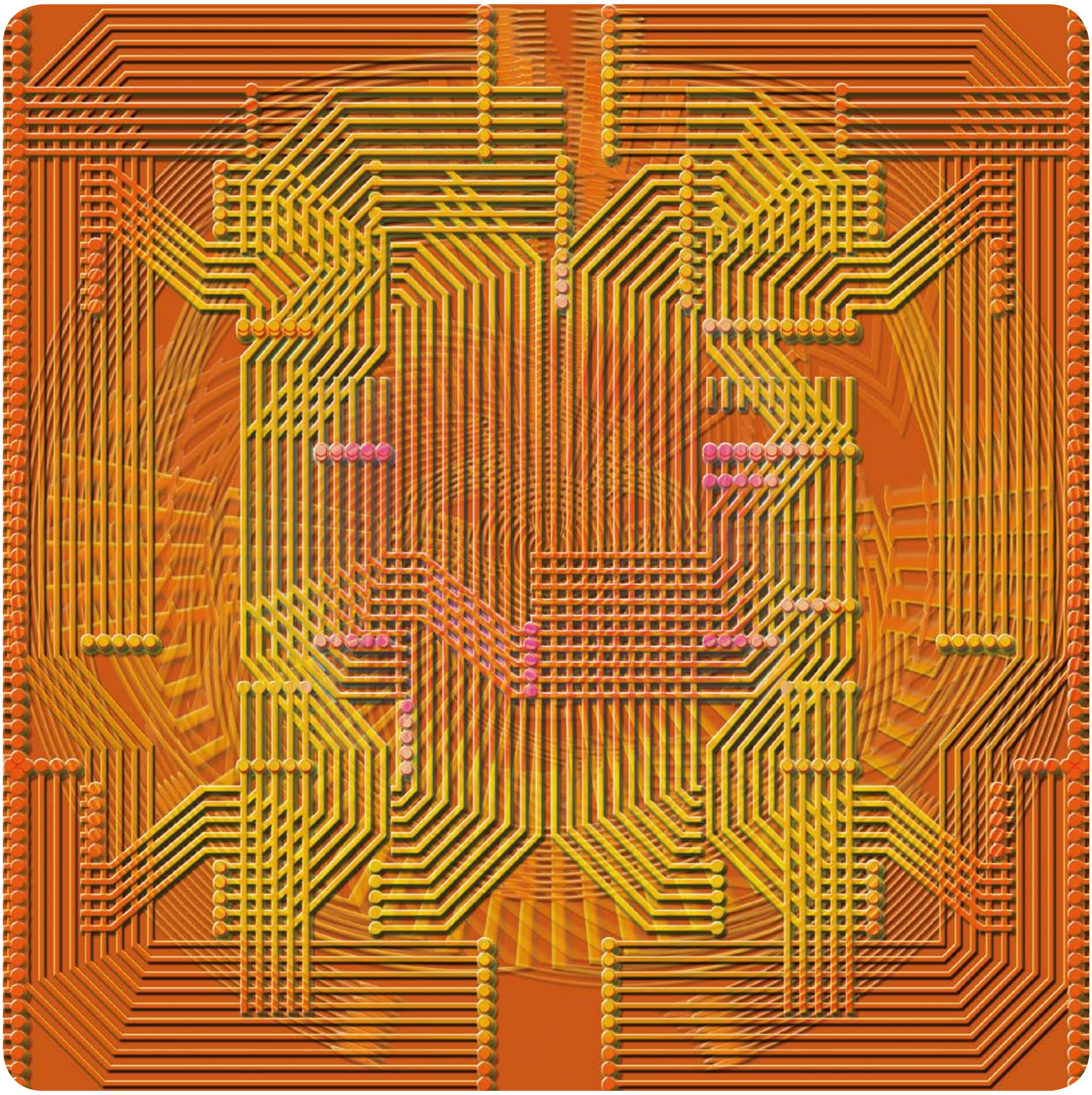
Heating materials / Electrical resistance materials / Heat-resistant construction materials

PYROMAX



RIKEN ENVIRONMENTAL SYSTEM Co., Ltd.

TABLE OF CONTENTS

PYROMAX–SUPER (Ceramic Heating Element)

The catalog of the Pyromax-Super is available separately.

RIKEN ENVIRONMENTAL SYSTEM CO., LTD.

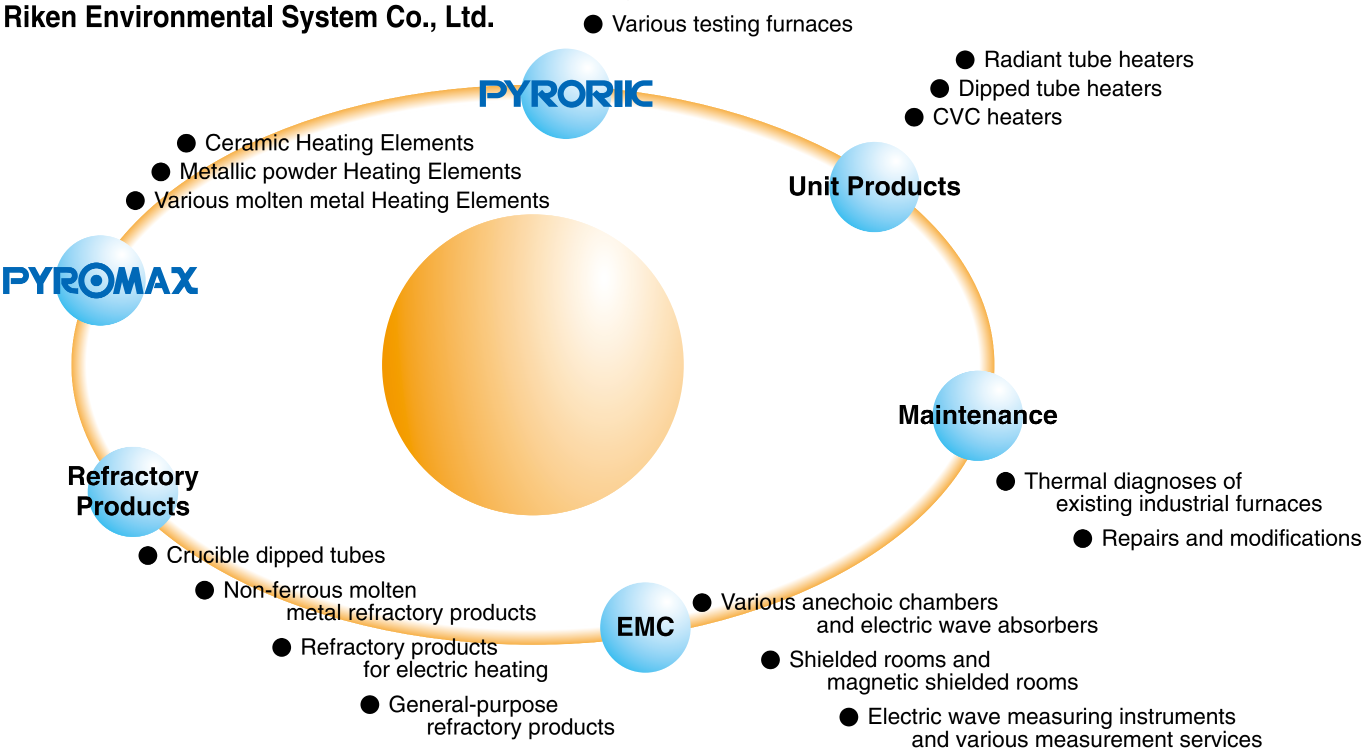
Riken Environmental System Co., Ltd., integrated and developed its engineering businesses and made a fresh start in August 2008, based on original thermo-control technologies developed by Riken Corporation. Industrial furnaces and testing furnaces are indispensable for the development and production of new ceramics, new materials, LCDs, and semiconductors. Riken Environmental System develops general-purpose thermo-processing furnaces, hydrogen gas heating furnaces, magnetic field thermo-processing furnaces, vacuum furnaces, continuous ceramic sintering furnaces and other various furnaces and strongly supports techno-frontier industries.

PYRORIK (Industrial Furnaces)

As one of the major manufacturers of heating wires used for these furnaces, Riken Environmental System offers heating materials for a wide variety of applications, including domestic heating appliances and industrial furnaces producing very high temperatures, such as powder alloy heating elements, the molten alloy heating element PYROMAX, first developed by Riken Environmental System and featuring superior durability, and the ceramic heating element PYROMAX-SUPER, which can sustain produces a maximum temperature of 1800ºC. The company’s ceramic refractory and heat-resistant products are widely used in aluminum and other non-ferrous metal dissolution, IC sintering, and other industrial processes. In the field of EMC, Riken Environmental System offers large-scale electric wave shielded rooms, with the top market share in Japan, and other electric wave anechoic chambers, shielded rooms, and magnetic shielded rooms for various applications.

10m Method Anechoic Chamber

Business Configuration of Riken Environmental System Co., Ltd.



PYRORIK
- Various industrial furnaces
- Various testing furnaces

Unit Products
- Radiant tube heaters
- Dipped tube heaters
- CVC heaters

Maintenance
- Thermal diagnoses of existing industrial furnaces
- Repairs and modifications

EMC
- Various anechoic chambers and electric wave absorbers
- Shielded rooms and magnetic shielded rooms
- Electric wave measuring instruments and various measurement services

Refractory Products
- Crucible dipped tubes
- Non-ferrous molten metal refractory products
- Refractory products for electric heating
- General-purpose refractory products

PYROMAX
- Ceramic Heating Elements
- Metallic powder Heating Elements
- Various molten metal Heating Elements

1. TYPES AND CHARACTERISTICS OF PYROMAX

A) Fe – Cr – Al Heating Materials

Pyromax-C (PX-C)

Pyromax-C, a high-Al and high-Cr alloy, is a high-grade electric heating material, whose electric resistance is 1.60 μΩ-m. The heating element features a maximum service temperature as high as 1400ºC and is suitable for high-temperature furnaces. It has a longer service life than other materials even in a carburizing atmosphere such as RX and DX as well as AX, N_2, and other atmospheres. It is thus economical. With its high resistance, Pyromax-C is also used as a resistant material.

Pyromax-DS (PX-DS)

Pyromax-DS is an alloy whose electric resistance is 1.45 μΩ-m. It is a high-grade heating material for high-temperature furnaces that features the same maximum service temperature of 1400ºC as PX-C. The alloy features superior oxidation resistance in the atmosphere and is suitable for high-temperature industrial furnaces and electric heating equipment as well as domestic electric heating appliances with fine wires. The alloy may also be widely applied to heat-resistant structural members and as a resistant material for the electronic industry.

Pyromax-D (PX-D)

Pyromax-D is an alloy whose electric resistance is 1.40 μΩ-m. The alloy features a relatively high maximum service temperature of 1300ºC, and superior mechanical characteristics and workability. The material is easy-to-use and may be widely used as the heating element for industrial furnaces and domestic electric heating appliances.

Pyromax-D1 (PX-D1)

Pyromax-D1 is a heating material that falls under the category of JIS FCH-1. It is applicable to a variety of different industrial furnaces.

Pyromax-D2 (PX-D2)

Pyromax-D2 is a heating material that falls under the category of JIS FCH-2. It is applicable to a variety of different industrial furnaces and may be used as an electric resistant material.

PYROMAX-PM-D (PX-PM-D)

Pyromax-PM-D is a metallic heating material that features the maximum service temperature of 1420ºC. Developed in cooperative research with Kobe Steel Inc., the heating material is manufactured by making full use of powder metallurgical and various processing technologies. The material features high deformation resistance at high temperature and oxidation resistance, which have been impossible in traditional molten metal heating materials.

Features

- Superior deformation resistance at high temperature

Almost free from sagging and deformation of heating wires at high temperature (1100 to 1420ºC).

- Superior oxidation resistance

Strong alumina film is formed on the heating wire surface, resulting in a long service life.

- Superior workability

Has superior mechanical properties, ensuring easy formation and machining.

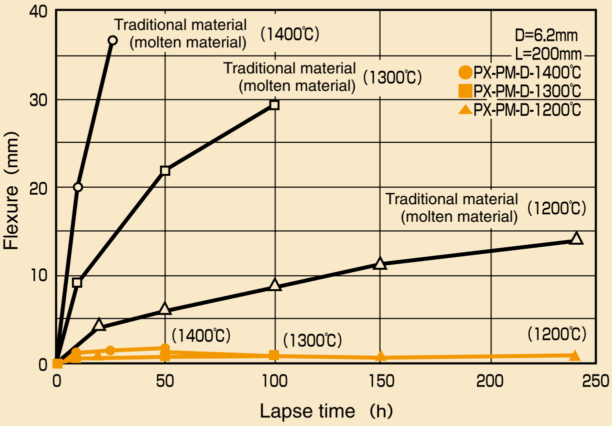
- Easy heating wire design and work

When determining the shapes of heating wires made of molten alloy, it is normally necessary to take deformation into consideration. However, the Pyromax-PM-D is almost free from deformation after long use and features superior welding performance. Thus, it is easy to design and process heating elements.

