Fast Guide to Furnaces

Carbolite offer you more than 150 standard furnaces to choose from, plus a custom design capability. We could make you a furnace as small as a cigarette packet, or as big as a bus, and with operating temperatures as high as 2000°C.

How should you select the right furnace from such a wide range?

Take 10 minutes to read this guide, then ask yourself these five questions:-

1 How hot?
2 Tube furnace or chamber furnace?
3 What heating elements?
4 How big?
5 What controls and options?

When you have the answers, choosing a furnace will be a logical process.

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1. How Hot?

What maximum temperature do you need now? And what will you need in the future?

An Oven? or a Furnace?

We say that an oven has a maximum temperature of 600°C or less, and transfers heat into the work mostly by convection.

Simple ovens have heaters mounted near the bottom of the chamber to warm the cold air that naturally sinks to the bottom due to convection.

A fan is fitted in more sophisticated ovens. This thoroughly mixes the air and evens out the temperature. It also speeds up heat transfer to the work placed in the oven. (Fans are now fitted to domestic ovens for the same reasons).

Furnaces have higher maximum temperatures (above 600°C) and are designed to transfer heat into the work mostly by radiant heating.

Furnaces can work at temperatures below 600°C, but air convection currents can make the temperature uniformity worse.

Also, at low temperatures heat from the elements is slow to reach the temperature sensor and this can cause the furnace to overshoot a low "set temperature". Certain controllers allow you to limit the furnace power to prevent overshoot on initial warm-up.

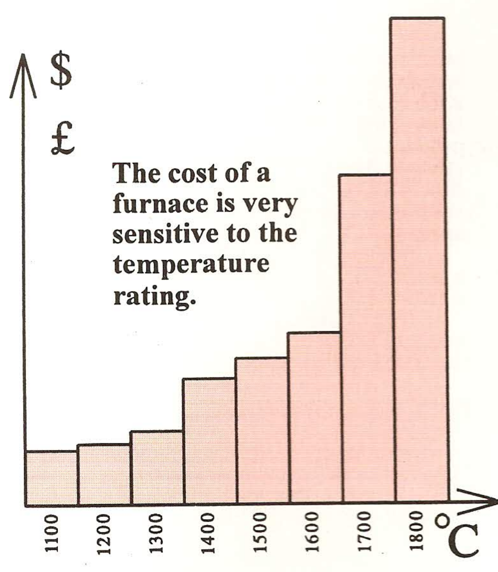
This guide is about furnaces.
See separate literature for details of ovens.

Not too cold!

The life of a heating element is shortened considerably when it is used close to its maximum temperature. So you should choose a furnace with a maximum temperature about 100 degrees higher than you will regularly use.

Not too hot!

If you specify a maximum temperature that is much higher than you need, the furnace will be unnecessarily expensive. The cost of manufacturing a furnace increases in steps at certain temperatures because of the need to use higher quality materials as shown below:-



Thermocouples

Low cost thermocouple materials can be used up to 1100°C (type K, NiCr/NiAl) or 1200°C (type N, nicrosil/nisil).
Above this temperature these materials have only a short life so more expensive platinum/rhodium (Pt/Rh) thermocouples must be used eg types R, B, 20/40.

Heating Elements

FeCrAl resistance wire can be used up to 1300°C. Above this temperature more expensive silicon carbide (SiC) elements are used. And from 1500°C to 1600°C a higher grade of silicon carbide is required.

From 1600°C to 1800°C we move to a choice between Kanthal Super (molybdenum disilicide $MoSi_2$), Pyrox (lanthanum chromite $LaCrO_3$), or platinum wire Pt.

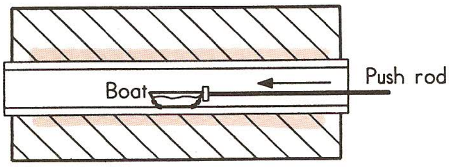
The cost of using $MoSi_2$ elements is increased by their need for low voltage transformers and a current limiting control system.

Above 1800°C graphite (C), molybdenum (Mo) or zirconia (ZrO_2) elements are used.

Insulation costs also increase steeply with temperature. 1700°C insulation costs nearly 20 times more than 900°C insulation.

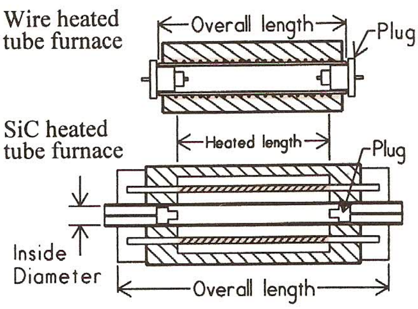
Do you need a Tube Furnace? or

Tube furnaces offer the cheapest way to heat small work pieces. A simple push rod can be used to move work pieces between different temperature zones to give fast heating and cooling.



The worktube offers a clean, dust-free environment, easily adapted to contain an atmosphere - either excluding oxygen (O_2); or allowing reaction gases to be collected for analysis; or to keep corrosive reaction products away from the heating elements.

Wire-heated tube furnaces are simple and inexpensive, but costs start to increase steeply if the bore diameter exceeds 150mm or if the maximum temperature exceeds 1200°C.

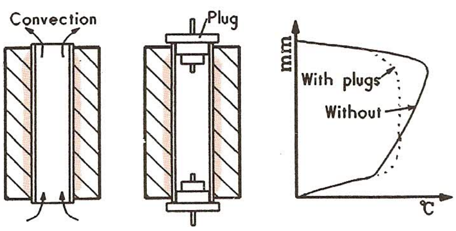


Tube Materials

Ceramic worktubes are usually IAP (Impervious Aluminous Porcelain) up to 1400°C, Mullite up to 1500° and Re-Crystallised Alumina (RCA) up to 1800°C. Worktubes are also available in Quartz 1000°C, metal 1200°C and SiC 1600°C

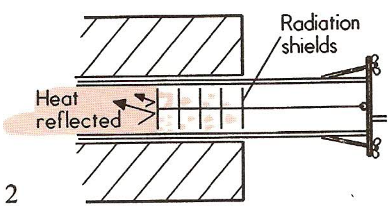
Temperature Uniformity

To get the most uniform temperature inside a tube furnace, both ends of the tube should be plugged with insulation, near to the ends of the heated zone.

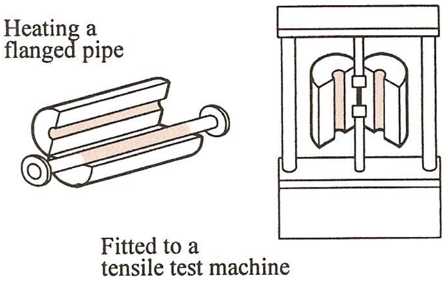


In vertical tube furnaces, such plugs also stop the air convection currents which cause the top of the furnace to be hotter than the bottom.

