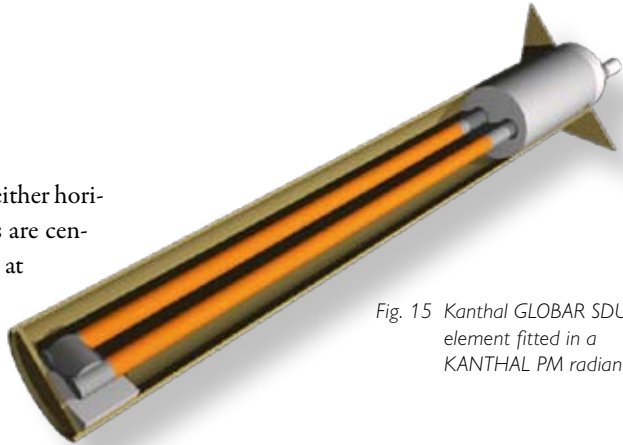


Fig. 15 Kanthal GLOBAR SDU element fitted in a KANTHAL PM radiant tube.

GLOBAR SGR Element in Single-Ended APM Tubes

GLOBAR SGR elements can also be fitted into single-ended heating systems, with both electrical connections at one end. SGR elements are simply located by ceramic or fiber sleeves at the terminal end, and may require an insulating locator at the dump end also, depending on the clearance available. Horizontally mounted elements must be supported at the dump end.

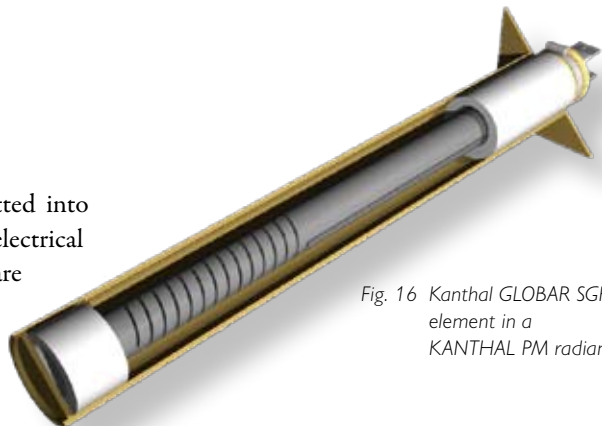


Fig. 16 Kanthal GLOBAR SGR element in a KANTHAL PM radiant tube.

KANTHAL® Super Heating Systems – Extremely Long Service Life

KANTHAL Super electric heating elements operate without protection tubes in the vast majority of applications. However, there are some specific cases where elements will benefit from installation inside tubes.

- In horizontal installations, when elements have to be supported
- The furnace atmosphere is too aggressive
- It is necessary to change elements without interrupting the process
- Elements have to be protected from mechanical damage

KANTHAL PM tubes have become the natural choice of metallic tube material, due to its excellent form stability, high loading capability and resistance to the process gases used in the majority of heat treatment furnaces.

Mostly Used in Continuous Operations

The majority of furnaces equipped with the combination of KANTHAL Super and APM tubes are in continuous operation, horizontally installed, and used mainly for heat treatment processes in the steel and heat treatment industries.

Another option is to fit a KANTHAL Super element

vertically inside a KANTHAL PM tube. In such an installation only one or two supports are needed, since the main function is as a guiding system to centre the element in the tube and to prevent possible contact with the tube wall. This kind of solution is beneficial, for example, in sealed quench furnaces or Carburizing furnaces operating with very high carbon potentials.

The extremely long life of the elements can be exploited to the full by removing any possibility of carbon build-up around the elements that could result in electrical arcing.

