

**KANTHAL<sup>®</sup>**

# SILICON CARBIDE HEATING ELEMENTS

GLOBAR<sup>®</sup> SG AND SR





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# INTRODUCTION

## FEATURES

- Unparalleled resistance to oxidation and chemical attack
- Excellent performance at element temperatures up to 1650°C (3000°F)
- Repeatable and reliable results in the most aggressive high temperature processes

**Kanthal® is the world's leading manufacturer of silicon carbide (SiC) heating elements.**

Conventional silicon carbide heating elements are manufactured using a recrystallisation process, where there is no increase in density during firing. In contrast, Globalbar® SG and SR elements are made by a unique, reaction-sintering process. The result is a tough, oxidation resistant material, with controlled resistance and uniform heating characteristics.

Globalbar® SG and SR are Kanthal's highest performance silicon carbide (SiC) heating elements, designed to exceed the requirements of today's most demanding high temperature processes. With a porosity of less than half of conventional recrystallised silicon carbide heating elements, Globalbar® SG and SR elements react much more slowly with the process atmosphere, whether this be oxidizing or reducing. This allows Globalbar® SG and SR elements to be applied in equipment where conventional elements cannot be used, extends the element life, and permits the use of a less expensive electrical power supply.

Globalbar® SG and SR elements are used in applications ranging in temperature from below 600°C (1110°F) up to 1600°C (2910°F) in both air and controlled atmospheres, although the type of atmosphere used will determine the maximum recommended operating temperature.

Globalbar® SG and SR elements may be mounted either vertically or horizontally, and as the material remains rigid, even at the maximum operating temperatures, the heated length does not require any form of support. This results in reduced thermal mass and improves the thermal efficiency of the equipment, especially in intermittent operation. Elements can be replaced easily, even when the furnace is hot, resulting in reduced downtime.

Globalbar® SG and SR elements will accept significantly higher electrical loadings than metallic elements whilst maintaining superior performance in both continuous and intermittent heat processes.

Globalbar® SG and SR elements are available in tubular form, with the hot section formed by helical cutting of the tube, in standard diameters from 12 mm – 54 mm (0.47 – 2.13 in), but diameters up to 75 mm (2.95 in) are available on request. The SG element has one terminal at each end of the element, and the SR has a two-start helical cut, so that both terminals are at the same end.

# PRODUCT RANGE

## GLOBAR® SG ELEMENTS

Globar® SG elements have the conventional central hot zone and two low resistivity cold ends. Elements with unequal cold end lengths, or with multiple hot zones can also be supplied if required. Elements are supplied as standard in one-piece construction, with no joints between the hot zone and the cold ends. The helical cut in the hot section increases the length and reduces the cross-section of the current path, forming a high resistance area, where most of the resistive heat is dissipated.

Standard elements are available in a range of diameters between 12 and 54 mm (0.47 and 2.13 in) as detailed in Fig. 4, but diameters up to 75 mm (2.95 in) are available on request.

Globar® SG elements are available in a wide range of standard sizes, and non standard sizes will be considered.

The cold ends, which pass through the furnace lining, remain relatively cool, and are sprayed over a short length at the end with aluminum, to form a low resistance contact for the aluminum terminal braids.

## STANDARD DIMENSIONS FOR GLOBAR® SG ELEMENTS

Ø A, MM	12	16	19	25	32	38	44	54
B max.	275	325	425	625	725	975	1075	1275
L max.	775	850	950	1450	1550	1800	1900	2150

Ø A, IN	1/2	5/8	3/4	1	1 1/4	1 1/2	1 3/4	2 1/8
B max.	11	13	17	24.5	28.5	38	42	50
L max.	30.5	33.5	37.5	57	61	71	75	85

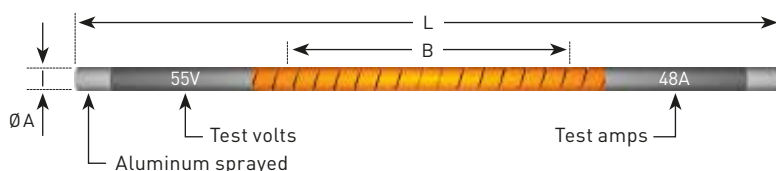


Fig. 1 Globar® SD elements standard dimensions.

## GLOBAR® SR ELEMENTS

Global® SR elements have a two-start helical cut, and are supplied complete with the terminal assembly at one end. The split cold end terminal enables the current to flow through one spiral and return through the second, via the dump end (Fig. 2 – dimension D).

Standard elements are available in a range of diameters between 12 and 54 mm (0.47 and 2.13 in) as detailed in Fig. 2, though diameters of up to 75 mm (2.95 in) are available on request. Global® SR elements are available in a wide range of standard sizes, and non standard sizes will be considered on request.

Global® SR elements come fitted with short aluminum braids or tags in the case of 12 mm (0.47 in) diameter elements. To extend the length of these connections, we recommend the use of Kanthal type Q high purity, fully annealed aluminum braids.

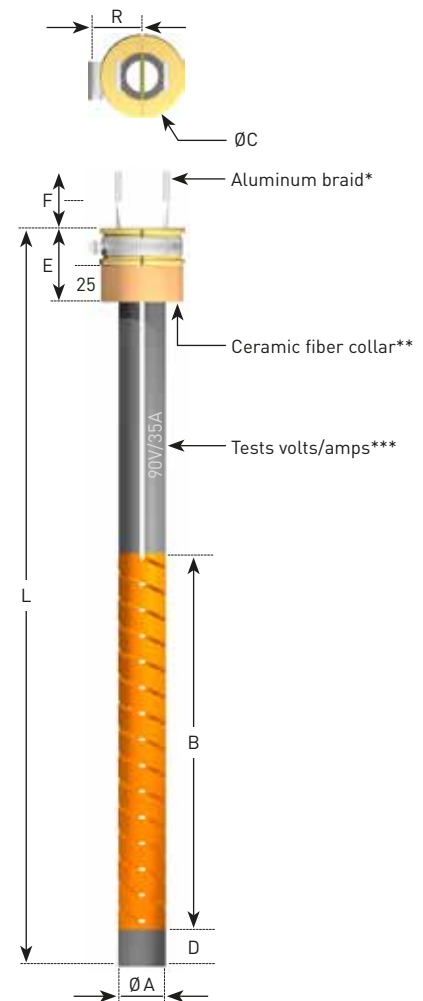
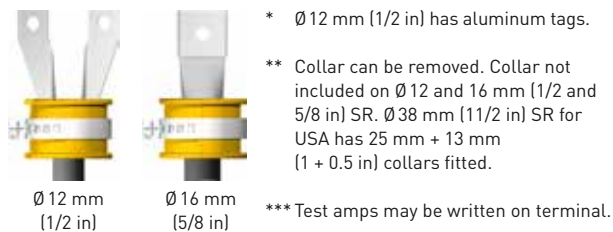


Fig. 2 Global® SR standard dimensions.

## STANDARD DIMENSIONS FOR GLOBAL SR ELEMENTS

Ø A		B MAX		L MAX		Ø C		D		E		F		R	
MM	IN	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN
12	1/2	225	9	425	17	41	1.6	13	0.50	26	1.0	38	1.5	27	1.1
16	5/8	225	9	425	17	42	1.7	13	0.50	26	1.0	38	1.5	27	1.1
19	3/4	275	11	525	21	49	1.9	13	0.50	50	2.0	38	1.5	35	1.4
25	1	375	15	725	28.5	54	2.1	13	0.50	50	2.0	38	1.5	37	1.5
32	1 1/4	475	19	825	32.5	64	2.5	13	0.50	50	2.0	38	1.5	43	1.7
38	1 1/2	550	22	950	37.5	72	2.8	19	0.75	50	2.0	38	1.5	48	1.9
44	1 3/4	550	22	1000	39.5	85	3.4	19	0.75	63	2.5	55	2.2	54	2.1
54	2 1/8	600	24	1050	41.5	93	3.7	25	1.00	63	2.5	65	2.5	58	2.3

## APPLICATIONS

All Global® SG and SR elements may be mounted vertically or horizontally as shown in Fig. 3. The single ended connection of Global® SR elements makes them ideally suited to various applications where standard Global® SG elements cannot conveniently be used, such as where access would be difficult, or in any case where single ended connections are essential.

Global® SG and SR elements are used in a wide variety of furnace applications, from small laboratory furnaces to large industrial heating processes, in different atmospheres and temperature ranges. The elements allow great freedom in furnace design which, combined with simple installation and long operating life, makes them the preferred choice in many applications including: Glass, ceramics, electronics and metal industries and also for research and development. Examples of some typical furnaces where Global® SG and SR elements are the natural choice are illustrated below.