Applications

Pyromax-PM-D may be used for high-temperature furnaces (1100ºC to 1400ºC), diffusion furnaces, and ceramic sintering furnaces. The material may also be used as structural members for use at high temperatures. The brackets for supporting Pyromax-PM-D heating wires are also available for use. Please consider using them.

Reference: Deformation resistance graph at high temperature



B) NI – Cr Heating Material

Pyromax-N1 (PX-N1)

Pyromax-N1 is a heating material that falls under the category of the JIS NCH-1 and features high strength at high temperature, enables easy cold processing and welding, and will not become brittle after use at high temperature. The material is applicable for a variety of different industrial furnaces and may be used as an electric resistant material.

Pyromax types (codes) Characteristics	**Fe-Cr-Al Heating Materials**						**Ni-Cr Heating Material**
	PX-C	**PX-DS**	**PX-D**	**PX-D1**	**PX-D2**	**PX-PM-D**	**PX-N1**
Standard chemical components %	Al 7.5 Cr 26 Fe remainder	Al 6.0 Cr 23 Fe remainder	Al 5.5 Cr 23 Fe remainder	Al 4 ～ 6 Cr 23 ～ 26 Fe remainder	Al 2 ～ 4 Cr 17 ～ 21 Fe remainder	Al 6.0 Cr 23 Fe remainder Other elements in small q' ty	Cr 19 ～ 21 Fe 1 or less Ni77 or more
Specific gravity	7.00	7.10	7.20	7.20	7.35	7.10	8.40
Thermal expansion factor 20℃～1,000℃ (℃$^{-1}$)	17×10^{-6}	15.1×10^{-6}	13.6×10^{-6}	13.6×10^{-6}	13×10^{-6}	14.8×10^{-6}	17.6×10^{-6}
Melting point (℃)	1,490	1,500	1,500	1,500	1,520	1,500	1,400
Electric resistivity 20℃ ($\mu\Omega$ -m)	1.60 ± 5%	1.45 ± 5%	1.40 ± 5%	1.42 ± 5%	1.23 ± 5%	1.45 ± 5%	1.08 ± 5%
Electric resistance temperature coefficient	-14×10^{-6}	33×10^{-6}	52×10^{-6}	58×10^{-6}	92×10^{-6}	15×10^{-6}	58×10^{-6}
Max. service temp. (Heating element) (℃)	1,400	1,400	1,300	1,200	1,100	1,420	1,100
Increase by oxidation 1,200℃ ($mg/cm^2 \cdot h$)	0.05	0.05	0.07	0.10	0.20	0.05	0.25 or less
Tensile strength MPa (kgf/mm^2)	700 ～ 1,000 (70 ～ 100)	650 ～ 900 (65 ～ 90)	650 ～ 900 (65 ～ 90)	650 ～ 850 (65 ～ 85)	600 ～ 750 (60 ～ 75)	650 ～ 900 (65 ～ 90)	700 ～ 900 (70 ～ 90)
Elongation (%)	10 ～ 25	15 ～ 25	15 ～ 30	10 ～ 30	10 ～ 30	15 ～ 25	20 or more
Hardness Hv	250 ～ 270	220 ～ 240	220 ～ 240	220 ～ 240	200 ～ 220	220 ～ 240	150 ～ 190
Service life index	Ⓤ 300 or more	Ⓤ 300 or more	Ⓤ 300 or more	Ⓤ 100 or more	Ⓤ 70 or more	Ⓤ 300 or more	Ⓘ 300 or more

NOTES:

- Value of service life JIS U method at 1300ºC JIS I method at 1200ºC (Compared value)
- Electric resistance temperature coefficient
  Fe-Cr-Al Heating Element: 20 to 1300ºC
  Ni-Cr Heating Element: 20 to 1100ºC
- The mechanical properties are the values of the standard round wires of 1 to 5 mm in diameter.

2. PYROMAX AS A METALLIC HEATING ELEMENT

A) Formation of Protective Film and Adhesion

A-1 Formation of protective film

When heating elements are used in an oxidizing atmosphere, Al_2O_3 oxide film is formed on the surface of the Fe-Cr-Al alloy or Cr_2O_3 oxide film on the surface of the Ni-Cr alloy. This oxide film serves as a protective film and prevents oxidation in the inner part of the heating element. Thus, the properties of the formed protective film have great influences upon the oxidation resistance and service life of the heating element at high temperatures.

In general, oxidation corrosion of metals and alloys at high temperature develops when oxygen in the atmosphere diffuses and penetrates from the material surface, reacts with metallic elements and components of the heating element, and gradually makes oxide. If a protective film is formed on the surface, diffusion of oxygen in the film is suppressed, and oxidation resistance at high temperature is increased. Normally, the Al_2O_3 protective film formed on the surface of the Fe-Cr-Al alloy withstands higher temperatures than the Cr_2O_3 film on the Ni-Cr alloy. Therefore, the former heating element may be used at higher temperatures than the latter.

The oxide reaction on the heating element surface in the atmosphere is as shown below:

○Fe-Cr-Al alloy

At temperatures lower than approx. 700°C

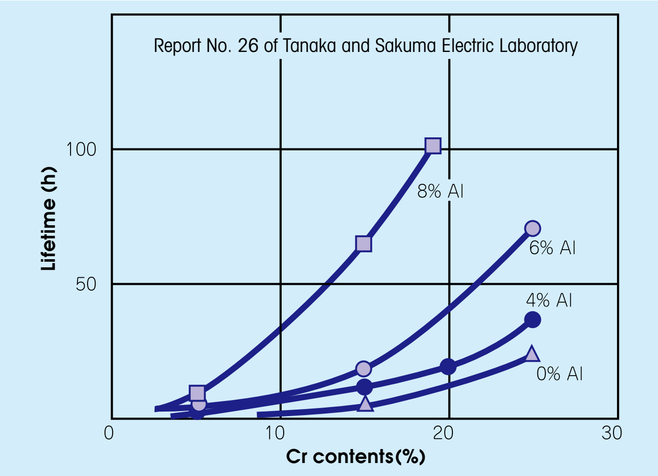
$$2\,(Fe,\ Cr,\ Al) + 4.5\ O_2 \rightarrow Fe_2O_3 + Cr_2O_3 + Al_2O_3 \quad \cdots\cdots \quad (1)$$

At temperatures higher than approx. 700°C

$$\left.\begin{array}{l} Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe \\ Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr \end{array}\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

If the heating element is heated at temperatures over 700ºC, the oxide film formed in reaction (1) changes into Al_2O_3 film in reaction (2), and the Al_2O_3 film has superior oxidation resistance. FeO • Cr_2O_3 and FeO• Al_2O_3 films of the spinel structure may be formed, depending on the Al contents. They are not high-quality protective films. It is clear from reactions (1) and (2), higher-quality Al_2O_3 protective film is produced if more Al is contained in the Fe-Cr-Al Heating Elements. To obtain a higher-quality protective film, Pyromax contains ample amounts of Al and Cr. Figure 1 shows the relationship between the Al and Cr contents in the Fe-Cr-Al Heating Elements and lifetime.

Figure 1 Influences of Al and Cr Contents in Fe-Cr-Al Heating Elements upon Atmospheric Lifetime



○Ni-Cr alloy

$$4\,(Ni,\ Cr) + 5\ O_2 \rightarrow 4NiO + 2Cr_2O_3 \quad \cdots\cdots\cdots\cdots \quad (1)$$

$$3NiO + 2Cr \rightarrow Cr_2O_3 + 3Ni \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

At the beginning of usage, the oxide film formed by reaction (1) changes into the Cr_2O_3 protective film at high temperature by reaction (2).

A-2 Adhesion of protective film

The Al_2O_3 or Cr_2O_3 protective film formed on the surface of metallic heating element should desirably be fine and pure and have a low oxygen diffusion speed. Such a protective film remarkably increases the oxidation resistance of a heating element. However, a heating element is rarely used in conditions that remain constant at high temperature; it is normally heated and cooled repeatedly. In such sequences, the protective film on the heating element surface is cracked and separated due to differences in the thermal expansion of the film and internal alloy, resulting in a reduction in oxidation resistance. Thus, a protective film featuring superior adhesion that will seldom separate during repeated heating and cooling is needed. Phenomenally, it is known that such a protective film featuring superior adhesion may be made more effective by adding a very small quantity of rare earth metals such as Mg, Ca, Ti, or Zr to the heating element materials. To make Pyromax, Riken Environmental System uses several techniques to form a high-adhesion and high-purity protective film in the manufacturing processes in order to improve product quality.

B) Maximum Service Temperature and Lifetime of Heating Element

A heating element with higher service temperature limits may be applied to high-temperature furnaces and offers good design flexibility. However, the characteristics are restricted by the following.

B-1 Oxidation resistance limit temperature

In general, when a metal or alloy is heated in the atmosphere over a certain temperature, oxidation develops, and the oxidation resistance is quickly lost. This temperature is called the oxidation resistance limit temperature of each kind of metal or alloy. When the metal or alloy is heated over this limit temperature, significant oxide penetrates through the oxide film on the surface and diffuses into the material. Some types of film begin to melt, and the oxidation resistance of the material deteriorates remarkably. Therefore, the metallic heating element also has its own oxidation resistance limit temperature, which restricts the maximum service temperature. In the case of the heating element, the maximum service temperature has a direct relationship on the quality of the protective film formed on the surface. Pyromax contains Al is very fine and has good adhesion as mentioned above, and a pure Al_2O_3 protective film is formed on it. With these features, the maximum service temperature is high. For example, the PX-C and PX-DS feature a maximum service temperature of 1400ºC, which is the highest value among maximum service temperatures of alloy heating elements.

Of course, the maximum service temperature of a heating element depends greatly on the materials composition. It also varies with the heating element dimensions and use conditions. Table 1 shows the relationship between the maximum service temperatures of Pyromax heating materials in the atmosphere and wire diameters. As shown in Table 1, the maximum service temperature depends on the steel types and wire diameter of Pyromax elements and drops when the wire diameter becomes thinner.

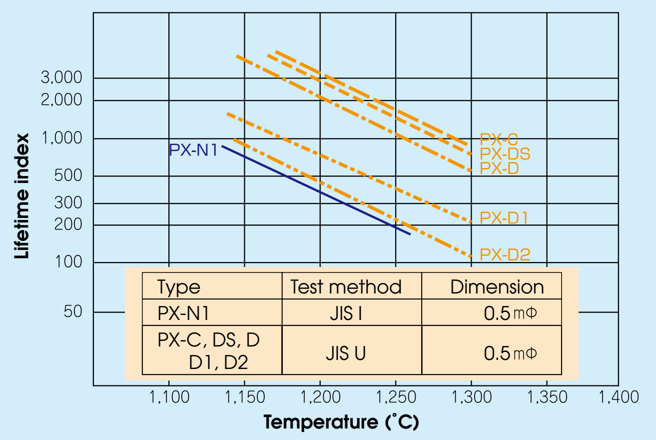
B-2 Lifetime of Heating Elements

Figure 2 shows the relationship between the lifetime of Pyromax and temperature. The lifetime of the heating element depends on the service temperature, as clearly shown. In general, the lifetime of the heating element is shown in measurements in accordance with JIS C 2524 that specifies the method of measuring the lifetime of heating wires. The lifetime of an actually used heating element for industrial furnaces is determined by not only the composition of the heating material itself and the service temperature but also the design and dimensions of the heating element, furnace structure, use ambience, use conditions, and other factors.