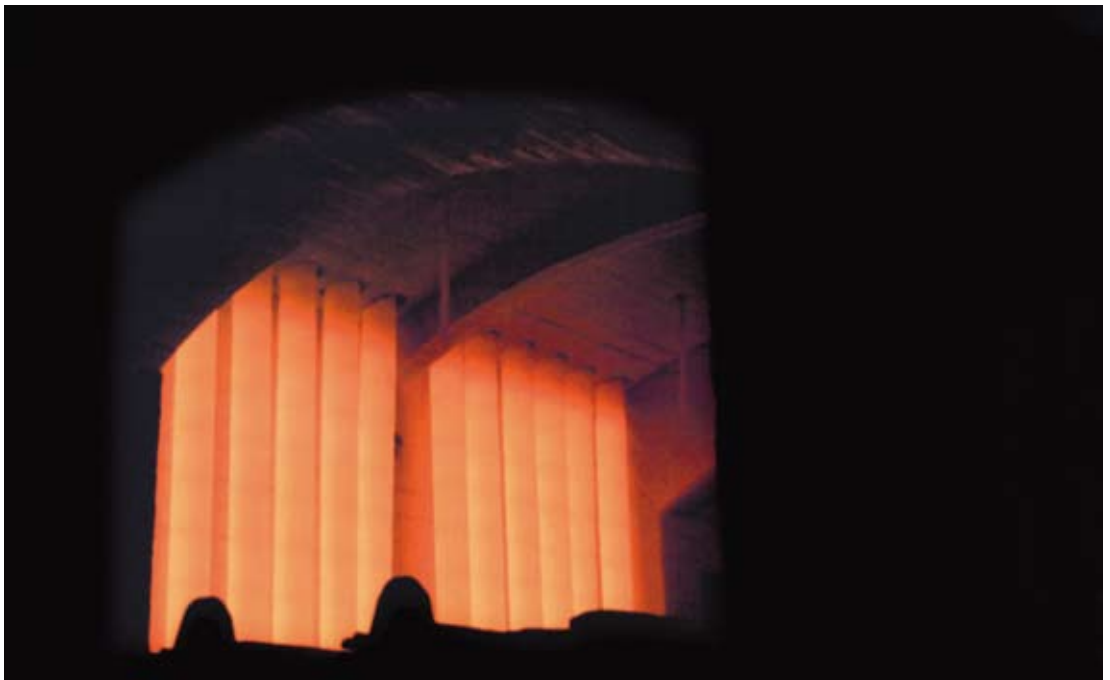


*Horizontal and vertical
KANTHAL Super heated PM tubes.*

Features and Benefits of the System

Long experience of the use of KANTHAL Super elements in radiant tube systems, has highlighted the following features and benefits of the element system.

- Extremely long element life – more than 10 years recorded
- Elements are easily replaced while the furnace is in operation
- Low element weight reduces stress on the radiant tube
- Maintenance costs almost negligible
- High power density
- Reliable installation
- No ageing – no need to match elements



New Areas of Applications

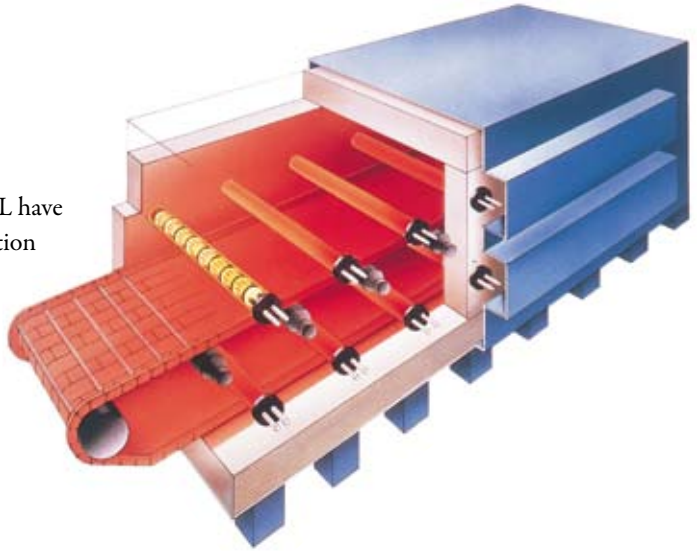
The introduction of KANTHAL PM extruded tubes has rewritten the rulebook. The combination of good hot strength, superior oxide properties, and a far higher temperature capability have opened up entirely new areas of application, previously the domain of NiCr and ceramic tubes, but with none of their drawbacks.

increased without putting tube life at risk. A retrofit with PM tubes for gas or electric furnaces is easily carried out, resulting in higher production and reliable long-term operation.