Radiation shields are dust-free and non-porous so they are preferred where cleanliness or high vacuum is required. Both plugs and radiation shields must be carefully designed to avoid steep temperature gradients and thermal stresses that could crack the tube.

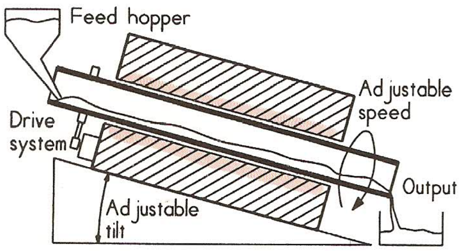


Split Furnaces



Some tube furnaces are made in two halves, hinged together for ease of loading. A furnace can then be moved into place around a fixed item (such as a pipe with flanges that are too big to pass through a one-piece furnace) or around a sample fixed into a tensile test machine.

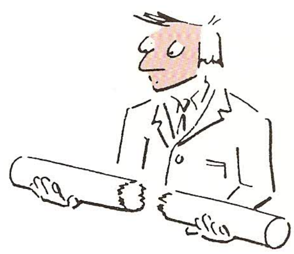
Rotating Tubes



This type of furnace is useful for heating powders. It exposes all the particles to the atmosphere so that reactions take place about ten times faster - compared with heating powder in dishes. It simulates, in the laboratory, the way powders are heated on an industrial scale.

Simple rotating drives can be added to horizontal tube furnaces for processing a batch of powder, or the furnace can also be tilted to heat a continuous flow of powder, either in air or under a controlled atmosphere.

Thermal Shock



Most people have at some time in their life broken a glass or a plate by heating or cooling it too quickly. These "Thermal Shock" failures happen when one part of the brittle material is suddenly heated (or cooled) more strongly than the rest. The resulting localised expansion (or contraction) causes huge stresses and the material simply breaks itself apart.

Pushing cold crucibles into hot ceramic tubes is risky, and for this reason Carbolite offer no warranty against this kind of failure.

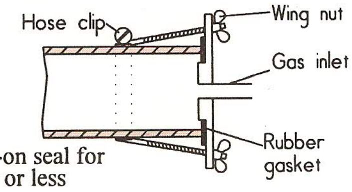
Usually the problem can be avoided by careful loading of the furnace. We have a separate bulletin on this subject.

Safety

Ceramics become slightly electrically conductive at high temperatures.

Tube furnaces should be switched off for loading, and any metal tools used should have insulated handles. See back page.

Gas-tight tubes



Clamp-on seal for 0.3 bar or less

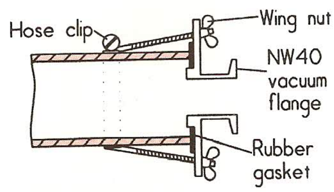
We can seal the ends of worktubes (up to about 200mm diameter) by clamping stainless steel discs onto each end of the tube. The worktube must be long enough to project from the furnace by 3 or 4 times the tube diameter so that the ends are cool enough to allow us to use a heat-resisting rubber seal.

Each disc has a gas connection that can be either an inlet or outlet.

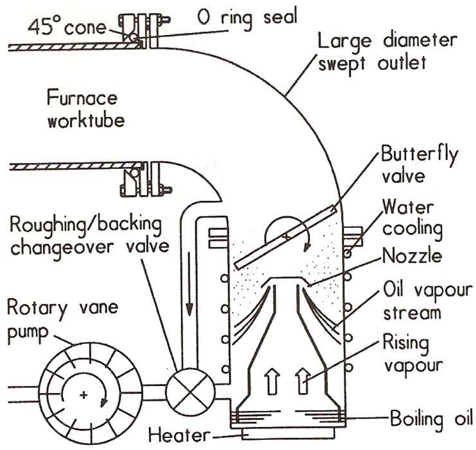
We can also fit a sealing gland into the disc so that a probe thermocouple can be inserted into the tube to measure the temperature inside.

Vacuum (hot wall)

The clamp-on seal (above) is suitable for rough vacuum (1×10^{-3}mb) but we replace the gas outlet with a standard NW25 or NW40 flange for connection to a mechanical displacement pump (usually a rotary vane pump).



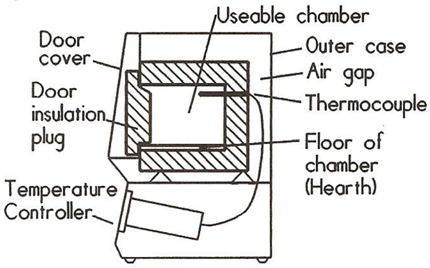
For higher vacuum (1×10^{-5}mb) we use an "O" ring seal which is compressed onto the outside diameter of the tube by conical surfaces machined in stainless steel discs. A large diameter swept 90° outlet is fitted to make the connection with the diffusion pump.



Gas molecules from the furnace worktube diffuse into the mouth of the pump and collide with heavier molecules in a downwards stream of oil vapour. They become trapped under this stream of oil vapour and are removed by the rotary pump. The oil vapour condenses on the cooled walls and returns to the oil boiler.

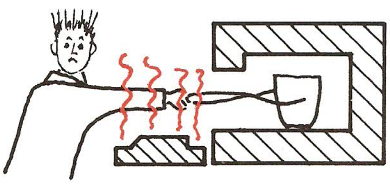
Cold wall vacuum systems are not one of our standard products. The pressure vessel is a steel fabrication outside the heating elements and insulation. These designs can be very big (and expensive). They allow quenching of the work by the admission of cold inert gas. In a hot wall design, quenching would crack the worktube - unless a heat resisting steel tube was used instead of the usual ceramic one.

... a Chamber Furnace?

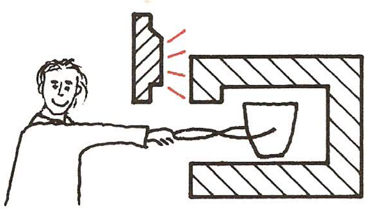


Chamber furnaces are more complex to make than tube furnaces and are correspondingly more expensive. However, they usually have a larger capacity and can be made to accept large objects and awkward shapes such as trays. The three main types of chamber furnace have different door positions:-

Front loading is the most common arrangement. The cheapest furnaces have simple hinge-down doors which you can use as a shelf while loading or unloading. However, the hot door insulation radiates heat towards the user when open.



Most users prefer to pay a little more to have a lift up door. This makes loading a much cooler job and also allows the door to be left partly open to speed up cooling.