## HIGH TEMPERATURE LABORATORY FURNACES

- Creep testing, MOR and DTA
- General purpose box and tube furnaces

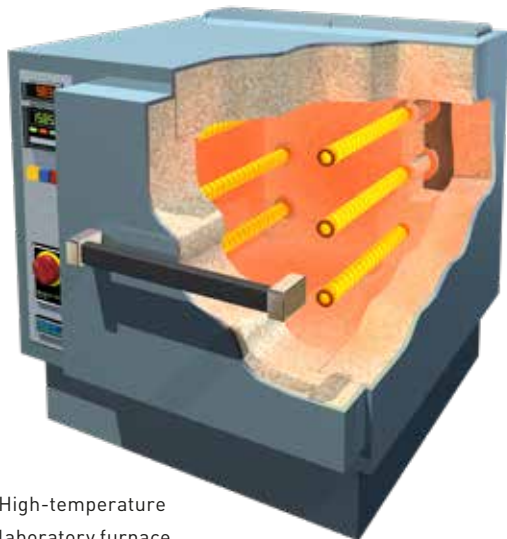
## BATCH AND CONTINUOUS FURNACES TO 1600°C (2910°F)

- Alumina ceramics
- Electronics components
- Tin oxide electrodes
- Luminous powders
- Powder metal sintering

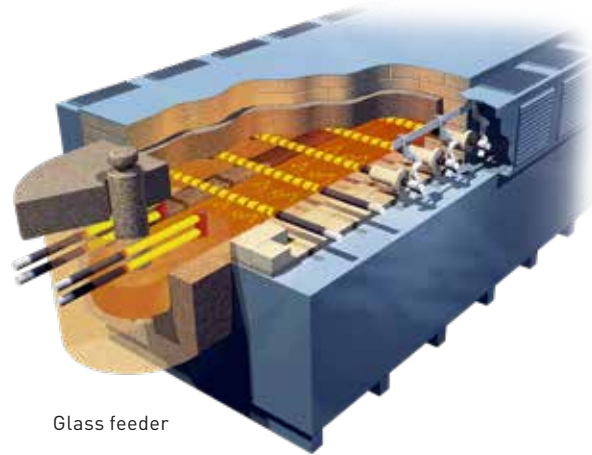
## MELTING AND HOLDING OF NON FERROUS METALS

- Crucible or reverberatory
- Immersion heater

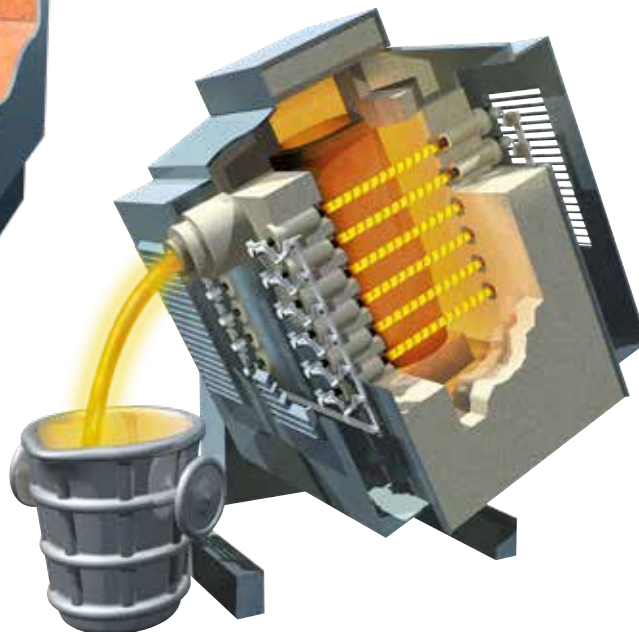
## GLASS FEEDERS



High-temperature laboratory furnace



Glass feeder



Melting and holding furnace

Fig. 3 Example furnaces using Global® SG and Global® SR element.

# INSTALLATION METHODS

## GLOBAR® SG ROD ELEMENT INSTALLATION

Although silicon carbide is rigid and self supporting, it has a fairly low impact strength, and care must be taken when unpacking and handling the elements so that they are not subjected to mechanical shock. Elements should always be supported in both hands.

It is important to ensure that the elements are not restricted in any way and are free to move radially, as well as axially, in their support holes. Element holes must be in line, and the hole alignment should be checked by passing a straight bar, of the same diameter as the support holes, right through the furnace, before fitting the elements.

Under no circumstances should the element hot zone be allowed to enter the element support holes as this will lead to localised overheating and premature failure.

Special lead-in sleeves are available for installing all diameters of Globar® SG and SR elements and these are detailed in Fig. 4 and in the Accessories size list. Sleeves should be fitted from the outside of the furnace, in holes bored to a diameter that will ensure a loose fit, and the sleeves should never be cemented

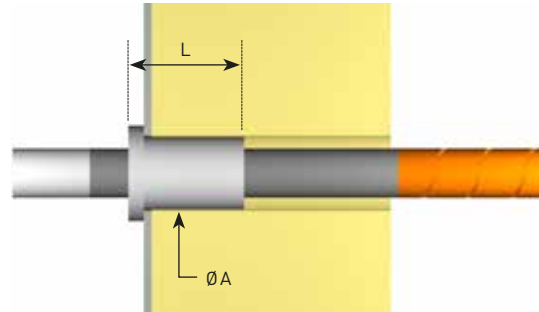


Fig. 4 Globar® SG element installed horizontal in sleeve.

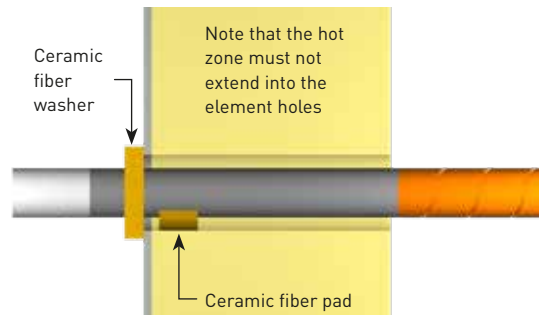


Fig. 5 Globar® SG element installed horizontal without sleeves.

## PATTERN STANDARD DIMENSIONS

PATTERN	Ø ELEMENT		Ø A		L	
	MM	IN	MM	IN	MM	IN
SL10	10	3/8	18	0.71	75	2.95
SL14	12, 14	1/2, 5/9	26	1.02	75	2.95
SL20	16, 19	5/8, 3/4	31	1.22	75	2.95
SL29	25	1	43	1.69	75	2.95
SL32	32	1 1/4	47	1.85	75	2.95
SL38	38	1 1/2	56	2.20	75	2.95
SL45	45	1 3/4	62	2.44	75	2.95
SL55	54	2 1/8	70	2.76	150	5.91



into position. In general, the sleeves will be far shorter than the thickness of the furnace insulation, but the clearance holes should be drilled right through to the hot face, as shown in Fig. 4, to prevent any contact between the elements and the lining, as this can lead to adhesion, and premature failure.

If sleeves are not to be used, for example in brick-lined furnaces, then the elements may be fitted through holes about 4–5 mm (0.16–0.2 in) larger than the element diameter for element sizes up to 19 mm (0.75 in), and about 8–10 mm (0.31–0.39 in) larger for elements from 25–54 mm (1–2.13 in) diameter. Even larger holes may be required where there is a possibility of volatiles condensing in the element holes or on to the cold ends, or where the furnace lining is exceptionally thick.

Elements should always be centralised by supporting each cold end on a small pad of ceramic material, to prevent contact between the element cold ends, and the lead-in holes. Under no circumstances should the cold ends be wrapped with ceramic fiber or other insulation, as this will lead to restriction and possible premature failure. To prevent radiation on to the terminal connections and minimise heat losses, a flexible ceramic fiber washer may be fitted over each terminal end and positioned so that it rests against the outer face of the furnace (Fig. 5).

In all cases, the element ends should extend beyond the sleeve flange, or the outer face of the fiber washer, by a distance of approximately 2–3 times the element diameter.

The use of aluminum braid is recommended for making terminal connections as it does not suffer from progressive oxidation and is sufficiently flat and soft to allow a good connection to be made. Braids are normally attached using type HC spring clips, which are easy to install and require no tools. Where space is restricted, type CC clips may be used, and these require a special tool for installation. Both HC and CC clips rely on spring steel to maintain a good contact, and must be maintained at a temperature below about 250°C (480°F). For higher temperatures, types G or D clamps may be used. These are clamped to the elements using stainless steel set screws, and high temperature lubricant should be applied to the threads before installation, to prevent seizing and later difficulty in tightening

and removal. Screws should be retightened after 24 hours use.

Element connections must be kept reasonably cool and any terminal guards fitted should be well ventilated. Where sealed terminal boxes are essential, for example in controlled atmosphere furnaces, then the following procedures should be followed:

- Increase the free length of cold end outside the furnace to 4–5 times the element diameter.
- Ensure that the surface area of the terminal covers is sufficient to ensure adequate cooling. It may be necessary to provide finned covers to increase the surface area.
- Use type D terminal clamps, and larger section connecting braids than normal.
- Introduce a proportion of the process gas via the terminal boxes, to assist in cooling.
- In very severe cases, some kind of forced cooling may be required.

Where Globar® SG elements are to be installed vertically, a support of electrically insulating, heat-resistant material should be provided below the terminal end.

### **GLOBAR® SR ELEMENT INSTALLATION**

Globar® SR elements are suitable for both horizontal and vertical installation.

As with Globar® SG elements, care must be taken when unpacking and handling Globar® SR elements, so that they are not subjected to mechanical shock. Elements should always be supported using both hands.

### **VERTICAL INSTALLATION**

The elements should be installed in an insulating, ceramic sleeve to prevent possible shorting between both cold end halves, because full element voltage exists along the entire length of the terminal.