Heat Treatment Processes

Continuous Hardening, Carburizing and Tempering Furnaces

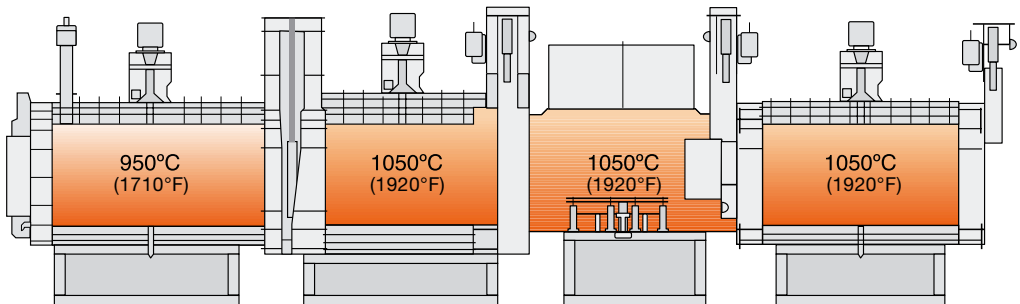
KANTHAL PM tubes and TUBOTHAL have proved to be a maintenance free combination in this type of operation. Aluminum oxide scale protects the tube from carburization, and because of the higher rating potential, productivity can be



High Temperature Carburizing

Carburizing normally takes place at 930°C (1710°F) but with Kanthal TUBOTHAL, it is possible to increase the temperature to 1050°C (1920°F) and the furnace capacity by some 30%. The TUBOTHAL system is in fact the only metallic system that could

work at this elevated temperature. The furnace atmosphere, endothermic with a high carbon potential at the Carburizing zone, is not a problem for PM tubes.



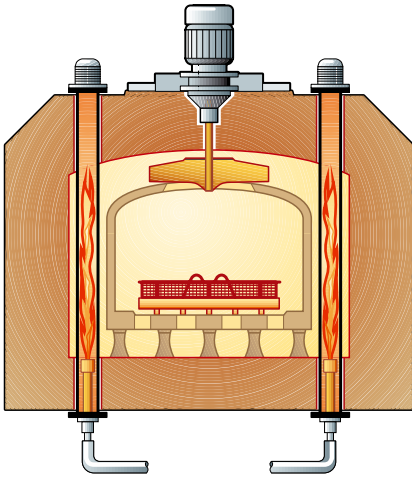
A schematic outline of the furnace type with typically four zones.

No 1 heating at 950°C (1710°F), No 2 heating at 1050°C (1920°F), No 3 Carburizing and No 4 diffusion both at 1050°C (1920°F).

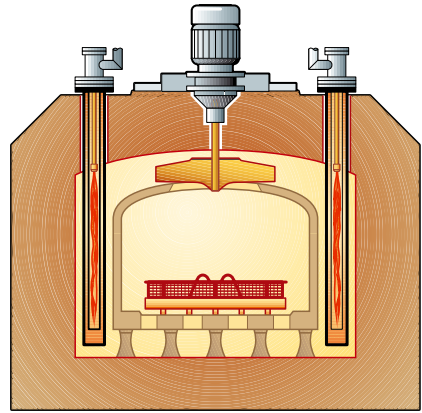
Sealed Quench Furnaces

The carburization resistant properties of KANTHAL PM tubes make them ideal for use in sealed quench furnaces with high carbon potential atmospheres. High loading and temperature possibilities can uprate the furnace and increase production at low cost.

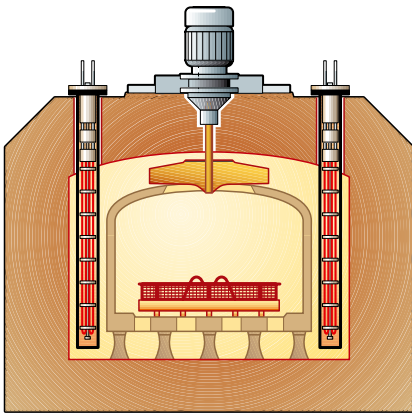
Kanthal offers a complete heating range:
Gas heated – with or without inner tubes
Electric heated – TUBOTHAL, KANTHAL Super or GLOBAR heated



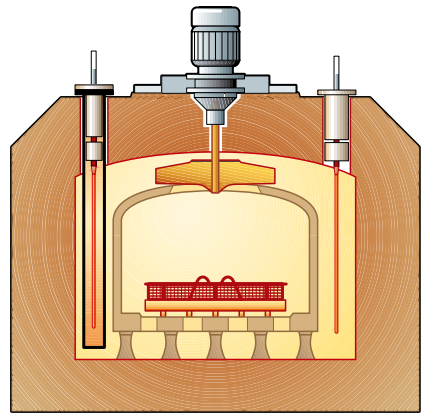
Gas heated – straight through.