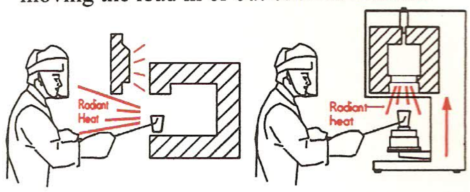


Top loading furnaces are useful for tall items, such as crucibles containing materials to be melted. Such furnaces have heaters in the sides only, so that minor spillage onto the bottom of the chamber does no harm to the heaters (see element types).

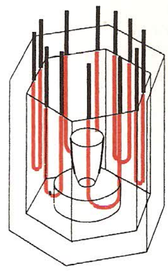
Bottom loading furnaces usually have a power operated hearth to lift the work into the furnace, and have many advantages:-

Heat from the furnace opening radiates downwards, instead of directly at the operator

Fast heating or cooling can be acheived by moving the load in or out of a hot furnace.



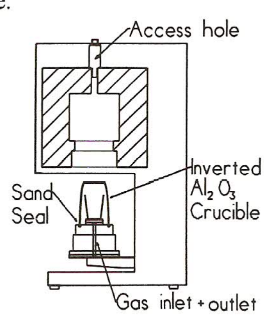
The heating elements can be placed on all sides of the work for the most even heating.



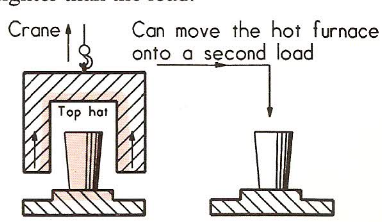
A hole in the top of the furnace gives easy access for adding ingredients, stirring or a probe thermocouple.

These furnaces are relatively easy to make gas-tight.

We can put a metal bell jar or a ceramic crucible inside the furnace, resting in a sealing trough containing sand or a low melting point metal alloy.



Top Hat" furnaces have the advantages of the the "Elevator Hearth" furnaces shown above, but the hearth stays still while the furnace body is lifted. This is often prefered for very large furnaces where the furnace may be lighter than the load.



The heat stored in the furnace insulation can be put to good use. If a second hearth has been loaded with work, the hot furnace is simply transferred onto that hearth with a resultant saving of time and energy

Ventilation

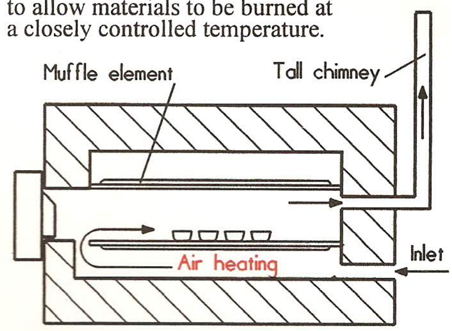
Chimneys are fitted to all chamber furnaces to pull air through the chamber for faster burning or drying of samples. This airflow can extend heating element life by quickly removing reaction products that could attack the elements. "Burn-off" furnaces have extra air inlets to further improve ventilation.

Furnaces that are used for burning materials tend to accumulate soot (C) both inside the chamber and between the layers of insulation. Since carbon conducts electricity this can cause a short circuit of the heaters.

This problem is best avoided by good ventilation and heating the furnace to maximum temperature for 30 mins each week. This will burn away the carbon.

A silica (SiO_2) muffle can sometimes be fitted to prevent soot from entering the insulation layers. (see page 4.)

Ashing furnaces are designed to allow materials to be burned at a closely controlled temperature.

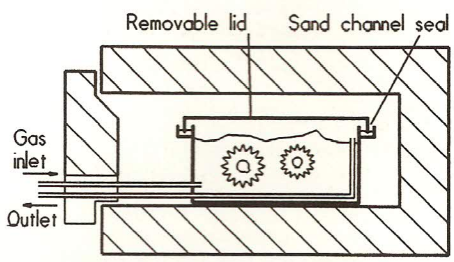


Air, drawn into the chamber by a tall chimney, is forced to pass between the insulation layers so that it is pre-heated before entering the chamber. This ensures that samples near the air inlet are not cooled by the airflow.

Atmosphere Control

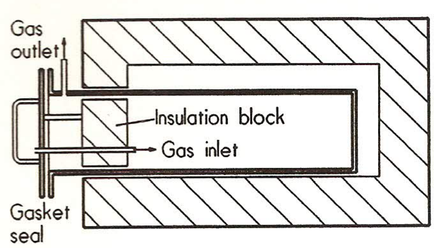
Tube furnaces offer the simplest way to control the atmosphere around the workpiece, but chamber furnaces can have a simple inert gas inlet. This can reduce oxygen levels in the chamber to 1 - 0.1%, but there will be very high leakage around the door and through the fibrous insulation materials. A metal retort inside the chamber is much better and can operate up to 1100°C. There are two types :-

Sand Sealed Retorts



A sand channel seals around the lid and allows oxygen (O_2) levels to be reduced to about 0.01%. The retort can be packed with carbon-rich powder for carburising (surface hardening) of components. The box must be removed from the furnace for loading and unloading. You can cool the workpieces faster by removing the box while it is still hot and maintaining the atmosphere until cooling is complete. Big furnaces can have rollers fitted in the hearth so that a heavy retort can be moved easily.

Gasket Sealed Retorts



The gasket seal allows O_2 levels to be much lower (typically only ten times higher than the O_2 levels in the supply gas).

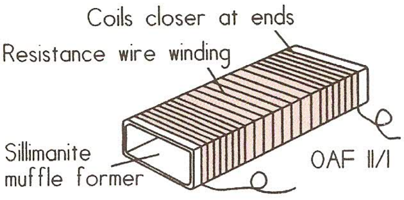
This type can be loaded and unloaded without removal from the furnace.

Hydrogen Atmospheres can be operated safely using our optional automatic safety system to ensure that explosive mixtures are not allowed to develop in the retort and that the gas leaving the retort is burned safely.

Which Heating

Wire Elements (FeCrAl) - 1300°C maximum

Wound Muffle + Tube



OAF 11/1

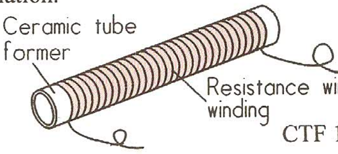
These elements are made by winding wire around a ceramic former (the muffle) and holding it in place with a thin coat of cement. The ceramic former used in <u>tube</u> furnaces is usually impervious and dust free. The sillimanite muffle former used in <u>chamber</u> furnaces is not. However, the GSM furnace uses an impervious silica (SiO_2) muffle which is better in both respects.