Table 1 Pyromax Wire Diameter and Maximum Service Temperature (℃) (Reference values)

Wire diameter and maximum service temperature ℃ Steel type	Round wire dia.(mm)			
	0.1 ～ 0.45	0.5 ～ 0.95	1.0 ～ 3.0	> 3.0
PX – C	975 ～ 1,100	1,125 ～ 1,225	1,250 ～ 1,375	1,400
PX – DS	950 ～ 1,075	1,100 ～ 1,200	1,225 ～ 1,350	1,400
PX – D	925 ～ 1,050	1,050 ～ 1,150	1,150 ～ 1,250	1,300
PX – D1	900 ～ 950	950 ～ 1,050	1,050 ～ 1,150	1,200
PX – D2	850 ～ 900	900 ～ 1,000	1,000 ～ 1,050	1,100
PX – N1	825 ～ 900	900 ～ 1,000	1,000 ～ 1,050	1,100

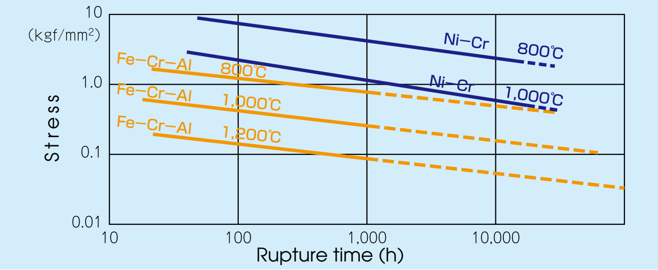
Figure 2 Relationship between Heating Element Lifetime and Temperature



C) High-Temperature Strength

Like general metallic materials, Pyromax is subject to creep deformation due to increased plasticity at high temperatures. This should be taken into consideration when using Pyromax as a heating element or a structural member at high temperature. (See Figure 3) In particular, a Fe-Cr-Al Heating Element has a lower high-temperature strength than a Ni-Cr Heating Element and heating element dimension and shape should be determined with care.

Figure 3 Rupture Strength



D) Influences of Various Ambient Gases

D-1 Normal atmosphere

Pyromax (Fe-Cr-Al Heating Element) has a protective film mainly composed of Al_2O_3 on its surface and demonstrates great oxidation resistance even in the atmosphere. This Al_2O_3 film is grayish white in color, has superior chemical stability and corrosion resistance, and demonstrates performance most effectively in the atmosphere.

D-2 Carburizing atmosphere

RX and DX gases are used most widely. Even in such carburizing environments, Pyromax (Fe-Cr-Al Heating Element) is covered with an Al_2O_3 protective film on its surface, which prevents carburization toward the inside of the material, and shows better high-temperature corrosion resistance than Ni-Cr Heating Elements. Pyromax shows high-temperature corrosion resistance more effectively if the heating element use conditions are considered properly. For example, if the heating element is heated in the atmosphere (for five hours or more at 1000ºC to 1100ºC) before using it in a carburizing atmosphere to form an Al_2O_3 protective film on the surface, carburization toward the inside of the heating element is prevented, and the lifetime is prolonged. Re-oxidation processing in the middle of the operation cycle is also recommended to increase the lifetime of the heating element. In general, CO reacts as shown below in a carburizing atmosphere such as RX and DX:

$$2\,CO \rightarrow CO_2 + C\,(\text{Carbon}) \quad \cdots\cdots\cdots \quad (1)$$

In this reaction, quite active carbon is produced. This active carbon adheres to the heating element surface, diffuses and penetrates into the heating element and develops carburization or reduces metal oxide on the heating element surface and nullifies the characteristics of the protective film. The temperature at which metal oxide is reduced by active carbon at normal atmospheric pressure is as shown below:

FeO	→	740℃ above
NiO	→	220℃ above
Cr_2O_3	→	1,240℃ above
Al_2O_3	→	2,110℃ above

The temperature differs with different oxide types. The above temperatures should not be exceeded. This means that metal oxide is seldom reduced by carbon, and the characteristics are seldom changed by carburization if the Al_2O_3 concentration on the heating element surface is high. As stated above, Pyromax is covered with a high-quality protective film and shows good results even in a carburizing atmosphere.

D-3 H_2 and N_2 atmosphere

H_2 or AX gas (dissolved ammonium gas) will not have a negative influence upon Pyromax, in particular. If AX gas is insufficiently dissolved and the atmosphere contains NH_3 gas, it reacts with the heating element, and lifetime is reduced. Be aware. It is believed that a Ni-Cr Heating Element demonstrates better performance than a Fe-Cr-Al Heating Element in NX gas (96% N_2 + H_2 + CO), widely used as a protective gas for thermal processing. High-performance PX-C and PX-DS containing ample Al provides better performance than the Ni-Cr Heating Elements even in such an atmosphere and used at temperatures up to approximately 1200°C. In a high-purity N_2 atmosphere with a very low dew point, Fe-Cr-Al Heating Elements produce nitride at high temperature and even Pyromax should be used at restricted service temperatures.

It is recommended that the heating element be heated in normal atmosphere before using it in order to form the Al_2O_3 protective film on the surface, as in the carburizing case.

D-4 Others

All substances that hinder the formation of Al_2O_3 and Cr_2O_3 protective films and all substances that react with the protective films and reduce the melting point are harmful to a metallic heating element.

(1) Sulfur

In an atmosphere containing H_2S or SO_2, the Ni-Cr Heating Element reacts with S and the melting point drops. The Ni-Cr Heating Element in this case is not suitable. Fe-Cr-Al Heating Elements yield better results.

(2) Halogen and salts

Halogen elements such as Cl and F and alkali metals, such as Na and K, hinder formation of the protective film. All are harmful to the process.

(3) Molten metal and oxide

Some molten metals such as Cu, Zn, and Al melt the heating element. Oxides of Pb and V are also harmful. In addition, iron oxide reacts with the protective film at high temperature. Thus, the refractory material in contact with the heating element should be selected with care.

Table 2 Service Temperature of Pyromax in Various Gases (Reference values)

Steel type / Ambience	Max. service temperature (˚C) (Heating Element temperature)			
	PX－C	PX－DS	PX－D	PX－N1
Atmosphere	1,400	1,400	1,300	1,100
H_2 gas	1,400	1,400	1,300	1,100
Dissolved ammonium gas	1,300	1,300	1,150	1,100
N_2 gas	1,050	1,000	900	1,050
DX gas	1,250	1,150	1,050	1,050
RX gas	1,200	1,100	1,000	1,050

A) Surface Load Concentration

The heating element is heated by Joules of heat produced by flowing current. Heat is transferred to a variety of different places in a furnace by radiation and/or convection. In general, the magnitude of the power load to the heating element is expressed in electric energy per unit area of the heating element, i.e., surface load concentration. The surface load concentration Wd is expressed as shown below

$$Wd = P/A \ (W/cm^2)$$

Where,

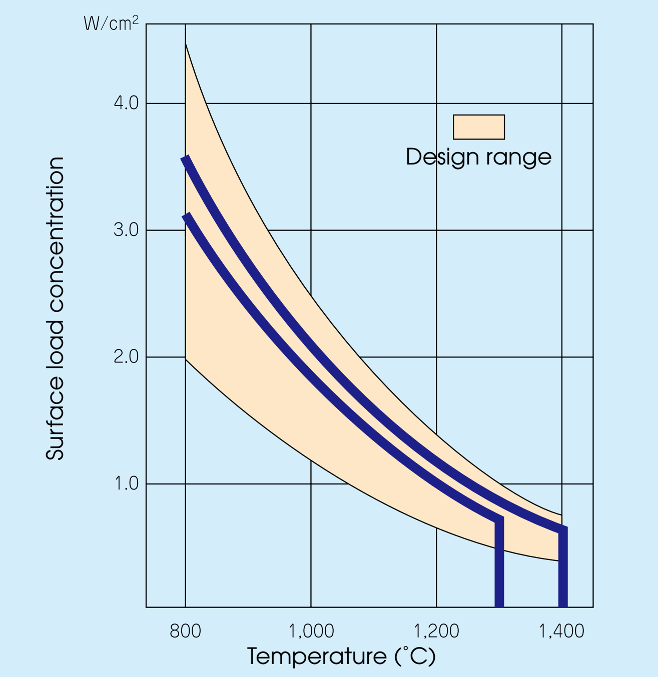
P: Power (W)

A: Surface area of Heating Element (cm^2)

As shown above, the surface load concentration corresponds to the heat quantity per unit area of the heating element. It is an important factor that determines the surface temperature and lifetime of the heating element. Thus, it is necessary to reduce the surface load concentration to lower the surface temperature of the heating element and reduce the difference between the heating element temperature and furnace temperature as far as possible to prolong the service life of the heating element. However, increasing the volume of the heating element to reduce the surface load concentration is not economical, and the heating element volume cannot be reduced as desired.

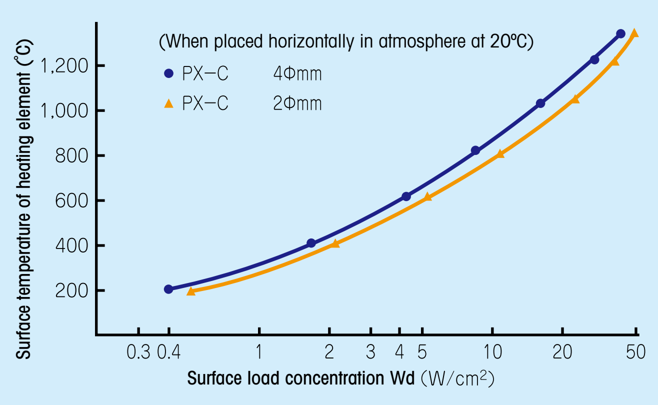
When designing the heating element, the surface load concentration depends on many factors, including furnace temperature, heating element material, use atmosphere, furnace use cycles, and heating element design. There is no general rule. Figure 4 shows the possible range of furnace temperature, which has the greatest influence, and the surface load concentration of Pyromax, based on many application examples.

Figure 4 Furnace Temperature and Surface Load Concentration of the Pyromax



As shown in Figure 4, as the furnace temperature becomes higher it is necessary to reduce the surface load concentration of the heating element to reduce the loads applied to the heating element. In other words, a large quantity of heating elements should be used in furnaces of the same capacity. Figure 5 shows the relationship between the surface load concentration and surface temperature of the heating element. It clearly shows that the heating element temperature greatly depends on the surface load concentration.

Figure 5 Relationship between Surface Load Concentration and Surface Temperature of Heating Element



B) Current Density

If the heating element has a regular cross-sectional shape, such as a round wire, it is convenient to express the load to the heating element in surface load concentration. However, as for a band wire, it is possible to reduce the surface load concentration to zero if the thickness is reduced for a specific cross-sectional area. In such a case, the lifetime of the heating element is not always prolonged, even though the surface load concentration is reduced. For example, if the heating element becomes thinner than the thickness limit, the area exposed to the atmosphere increases, and Al replenishment from the inside is restricted, resulting in difficulty in maintaining the characteristics of the protective film and accordingly reduces lifetime. In particular, it is not desirable to make the heating element thinner than a certain limit, if the heating element is used in high-temperature furnaces or a carburizing atmosphere such as RX and DX. When band wires are used in high-temperature furnaces or a carburizing atmosphere, the heating element lifetime may increase in many cases if the band wire thickness is increased at the expense of the surface load concentration. In such a case, we need to take the current density into consideration, not the surface load concentration, to determine the loads on the heating element. In general, the quantity of heat produced by a heating material is in proportion to the square of the current flowing through the heating element. Thus, it is possible to express the loads to the heating element in the current flowing through a unit area of the heating element, i.e., current density.
Current density Id is expressed as shown below:

$$Id = I/S \ (A/mm^2)$$

Where, I: Current flowing through Heating Element (A)
S: Cross-sectional area of Heating Element (mm^2)

Current density is another important factor for finding the loads on the heating element. When designing a heating element, especially band wires, it is practical to place the highest importance on current density rather than surface load concentration and place second importance on surface load concentration. Table 3 shows furnace temperature and the maximum values of current density of Pyromax.

Table 3 Relationship between Furnace Temperatures and Current Density of Pyromax(Reference values)

Furnace temperature (℃)	Band thickness (mm)	Current density (A/mm²)
1,300	2.9 or more	2.3 or less
1,200	2.6 or more	2.7 or less
1,100	2.3 or more	3.0 or less
1,000	2.0 or more	3.5 or less
800	1.6 or more	4.0 or less

Steel type: PX-C and PX-DS used in atmosphere

1) Calculation example based on surface load concentration

● Design conditions
Electric capacity P = 10 (kw)
Service voltage E = 200 (V)
Current $I = P/E = 10^4/200 = 50$ (A)
Heating element temperature: 1,300℃

How to find the heating element dimensions, provided PX-DS is used and its surface load concentration is 0.7 W/cm²

Find the cm²/Ω value using the following expression based on the resistance temperature coefficient Ct = 1.04 of PX-DS at 1300℃.

$$\begin{aligned} cm^2/\Omega &= I^2 \cdot Ct / Wd \\ &= 50^2 \times 1.04/0.7 = 3{,}714 \ (cm^2/\Omega) \end{aligned}$$

Find the cm²/Ω value closest to the above value in the PX-DS round wire resistance weight table. It is 3.676 and the wire diameter is φ6.0 mm.