Gas heated – S.E.R.



Electric – TUBOTHAL.

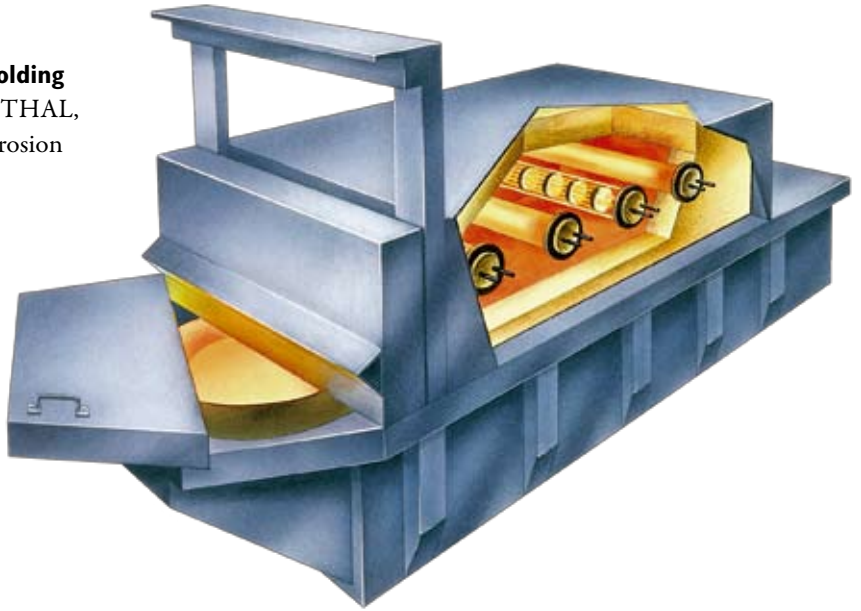


Electric – KANTHAL Super or GLOBAR.

Non-Ferrous Industry

Aluminum Melting and Holding

The high power of TUBOTHAL, combined with the corrosion resistant oxide surface of PM tubes, is the main reason for the success of this system in melting and holding furnaces. A lifetime of up to three trouble free years is not unusual.



Dosing Furnaces

Kanthal GLOBAR silicon carbide elements are normally used without protection tubes. The use of PM tubes has, however, several advantages. Dross and slag is often removed manually with a risk of breaking the elements and contaminating the aluminum bath. PM tubes will protect the elements and contribute to a long maintenance free operation.



Other Areas of Application

Die-casting furnaces.

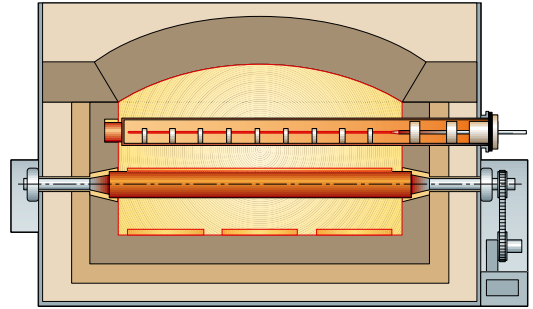
Aluminum filter boxes.

Magnesium melting and holding.

The Steel Industry

Continuous Annealing Lines (CAL) and Galvanizing Lines (CGL)

The high demands for uninterrupted production and furnace capacity are met by KANTHAL PM tubes. High loading potential, long service life and the possibility to exchange elements without interrupting production are the key reasons for their selection in this type of continuous process. PM tubes with TUBOTHAL, KANTHAL Super or GLOBAR heating elements can be installed horizontally or vertically.