Precautions must be taken to prevent the terminals from overheating, especially if the elements are operating at the higher end of their temperature range or if the roof lining is relatively thin. In most cases a 25 mm (1 in) thick pad of ceramic fiber fitted below the terminal assembly will be sufficient, providing the terminal boxes are adequately ventilated. In more severe cases it may be necessary to mount the elements through

a separate support plate, fitted about 75–100 mm (2.95–3.9 in) above the furnace casing, to allow a free flow of air or process gas over the exposed cold ends.

Sleeves must be manufactured from a refractory material capable of withstanding the maximum element temperature (which may be considerably higher than the furnace temperature) and should have a sufficiently high electrical resistivity to prevent conduction between both cold end halves at that temperature. Generally, a high alumina, low iron refractory or vacuum-formed ceramic fiber material will be most suitable.

Sleeves should be fitted from the outside of the furnace, in holes bored to a diameter that will ensure a loose fit, and the sleeves should never be cemented into position. The clearance holes should be drilled right through to the hot face as shown in Fig. 6, and the holes may be flared at the hot face to help prevent any contact between the elements and the lining. Under no circumstances should the element hot zones be allowed to enter the element support holes as this will lead to localised overheating and premature failure.

Elements may also be installed vertically with the terminals at the base and should be located on an electrically insulating, heat resistant support fitted below the terminal end.

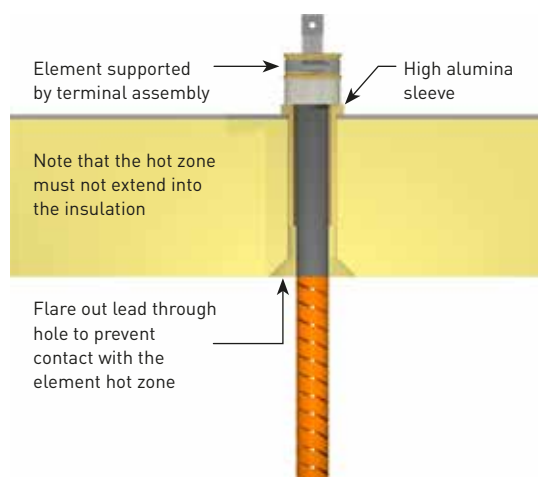


Fig. 6 Globar® SR vertical element.

## HORIZONTAL INSTALLATION

Special precautions are required where Globar® SR elements are to be installed horizontally (Fig. 7), especially with long elements where support at both ends is required, and a longer than standard dump end should be specified when ordering. In this case, the dump end must be supported on a hard smooth surface (a high alumina, low iron refractory) in such a way that the element is free to move laterally during heating and cooling. Although cantilevering of short Globar® SR elements may be possible, Kanthal generally recommend that the dump end should always be supported. It is important to ensure that the dump end support is level and co-planer with the ceramic tube supporting the terminal end, otherwise the element may not be fully supported and may fail prematurely.

Globar® SR elements must always be installed so that the slots in the cold ends are horizontally aligned, otherwise tracking across both cold end halves may occur.

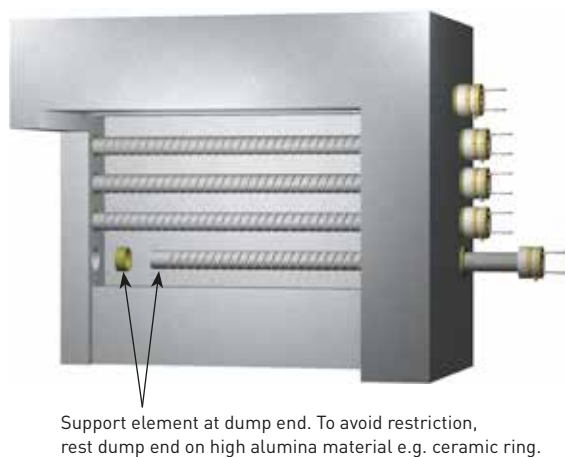


Fig. 7 Globar® SR horizontal element.

### ELEMENT SPACING – ALL ELEMENT TYPES

Elements should be spaced at a minimum of two diameters between centres, but 2.5–3 times the diameter is preferred. There should be 1.5 diameters between element centres and the refractory lining, and a distance of at least two diameters should be allowed between the element centres and the products being fired. It may be necessary to increase this if uniformity of heating is required, especially if the distance between adjacent elements is large (Fig. 8).

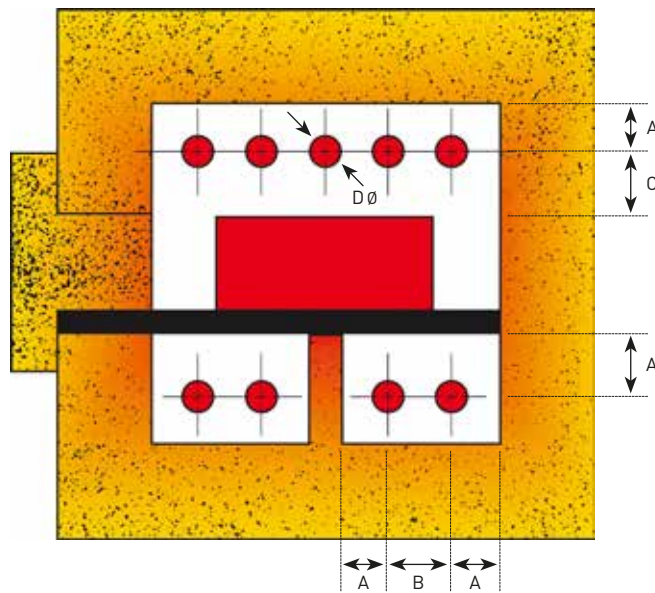
### ELECTRICAL CHARACTERISTICS

Kanthal silicon carbide elements have a much higher resistivity than metallic elements and can be operated at higher surface loadings i.e.  $W/cm^2$  ( $W/in^2$ ) of the hot zone surface area. Globar® SG and SR elements have a high and variable resistivity at room temperature, but this falls with increasing temperature, reaching a

minimum at about 700°C (1290°F). At element temperatures above 700°C (1290°F), resistivity increases with rising temperature. The resistivity/temperature characteristic is shown in Fig. 9.

Minute variations in the quantities of minor impurities in the material have a disproportionate effect on the cold resistance value, as indicated by the dotted curves, and room temperature resistance measurements give no indication of the resistance at working temperature.

Resistance measurements should always be carried out at a constant temperature at or above 1000°C (1830°F), and the value determined by dividing the voltage across each element by the current passing through it.



- A =  $(1.5 \times D)$  = Minimum spacing between element center and any adjacent refractory
- B =  $(2 \times D)$  = Minimum spacing between adjacent element centers
- C =  $(2 \times D)$  = Minimum spacing between element centers and hearth plates or work
- D = Element diameter

Fig. 8 Recommended element spacings.

#### Note:

If under hearth heating is to be used then the hearth plates should be as thin as possible and have a thermal conductivity of at least 14 W/mK.

It may be necessary to limit the power output to prevent overheating.

## ELECTRICAL SPECIFICATIONS

The nominal resistance values detailed in the element size lists are based on an element temperature of 1000°C (1830°F), as illustrated in Fig. 9. The resistance values are subject to a tolerance of ±15% and ±20% for Kanthal® Globar® SG and SR respectively, and although the nominal value is generally used when calculating the voltage range of the power supply, the negative resistance tolerance must be considered when calculating the maximum current drawn (see page 19).

Globar® SG and SR elements are marked with a standard test voltage, calculated to raise an element of nominal resistance to a temperature of 1000°C (1830°F) in free air. The test current value at this voltage is also marked on each element, and should be used when matching element resistances. The test voltage is for calibration purposes only, and the maximum recommended voltage with new elements will not normally exceed 80% of the test voltage.

The size lists detail the range of preferred element resistances, but non-standard resistances can also be supplied.

## ELEMENT PERFORMANCE

All silicon carbide elements increase in resistance during their life in operation, and the rate at which this occurs is affected by the following factors:

- Furnace temperature
- Element surface loading in W/cm<sup>2</sup> (W/in<sup>2</sup>)
- Atmosphere surrounding the elements
- Mode of operation – continuous or cyclic
- Operating practices and power control methods used

As a general guide, Globar® SG and SR elements may increase in resistance at a rate of about 3% per 1000 hours operating continuously in clean air at a temperature of 1400°C (2550°F). It should be noted that small changes in operating conditions can alter these rates considerably.