All muffle designs have very good resistance to abrasion and vapour attack, but they can be damaged by spillage if not protected by a metal hearth tray.

A further advantage of these designs is that by reducing the spacing of the wire coils at each end of the former, extra heat can be provided to compensate for the heat losses at the ends of the element.

The thickness of formers ranges from 3-15mm. This increases wire temperatures and shortens life at temperatures close to 1200°C.

Replacing a failed element is a lengthy job requiring dismantling of the furnace insulation.



CTF 12/65

In **<u>tube furnaces</u>**, wire wound designs are the most popular construction. Insulation is simply wrapped around the tube and element. But in **<u>chamber furnaces</u>**, muffles are becoming less popular because of cost, slow heating and cooling, and difficult element changing. However, they are still popular where aggressive vapours are present because the thickness of the former protects the wire - even if the surface of the former itself is slowly corroded away.

Chemical Attack

Furnaces are mostly made from oxides of aluminium and silicon (Al_2O_3 and SiO_2).

Even the wire heating elements have a protective alumina surface coating. These oxides can be chemically attacked by some materials. The most common ones are:-

Low melting point metal oxides:- Lead Pb, Sodium Na (and fluxes used in melting such as borax $Na_2B_4O_7$ and potassium K (such as case hardening salt e.g. potassium cyanide KCN).

Sulphur S and its compounds.

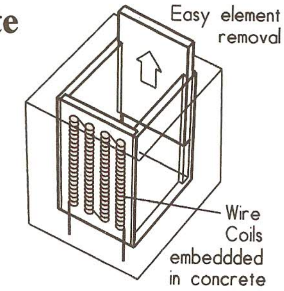
Halogens:- chlorine Cl, fluorine F, iodine I

Water vapour can cause problems where it condenses, and its presence accelerates chemical attack by the materials listed above.

By careful design, we can overcome these problems, but our engineers will need to know the quantities of material involved, the temperature and duration of the process.

Spillage: If molten waxes, metals, salts, case hardening compounds or fluxes are put in the chamber, they will probably be spilled onto the hearth. Avoid furnaces with heating elements in the hearth as they will surely be attacked by any spillage.

Concrete Slab



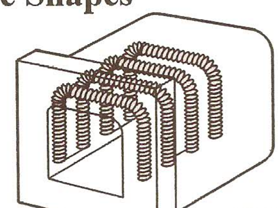
VCF 12/23

Slab elements were introduced to enable faster element changing than with muffle elements. The slabs line the sides of the chamber (and sometimes the roof and hearth) and contain spirals of wire just below the surface.

It is easy to replace slab elements on small chamber furnaces, simply by sliding the faulty slab out of the mouth of the chamber.

The concrete gives good resistance to abrasion but its weight makes the furnace slow to heat up and cool down. The wire is closer to the inner surface of the chamber than in muffle types, so resistance to chemical attack is not as good. Maximum temperature and element life are very similar to wound designs.

Coils Embedded in Ceramic Fibre Shapes



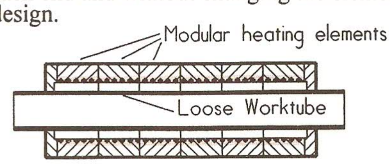
ELF 11/14

By replacing the refractory concrete of the slab elements with moulded ceramic fibre, we can mould the entire chamber and insulation of a small furnace in one piece, with a coiled wire element embedded in the walls and roof. These designs are low in cost, and extremely lightweight, with fast heating and cooling rates (10 mins to 1000°C), but the ceramic fibre is very soft and has limited resistance to impact and abrasion.

In **chamber furnaces**, the hearth can be protected from abrasion by fitting a hard refractory tile.

In **tube furnaces** abrasion resistance is not a problem because the elements are protected by the worktube. These elements are formed into cylinders with a large internal diameters - larger than the outside diameter of the work tube.

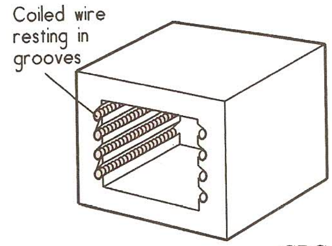
The worktube is a loose item that can be changed easily - rather than a fixed part of the heating element itself. The furnace can be adapted easily to accept smaller worktubes - by cutting a smaller hole in the insulation at each end and without changing the element design.



The maximum temperature is normally 1100°C if the coil is fully immersed in the fibre, but 1200°C is achieved if the fibre is kept clear of the front and the centre of the coils during the moulding process, so that the element is effectively an open spiral design.

Replacing a failed element is a lengthy job requiring dismantling of the furnace insulation.

Open Spiral, Free Radiating



GPC 13/36

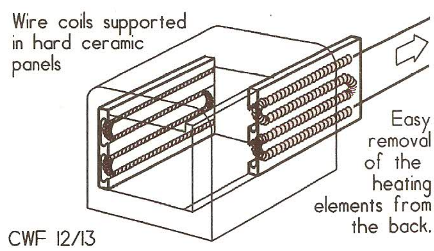
The highest temperatures are achieved by wire elements when coils of wire are supported on horizontal ceramic tubes or held in grooves in the walls of the chamber.

The heat from the wire is radiated directly into the chamber without having to pass through any insulating materials. This enables fast warm up and, since the heating wire is not much hotter than the chamber, these furnaces have good element life at high chamber temperatures, allowing use up to 1300°C.

There are three distinct open spiral designs:-

1. Coils embedded in ceramic fibre (see below left)

2. Coils on tubes or in grooves. (Shown above) This arrangement is used on larger chamber furnaces. Each element comprises two coils joined at the front and terminated at the back of the chamber. It is easy to replace elements by placing a fresh pair of coils into the groove in the wall, or onto the supporting tubes.



CWF 12/13

3. Coils in hard ceramic panels. These elements have many advantages in small chamber furnaces:- the hard ceramic carrier gives good resistance to impact and abrasion, and makes the element easy to slide out for changing. The open design allows 1300°C operation and fast heating (but not quite as fast as with moulded elements). The coil spacing is not constant. Temperature uniformity is improved by making the wire coils closer together where extra heat is needed.

Open spiral elements are vulnerable to splashes of molten materials, but because they are the hottest item in the chamber they are not attacked by condensing vapours.

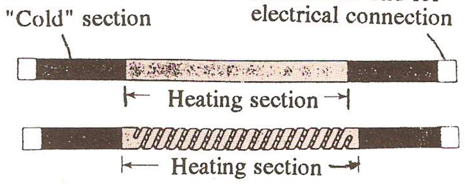
Overall, these elements offer excellent performance and life. In chamber furnaces, they have largely superseded wound muffles and slab elements.