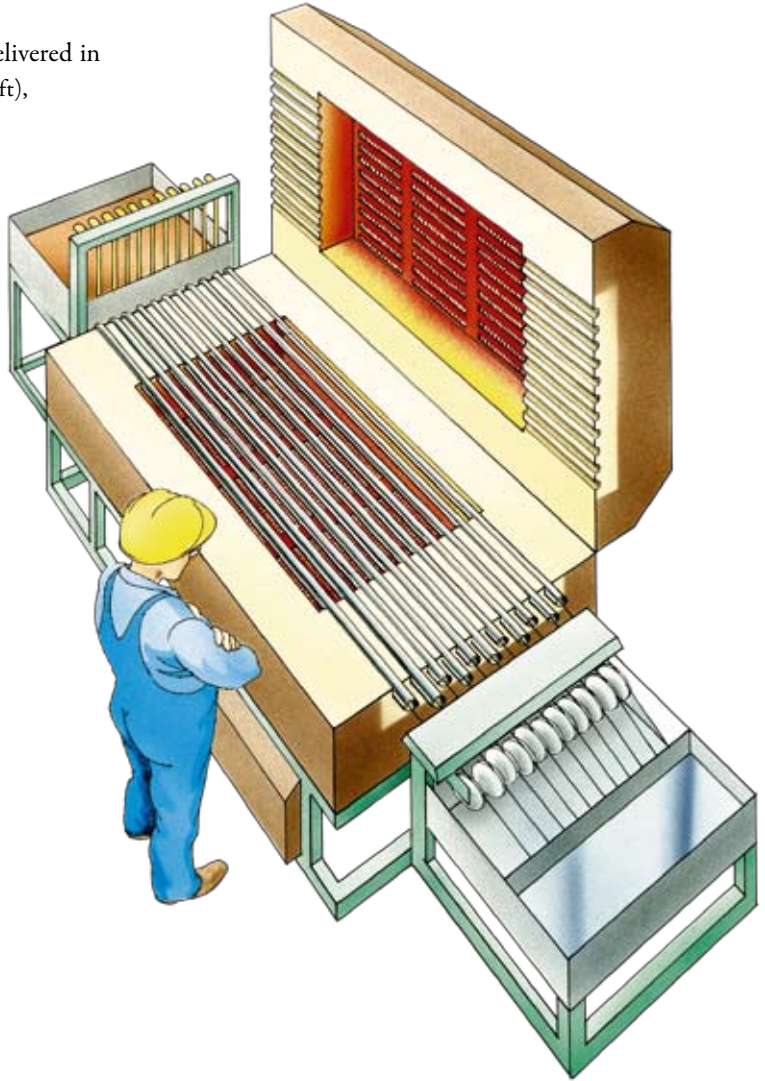


Installation of TUBOTHAL and PM tubes in a continuous annealing line.



Strand Annealing

KANTHAL PM tubes can be delivered in lengths of up to 13 meters (42.6 ft), without welding. They work well in pure hydrogen, where NiCr tubes normally fail due to high temperature scaling. The possibility of using PM tubes at a higher temperature means higher production rates.



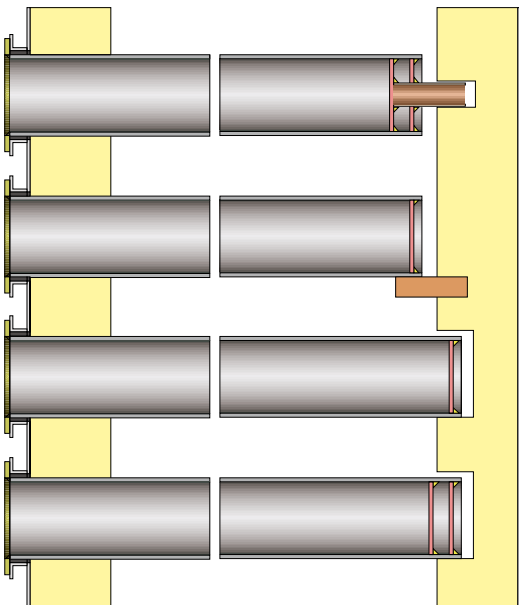
Design and Installation Guidelines

How tubes are supported is a key factor in achieving a long working life. The recommendations on how to support tubes depend on many factors, such as temperature, tube dimension, unsupported length, element weight etc.