Therefore, the values of the heating element are as shown below.
Steel type : PX-DS
Wire diameter : ϕ 6.0 mm round wire
Total resistance : $R = E^2 / P \cdot Ct = 3.85$ (Ω)
Length : $l = R / (\Omega/m) = 75.0$ (m)
Weight : $l \times (g/m) \times 10^{-3} = 15.1$ (kg)
Current density : $Id = I / (S) = 1.77$ (A/mm²)
Surface load concentration : $Wd = P/l \times (cm^2/m) = 0.71$ (W/cm²)

2) Calculation example based on current density

● Design conditions
Electric capacity P = 14 (kw)
Service voltage E = 100 (V)
Current $I = P / E = 14 \times 10^3 / 100 = 140$ (A)
Heating element temperature: 1,200℃

How to find the heating element dimensions, provided the PX-C is used and its current density is 2.5 A/mm²

Find the cross-sectional area of the heating element as shown below:

$$\begin{aligned} S &= I / Id \\ &= 140 / 2.5 = 56 \ (mm^2) \end{aligned}$$

Find the cross-sectional area (mm²) close to the above value in the PX-C band wire resistance weight table. 20 W x 2.9 t and 25 W x 2.3 t are found in the table. The thicker one, which is 20 W x 2.9 t, is selected here.

Therefore, the values of the heating element are as shown below.
Steel type : PX-C
Wire diameter : (w) 20 × (t) 2.9
Total resistance : $R = E^2 / P \cdot Ct = 0.729$ (Ω)
Length : $l = R / (\Omega/m) = 26.13$ (m)
Weight : $l \times (g/m) \times 10^{-3} = 10.5$ (kg)
Current density : $Id = I / (S) = 2.44$ (A/mm²)
Surface load concentration : $Wd = P/l \times (cm^2/m) = 1.17$ (W/cm²)

C) Relationship between Heating Element Temperature and Current

(when held horizontally in atmosphere at 20℃)

* The tables below show reference values only. They may not be applicable to specific heating element designs.

Pyromax-D (PX-D)

Wire type （Φ mm）	Heating Element temperature （℃）						
	200	400	600	800	1,000	1,200	1,300
7.0	45.5	93.3	143	206	289	385	438
6.0	37.7	76.4	117	165	231	307	351
5.5	33.6	67.3	103	146	204	271	310
5.0	29.5	59.7	90.7	128	179	235	270
4.5	25.4	51.8	78.7	111	154	202	231
4.0	21.4	44.0	67.0	93.9	130	170	195
3.5	17.9	36.6	55.9	78.2	109	141	160
3.0	14.6	29.6	45.3	63.6	87.7	113	129
2.5	11.4	23.1	35.4	49.8	68.3	87.7	99.6
2.0	8.39	17.2	26.1	36.6	50.0	64.0	72.7
1.8	7.27	14.9	22.6	31.7	43.2	55.3	62.5
1.6	6.19	12.6	19.3	26.9	36.7	46.8	52.8
1.4	5.16	10.5	16.1	22.4	30.3	38.7	43.7
1.2	4.17	8.58	13.1	18.2	24.6	31.3	35.3
1.0	3.29	6.73	10.2	14.4	19.1	24.1	27.2
0.8	2.45	4.97	7.57	10.5	14.0	17.7	19.9
0.6	1.66	3.36	5.14	7.11	9.39	11.8	13.2
0.4	0.96	1.96	2.98	4.14	5.37	6.72	7.48
0.2	0.38	0.78	1.17	1.62	2.07	2.48	2.77

* Multiply the values shown above by the conversion factors shown on the right to find the current values of other steel types.

Steel type	PX – C	PX – DS	PX – D1	PX – D2
Conversion factor	0.95	0.98	0.99	1.06

Pyromax-N1 (PX-N1)

Wire type （Φ mm）	Heating Element temperature （℃）						
	200	400	600	800	1,000	1,200	1,300
7.0	54.7	116	184	270	365	473	
6.0	43.4	93.2	146	214	289	375	
5.5	38.6	82.5	128	187	254	329	
5.0	33.5	71.9	112	163	220	285	
4.5	29.0	62.2	95.6	139	188	244	
4.0	24.5	52.8	80.3	117	158	204	
3.5	20.3	43.7	65.9	95.4	129	166	
3.0	16.3	35.1	52.5	76.0	103	133	
2.5	12.7	27.0	40.0	57.8	78.9	101	
2.0	9.37	19.6	28.8	41.5	57.2	72.8	
1.8	8.16	17.1	24.8	35.6	49.1	62.2	
1.6	6.91	14.5	21.0	29.0	41.5	52.3	
1.4	5.76	12.0	17.3	25.0	34.1	43.0	
1.2	4.74	9.70	13.8	20.1	27.2	34.2	
1.0	3.67	7.52	10.6	15.3	20.8	26.1	
0.8	2.73	5.59	7.79	11.1	15.2	19.4	
0.6	1.90	3.89	5.29	7.35	10.3	13.2	
0.4	1.10	2.36	3.11	4.25	5.99	7.58	

4. FORMATION AND WELDING OF HEATING ELEMENTS

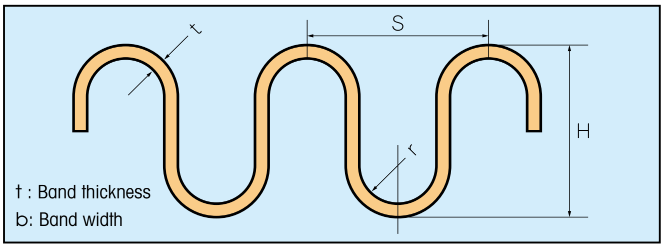
Pyromax has superior mechanical properties and may be formed and machined easily. However, the Fe-Cr-Al Heating Elements Pyromax-C and Pyromax-D have slightly lower tenacity than general steel materials as in other heating elements of the same type. Besides, if they are heated at high temperature for too long, they inevitably become brittle in cold processing.

Take the expansion of the heating element itself into consideration when deciding heating element shapes. The heating element should move freely on its supports. Attention should also be paid to thermal deformation (creeping and sagging) at high temperature.

A) Formation of Wavy Bands

Apply a current to PX-C and PX-D with large cross-sectional areas or heat them with gas burners from 200ºC to 800ºC to form them. Other Heating Elements may be processed at normal temperatures. Figure 1 shows a general forming dimension ratio.

Figure 1 Forming Dimension Example



Radius r = 5 to 8 t
Wave height H = 10b or less
Pitch S = 2 to 4b
Width b = 5 to 12t

When the linear parts of waves are in parallel:

The heating element length of a ridge

$L=2\ (H-t)\ +0.57\cdot S$

The heating element is subject to creep elongation or sagging due to its weight when used at high temperature. Thus, the value of H should be kept low. (See Table 1)

Table 1 (Reference values)

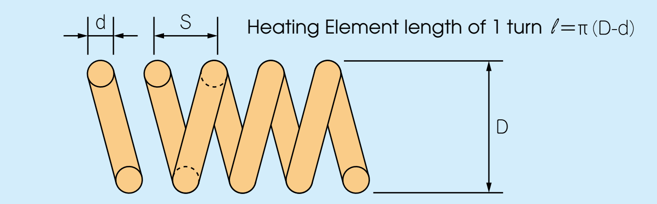
Furnace temperature (℃)	Wave height (mm)	Band thickness (mm)
1,000	250 or lower	2.0 or thicker
1,100	200 or lower	2.3 or thicker
1,200	150 or lower	2.6 or thicker
1,300	120 or lower	2.9 or thicker

B) Formation of Round Wires

Heat the material from 200ºC from 300ºC to form PX-C of 2 mm or more in diameter or make large-diameter (D) coils of large-diameter wires. The relationship between the spiral outer diameter (D) and the wire diameter (d) should be as shown below. (See Figure 2)

Service temperature less than 1000ºC: D = 6 to 8 d
Service temperature over 1000ºC: D = 5 to 7 d
The pitch must be at least twice as large as the wire diameter.

Figure 2



C) Formation of Terminals

Heating element terminals outside the furnace must have a cross-section twice as large as the heating element cross-section in order to prevent overheating. Terminals are normally made of the same or similar type of material as the heating element. For applications at low temperatures, they may also be made of stainless steel (SUS310S or SUS304).

D) Welding of Heating Elements

Pyromax is joined by means of arc welding, resistive welding, gas welding, and soldering according to its application. The most appropriate method for a heating element is argon arc (TIG) welding. Carbon arc welding is also appropriate. When DC current is used for carbon arc welding, use a point-tip carbon electrode as the negative electrode and Pyromax as the positive electrode. After welding the Fe-Cr-Al Heating Elements (PX-C or PX-D), it is necessary to anneal the welded part at 800ºC to 1100ºC immediately to remove any welding distortion. Then cool the welded material naturally in air.

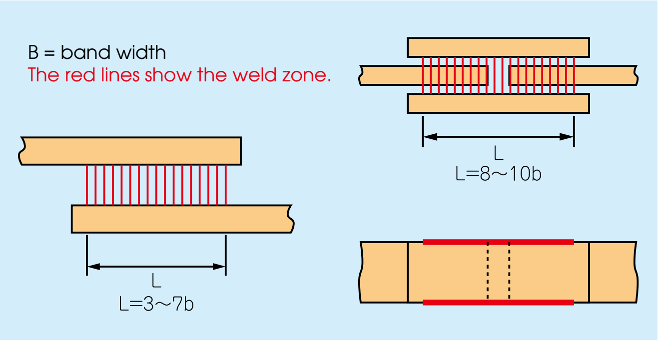
Table 2 Welding Current Table (Reference values)

Band thickness (mm)	Round rod diameter (mm)	Argon arc welding				Carbon arc welding current
		Current (A)	Tungsten rod (diameter in mm)	Argon gas flow rate (m^3/min.)	Welding rod (diameter in mm)	
1.0	2.0	30～70	2.0	5～10	2.0	50～75
1.5	3.0	30～70	2.0	5～10	2.0	75～100
2.0	4.0	100～130	3.0	10～15	3.0	100～125
2.6	5.0	100～150	3.0	10～15	3.0	125～150

D-1 Welding of bands

Overlap the bands to weld them. (See Figure 3)

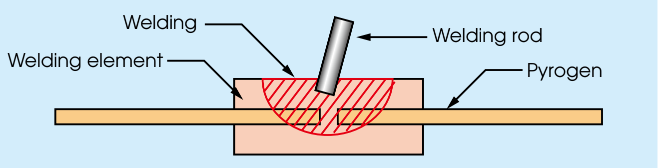
Figure 3



D-2 Welding of round rods

It is recommended that welding elements be used for welding round rods. Machine press joining is also acceptable. (See Figure 4)

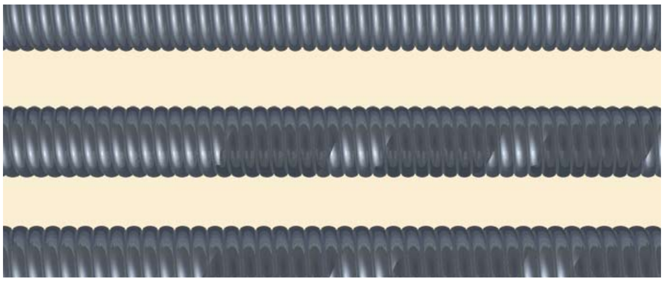
Figure 4



5. APPLIED PRODUCTS

A) Insulated Coil Heaters

Pyromax-DS is a coil heater materials with special insulation processing on the surface and may be used where coil wires are in close contact with each other. In conventional heater designs, a pitch of twice or more as large as the heating element diameter has been required in order to prevent the contact of coil wires. Our insulated coil heaters may be used in close contact conditions.



A-1 Characteristics of insulation film

1) Composition

The insulation film is made of alumina (Al_2O_3) featuring superior insulation characteristics. It is not made by coating but by condensing aluminum, one of the components of the base material alloy of Pyromax, and oxidizing it on the surface. (Patent pending) It has superior adhesion.

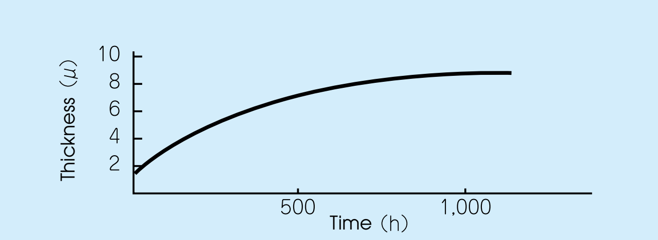
2) Insulation characteristics

The wire-to-wire withstand voltage is 1 V at a coil heater temperature of 800ºC and 0.5 V at 1000ºC. The coil heaters may be used free from problems in this range.

3) Secular changes

As use continues, the insulation characteristics of the film increase. When the coil heater is used at high temperature, aluminum, one of the base components of Pyromax, diffuses to the surface and grows gradually through selective oxidation, and the film accordingly becomes thicker.