Mineral Insulated elements are used up to 750°C. A fan circulates air over the elements and around the chamber. They are made by putting a very thin coiled heating wire inside a heat resistant metal sheath tube. Magnesium Oxide (MgO) is packed around the coil. This electrically insulates the coil from the sheath and keeps the coil centred inside the sheath. The elements can be bent to fit the space available and are very robust. They are also used in domestic electric water heaters.

Element Type?

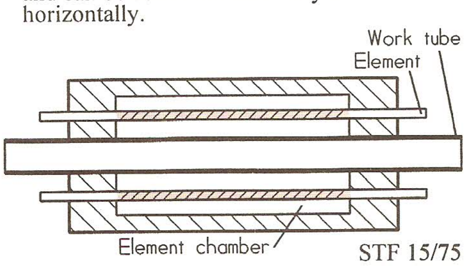
High Temperature Elements - above 1300°C

Silicon Carbide (SiC) - 1600°C



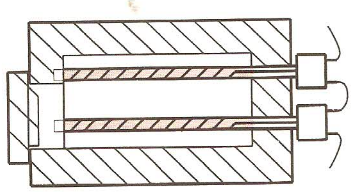
SiC elements are compact units that can put a lot of power into a small furnace. However, they are fragile and their high cost makes accidental breakages expensive.

The elements are available in rod form and can be used both vertically or horizontally.

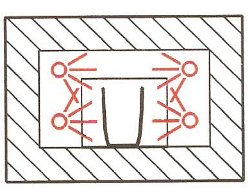


STF 15/75

Double spiral types have both electrical terminals at the same end to make element fitting easy.



Inserted from the back of a chamber furnace, the elements radiate heat evenly onto both sides of the work piece.



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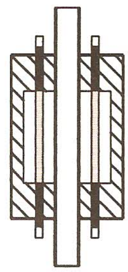
Lanthanum Chromite ($LaCrO_3$) - 1800°C

"*Pyrox*"



PVT 18/--

Lanthanum chromite rod elements become very soft when hot and must be suspended vertically. They have similar size and weight to SiC, but higher cost. Having very high resistance at low temperatures, they (like SiC) can be used without voltage reducing transformers, but warm up more slowly than $MoSi_2$

A small amount of chromium vapour is given off and may colour other ceramics pink.

Platinum alloy wire (Pt)- 1700°C

Platinum can be wound onto ceramic formers to make very compact, high temperature, tube furnaces, but the high value of platinum can make this type of furnace a security risk.

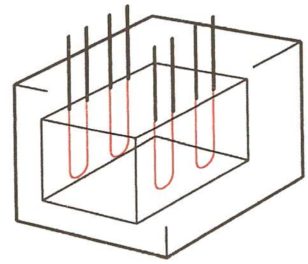
Above 1800°C?

Molybdenum (Mo) wire and graphite (C) are used where very high temperatures are required. They can be used only in furnaces where oxygen can be excluded, otherwise the elements would simply burn away. Achieving these conditions greatly increases the complexity and cost of a furnace.

Zirconia (ZrO_2)
Yttria stabilised zirconia can be used in air at 2000°C, but does not conduct electricity below 800°. So, wire elements are embedded in the insulation to preheat the furnace to 800°C, then the Zirconia elements take over. Their resistance falls quickly as temperature rises so the current flowing in each element has to be separately limited - requiring costly controls. Heating and cooling is slow to avoid thermal shock failure of the elements.

Molybdenum Disilicide ($MoSi_2$) - 1700°C ($MoWSi_2$) - 1800°C

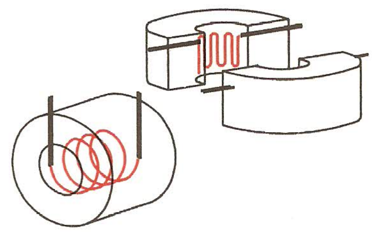
"*Kanthal Super*"



RHF 17/3

Molybdenum Disilicide is more expensive than SiC and shares its cold brittleness problems. But when hot it becomes very plastic, so "U" shaped elements are suspended inside furnaces for 1700°C or 1800°C.

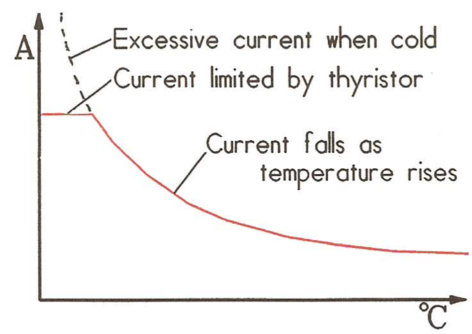
If limited to 1600°C, $MoSi_2$ can be fixed into ceramic fibre tubes and half-tubes to make very compact tube furnaces (either split or one-piece designs).



All $MoSi_2$ elements are very lightweight and very powerful, allowing extremely fast warm up times, but their very low resistance when cold makes a low-voltage transformer necessary on small furnaces.

The cold element resistance is 1/10th of the hot resistance, so the element current could be 10 times greater when the furnace is cold.

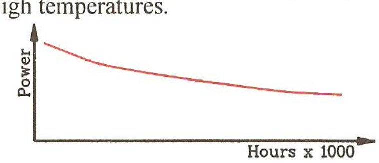
Carbolite use special thyristors that measure the element current and switch on and off very rapidly to limit the element current at a safe level. As the furnace heats up, the resistance rises and the element current naturally reduces to within acceptable limits. The thyristors then apply full power to the elements until the furnace approaches the desired operating temperature.



The costs of this sophisticated power control circuit and the low-voltage transformer, make $MoSi_2$ furnaces much more costly than SiC furnaces and *Pyrox* furnaces.

Life of SiC elements

Element life is partly limited by a slow increase in resistance due to oxidation called "ageing". This is accelerated by long use at high temperatures.



Carbolite compensate for this effect, on all except the cheapest SiC furnaces, by fitting elements which have around double the required power when they are new.
The temperature controller is then preset to reduce the element power by rapidly switching it on and off about three times per second.

This setting can later be "turned up" to restore normal power when the resistance has increased after prolonged use.

The average current supplied to the furnace is lower than the current which flows during the brief pulses. The power consumption of the furnace is calculated from the average current, but the supply cables often need to be rated for 50% more current to carry the brief pulses.

This is fully explained in a separate bulletin which is available on request.