## RESISTIVITY/TEMPERATURE CHARACTERISTIC CURVE

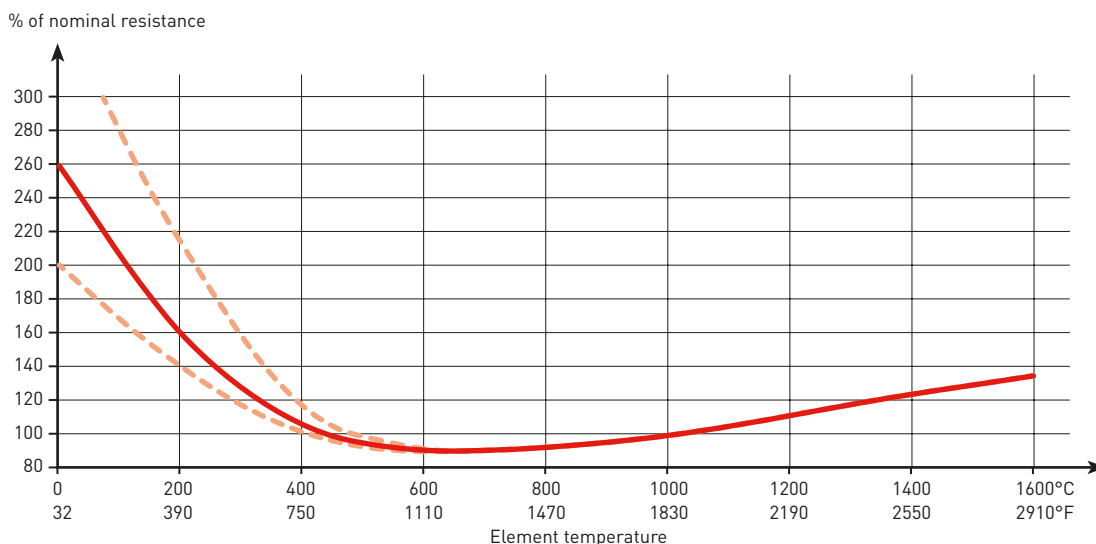


Fig. 9 Typical R/T curve.

## ELEMENT LOADING

Silicon carbide elements do not have a specific rating in watts, and the rated power is a function of the required temperature, the atmosphere in which the elements will be used, and the operating cycle. Expressed in  $W/cm^2$  ( $W/in^2$ ), the surface loading is derived by dividing the power from each element, by the surface area of the hot zone section, which is detailed in the element size lists, or can be calculated by:

$$P = D \times L,$$

where D is the outer diameter of the element in cm (in), and L is the hot zone length in cm (in).

As the element temperature is directly proportional to the surface loading applied, the lowest power loading consistent with the furnace design should be used for optimum element life, and this is usually in the range  $3-8 W/cm^2$  ( $19-52 W/in^2$ ).

Fig. 10 illustrates the relationship between furnace temperature, element surface loading and element temperature.

Example:

At a furnace temperature of  $1400^\circ C$  ( $2550^\circ F$ ) and an element loading of  $5 W/cm^2$  ( $32 W/in^2$ ) the element temperature would be  $1450^\circ C$  ( $2640^\circ F$ ), as indicated by the red line. At a furnace temperature of  $1100^\circ C$  ( $2010^\circ F$ ) and a loading of  $6 W/cm^2$  ( $39 W/in^2$ ) the element temperature would be about  $1200^\circ C$  ( $2190^\circ F$ ) as indicated by the brown line.

The chart shows maximum recommended element loadings for elements operating in air. These values may be used as a guide, but for maximum element life a lower loading should be used wherever possible. A lower loading may also be required where elements are to be operated in reducing or other process atmospheres, to maintain element temperatures within the limits detailed in the table, page 15. The minimum recommended surface loading is  $3 W/cm^2$  ( $19 W/in^2$ ), although lower values are possible, where the power supply has sufficient voltage available to overcome the high cold resistance of the elements.

## START UP PROCEDURE

Rapid heating is detrimental to all ceramic materials, and although Globar® SG and SR are particularly resistant to thermal shock, care must be taken when heating up from cold to limit the applied voltage, and hence the element heating rate. The test voltage marked on every element must never be exceeded, but in general, it will be beneficial to limit the applied voltage to a lower value, calculated from the element design power, and the nominal element resistance:

$$V = \sqrt{WR}$$

Where W is the design power of the element in watts, and R is the nominal element resistance in ohms.

## OPERATING TEMPERATURE

Globar® SG and SR elements may be used in air at furnace temperatures up to maximum of  $1600^\circ C$  ( $2910^\circ F$ ), but the use of other atmospheres may reduce this limit considerably. There is no lower limit to the operating temperature of the equipment, but the element surface loading should be set to achieve an element temperature of at least  $900^\circ C$  ( $1650^\circ F$ ).

## EFFECT OF ATMOSPHERES

Globar® SG and SR elements are normally operated in a clean, dry air atmosphere. Other process atmospheres may react with the element material or the oxide formed as the elements are used.

In air, the product of oxidation, silicon dioxide, forms a stable, protective silica film over the silicon carbide grains, thus retarding the later rate of oxidation, which is limited by diffusion of oxygen through the silica layer. This passive oxidation requires a free oxygen content of at least 1%, and at lower oxygen levels, active oxidation may occur due to the inability to form a stable silica film. Active oxidation can result in a loss of SiC material causing hot spots and a weakened material structure.

### SURFACE LOADING CHART FOR GLOBAL® SG AND SR ELEMENTS

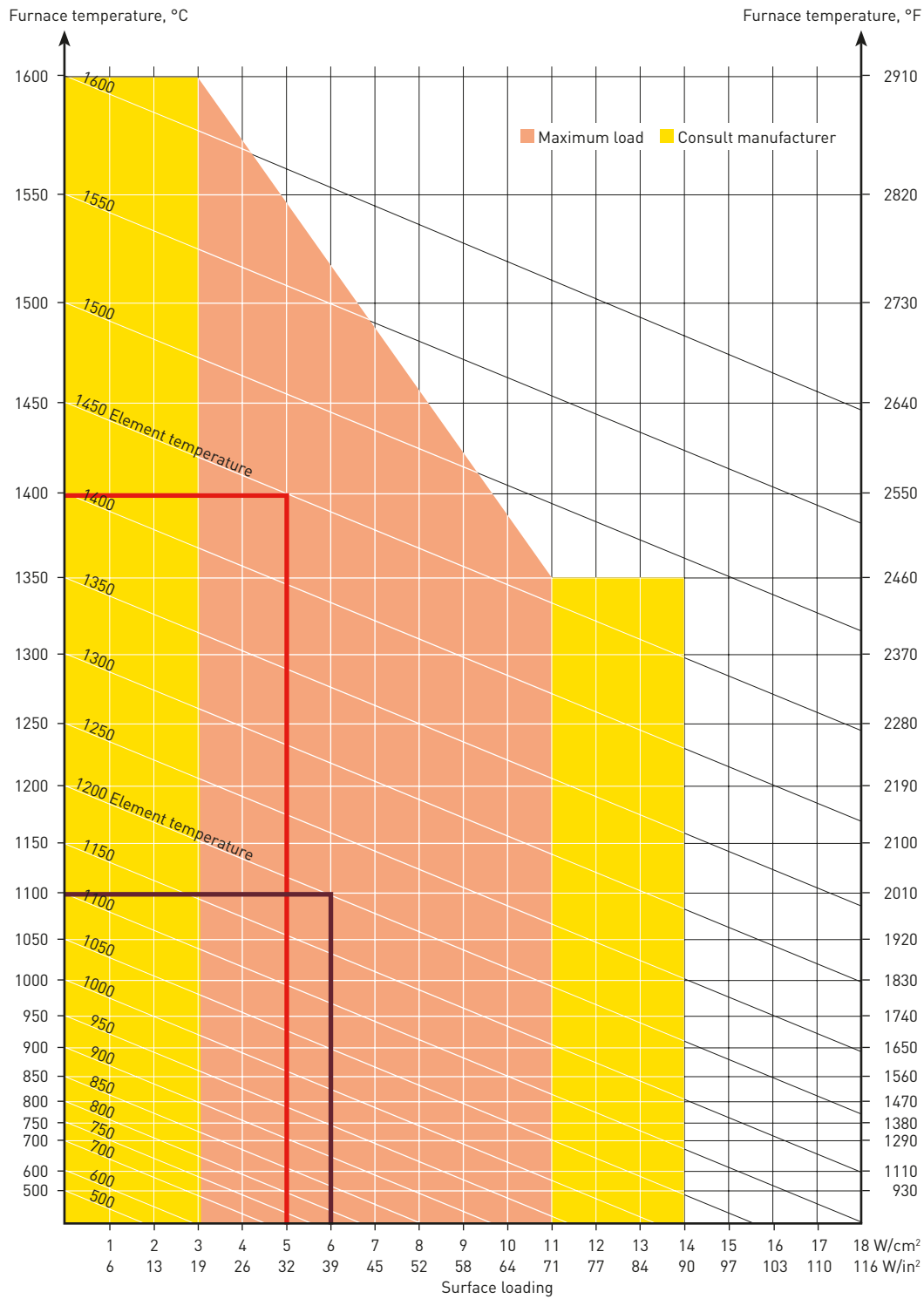


Fig. 10 Surface loading chart.

Active oxidation also occurs if the elements are subjected to an atmosphere containing water vapour. The silicon dioxide formed is likely to be crystalline and non-protective. Elements exposed to water vapour, even for a short period of time, will be seriously damaged and will never revert to normal oxidation, even in a dry air atmosphere. Furnaces should be thoroughly dried before the elements are installed, but if it is essential to use the elements for drying, then the furnace must be very well ventilated and no build up of steam must be allowed to occur.

Care must also be taken to ensure water vapour does not condense on the terminals of Globar® SR type elements otherwise a short circuit may occur.

Globar® SG and SR elements are also used successfully in neutral or reducing atmospheres and the table shows the recommended maximum element temperatures for various common process gases. High density Globar® SG and SR elements will react with a process atmosphere at a much slower rate compared to conventional standard density elements.