Figure 5 Change of Film Thickness at 1050℃



A-2 Applications and advantages

1) Long lifetime

In conventional coil heater designs, a pitch of twice or more as large as the heating element diameter has been required, and restrictions have been placed upon wire diameters (i.e., impossibility of using large-diameter wires). Furthermore, there was a drawback that if the pitch changes during operation, the parts with irregular pitches overheat and deteriorate quickly, resulting in variances in the service life. When an insulated coil heater is used, the coil pitch may be reduced and larger size heating wires may be used, resulting in a prolonged lifetime and stable operations.

2) Compact size

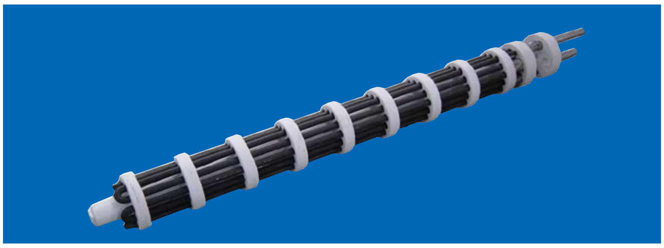
Since larger size wires may be used rather than conventional heating elements, coil heater space may be reduced without reducing lifetime.

3) Vertical use of coil heaters

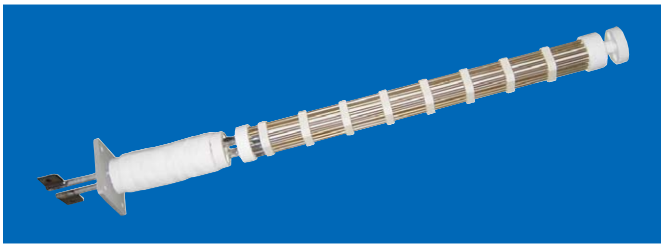
There was no other way than winding coil heaters around insulators when using conventional coil heaters vertically. Insulated coil heaters may be used vertically in close contact conditions.

B) PX – Radiant Tube Heaters

Electrical radiant tube heaters consist of heating elements installed in tubes made of a heat-resistant alloy and radiate heat from the outer surface of the tubes to heat objects. They are mainly used for heating in carburizing gas (such as RX gas) which are subject to electric shorting of the heating elements due to soot and as heaters for furnaces with an ambient unsuitable to heater wire materials. They are also widely used for general-purpose furnaces such as furnaces with a ceramic fiber lining, since they may be installed and replaced relatively easily.



●This type of radiant heater has long been used in a normal combination of a round insulating refractory and U-shaped heater wires.

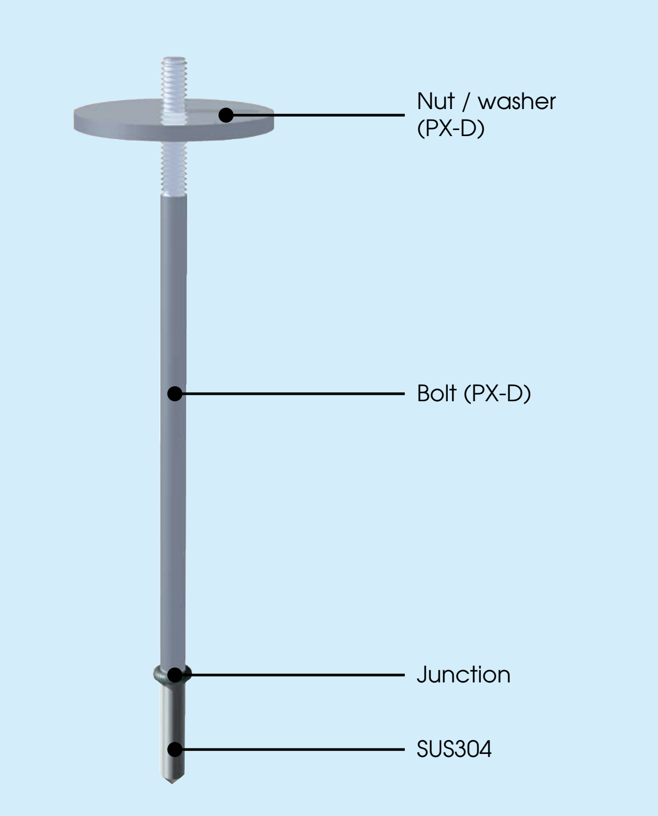


●This was originally developed by Riken Environmental System (Patent pending) and is a combination of a square insulating refractory and U-shaped heater wires. The contact surface between the tube and insulating refractory is small and the gap is large, resulting in improved electric insulation and reduced negative effect on the scales separated from the tube inner surface.

●This was originally developed by Riken Environmental System and is a combination of a special-shape insulating refractory and spirally shaped heater wires. With heater wires made of PX-DS featuring superior heat resistance, this type withstands higher temperatures than conventional types. The device is widely used as a unit heater without tubes.

C) PX – Stud Bolts

Recently, various new technologies and new materials have been developed and applied to industrial furnaces for energy savings and improvement of production efficiency. These new materials include ceramic fibers and irregular-shaped refractories. However, there are no stud bolts and hooks for fixing and supporting these refractories and heat insulating materials, which must withstand high temperatures over 1000ºC and are low in price. PX-stud bolts (made of Pyromax), developed by Riken Environmental System, withstand temperatures as high as 1300ºC and have superior characteristics compared with traditionally used austenite stainless steel bolts.



C-1 Advantages

1) High oxidation resistance. Usable at high temperature over 1000ºC.
Pyromax (PX-DS) has a higher oxidation resistance (especially corrosion resistance in high-temperature gas containing sulfur with sulfur attack effects) than traditional austenite stainless steels (SUS304 and SUS310) and withstands high temperatures over 1000ºC. In many cases it is used at temperatures over 1300ºC in normal atmosphere.

2) Longer lifetime and economical
With superior oxidation resistance, PX-stud bolts may be used at higher temperatures than conventional bolts and have a longer lifetime, resulting in advantageous maintenance and economic efficiency.

3) Little heat loss helpful to energy saving
PX-stud bolts feature less heat conduction and less heat loss from furnace walls than conventional bolts, resulting in energy savings.

4) Easy welding and furnace construction
PX-stud bolts are made by joining Pyromax on the high-temperature side of furnaces and SUS304 on the mounting side to the steel plates of furnaces in a special way. It ensures easy joining with the steel plates of furnaces and efficient furnace construction.

C-2 Characteristics of PX-stud bolt material PX-D

1) Physical characteristics

Material name	Specific gravity g/cm^3	Electric resistivity $\mu\Omega$ -m	Thermal conductivity (500℃) Cal/s·cm·℃	Melting point ℃	Thermal expansion coefficient (20～1,000℃)
PX-D	7.2	1.40	0.035	1,500	13.6×10^{-6}
SUS310	8.0	0.78	0.045	1,450	19.0×10^{-6}

2) Corrosion resistance at high temperatures

Oxidation resistance in atmosphere

Material name	High-temperature oxidation increase in atmosphere Heating time: 4 hours（mg/cm^2h）	
	1,100℃	1,200℃
PX-D	0.05	0.07
SUS310	0.2	0.6

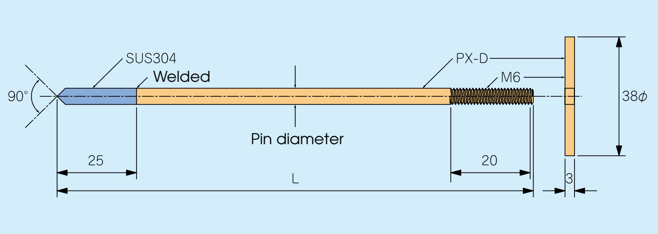
Oxidation resistance in sulfurous acid gas

Material name	High-temperature oxidation increase in sulfurous acid gas Heating time: 4 hours（mg/cm^2h）	
	1,000℃	1,100℃
PX-D	0.25	0.80
SUS310	2.1	5.5

Oxidation resistance in combustion ash (V_2O_5)

Material name	Corrosion loss when carburization-heated in V_2O_5 80 mol% + Na_2So_4 20 mol% 900℃× 10 mg/cm^2h
PX-D	340
SUS310	760

C-3 Standard dimensions of PX-stud bolts

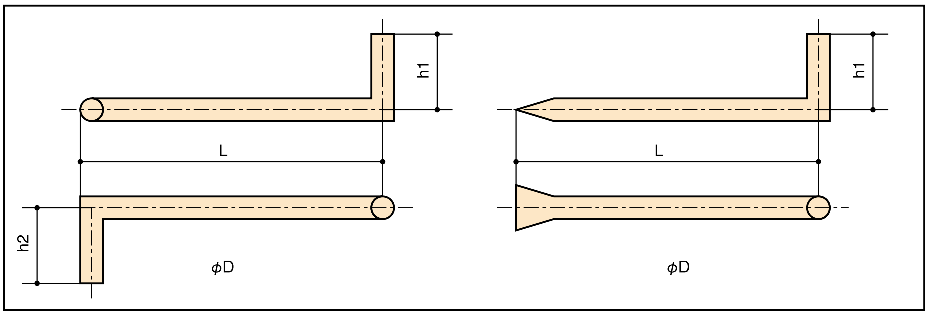


Pin diameter (mm ϕ)	Overall length L (mm)	SUS304 length (mm)	Thread length (mm)	Nut washer thickness x diameter (mm)
(5.2) 6.0 8.0	95 or less	25	20	3 × 38 ϕ
	100			
	125			
	150			
	175			
	200			
	250			
	300			

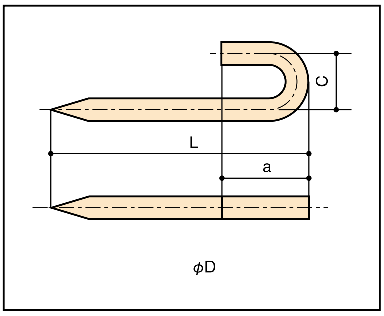
D) Hanger Pins and Separator Pins

Hanger pins are made-to-order products. Specify the dimensions shown in the figure below when placing an order. We will make hanger pins in shapes not shown below upon deliberation. Please consult us.

Hanger pin shape

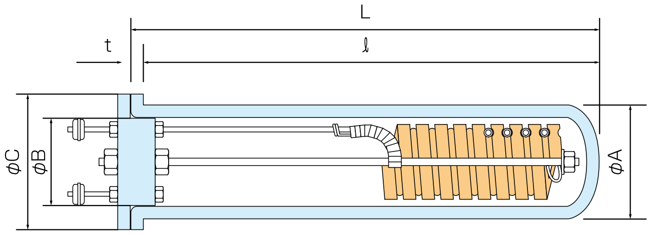


Separator pin shape



E) Dipped Tube Heaters

Dipped tube heaters are designed for aluminum melting and retaining furnaces of the direct heating type. Riken's dipped tube heaters feature long life and high heat efficiency based on long-cultivated Pyromax technologies and refractory manufacturing technologies



Standard dimensions of dipped tube heaters

Dimensions Type	Overall length	Length below collar	Collar thickness	O.D.	I.D.	Collar diameter	Remark
	L	ℓ	t	φ A	φ B	φ C	
RK – 560	560	535	25	110	80	150	
RK – 650	650	625	25	110	80	150	
RK – 775	775	750	25	110	80	150	
RK – 900	900	880	20	110	80	150	
RK – 1030	1,030	1,000	30	110	80	150	
RK – 900G	900	885	15	130	110	145	For gas heating

F) Refractory Products

Riken's refractory products are used in many fields, including dentistry, non-ferrous metal melting, electric heating, gas heating, and IC sintering. Riken Environmental System uses the most appropriate manufacturing methods such as zirconal process, press formation, slurry method, hot press method, ejection method, and other technologies to its refractory products according to the product requirements.