Remember

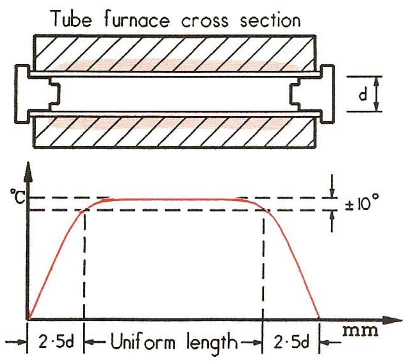
For over 20 years, Carbolite has successfully made 1600°C furnaces, using SiC elements, at lower prices than our competitors who use $MoSi_2$ elements for this temperature.

How Big?

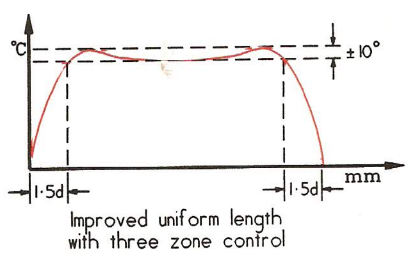
Uniformity

It is inevitable that there will be measurable variation in the temperatures recorded in different parts of the furnace. If great precision is required, it is good practice to choose a furnace with ample space inside to allow the workpieces to be placed in the area having the most even temperature. A good rule of thumb is to use only the middle two-thirds of a chamber floor dimensions.

In a tube furnace avoid using the part which falls within two and a half tube diameters of the ends of the heated length. This assumes that the ends of the tube can be plugged with insulation to minimise heat losses. If this is not possible, then a smaller length will be at an even temperature (particularly if the tube is used vertically).

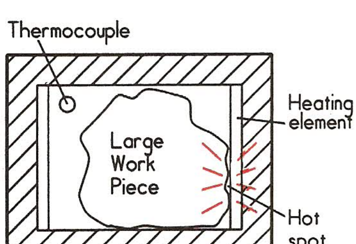


Three Zone Furnaces



In order to improve the usable length of a furnace, the heaters can be divided up into "zones" (usually three) and each zone is given its own temperature controller. These controllers are then linked so that they act to keep all three zones at the same temperature. See page 7 "Slave Control".

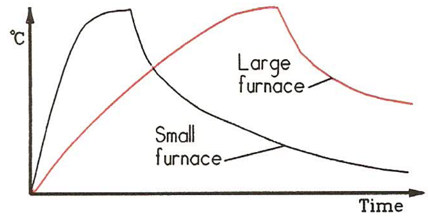
Over-filling



If you over-fill a chamber with a large workpiece it may shield the controlling thermocouple from the heat generated by some of the heating elements. This can lead to temperature fluctuations and may cause element failure due to hot spots.

Speed

Large furnaces are slower to heat up and cool down than small ones, but once they are hot their greater heat storage capacity allows them to regain temperature more quickly after cold workpieces are inserted.



Energy

Larger furnaces use more energy to heat themselves up to temperature and have higher heat losses - which increase electricity costs and raise the surrounding room temperature.

Low Thermal Mass (LTM)

is the name given to furnace designs using lightweight, usually fibrous, insulation materials rather than the solid traditional refractory bricks. They dramatically cut furnace heat up times (eg. 10mins to 1000°C).

Because only a small amount of heat is stored in LTM insulation, very little energy is used in heating up the furnace, and cool-down times are also much shorter.

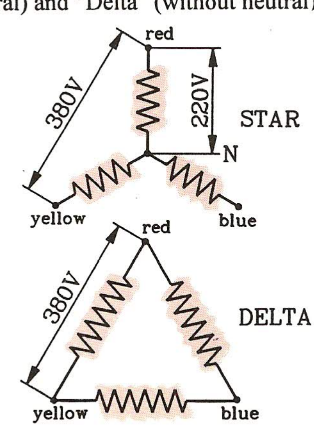
The disadvantages include higher materials cost. Also, the lack of abrasion resistance can lead to rapid hearth wear if not used carefully. So a good compromise is the LTM furnace fitted with a hard wearing ceramic hearth. It is a good idea to equip an LTM furnace with a programmer so that the warm up speed can be reduced if there is a risk of cracking the work.

Supply Cables

Large furnaces are more powerful and need larger supply cables and fuses. This can be important because some customers may be reluctant to install new supply cables solely to accommodate a new furnace.

Ask if there is an electrical supply of the required current, voltage and number of phases near to where the furnace will be placed? Many furnaces can be run on three phase supplies but this is not practical on some smaller units - simply because they have only one heater and this cannot be split into the necessary three circuits.

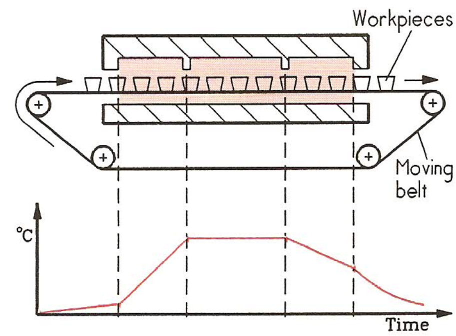
The most common three phase supply configurations are known as "Star" (with a neutral) and "Delta" (without neutral).



Continuous Furnaces

If a large number of components are being heated on a regular basis, there can be many benefits in heating them in a continuous flow rather than in a series of batches.

Components can be loaded onto a heat-resistant conveyor belt which carries them through a heated tunnel. By having separate zones at different temperatures, components can be given a specific time/temperature cycle. The effect is the same as fitting a programmer to a chamber furnace (see next page), but there are considerable savings in time and energy consumption.

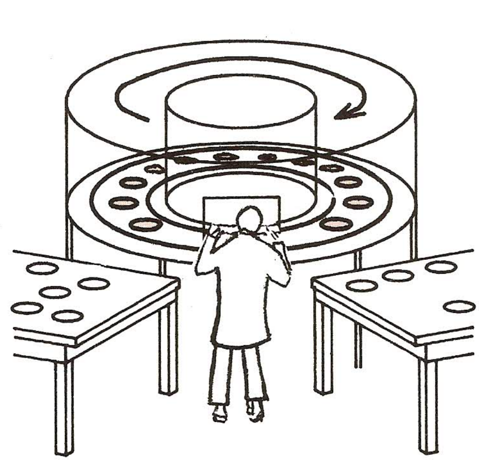


Continuous furnaces can be made to work under atmosphere, retaining the gas inside a metal retort and using one of several techniques to keep air out of the ends of the retort.

The conveyor furnace is not the most efficient continuous furnace. The belt cools on leaving the furnace and this heat energy is wasted.

Depending on the size and shape of the components, various shaking and pushing mechanisms can be used to move the components without wasting heat, but perhaps simplest of all is the rotary hearth furnace.