In pure dry hydrogen for example, the maximum element temperature at which a useful life may be obtained is about 1200°C (2190°F). With lower percentages of hydrogen however, the maximum temperature may be raised and elements are successfully operated at temperatures of over 1300°C (2370°F) in commer-

cial reducing atmospheres such as exothermic and endothermic gases. In pure nitrogen there is likely to be some reaction causing the formation of silicon nitride at furnace temperatures over 1300°C (2370°F). A pure oxygen atmosphere can be used, with only a slight increase in oxidation rate, but aluminum braid connections may react exothermically with the atmosphere, unless maintained in very good condition.

Other process volatiles may also adversely affect element life by attacking either the silicon carbide or the protective silica coating. Alkali vapours, halogens, metal oxides and halides are particularly reactive and precautions must be taken to minimise any attack, by adequate ventilation of the furnace chamber, or by minimising the transfer of aggressive media to the elements. Ventilation will also assist in preventing condensation of volatiles in the element location holes, where they may cause sticking and subsequent element breakage due to restriction. Although it is possible in most cases to reduce volatile attack to an acceptable level, it may be necessary in severe cases to sheath the elements in suitable refractory or metallic tubes. The use of sheaths can result in a considerable increase in element temperature, particularly if ceramic sheath materials having relatively poor emissivity and thermal conductivity values are used and it may be necessary to reduce the element loading to prevent overheating.

#### MAXIMUM ELEMENT TEMPERATURE IN ATMOSPHERES

ATMOSPHERE	MAXIMUM ELEMENT TEMPERATURE		COMMENTS
	°C	°F	
Clean air	1650	3000	
Pure oxygen	1500	2730	Faster oxidation than in air
Nitrogen	1350	2460	Forms silicon nitride at >1350°C (2460°F)
Dry hydrogen	1200	2190	Oxidizes in wet hydrogen
Dry exothermic gas	1400	2550	Very dependent on composition
Dry endothermic gas	1250	2280	Very dependent on composition
Vacuum	1200	2190	Generally for short term use only

Where Globalbar® SG elements are operated in an atmosphere containing hydrocarbons, deposition of electrically conductive carbon can occur on the furnace walls, inside the pore structure of the refractories, and also on Globalbar® SG elements themselves, causing tracking of the electrical supply. This problem can be minimised by strict control of the carbon potential of the gas, but it may be necessary to open the furnace to air periodically to burn off the carbon deposits. Note that carbon deposited in cooler areas of the furnace cannot be removed by this method, if the local temperature is insufficient to cause the carbon to burn.

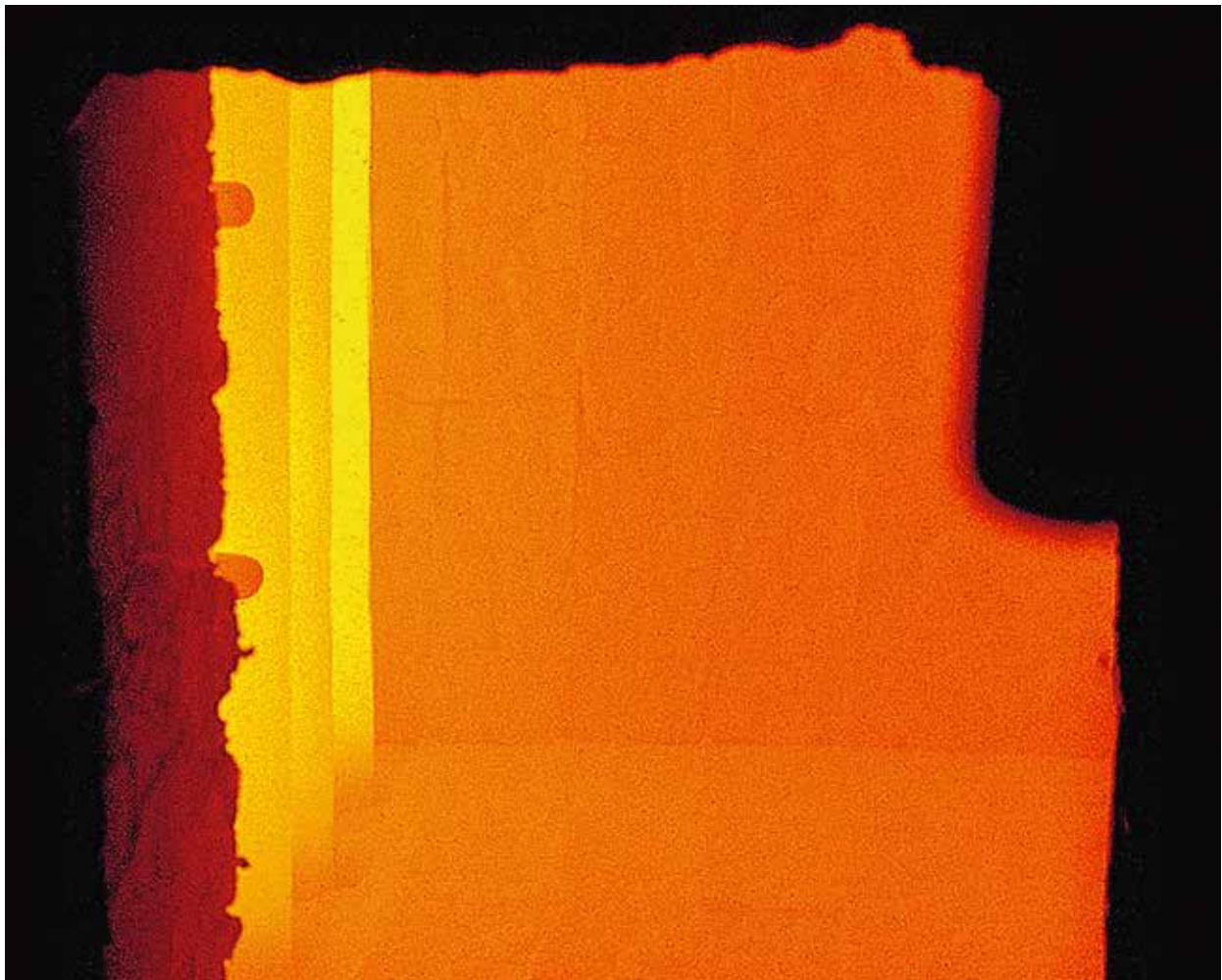
### **ATMOSPHERES AND GLOBALBAR® SR ELEMENTS**

A clean atmosphere is particularly important when using Globalbar® SR elements. These elements are formed with a high resistance double-spiral heating section and a split cold end – the voltage potential across the split and spiral sections can be much higher than the voltage potential across the spirals of a Globalbar® SG type single-spiral element.

Any conductive deposits that accumulate across the air gap between either spirals or the cold end are likely to cause a short circuit and arcing, resulting in premature failure of a Globalbar® SR element.

This can be a particular problem in an atmosphere containing metal oxides, lead or other glassy volatiles as the glass formed on the surface of a Globalbar® SR element is likely to have a low melting point causing it to drip and bridge the air gap between the spirals or the cold ends.

Arcing may also occur if these elements are operated in inert gases such as argon, neon or helium, due to gas ionisation at high temperatures and voltages. Carbon build up in hydrocarbon atmospheres can also cause Globalbar® SR elements to fail prematurely as a result of arcing and therefore Globalbar® SR elements are not recommended for use in atmospheres where electrically conductive carbon build up might occur.





# POWER SUPPLIES

Globar® SG and SR elements can be considered as simple resistive loads and the normal electrical laws apply: i.e. where V = volts; I = amperes; W = watts; R = resistance in  $\Omega$

It is important to install, connect and control the elements in the recommended way, to ensure optimum life.

## ELEMENT CONNECTIONS

Globar® SG and SR elements may be connected in parallel, series or combinations of the two.

Parallel connection is ideal, as any small variations in resistance value will tend to balance with use, whereas with series connection, the variation will tend to increase, resulting in a reduced element life.

As Globar® SG and SR elements increase in resistance fairly slowly, the effect of any imbalance is small. Therefore up to four Globar® SG elements or two Globar® SR elements may be connected in series, providing that they are well matched in resistance

value. At furnace temperatures above 1400°C (2550°F) it is recommended that the number of series connected elements should be limited to two for Globar® SG type and SR type should all be connected in parallel.

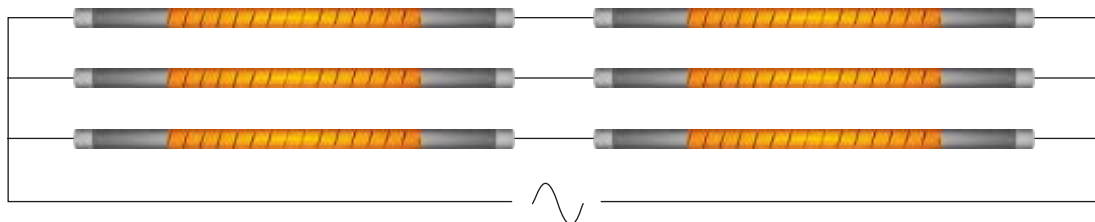
$$V = IR = \sqrt{WR} = \frac{W}{I}$$

$$W = VI = I^2R = \frac{V^2}{R}$$

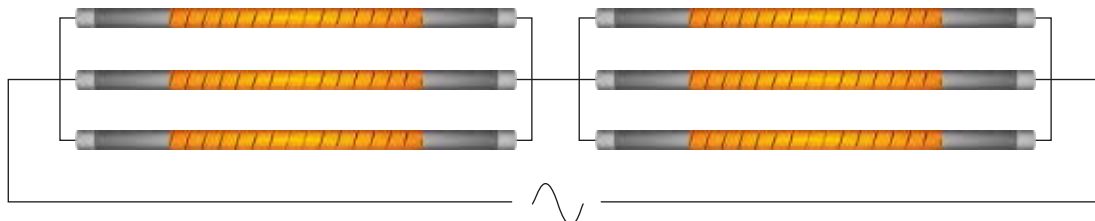
$$I = \frac{V}{R} = \sqrt{\frac{W}{R}} = \frac{W}{V}$$

$$R = \frac{V}{I} = \frac{V^2}{W} = \frac{W}{I^2}$$

A series-parallel combination is usually an effective compromise, and in this case, the series groups should be connected in parallel. Elements should never be connected with parallel groups connected in series, as failure of one element will result in overloading of the remaining elements in that group. (Fig. 11)



Preferred method of series/parallel connection



Alternative method of series/parallel connection, not recommended

Fig. 11 Series/parallel connection.