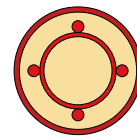
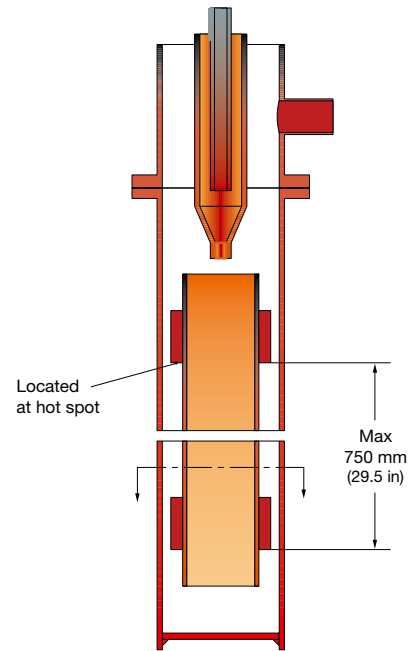
Supports should be designed with as large a support area as possible in order to spread weight and reduce the risk of indentation.

With thermally isolating support materials, the risk of local overheating due to the shielding effect at the contact area, needs to be considered.

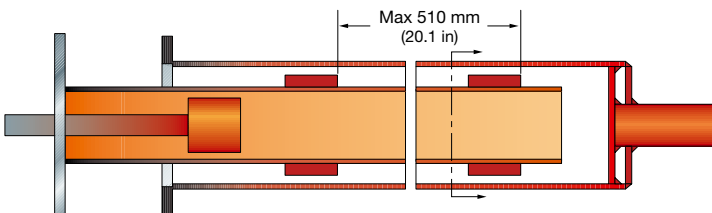
Supports should be designed in such a way that thermal expansion is not restricted.



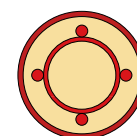
Design of different furnace wall supports.



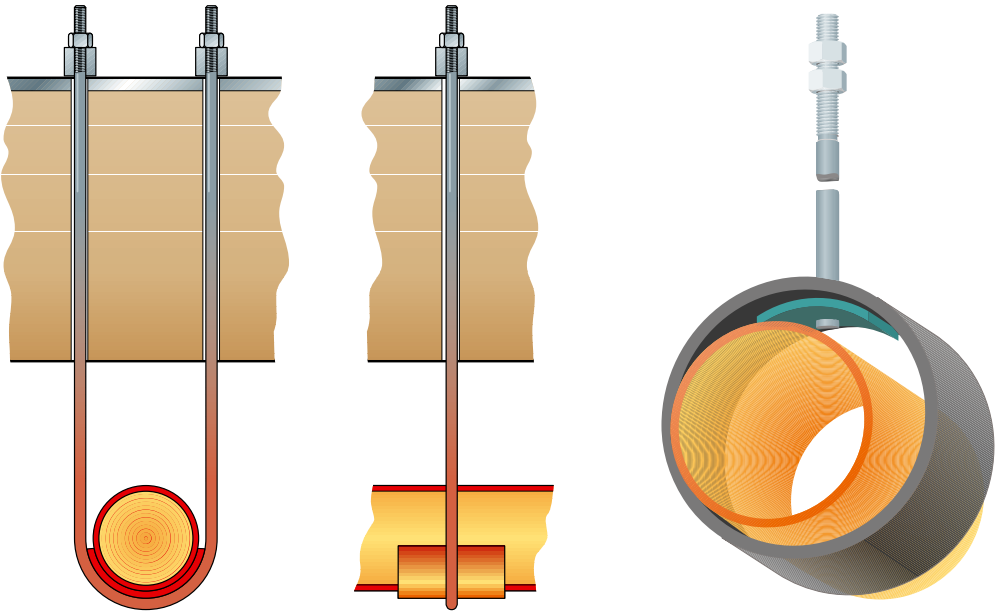
S.E.R. systems, vertically installed.



S.E.R. systems, horizontally installed.



The hangers below are a common solution for reducing the unsupported length and stress on the tube at the support points.



Designs of hanger systems for long tubes.

PM Protection Tubes for Thermocouples and Gas Analysers

KANTHAL PM tubes have a long record of successful installation as protective tubes for thermocouples and gas analysers up to temperatures of 1250°C (2280°F). There are also some installations where tubes have been used up to 1400°C (2550°F), after special design considerations

The most commonly used tubes are in the smaller outer diameters- 26.67, 33.4 and 40 mm (1.05, 1.31 and 1.57 in) OD.