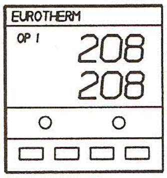
Rotary Hearth Furnaces



These have a large diameter circular rotating hearth inside a cylindrical chamber. A small doorway allows components to be loaded and unloaded by a single operator. (Straight conveyor furnaces often need two operators). These furnaces occupy very little floor space and can provide a temperature cycle as discussed above. See separate leaflet.

What Controls ?

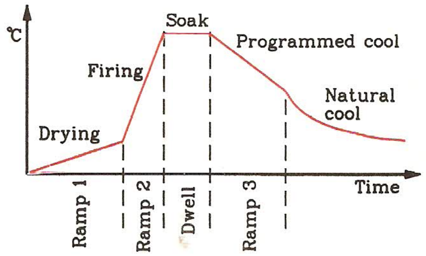
Temperature Controllers



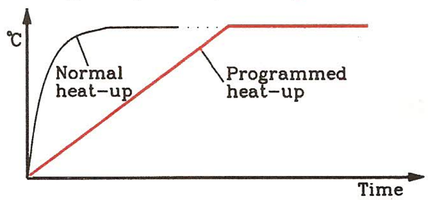
Microprocessor based digital temperature controllers have now almost completely replaced the analogue type. Digital controllers can be set more precisely (to 1°C) and the setting is repeatable from day to day.
They give a clear digital display of both the furnace temperature and set temperature, and they use sophisticated software (known as PID) to stabilise the temperature quickly with minimal overshoot on warm up.

Temperature Programmers

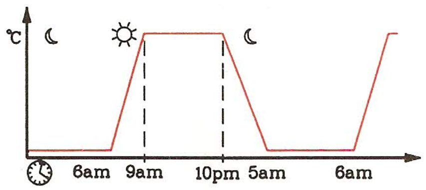
Programmers are ideal where workpieces need a closely controlled rise or fall in temperature, for example in the drying and subsequent firing of ceramics (see also Continuous Furnace page 6.)



By controlling the heat-up speed of LTM furnaces, a programmer can avoid the risk of cracking workpieces by heating too fast.

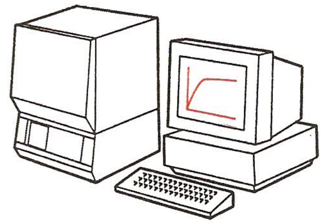


A less obvious benefit of programmers is that they can extend the furnace's working day, pre-heating the furnace so it is ready immediate use when staff start work in the morning, or processing material without supervision during the night and possibly making use of cheap "off peak" electricity.



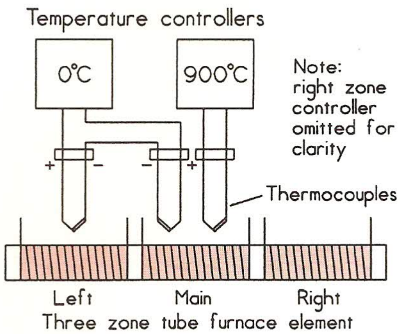
Programmers are now very easy to set, and even easier to use as an ordinary digital controller - if you only want to hold one temperature for a long time.

Computer Links



Temperature controllers can communicate with a PC, using serial communications such as RS232 or RS422/485. This can be useful to allow a program running on the PC to control the furnace temperature, but the biggest use of communications is for data-logging. The PC reads the furnace temperature at intervals and writes the data to a disc file. Then you can use spreadsheet software to draw a graph showing the furnace time/temperature cycle or to produce a certificate of the heating cycle for ISO 9000 purposes.

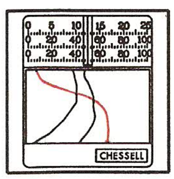
Slave Control



Slave control is used in our TZF 12/- three zone tube furnace range. A reference thermocouple is put in the main zone beside the normal thermocouple. Each outer zone thermocouple is wired in series with the reference, but with polarity reversed, so that the combined output of the thermocouples is zero when they are at the same temperature.
The outer zone controller receives this combined signal and adjusts the power supplied to its zone until the outer thermocouple is at the same temperature as the reference. In this way one programmer on the main zone can be made to influence the temperature in all zones.

Relay Outputs can be provided to allow other electrical equipment to be switched on or off when the furnace temperature passes through pre-set levels, or when the furnace enters a particular programme segment. For example this could control a fan operating only in cooling segments of a programme.

Chart Recorders provide a permanent analogue record of the temperature in the furnace over a period of time. Consider the number of pens and the speed of the paper that you will need.



Over-temperature Protection

Modern solid state furnace control systems are now very reliable, but you may wonder what would happen if the furnace should over-heat. Could this cause a fire?

All heating elements melt and stop heating at about 10% above their maximum temperature. So the worst thing that could happen is that outside of the furnace would be about 10% hotter than normal. This is not a fire risk.

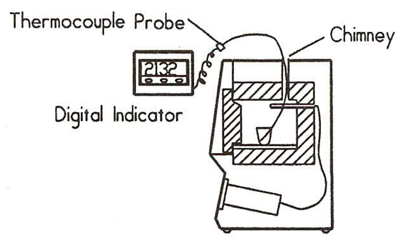
If the control system fails, the main problem is the cost of replacing the heating elements and of damage to workpieces inside the furnace.

To protect against this, we offer a second temperature controller with an independent thermocouple. This operates a contactor and shuts down the furnace until manually reset. There is also a visual warning of the fault condition. The limiting temperature is not fixed. You can reduce it to protect a valuable workpiece - rather than the furnace itself.

Accuracy

Calibration certificates can be purchased at the time of ordering. Routine checking to comply with ISO 9000 procedures is best done using a certificated digital indicator and probe thermocouple to measure the temperature close to the workpiece.

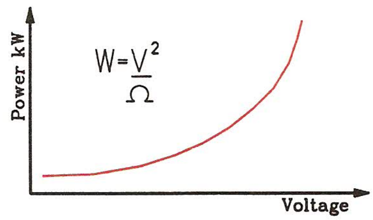
Probe Thermocouples are available for connection to a separate digital indicator for accurate measurement of the workpiece temperature. This allows the furnace set point temperature to be adjusted to correct for small differences in temperature between the position of the work and the control thermocouple position.



The probe thermocouple can be connected to a cascade control system to give the most precise control of the workpiece temperature.

Voltage

Furnaces will tolerate only small changes in their supply voltage. Their performance becomes extremely slow if they are operated on too low a voltage and their elements will give very short life if they are run on too high a voltage.

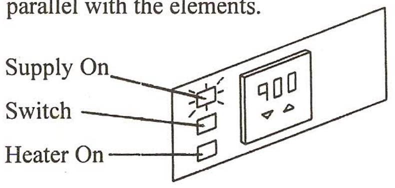


Furnace power is proportional to the square of the voltage - a 20 per cent drop in voltage produces a 36 per cent drop in power. It is therefore VITAL that the supply voltage is correctly specified when a furnace is ordered.