Three-phase connections may include star (wye) or delta. Where a star connection is to be used, a four-wire supply is recommended, to ensure that the phase voltages are balanced, irrespective of the phase resistances. If a three-wire star connection must be used, then the phase resistances must always be closely matched.

### **MATCHING OF RESISTANCE VALUE**

It is recommended that any series connected elements be selected within a resistance range of  $\pm 5\%$  of each other, and elements connected in parallel may have a wider range of  $\pm 10\%$ .

If any element fails or is broken after only a short period in use it can usually be replaced with a new element; preferably one from the higher end of the resistance tolerance (low amp value). If the elements have been in use for a considerable time however, the entire group should be replaced; otherwise an excessive load will fall on either the new or the old elements, resulting in premature failure.

It is good practice to divide the total number of elements in the furnace into relatively small control groups, to simplify matching at a later date. For example, a furnace fitted with 48 elements, will be far more flexible if the elements are divided into eight groups of six, than with three groups of 16 elements, and matching of element resistances will be greatly simplified.

When a group of elements has been replaced, it is essential to ensure that the voltage output of the power supply equipment is reduced to the correct value before switching on, as overloading of elements, even for a very short period, can cause irreparable damage. The old elements may be retained for later use with others which have been in use for a similar period of time. If possible, voltage and current readings should be taken from each element before removal and the increased resistance value marked on the terminal to assist in matching at a later date.

It is important to note that the resistance values of elements at room temperature give no indication of their resistance at operating temperature and resistance measurements should always be taken at a constant temperature above  $1000^{\circ}\text{C}$  ( $1830^{\circ}\text{F}$ ).

Different types of heating elements should never be operated in the same electrical circuit, as variations in rates of resistance increase will cause overloading of one type or the other depending on the method of connection.

### **VOLTAGE RESERVE**

To compensate for the increase in element resistance which occurs with use, a variable voltage power supply is usually provided. The amount of voltage reserve required will depend upon the elements' rate of resistance increase and the life expected, but is usually in the order of 50–100% of the voltage required to give full power with new elements.

e.g. if 125 V is required to give full power with new elements, then a voltage range of 125–250 V will be required to give 100% voltage reserve, and a range of 125–187.5 V to give 50% reserve.

Where elements are to be operating for long periods at temperatures of about  $1400^{\circ}\text{C}$  ( $2550^{\circ}\text{F}$ ) or above, or where the furnace conditions are such that an excessively high rate of resistance increase will occur at a lower temperature, then allowance should be made for 100% voltage reserve. Conversely, if the element temperature is very low, or the furnace only infrequently used, a voltage reserve of 50% or less may be found sufficient.

### **POWER SUPPLY EQUIPMENT**

A variable voltage power supply is usually provided to enable the design power to be maintained throughout the life of the elements. The type of equipment used may have an effect on element performance and it is important that the correct selection procedures are adhered to if the best element life is to be obtained. Various types of power supply can be used:

1. Variable output transformer.
2. Thyristor unit (SCR)
  - a. Phase-angle firing
  - b. Cycle-proportioning
3. Combined thyristor/transformer system.
4. Direct-on-line connection

Generally speaking, tapped transformers provide only on-off control, unless used in combination with thyristors. Although robust, and insensitive to short term overloading, the transformer is considered to be heavy, bulky and relatively expensive in most cases. Thyristor control offers a far more compact solution, with the option of stepless variation of power, and three-term, accurate temperature control, but will require an over-rated supply, and may cause disturbance in the supply lines. It is not usually practical to provide a voltage reserve of more than 50% using thyristor control alone, and where a large voltage reserve is required, in combination with three-term control, the best, although most expensive, option is to combine the control benefits of the thyristor, with the large voltage span of a transformer.

Thyristor control alone is common in low temperature furnaces, laboratory furnaces, and other equipment where the rate of change of element resistance is likely to be low. For high temperature continuous industrial furnaces, where a large voltage reserve is required as well as accurate temperature control, then the additional costs of the combined transformer/thyristor system can usually be justified in terms of performance.

### 1 VARIABLE OUTPUT TRANSFORMER

Infinitely variable transformers are occasionally used to power small laboratory and experimental units but are usually too expensive for larger furnaces, where multi-tapped transformers with stepped outputs are more economic. The maximum voltage step on a tapped transformer should never exceed 7% of the initial, full power voltage ( $= \sqrt{WR}$ ), where  $W$  is the furnace design power and  $R$  is the network resistance based on the nominal resistance of the elements) and the element resistance tolerance must always be taken into account when calculating the maximum secondary current rating of the transformer ( $= \sqrt{\frac{W}{R_{\min}}}$ ).

For example, if a furnace is to be rated at 5 kW and fit with Global® SG elements having a network resistance of  $2\ \Omega$  ( $\pm 15\%$ ) then the transformer specification might be calculated as follows:

$$\begin{aligned} \text{Nominal full power voltage} &= \\ &= \sqrt{WR} = \sqrt{5000 \times 2} = 100\ \text{V} \end{aligned}$$

$$\begin{aligned} \text{Voltage steps must not be greater than} \\ 7\% \text{ of } 100\ \text{V} &= 7\ \text{V} \end{aligned}$$

$$\begin{aligned} \text{Minimum network resistance} &= \\ &= 2\ \Omega - 15\% = 1.7\ \Omega \end{aligned}$$

$$\begin{aligned} \text{Maximum secondary current} &= \\ &= \sqrt{\frac{5000}{1.7}} = 54.2\ \text{A} \end{aligned}$$

$$\begin{aligned} \text{Minimum voltage required} &= \\ &= \sqrt{5000 \times 1.7} = 92\ \text{V} \end{aligned}$$

Assuming that 100% voltage reserve is required then the specification could be as follows:

**Input:** Single-phase, to suit supply

**Output:** Variable from 92 V to 197 V in 15 steps of 7 V (= 4 coarse  $\times$  4 fine tapings)

**Rating:** 5 kVA from 92 V upwards (maximum secondary current 54.2 A)

(I) Where a tapped transformer is to be used then an allowance should be included in the furnace design power for the reduction in power output, which will occur between tap changes. With a 7% voltage step for example, the power will fall by about 12.5% before the voltage can be adjusted to the next setting.

(II) A few taps below 92 V may be included for lower powers if required.

(III) If an ammeter is to be used, then it should be installed in the primary circuit where the voltage is constant; the current reading will then give a true indication of the power dissipated by the elements, irrespective of the secondary voltage setting.

## 2 THYRISTOR (SCR) UNIT

A thyristor is a semi-conductor switching device which can control the average output to the elements by switching the mains supply on and off very rapidly. Each thyristor will conduct in only one direction and for control of a.c. loads the thyristors are installed in pairs, connected in inverse parallel. The thyristors are switched by a series of pulses fed from a suitable driver unit or temperature controller.

Thyristors can be simple devices, but are often provided with closed loop feedback, to compensate for variations in supply voltage, load characteristics, etc. Typical feedback modes include current control ( $I^2$  feedback), voltage control ( $V^2$  feedback) and true power control ( $VI$  feedback). In general, only  $V^2$  feedback is suitable for use with silicon carbide elements, although there are some exceptions.

Current control tends to increase the power to the elements as they increase in resistance, and both power and current control can cause serious damage to the elements when starting from cold, when the element resistance is high. When presented with this high load

resistance, both current and power control are likely to result in the application of maximum voltage to the elements, and if the available voltage is higher than the elements can withstand, then serious damage may occur. With voltage control, the delivery of power will be controlled by the resistance/temperature characteristics of the element, starting with a relatively low power, and gradually increasing as the elements heat up.

The output characteristics of the thyristor are governed by the firing method used and the two principal types are as follows:

### 2.1 PHASE-ANGLE FIRING

Each thyristor is triggered once in every half cycle of the a.c. supply, conduction ceasing at the end of the half cycle as the current falls to zero. In this way, the sinusoidal supply waveform is chopped, resulting in a reduction in the RMS output voltage of the thyristor stack. For control of silicon carbide elements, a manual voltage limit control must be provided to vary the conduction angle of the thyristors and thus compensate for resistance increase of the elements.