6. DIMENSION, WEIGHT AND RESISTANCE TABLES OF PYROMAX PRODUCTS

• Pyromax–C (PX-C)

Round wire resistance weight table

Round rod (dia.)	Cross-section (mm²)	Surface area/m (cm²/m)	Surface area/ Ω (cm²/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
8.0	50.3	251	7,896	0.0318	352
7.0	38.5	220	5,289	0.0416	269
6.5	33.2	204	4,235	0.0482	232
6.0	28.3	188	3,331	0.0566	198
5.5	23.8	173	2,566	0.0673	166
5.0	19.6	157	1,928	0.0815	137
4.5	15.9	141	1,405	0.101	111
4.0	12.6	126	987	0.127	88.0
3.5	9.62	110	661	0.166	67.3
3.2	8.04	101	505	0.199	56.3
2.9	6.61	91.1	376	0.242	46.2
2.6	5.31	81.7	271	0.301	37.2
2.3	4.15	72.3	188	0.385	29.1
2.0	3.14	62.8	123	0.509	22.0
1.8	2.54	56.5	89.9	0.629	17.8
1.6	2.01	50.3	63.2	0.796	14.1
1.5	1.77	47.1	52.0	0.905	12.4
1.4	1.54	44.0	42.3	1.04	10.8
1.3	1.33	40.8	33.9	1.21	9.29
1.2	1.13	37.7	26.6	1.41	7.92
1.1	0.950	34.6	20.5	1.68	6.65
1.0	0.785	31.4	15.4	2.04	5.50
0.90	0.636	28.3	11.2	2.52	4.45
0.85	0.567	26.7	9.47	2.82	3.97
0.80	0.503	25.1	7.90	3.18	3.52
0.75	0.442	23.6	6.51	3.62	3.09
0.70	0.385	22.0	5.29	4.16	2.69
0.65	0.332	20.4	4.24	4.82	2.32
0.60	0.283	18.8	3.33	5.66	1.98
0.55	0.238	17.3	2.57	6.73	1.66
0.50	0.196	15.7	1.93	8.15	1.37
0.45	0.159	14.1	1.41	10.1	1.11
0.40	0.126	12.6	0.987	12.7	0.880
0.35	0.0962	11.0	0.661	16.6	0.673
0.32	0.0804	10.1	0.505	19.9	0.563
0.29	0.0661	9.11	0.376	24.2	0.462
0.26	0.0531	8.17	0.271	30.1	0.372
0.23	0.0415	7.23	0.188	38.5	0.291
0.20	0.0314	6.28	0.123	50.9	0.220

Band wire resistance weight table

Band wire		Cross-section (mm²)	Surface area/m (cm²/m)	Surface area/ Ω (cm²/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	706	0.218	51.3
	1.0	6.11	150	573	0.262	42.8
	0.8	4.89	146	446	0.327	34.2
10	2.9	28.42	258	4,583	0.0563	199
	2.6	25.48	252	4,013	0.0628	178
	2.3	22.54	246	3,466	0.0710	158
	2.0	19.60	240	2,940	0.0816	137
	1.8	17.64	236	2,602	0.0907	124
	1.6	15.68	232	2,274	0.102	110
	1.2	11.76	224	1,646	0.136	82.3
	1.0	9.80	220	1,348	0.163	68.6
	0.8	7.84	216	1,058	0.204	54.9
13	2.9	36.9	318	7,343	0.0433	259
	2.6	33.1	312	6,459	0.0483	232
	2.3	29.3	306	5,604	0.0546	205
	2.0	25.5	300	4,778	0.0628	178
	1.8	22.9	296	4,242	0.0698	161
	1.6	20.4	292	3,720	0.0785	143
	1.2	15.3	284	2,714	0.105	107
	1.0	12.7	280	2,230	0.126	89.2
	0.8	10.2	276	1,758	0.157	71.3
16	2.9	45.9	378	10,852	0.0348	322
	2.6	41.2	372	9,575	0.0389	288
	2.3	36.4	366	8,334	0.0439	255
	2.0	31.7	360	7,128	0.0505	222
	1.8	28.5	356	6,344	0.0561	200
	1.6	25.3	352	5,576	0.0631	177
	1.2	19.0	344	4,087	0.0842	133
	1.0	15.8	340	3,366	0.101	111
20	3.2	63.4	464	18,374	0.0253	444
	2.9	57.4	458	16,436	0.0279	402
	2.6	51.5	452	14,543	0.0311	360
	2.3	45.5	446	12,694	0.0351	319
	2.0	39.6	440	10,890	0.0404	277
	1.8	35.6	436	9,712	0.0449	249
	1.6	31.7	432	8,554	0.0505	222
	1.2	23.8	424	6,296	0.0673	166
	1.0	19.8	420	5,198	0.0808	139
25	3.2	80.0	564	28,200	0.0200	560
	2.9	72.5	558	25,284	0.0221	508
	2.6	65.0	552	22,425	0.0246	455
	2.3	57.5	546	19,622	0.0278	403
	2.0	50.0	540	16,875	0.0320	350
	1.8	45.0	536	15,075	0.0356	315
	1.6	40.0	532	13,300	0.0400	280
32	3.2	102.4	704	45,056	0.0156	717
	2.9	92.8	698	40,484	0.0172	650
	2.6	83.2	692	35,984	0.0192	582
	2.3	73.6	686	31,556	0.0217	515
	2.0	64.0	680	27,200	0.0250	448
	1.8	57.6	676	24,336	0.0278	403
	1.6	51.2	672	21,504	0.0313	358

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300
Coefficient (Ct)	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

• Pyromax–DS (PX-DS)

Round wire resistance weight table					
Round rod (dia.)	Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
10.0	78.5	314	17,017	0.0185	558
8.0	50.3	251	8,712	0.0288	357
7.0	38.5	220	5,837	0.0377	273
6.5	33.2	204	4,673	0.0437	236
6.0	28.3	188	3,676	0.0513	201
5.5	23.8	173	2,831	0.0610	169
5.0	19.6	157	2,127	0.0738	139
4.5	15.9	141	1,551	0.0912	113
4.0	12.6	126	1,089	0.115	89.2
3.5	9.62	110	730	0.151	68.3
3.2	8.04	101	558	0.180	57.1
2.9	6.61	91.1	415	0.220	46.9
2.6	5.31	81.7	299	0.273	37.7
2.3	4.15	72.3	207	0.349	29.5
2.0	3.14	62.8	136	0.462	22.3
1.8	2.54	56.5	99.2	0.570	18.1
1.6	2.01	50.3	69.7	0.721	14.3
1.5	1.77	47.1	57.4	0.821	12.5
1.4	1.54	44.0	46.7	0.942	10.9
1.3	1.33	40.8	37.4	1.09	9.42
1.2	1.13	37.7	29.4	1.28	8.03
1.1	0.950	34.6	22.6	1.53	6.75
1.0	0.785	31.4	17.0	1.85	5.58
0.90	0.636	28.3	12.4	2.28	4.52
0.85	0.567	26.7	10.5	2.56	4.03
0.80	0.503	25.1	8.71	2.88	3.57
0.75	0.442	23.6	7.18	3.28	3.14
0.70	0.385	22.0	5.84	3.77	2.73
0.65	0.332	20.4	4.67	4.37	2.36
0.60	0.283	18.8	3.68	5.13	2.01
0.55	0.238	17.3	2.83	6.10	1.69
0.50	0.196	15.7	2.13	7.38	1.39
0.45	0.159	14.1	1.55	9.12	1.13
0.40	0.126	12.6	1.09	11.5	0.892
0.35	0.0962	11.0	0.730	15.1	0.683
0.32	0.0804	10.1	0.558	18.0	0.571
0.29	0.0661	9.11	0.415	22.0	0.469
0.26	0.0531	8.17	0.299	27.3	0.377
0.23	0.0415	7.23	0.207	34.9	0.295
0.20	0.0314	6.28	0.136	46.2	0.223
0.18	0.0254	5.65	0.0992	57.0	0.181
0.16	0.0201	5.03	0.0697	72.1	0.143
0.15	0.0177	4.71	0.0574	82.1	0.125
0.14	0.0154	4.40	0.0467	94.2	0.109
0.13	0.0133	4.08	0.0374	109	0.0942
0.12	0.0113	3.77	0.0294	128	0.0803
0.11	0.00950	3.46	0.0227	153	0.0675
0.10	0.00785	3.14	0.0170	185	0.0558

Band wire resistance weight table						
Band wire		Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	779	0.198	52.1
	1.0	6.11	150	632	0.237	43.4
	0.8	4.89	146	492	0.297	34.7
10	2.9	28.42	258	5,057	0.0510	202
	2.6	25.48	252	4,428	0.0569	181
	2.3	22.54	246	3,824	0.0643	160
	2.0	19.60	240	3,244	0.0740	139
	1.8	17.64	236	2,871	0.0822	125
	1.6	15.68	232	2,509	0.0925	111
	1.2	11.76	224	1,817	0.123	83.5
	1.0	9.80	220	1,487	0.148	69.6
	0.8	7.84	216	1,168	0.185	55.7
13	2.9	36.9	318	8,103	0.0392	262
	2.6	33.1	312	7,127	0.0438	235
	2.3	29.3	306	6,184	0.0495	208
	2.0	25.5	300	5,272	0.0569	181
	1.8	22.9	296	4,681	0.0632	163
	1.6	20.4	292	4,105	0.0711	145
	1.2	15.3	284	2,994	0.0948	109
	1.0	12.7	280	2,460	0.114	90.5
	0.8	10.2	276	1,940	0.142	72.4
16	2.9	45.9	378	11,975	0.0316	326
	2.6	41.2	372	10,566	0.0352	292
	2.3	36.4	366	9,196	0.0398	259
	2.0	31.7	360	7,865	0.0458	225
	1.8	28.5	356	7,000	0.0509	202
	1.6	25.3	352	6,152	0.0572	180
	1.2	19.0	344	4,509	0.0763	135
	1.0	15.8	340	3,714	0.0915	112
20	3.2	63.4	464	20,275	0.0229	450
	2.9	57.4	458	18,137	0.0253	408
	2.6	51.5	452	16,048	0.0282	366
	2.3	45.5	446	14,007	0.0318	323
	2.0	39.6	440	12,017	0.0366	281
	1.8	35.6	436	10,717	0.0407	253
	1.6	31.7	432	9,438	0.0458	225
	1.2	23.8	424	6,948	0.0610	169
	1.0	19.8	420	5,735	0.0732	141
25	3.2	80.0	564	31,117	0.0181	568
	2.9	72.5	558	27,900	0.0200	515
	2.6	65.0	552	24,745	0.0223	462
	2.3	57.5	546	21,652	0.0252	408
	2.0	50.0	540	18,621	0.0290	355
	1.8	45.0	536	16,634	0.0322	320
	1.6	40.0	532	14,676	0.0363	284
32	3.2	102.4	704	49,717	0.0142	727
	2.9	92.8	698	44,672	0.0156	659
	2.6	83.2	692	39,706	0.0174	591
	2.3	73.6	686	34,820	0.0197	523
	2.0	64.0	680	30,014	0.0227	454
	1.8	57.6	676	26,854	0.0252	409
	1.6	51.2	672	23,729	0.0283	364
40	3.2	128.0	864	76,270	0.0113	909
	2.9	116.0	858	68,640	0.0125	824
	2.6	104.0	852	61,109	0.0139	738
	2.3	92.0	846	53,677	0.0158	653
	2.0	80.0	840	46,345	0.0181	568
	1.8	72.0	836	41,512	0.0201	511

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (℃)	20	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300
Coefficient (Ct)	1.00	1.00	1.00	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.04

• Pyromax–D (PX-D)

Round wire resistance weight table

Round rod (dia.)	Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
10.0	78.5	314	17,624	0.0178	565
8.0	50.3	251	9,024	0.0279	362
7.0	38.5	220	6,045	0.0364	277
6.5	33.2	204	4,840	0.0422	239
6.0	28.3	188	3,807	0.0495	204
5.5	23.8	173	2,932	0.0589	171
5.0	19.6	157	2,203	0.0713	141
4.5	15.9	141	1,606	0.0880	115
4.0	12.6	126	1,128	0.111	90.5
3.5	9.62	110	756	0.146	69.3
3.2	8.04	101	578	0.174	57.9
2.9	6.61	91.1	430	0.212	47.6
2.6	5.31	81.7	310	0.264	38.2
2.3	4.15	72.3	214	0.337	29.9
2.0	3.14	62.8	141	0.446	22.6
1.8	2.54	56.5	103	0.550	18.3
1.6	2.01	50.3	72.2	0.696	14.5
1.5	1.77	47.1	59.5	0.792	12.7
1.4	1.54	44.0	48.4	0.909	11.1
1.3	1.33	40.8	38.7	1.05	9.56
1.2	1.13	37.7	30.5	1.24	8.14