The advantages offered by using KANTHAL PM protection tubes are:

- Resistant to temperatures 150° to 300°C (300 – 570°F) higher than other types of metallic protection tubes.
- High resistance to attack by sulphur compounds and to carburization.
- The high temperature resistance of the material makes it possible to produce tubes with thin walls with a long service life. Thin walls give rapid heat transmission, which means higher sensitivity to temperature variations.
- The aluminum oxide layer on the protection tube has a minimal tendency to spall, which means that contamination is avoided.
- No risk of short-circuiting caused by spalled oxide. In contrast to chromium oxide, aluminum oxide is not electrically conductive.

Thermocouple protection tubes are delivered with welded end caps and suitable threads at the other end.

Tube Dimension and Direct Thread

Ø 26.67 × 2.87 mm	(1.05 × 0.11 in)	¾" BSP
Ø 33.4 × 3.38 mm	(1.31 × 0.13 in)	1" BSP
Ø 40 × 3 mm	(1.57 × 0.12 in)	1 ¼" BSP

Product Range

OD [mm] (in)	Wall thickness [mm] (in)	Weight APM [kg/m] (lb/ft)	Weight APMT [kg/m] (lb/ft)	Max. length [m] (ft)	APM standard stock	APMT standard stock
26.67 (1.05)	2.87 (0.11)	1.52 (1.02)		13.0 (42.6)	•	
33.4 (1.31)	3.38 (0.13)	2.26 (1.52)		13.0 (42.6)	•	
33.7 (1.33)	6.0 (0.24)	3.71 (2.49)		10.5 (34.4)	•	
40 (1.57)	3.0 (0.12)	2.48 (1.67)		13.0 (42.6)	•	
50.8 (2.00)	6.35 (0.25)	6.30 (4.23)	6.39 (4.29)	7.0 (23.0)	•	•
60.33 (2.38)	3.91 (0.15)	4.92 (3.31)		8.0 (26.2)	•	
64 (2.52)	4.0 (0.16)	5.35 (3.60)	5.43 (3.65)	7.0 (23.0)	•	•
75 (2.95)	4.5 (0.18)	7.08 (4.76)	7.19 (4.83)	12.0 (39.4)	•	•
83 (3.27)	5.0 (0.20)	8.70 (5.85)	8.83 (5.93)	12.0 (39.4)	•	•
89 (3.50)	5.5 (0.22)	10.2 (6.85)	10.4 (6.99)	12.0 (39.4)	•	•
100 (3.94)	5.0 (0.20)	10.6 (7.12)	10.8 (7.26)	11.5 (37.7)	•	•
109 (4.29)	5.0 (0.20)	11.6 (7.79)		10.0 (32.8)	•	
115 (4.53)	5.5 (0.22)	13.4 (9.00)	13.6 (9.14)	8.0 (26.2)	•	•
128 (5.04)	5.5 (0.22)	15.0 (10.08)		12.0 (39.4)	•	
146 (5.75)	6.0 (0.24)	18.7 (12.57)		9.5 (31.2)	•	
154 (6.06)	6.0 (0.24)	19.8 (13.30)	20.1 (13.51)	8.0 (26.2)	•	•
164 (6.46)	6.0 (0.24)	21.2 (14.25)		7.0 (23.0)	•	
178 (7.01)	8.0 (0.31)	30.3 (20.36)		6.5 (21.3)	•	
198 (7.80)	9.0 (0.35)	37.9 (25.47)		5.0 (16.4)	•	

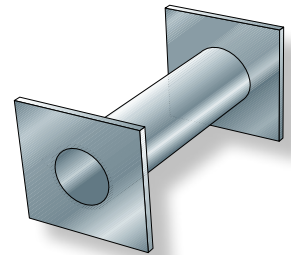
Tolerances

Tubes ≤ OD 50 mm

OD	± 1.5 %, min ± 0.75 mm (0.030 in)
Wall thickness	± 15 %, min ± 0.6 mm (0.024 in)
Straightness	Max height of arc 3 mm/1000 mm (0.12 in/39.4 in)

Tubes > OD 50 mm

OD	± 1 %
Wall thickness	± 15 %
Straightness	Max height of arc 3 mm/1000 mm (0.12 in/39.4 in)



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

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