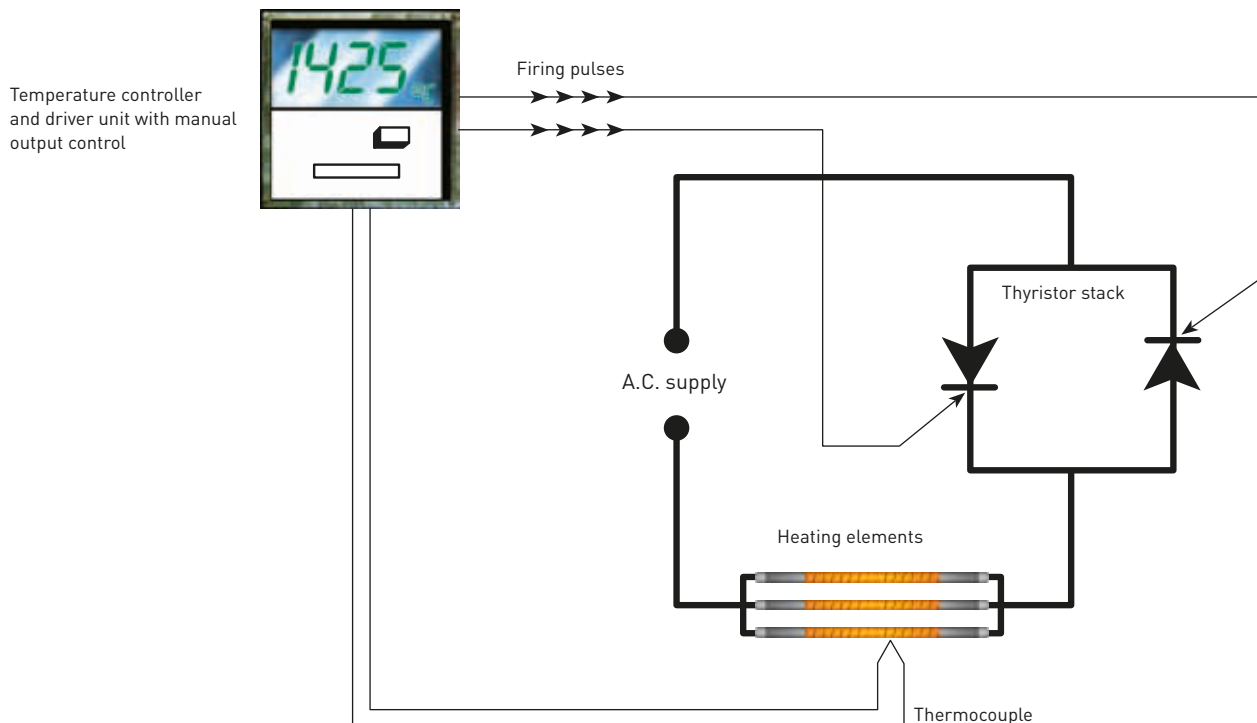


Fig. 12 Thyristor (SCR) unit.

Phase-angle fired units may also be fit with a current limiting device, which may protect the thyristors from accidental overload, by preventing the current output from exceeding a pre-set value, irrespective of the voltage setting. This current limit must not be used to control the power input to the elements, as the power input ( $= I^2R$ ) will gradually rise with increasing element resistance, resulting in progressive overloading of the elements, and possible damage when starting from cold.

As phase-angle fired thyristors give smooth, stepless control of the applied voltage, they are ideally suited for use with silicon carbide elements. However, they can cause both radio frequency interference and supply waveform distortion, and consideration should be given to these factors when selecting the system to be used. The use of phase-angle firing is discouraged in many countries, or severely limited by local regulations.

As there is no current flow for part of the supply cycle, phase-angle controlled loads will give rise to an apparently poor power factor, even with a purely resistive load, and this can lead to problems on large installations, especially if the firing angle is small. Generally, the starting voltage with new elements should not be less than 60% of the supply voltage, to minimize this effect.

Supply cables must be rated at the RMS current drawn by the elements ( $= \text{power} \div \text{thyristor output voltage}$  and *not*  $\text{power} \div \text{supply voltage}$ ). This means that the power supply will be rated higher than the furnace design power, and the more voltage reserve is provided, the higher will be the required over-rating.

In three-phase installations, generation of third harmonics will give rise to cumulative distortion of the supply waveform and may result in excessively high neutral currents of up to twice the line current in three-phase, four-wire, star-connected loads. Neutral cables must be adequately rated to carry this excess current. Although three-wire star connection can be used to eliminate this problem, this can result in voltage imbalances between phases, especially where elements are not perfectly matched in resistance.

To minimize supply distortion in large installations, the use of a six-wire, open-delta arrangement is recommended. The thyristors are required to carry only the phase current and not the line current as would be required in a closed delta installation, leading to a reduction in cost, and phases can be controlled independently, leading to more flexibility of control.

Calculation of the voltage output and current rating of phase-angle fired thyristor units is carried out in the same way as for a transformer, taking account of the element resistance tolerance when calculating the maximum current drawn.

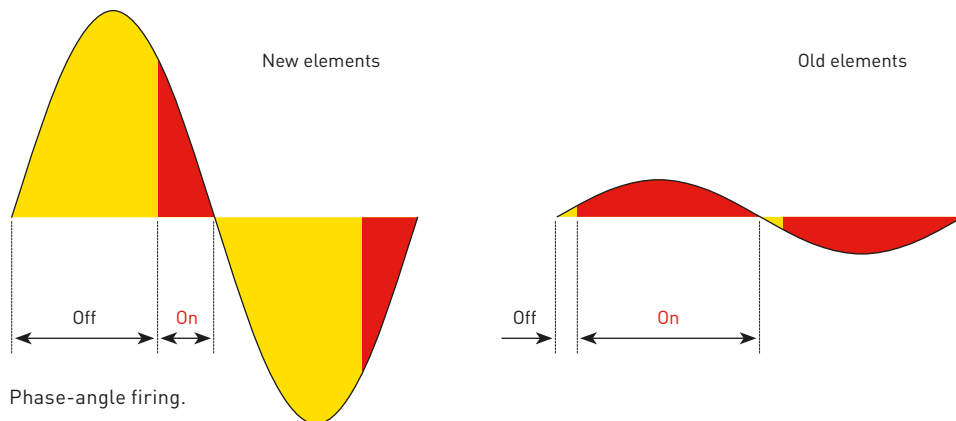
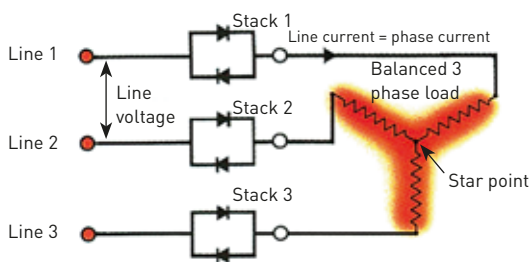


Fig. 13 Phase-angle firing.

### POWER MONITORING - PHASE-ANGLE

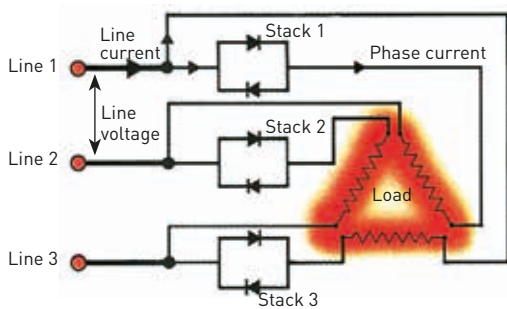
Most voltmeters and ammeters will not indicate a true RMS reading from phase-angle controlled loads, and great care must be taken to ensure that the elements are not inadvertently overloaded. Some of the digital meters currently available will respond accurately to non-sinusoidal waveforms, but the manufacturer should be consulted to ensure that a suitable instrument is supplied. True RMS, hall-effect meters, with a crest factor of 7 or above, is recommended for an accurate response.



### Three-phase, three-wire, star-connection (phase-angle firing)

Stack voltage rating = line voltage = phase voltage  $\times \sqrt{3}$   
 Stack current rating = line current = phase current  
 Note: phase resistances and loads must be balanced

Fig. 14 Phase-angle firing: three-wire star.



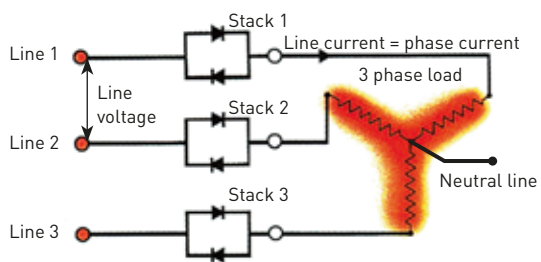
### Three-phase, open delta connection

Stack voltage rating = line voltage  
 Stack current rating = phase current ( $= \frac{\text{line current}}{\sqrt{3}}$ )

Fig. 16 Open delta: six-wire.

### 2.2 FAST-CYCLE FIRING

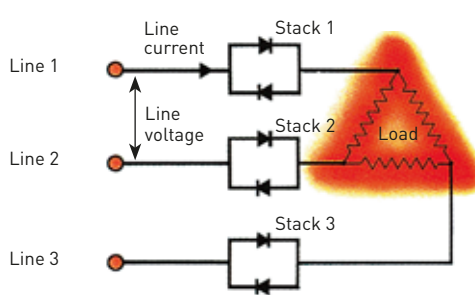
The thyristors are triggered at the beginning of a mains cycle and remain conductive for one or more complete cycles before being switched off for one or more cycles. This operation is continuously repeated, thus limiting the effective input to the elements. A manual control must be provided to vary the on/off ratio, and thus compensate for the gradual resistance increase of the elements.