Band wire resistance weight table

Band wire		Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	807	0.191	52.8
	1.0	6.11	150	655	0.229	44.0
	0.8	4.89	146	510	0.286	35.2
10	2.9	28.42	258	5,237	0.0493	205
	2.6	25.48	252	4,586	0.0549	184
	2.3	22.54	246	3,961	0.0621	162
	2.0	19.60	240	3,360	0.0714	141
	1.8	17.64	236	2,974	0.0794	127
	1.6	15.68	232	2,598	0.0893	113
	1.2	11.76	224	1,882	0.119	84.7
	1.0	9.80	220	1,540	0.143	70.6
	0.8	7.84	216	1,210	0.179	56.4
13	2.9	36.9	318	8,392	0.0379	266
	2.6	33.1	312	7,382	0.0423	239
	2.3	29.3	306	6,405	0.0478	211
	2.0	25.5	300	5,460	0.0549	184
	1.8	22.9	296	4,848	0.0611	165
	1.6	20.4	292	4,252	0.0687	147
	1.2	15.3	284	3,101	0.0916	110
	1.0	12.7	280	2,548	0.110	91.7
	0.8	10.2	276	2,009	0.137	73.4
16	2.9	45.9	378	12,403	0.0305	331
	2.6	41.2	372	10,943	0.0340	297
	2.3	36.4	366	9,524	0.0384	262
	2.0	31.7	360	8,146	0.0442	228
	1.8	28.5	356	7,250	0.0491	205
	1.6	25.3	352	6,372	0.0552	182
	1.2	19.0	344	4,671	0.0737	137
	1.0	15.8	340	3,847	0.0884	114
20	3.2	63.4	464	20,995	0.0221	456
	2.9	57.4	458	18,770	0.0244	413
	2.6	51.5	452	16,618	0.0272	371
	2.3	45.5	446	14,528	0.0307	328
	2.0	39.6	440	12,446	0.0354	285
	1.8	35.6	436	11,099	0.0393	257
	1.6	31.7	432	9,776	0.0442	228
	1.2	23.8	424	7,196	0.0589	171
	1.0	19.8	420	5,940	0.0707	143
25	3.2	80.0	564	32,229	0.0175	576
	2.9	72.5	558	28,896	0.0193	522
	2.6	65.0	552	25,629	0.0215	468
	2.3	57.5	546	22,425	0.0243	414
	2.0	50.0	540	19,286	0.0280	360
	1.8	45.0	536	17,229	0.0311	324
	1.6	40.0	532	15,200	0.0350	288
32	3.2	102.4	704	51,493	0.0137	737
	2.9	92.8	698	46,267	0.0151	668
	2.6	83.2	692	41,125	0.0168	599
	2.3	73.6	686	36,064	0.0190	530
	2.0	64.0	680	31,086	0.0219	461
	1.8	57.6	676	27,813	0.0243	415
	1.6	51.2	672	24,576	0.0273	369
40	3.2	128.0	864	78,994	0.0109	922
	2.9	116.0	858	71,091	0.0121	835
	2.6	104.0	852	63,291	0.0135	749
	2.3	92.0	846	55,594	0.0152	662
	2.0	80.0	840	48,000	0.0175	576
	1.8	72.0	836	42,994	0.0194	518

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (℃)	20	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300
Coefficient (Ct)	1.00	1.00	1.00	1.01	1.02	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.06

• Pyromax–D1 (PX-D1)

Round wire resistance weight table

Round rod (dia.)	Cross-section (mm²)	Surface area/m (cm²/m)	Surface area/ Ω (cm²/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
8.0	50.3	251	8,897	0.0283	362
7.0	38.5	220	5,960	0.0369	277
6.5	33.2	204	4,772	0.0428	239
6.0	28.3	188	3,753	0.0502	204
5.5	23.8	173	2,891	0.0598	171
5.0	19.6	157	2,172	0.0723	141
4.5	15.9	141	1,583	0.0893	115
4.0	12.6	126	1,112	0.113	90.5
3.5	9.62	110	745	0.148	69.3
3.2	8.04	101	569	0.177	57.9
2.9	6.61	91.1	424	0.215	47.6
2.6	5.31	81.7	305	0.267	38.2
2.3	4.15	72.3	211	0.342	29.9
2.0	3.14	62.8	139	0.452	22.6
1.8	2.54	56.5	101	0.558	18.3
1.6	2.01	50.3	71.2	0.706	14.5
1.5	1.77	47.1	58.6	0.804	12.7
1.4	1.54	44.0	47.7	0.922	11.1
1.3	1.33	40.8	38.2	1.07	9.56
1.2	1.13	37.7	30.0	1.26	8.14

Band wire resistance weight table

Band wire		Cross-section (mm²)	Surface area/m (cm²/m)	Surface area/ Ω (cm²/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	795	0.194	52.8
	1.0	6.11	150	645	0.232	44.0
	0.8	4.89	146	503	0.291	35.2
10	2.9	28.42	258	5,164	0.0500	205
	2.6	25.48	252	4,522	0.0557	184
	2.3	22.54	246	3,905	0.0630	162
	2.0	19.60	240	3,313	0.0724	141
	1.8	17.64	236	2,932	0.0805	127
	1.6	15.68	232	2,562	0.0906	113
	1.2	11.76	224	1,855	0.121	84.7
	1.0	9.80	220	1,518	0.145	70.6
	0.8	7.84	216	1,193	0.181	56.4
13	2.9	36.9	318	8,274	0.0384	266
	2.6	33.1	312	7,278	0.0429	239
	2.3	29.3	306	6,314	0.0485	211
	2.0	25.5	300	5,383	0.0557	184
	1.8	22.9	296	4,780	0.0619	165
	1.6	20.4	292	4,192	0.0697	147
	1.2	15.3	284	3,058	0.0929	110
	1.0	12.7	280	2,512	0.112	91.7
	0.8	10.2	276	1,981	0.139	73.4
16	2.9	45.9	378	12,228	0.0309	331
	2.6	41.2	372	10,789	0.0345	297
	2.3	36.4	366	9,390	0.0390	262
	2.0	31.7	360	8,032	0.0448	228
	1.8	28.5	356	7,148	0.0498	205
	1.6	25.3	352	6,282	0.0560	182
	1.2	19.0	344	4,605	0.0747	137
	1.0	15.8	340	3,793	0.0896	114
20	3.2	63.4	464	20,704	0.0224	456
	2.9	57.4	458	18,520	0.0247	413
	2.6	51.5	452	16,387	0.0276	371
	2.3	45.5	446	14,303	0.0312	328
	2.0	39.6	440	12,270	0.0359	285
	1.8	35.6	436	10,943	0.0398	257
	1.6	31.7	432	9,638	0.0448	228
	1.2	23.8	424	7,095	0.0598	171
	1.0	19.8	420	5,856	0.0717	143
25	3.2	80.0	564	31,775	0.0178	576
	2.9	72.5	558	28,489	0.0196	522
	2.6	65.0	552	25,268	0.0218	468
	2.3	57.5	546	22,109	0.0247	414
	2.0	50.0	540	19,014	0.0284	360
	1.8	45.0	536	16,986	0.0316	324
	1.6	40.0	532	14,986	0.0355	288
32	3.2	102.4	704	50,767	0.0139	737
	2.9	92.8	698	45,616	0.0153	668
	2.6	83.2	692	40,545	0.0171	599
	2.3	73.6	686	35,556	0.0193	530
	2.0	64.0	680	30,648	0.0222	461
	1.8	57.6	676	27,421	0.0247	415
	1.6	51.2	672	24,230	0.0277	369
40	3.2	128.0	864	77,882	0.0111	922
	2.9	116.0	858	70,090	0.0122	835
	2.6	104.0	852	62,400	0.0137	749
	2.3	92.0	846	54,811	0.0154	662
	2.0	80.0	840	47,324	0.0178	576
	1.8	72.0	836	42,389	0.0197	518

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (℃)	20	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300
Coefficient (Ct)	1.00	1.00	1.01	1.02	1.03	1.04	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.06

• Pyromax–D2 (PX-D2)

Round wire resistance weight table

Round rod (dia.)	Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
5.0	19.6	157	2,508	0.0626	144
4.5	15.9	141	1,828	0.0773	117
4.0	12.6	126	1,284	0.0979	92.4
3.5	9.62	110	860	0.128	70.7
3.2	8.04	101	657	0.153	59.1
2.9	6.61	91.1	489	0.186	48.5
2.6	5.31	81.7	353	0.232	39.0
2.3	4.15	72.3	244	0.296	30.5
2.0	3.14	62.8	160	0.392	23.1
1.8	2.54	56.5	117	0.483	18.7
1.6	2.01	50.3	82.2	0.612	14.8
1.5	1.77	47.1	67.7	0.696	13.0
1.4	1.54	44.0	55.0	0.799	11.3
1.3	1.33	40.8	44.1	0.927	9.76
1.2	1.13	37.7	34.7	1.09	8.31

Band wire resistance weight table

Band wire		Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	918	0.168	53.9
	1.0	6.11	150	745	0.201	44.9
	0.8	4.89	146	580	0.252	35.9
10	2.9	28.42	258	5,961	0.0433	209
	2.6	25.48	252	5,220	0.0483	187
	2.3	22.54	246	4,508	0.0546	166
	2.0	19.60	240	3,824	0.0628	144
	1.8	17.64	236	3,385	0.0697	130
	1.6	15.68	232	2,958	0.0784	115
	1.2	11.76	224	2,142	0.105	86.4
	1.0	9.80	220	1,753	0.126	72.0
	0.8	7.84	216	1,377	0.157	57.6
13	2.0	25.5	300	6,215	0.0483	187
	1.8	22.9	296	5,519	0.0536	169
	1.6	20.4	292	4,839	0.0603	150
	1.2	15.3	284	3,530	0.0805	112
	1.0	12.7	280	2,900	0.0965	93.6
	0.8	10.2	276	2,287	0.121	74.9

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (℃)	20	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300
Coefficient (Ct)	1.00	1.00	1.01	1.02	1.04	1.05	1.07	1.09	1.10	1.10	1.11	1.11	1.11	1.11

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

• Pyromax–PM-D (PX-PM-D)

Round wire resistance weight table

Round rod (dia.)	Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
10.0	78.5	314	17,017	0.0185	558
8.0	50.3	251	8,712	0.0288	357
7.0	38.5	220	5,837	0.0377	273
6.5	33.2	204	4,673	0.0437	236
6.0	28.3	188	3,676	0.0513	201
5.5	23.8	173	2,831	0.0610	169
5.0	19.6	157	2,127	0.0738	139
4.5	15.9	141	1,551	0.0912	113
4.0	12.6	126	1,089	0.115	89.2
3.5	9.62	110	730	0.151	68.3
3.2	8.04	101	558	0.180	57.1
2.9	6.61	91.1	415	0.220	46.9
2.6	5.31	81.7	299	0.273	37.7
2.3	4.15	72.3	207	0.349	29.5
2.0	3.14	62.8	136	0.462	22.3
1.8	2.54	56.5	99.2	0.570	18.1
1.6	2.01	50.3	69.7	0.721	14.3
1.5	1.77	47.1	57.4	0.821	12.5
1.4	1.54	44.0	46.7	0.942	10.9
1.3	1.33	40.8	37.4	1.09	9.42
1.2	1.13	37.7	29.4	1.28	8.03
1.1	0.950	34.6	22.6	1.53	6.75
1.0	0.785	31.4	17.0	1.85	5.58

Band wire resistance weight table

Band wire		Cross-section (mm^2)	Surface area/m (cm^2/m)	Surface area/ Ω (cm^2/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	779	0.198	52.1
	1.0	6.11	150	632	0.237	43.4
10	2.9	28.42	258	5,057	0.0510	202
	2.6	25.48	252	4,428	0.0569	181
	2.3	22.54	246	3,824	0.0643	160
	2.0	19.60	240	3,244	0.0740	139
	1.8	17.64	236	2,871	0.0822	125
	1.6	15.68	232	2,509	0.0925	111
	1.2	11.76	224	1,817	0.123	83.5
	1.0	9.80	220	1,487	0.148	69.6
13	2.9	36.9	318	8,103	0.0392	262
	2.6	33.1	312	7,127	0.0438	235
	2.3	29.3	306	6,184	0.0495	208
	2.0	25.5	300	5,272	0.0569	181
	1.8	22.9	296	4,681	0.0632	163
	1.6	20.4	292	4,105	0.0711	145
	1.2	15.3	284	2,994	0.0948	109
	1.0	12.7	280	2,460	0.114	90.5
16	2.9	45.9	378	11,975	0.0316	326
	2.6	41.2	372	10,566	0.0352	292
	2.3	36.4	366	9,196	0.0398	259
	2.0	31.7	360	7,865	0.0458	225
	1.8	28.5	356	7,000	0.0509	202
	1.6	25.3	352	6,152	0.0572	180
	1.2	19.0	344	4,509	0.0763	135
	1.0	15.8	340	3,714	0.0915	112
20	3.2	63.4	464	20,275	0.0229	450
	2.9	57.4	458	18,137	0.0253	408
	2.6	51.5	452	16,048	0.0282	366
	2.3	45.5	446	14,007	0.0318	323
	2.0	39.6	440	12,017	0.0366	281
	1.8	35.6	436	10,717	0.0407	253
	1.6	31.7	432	9,438	0.0458	225
	1.2	23.8	424	6,948	0.0610	169
	1.0	19.8	420	5,735	0.0732	141
25	3.2	80.0	564	31,117	0.0181	568
	2.9	72.5	558	27,900	0.0200	515
	2.6	65.0	552	24,745	0.0223	462
	2.3	57.5	546	21,652	0.0252	408
	2.0	50.0	540	18,621	0.0290	355
	1.8	45.0	536	16,634	0.0322	320
	1.6	40.0	532	14,676	0.0363	284
	1.2	30.0	524	10,841	0.0483	213
	1.0	25.0	520	8,966	0.0580	178
32	3.2	102.4	704	49,717	0.0142	727
	2.9	92.8	698	44,672	0.0156	659
	2.6	83.2	692	39,706	0.0174	591
	2.3	73.6	686	34,820	0.0197	523
	2.0	64.0	680	30,014	0.0227	454
	1.8	57.6	676	26,854	0.0252	409
	1.6	51.2	672	23,729	0.0283	364
	1.2	38.4	664	17,585	0.0378	273
	1.0	32.0	660	14,566	0.0453	227
40	3.2	128.0	864	76,270	0.0113	909
	2.9	116.0	858	68,640	0.0125	824
	2.6	104.0	852	61,109	0.0139	738
	2.3	92.0	846	53,677	0.0158	653
	2.0	80.0	840	46,345	0.0181	568
	1.8	72.0	836	41,512	0.0201	511