Servicing

Fault Diagnosis

Our furnaces are very reliable, but we think of how they will be serviced when we design them. The control circuit includes a "Supply on" warning light and an instrumentation on/off switch. The heating elements are switched on and off by solid state relays, and the output of each relay is confirmed by a "heater on" warning light connected in parallel with the elements.



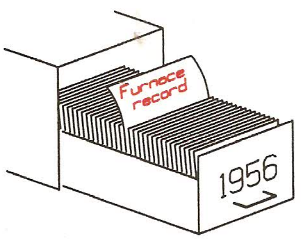
The temperature controller gives several helpful fault messages. If the thermocouple fails, the controller will shut down the furnace and display a message such as "SnSr FAil".

These features enable easy diagnosis of the need for routine replacement of consumable parts - either using the simple notes in the furnace operating instruction manual or by telephone discussion with your local Carbolite distributor.

Spare parts

Because we offer so many optional extras on our standard furnaces and make so many custom designed furnaces, we have a special system for identifying spare parts.

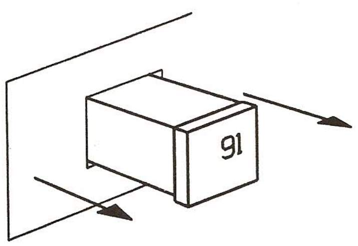
We give each furnace a serial number and each furnace has its own record card showing what parts were used to make it. These cards are kept at the factory and we refer to them before supplying any spare parts. The oldest card we have is dated 1956!



So when you need spare parts for your furnace, make sure you tell us the serial number.

Repair Techniques

All routine repair techniques are explained simply and clearly in the short instruction booklet supplied with every furnace.



The most complex part of the furnace is the temperature controller/programmer. Some of the controllers are sleeve mounted, so that they can be exchanged without any electrical knowledge simply by releasing just one fastener.
If you are a long way from the nearest Carbolite distributor this feature can save a great deal of time and money. You don't need to wait until an engineer can visit; you can make the repair yourself using a replacement unit supplied to you by post.

Materials

Alumina: Aluminium Oxide Al_2O_3. An ingredient of cement, also used as an abrasive (emery) and as a ceramic (in its recrystallised form) to make furnace worktubes for use up to 1800°C. "998" alumina is 99.8% pure.

Ceramic: Originally, "involving the use of clay or other silicates", but nowadays Alumina and Zirconia are also considered to belong to this group of materials.

Ceramic Fibre: A white insulation material made from fibres of alumina or alumino-silicate. Used in the form of blanket or vacuum-formed board. The basic ingredient of low thermal mass insulation.

FeCrAl is the most common heating element wire material. This iron chrome alloy forms an alumina surface coating to stop it oxidising away at high temperatures. Also used to make tubes using powder metallurgy techniques.

IAP: Impervious Aluminous Porcelain a group of alumino-silicate refractories used as an impervious worktube material up to 1400°C

Inconel: A heat resisting metal alloy (typically nickel Ni 80%, chrome Cr 14%, iron Fe 6%). Used as a furnace lining material up to 1100°C where gas sealing is required.

Mullite: $3Al_2O_3.2SiO_2$.A ceramic material made by sintering a mixture of Alumina and Silica to a specific crystal structure. Used by Carbolite as a work tube material up to 1500°C. Becomes porous to reducing atmospheres at high temperatures.

Silica: SiO_2 A clear or translucent glass . Often referred to as fused quartz. Melting point 1600°C, but tends to de-vitrify if cycled above 1000°C . Excellent thermal shock resistance. Used to make small crucibles, furnace worktubes and to glaze windows in furnace walls.

Silicon Carbide: SiC, a dark crystalline solid nearly as hard as a diamond. Also known as carborundum - hence the trade name. Used as an abrasive, a heating element and a refractory material in the form of bricks, thin tiles, tubes and moulded shapes.

Silicone Rubber: A heat resisting rubber used up to 250°C for seals and gaskets.

Sillimanite: $Al_2O_3.SiO_2$. A porous ceramic material, capable of 1650°C, comprising mainly silica and alumina, used by Carbolite as a muffle former material up to 1200°C.

Vacuum Formed Ceramic Fibre: Objects formed using vacuum to suck a slurry of ceramic fibre, water and binder into a mould fabricated from fine mesh. Used to make both flat boards and more complex shapes.

Zircon: Zirconium Silicate ($ZrSiO_4$) a natural sand found on the shores of South Africa, Australia and Florida. Melting point 2550°C

Zirconia: Zirconium Dioxide (ZrO_2) a white crystalline insoluble substance (melting point 2715°C). Used as a pigment and a refractory.

Safety

Chamber furnaces are fitted with positive-action door switches. Opening the door isolates the heating elements from all poles of the supply, except the earth (ground).
The type of switch used is fail-safe. If the contacts should become welded together, operating the door levers them apart again.
All ceramic materials become slightly electrically conductive at high temperatures. If metal tongs were used to load a furnace which had no door switch, it would be possible to receive an electric shock.

Tube furnaces cannot be provided with such automatic protection and the user must exercise care; switching off the furnace before loading/unloading and using only tools with insulated handles.
If neither of the above can be employed then the alternatives are as follows.

Low voltage and isolation

Furnaces which use low voltage elements can be fitted with isolating transformers. This is the method of protection used in bathroom shaver sockets. The supply voltage is no longer alternating about earth potential; it is fully floating. As a result, if any part of the circuit is connected to earth through a person, the supply begins to alternate about the person. No current flows and no shock is suffered.

Earth Leakage

Furnaces can be fitted with a special circuit breaker which responds to small earth leakage currents. (known as RCD, RCCB or ELCB)
These devices compare the current flowing in the live and neutral wires. Under normal circumstances these currents cancel each other out, but if even the tiniest amount of current is "lost" the trip assumes that this current is "leaking" to earth (possibly through someone's body) and switches off the supply.

Case Temperatures

The casing around a furnace opening inevitably gets hot, but it is important that if someone stumbles and reaches out with a hand to steady them self, they must not touch a surface that could give them a burn injury.
We solve this problem by giving almost all of our furnaces a double skinned case so that there is a ventilated air gap between the outer surface of the insulation and the inside of the outer metal case. By careful design of the natural convection airflow through the case we can make the furnace safe and silent. On the most difficult furnaces a small instrumentation cooling fan may be used to reduce the case temperature.

This document is available in Microsoft Word format

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