### Three-phase, four-wire, star-connection (phase-angle firing)

Stack voltage rating = phase voltage =  $\frac{\text{line voltage}}{\sqrt{3}}$   
 Stack current rating = line current = phase current  
 Neutral cable rating = line current  $\times 2$  for safety

Fig. 15 Phase-angle firing: four-wire star.



### Three-phase, closed delta connection

Stack voltage rating = line voltage  
 Stack current rating = line current = phase current  $\times \sqrt{3}$

Fig. 17 Closed delta: three-wire.

Although the average power input to the elements may be within the normal recommended limits for start-up, temperature and atmosphere, each full cycle of the full mains voltage may cause loadings of several times this value to occur, and this can result in increased rates of resistance increase and premature, if not immediate, element failure. For this reason, it is necessary to connect the elements in such a way that the element loading during full cycles of the supply voltage does not exceed 15 W/cm<sup>2</sup> (97 W/in<sup>2</sup>).

To minimize the effect of the 'on' burst, the time base of the firing cycle must be as short as possible and preferably less than 30 cycles of a 50 Hz supply (i.e. 50% power = 15 cycles 'on' + 15 cycles 'off').

Slow-cycle thyristors generally have cycle times of several seconds and are not suitable for direct control of silicon carbide elements. They may be used on the secondary side of tapped transformers however, in place of conventional electro-mechanical contactors.

The optimum type of burst-fired thyristor for use with silicon carbide elements is the single-cycle burst-firing type, where the required output is always reached over the minimum possible number of complete cycles (i.e. 50% power = 1 cycle 'on' + 1 cycle 'off').

The required voltage rating for the thyristors will be the same or higher than the supply voltage, but the current rating of the unit must be determined by dividing the RMS supply voltage by the minimum network resistance.

i.e.

$$\text{current rating of thyristor} = \frac{\text{supply voltage}}{\text{minimum resistance}}$$

The rating of the thyristor will therefore be much higher than that of an equivalent phase-angle fired unit.

To calculate the required output from the thyristors, the power at the supply voltage must be calculated, and the on/off ratio of the thyristor limited to whatever percentage will provide the required design power.

For example, if the supply voltage is 200 V, and the resistance of the element network is 4 Ω, then the power at 200 V will be  $\frac{200^2}{4} = 10000$  W. If the required power is 5 kW, then the thyristors must be set to give an output of  $\frac{5000}{10000} = 50\%$

Resistive loads controlled by fast-cycle thyristors have a unity power factor and, as only full mains cycles are delivered to the load, there is no cumulative distortion of the mains supply. With heavy loads however, voltage drop may cause flickering lights and also affect sensitive equipment.

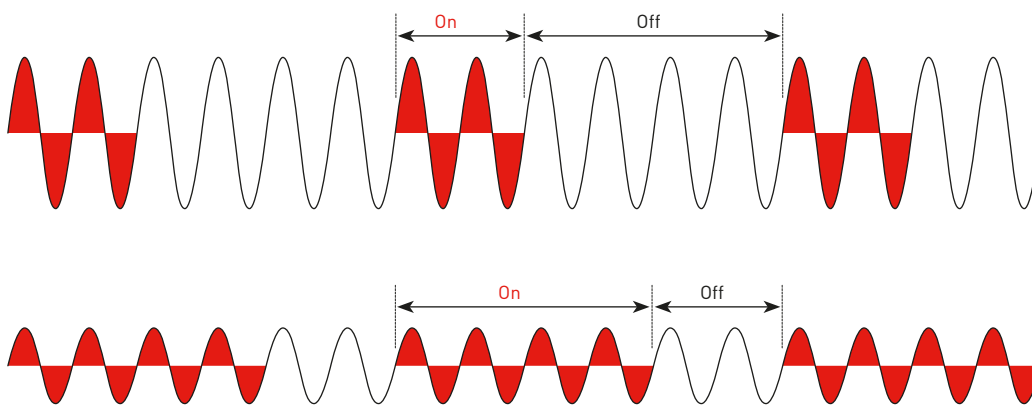


Fig. 18 Fast-cycle firing.

### **POWER MONITORING – FAST-CYCLE**

It is difficult to obtain voltmeters and ammeters which will respond accurately to fast-cycle controlled loads, and as most meters will indicate a reading considerably less than the actual thyristor output, great care must be taken to ensure that the elements are not inadvertently overloaded. The required output settings can be calculated, as above, based on the known resistance of the elements. If there is any doubt about the required setting, then the control should be set initially at a very low value and adjusted as required until sufficient power is available to raise the furnace to temperature. The control should be left at this setting until, due to resistance increase of the elements, insufficient power is available to maintain the furnace at temperature (or reach temperature if the furnace is in intermittent use). The control setting should then be increased slightly until sufficient power is again available.

### **3 TRANSFORMER + THYRISTOR (SCR)**

Due to the limitations imposed on the use of thyristor control, outlined in (2.1) and (2.2), it is sometimes not possible to provide an adequate voltage reserve, and it may be necessary to adopt a combined thyristor/tapped transformer power supply to ensure an adequate element life. Thyristors can be fit on either the primary or secondary side of the transformer, although precautions are especially required for primary connection. The transformers can be fit with only two or three tappings in most cases, as the intermediate steps can be accommodated by the thyristors. If the use of a combined system is being considered, then both transformer and thyristor manufacturers should be informed at the design stage, to ensure compatibility of the equipment supplied. Kanthal can provide suggestions for the design of the equipment, on receipt of the element details, required power and temperature, and the local supply voltage.

### **4 DIRECT-ON-LINE**

Networks of elements may be connected directly to the mains voltage providing that the network resistance is sufficiently high to prevent element overloading. The network should be designed so that the initial power output is higher than the furnace rating to provide a power reserve and compensate for element resistance increase. Although the capital cost of a variable voltage supply is saved by this method, only a minimal power reserve can be provided, and in addition, a larger number of elements may be required in the furnace to dissipate the initial excess power.

It may be possible to gain an extra power reserve by modifying the element connections after the elements have aged (e.g. from two parallel branches of three elements in series to three parallel branches of two elements in series; or from two elements in series connected in delta to two elements in parallel connected in star). Because of its inherent drawbacks, direct-on-line connection is normally limited to relatively low temperature applications (under 1100°C (2010°F)) or infrequently used cyclic furnaces up to 1300°C (2370°F).

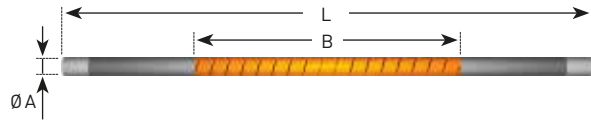


# ORDERING

## GLOBAR® SG ELEMENTS

The minimum information required when ordering Globar® SG elements is as follows:

- Element type (Globar® SG)
- Diameter, mm ( $\varnothing A$ )
- Hot zone length, mm (B)
- Overall length, mm (L)
- Nominal resistance,  $\Omega$



Globar® SG elements are specified as:

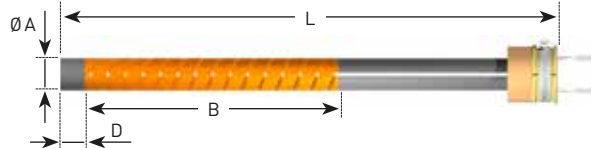
Type	Construction	Diameter	Hot zone length	Overall length	Nominal resistance	Tolerance on resistance
SG0	1	32	425	950	1.53	1515

Example: SG0-1-32-425-950-1.53-1515

## GLOBAR® SR ELEMENTS

The minimum information required when ordering Globar® SR elements is as follows:

- Element type (Globar® SR)
- Diameter, mm ( $\varnothing A$ )
- Hot zone length, mm (B)
- Overall length, mm (L)
- Dump end length, mm (D)
- Nominal resistance,  $\Omega$



Globar® SR elements are specified as:

Type	Construction	Diameter	Hot zone length	Overall length	Dump end length	Nominal resistance	Tolerance on resistance
SRO	1	25	150	400	13	3.54	2020

Example: SRO-1-25-150-400-13-3.54-2020

# ACCESSORIES

Accessories available from Kanthal (full size list on request).



LB block



HC clip



CC clip



SL sleeve



G clamp



D clamp



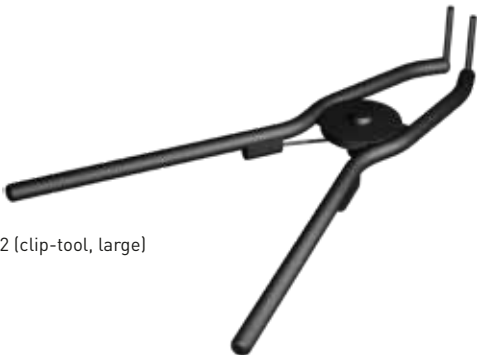
CT1 (clip-tool, small)



D1 braid



D2 braid



CT2 (clip-tool, large)



S1 braid



S2 braid



Q1 braid



Q2 braid