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (℃)	600	700	800	900	1,000	1,100	1,200	1,300	1,400
Coefficient (Ct)	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.04	1.04

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

• Pyromax–N1 (PX-N1)

Round wire resistance weight table					
Round rod (dia.)	Cross-section (mm²)	Surface area/m (cm²/m)	Surface area/ Ω (cm²/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
8.0	50.3	251	11,697	0.0215	422
7.0	38.5	220	7,836	0.0281	323
6.5	33.2	204	6,274	0.0325	279
6.0	28.3	188	4,935	0.0382	238
5.5	23.8	173	3,801	0.0455	200
5.0	19.6	157	2,856	0.0550	165
4.5	15.9	141	2,082	0.0679	134
4.0	12.6	126	1,462	0.0859	106
3.5	9.62	110	980	0.112	80.8
3.2	8.04	101	749	0.134	67.6
2.9	6.61	91.1	557	0.164	55.5
2.6	5.31	81.7	402	0.203	44.6
2.3	4.15	72.3	278	0.260	34.9
2.0	3.14	62.8	183	0.344	26.4
1.8	2.54	56.5	133	0.424	21.4
1.6	2.01	50.3	93.6	0.537	16.9
1.5	1.77	47.1	77.1	0.611	14.8
1.4	1.54	44.0	62.7	0.702	12.9
1.3	1.33	40.8	50.2	0.814	11.1
1.2	1.13	37.7	39.5	0.955	9.50

Band wire resistance weight table						
Band wire		Cross-section (mm²)	Surface area/m (cm²/m)	Surface area/ Ω (cm²/ Ω)	Resistance/m (Ω /m)	Weight/ meter (g/m)
Width (mm)	Thickness (mm)					
6.5	1.2	7.33	154	1,045	0.147	61.6
	1.0	6.11	150	849	0.177	51.3
	0.8	4.89	146	661	0.221	41.1
10	2.9	28.42	258	6,789	0.0380	239
	2.6	25.48	252	5,945	0.0424	214
	2.3	22.54	246	5,134	0.0479	189
	2.0	19.60	240	4,356	0.0551	165
	1.8	17.64	236	3,855	0.0612	148
	1.6	15.68	232	3,368	0.0689	132
	1.2	11.76	224	2,439	0.0918	98.8
	1.0	9.80	220	1,996	0.110	82.3
	0.8	7.84	216	1,568	0.138	65.9
13	2.9	36.9	318	10,879	0.0292	310
	2.6	33.1	312	9,569	0.0326	278
	2.3	29.3	306	8,302	0.0369	246
	2.0	25.5	300	7,078	0.0424	214
	1.8	22.9	296	6,285	0.0471	193
	1.6	20.4	292	5,511	0.0530	171
	1.2	15.3	284	4,020	0.0706	128
	1.0	12.7	280	3,303	0.0848	107
	0.8	10.2	276	2,605	0.106	85.6
16	2.9	45.9	378	16,078	0.0235	386
	2.6	41.2	372	14,186	0.0262	346
	2.3	36.4	366	12,346	0.0296	306
	2.0	31.7	360	10,560	0.0341	266
	1.8	28.5	356	9,398	0.0379	240
	1.6	25.3	352	8,260	0.0426	213
	1.2	19.0	344	6,054	0.0568	160
	1.0	15.8	340	4,987	0.0682	133
20	3.2	63.4	464	27,221	0.0170	532
	2.9	57.4	458	24,350	0.0188	482
	2.6	51.5	452	21,545	0.0210	432
	2.3	45.5	446	18,806	0.0237	383
	2.0	39.6	440	16,133	0.0273	333
	1.8	35.6	436	14,388	0.0303	299
	1.6	31.7	432	12,672	0.0341	266
	1.2	23.8	424	9,328	0.0455	200
	1.0	19.8	420	7,700	0.0545	166
25	3.2	80.0	564	41,778	0.0135	672
	2.9	72.5	558	37,458	0.0149	609
	2.6	65.0	552	33,222	0.0166	546
	2.3	57.5	546	29,069	0.0188	483
	2.0	50.0	540	25,000	0.0216	420
	1.8	45.0	536	22,333	0.0240	378
	1.6	40.0	532	19,704	0.0270	336
32	3.2	102.4	704	66,750	0.0105	860
	2.9	92.8	698	59,976	0.0116	780
	2.6	83.2	692	53,310	0.0130	699
	2.3	73.6	686	46,750	0.0147	618
	2.0	64.0	680	40,296	0.0169	538
	1.8	57.6	676	36,053	0.0188	484
	1.6	51.2	672	31,858	0.0211	430
40	3.2	128.0	864	102,400	0.00844	1,080
	2.9	116.0	858	92,156	0.00931	974
	2.6	104.0	852	82,044	0.0104	874
	2.3	92.0	846	72,067	0.0117	773
	2.0	80.0	840	62,222	0.0135	672
	1.8	72.0	836	55,733	0.0150	605

- The cross-sections (width x thickness) of the band wires are obtained by multiplying by the following coefficients:

6.5 W or less: 0.94, 10 and 13 W: 0.98, 16 and 20 W: 0.99

- Consult us for sizes not shown above.

Multiply the resistance at the normal temperature by the coefficient [Ct] shown below to obtain the resistance at working temperatures.

Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1,000	1,100
Coefficient (Ct)	1.00	1.00	1.01	1.02	1.02	1.02	1.01	1.00	1.00	1.01	1.02	1.03

7. PLACING ORDERS AND SHIPPING PACKAGE OPTIONS

• Placing Orders

Inform us of the following when placing an order for Pyromax.

1. Type of Pyromax
2. Dimensions of Pyromax (round wires or band wires)
3. Form of Pyromax
4. Weight
5. Period of delivery
6. Shipping package option
7. Use or use conditions

• Surface Finish Options

Pyromax is shipped in any of the following surface finishes.

1. Acid wash finish
Washed with acid after annealing
2. Oxidized
Annealed in an oxidizing atmosphere
3. Luster finish
Annealed in dissolved ammonia gas

• Shipping Package Options

Pyromax is shipped in loops or wound around bobbins.

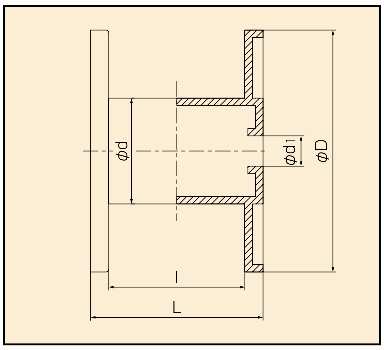
1. Loop

1.Acid wash finish		
Class	Applicable dimensions	I.D. (mm)
Round wire	4.0 mm dia. or more	700
	2.9 ～ 4.0mm φ	600
	1.2 ～ 2.8mm φ	400

2.Oxidized		
Class	Applicable dimensions	I.D. (mm)
Round wire	5.1 ～ 6.0mm φ	650
	3.5 ～ 5.0mm φ	600
	2.3 ～ 3.5mm φ	550
	1.5 ～ 2.2mm φ	500
	1.2 ～ 1.4mm φ	450
Band wire	10 ～ 40mm W	350 or more

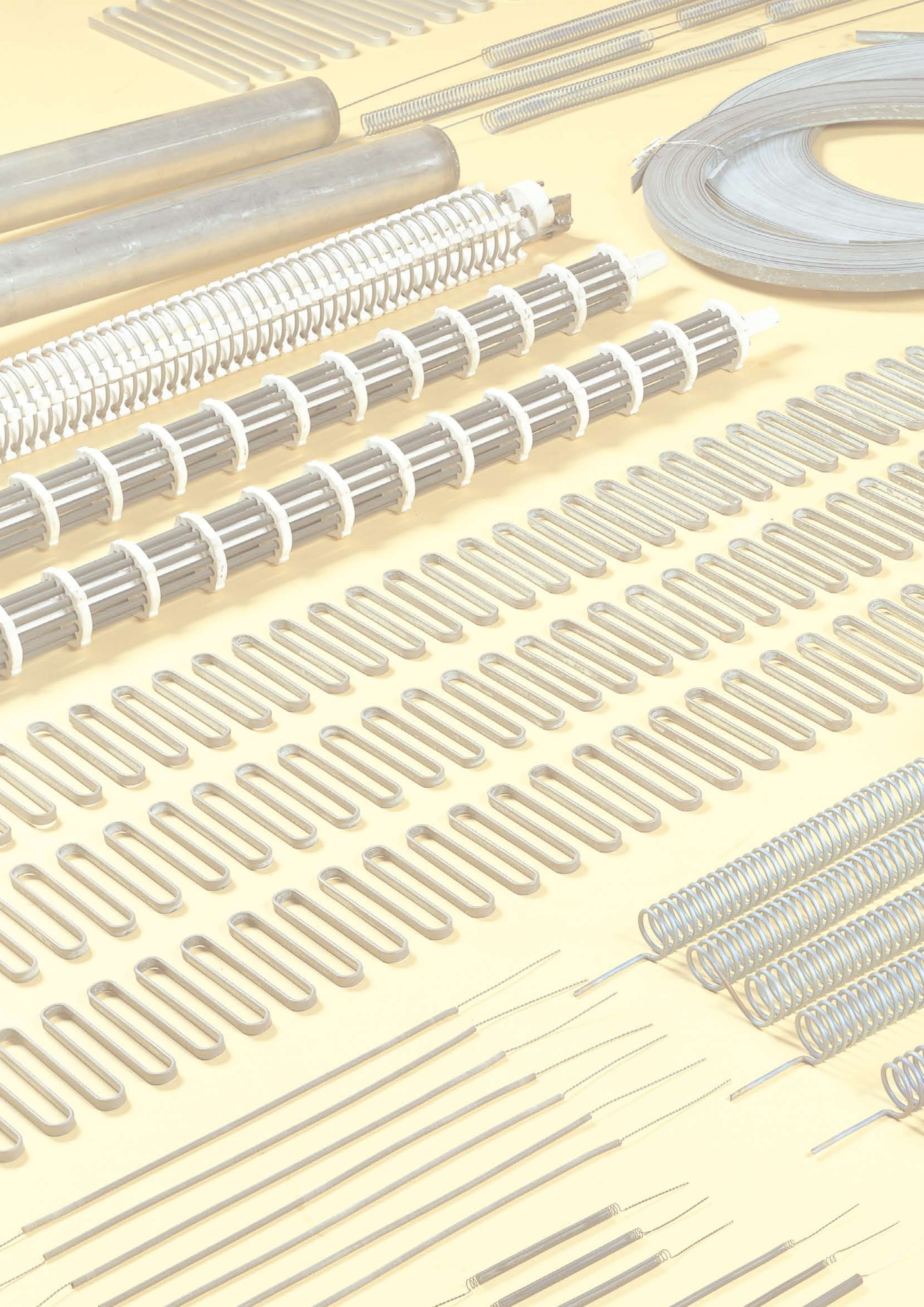
3.Luster finish		
Class	Applicable dimensions	I.D. (mm)
Round wire	1.0 mm dia. or less	Wound around bobbin

2. Wound around bobbin



Bobbin code	Standard weight (kg)	Wire dimension (mm φ)	Bobbin dimension (mm)				
			D	d	d_1	l	L
P－1 （※）	1	0.1 ～ 0.29	100	50	15.5	70	90
P－5	5	0.35 ～ 1.0	160	70	20	90	114
P－10	10	0.5 ～ 1.3	200	90	25	90	134
P－25	25	0.7 ～ 1.3	300	130	30	130	160

(*) Optional



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