

General Information and Instructions K2 – K12A Kilns



KILN AND FURNITURE PACKING

LOCAL AND INTERSTATE KILN PACKING

The packing of kilns that are delivered Locally or to Interstate are packed differently (as shown below)



Programmer
, Bungs and
Door
Handles

Kiln Delivered Locally
(**Note:** Local Delivery
of kiln does not require
a pallet)



Pallet
(**Note:** Kiln
will be
bolted onto
Pallet)

Programmer
, Bungs and
Door
Handles

Kiln Delivered
Interstate

KILN FURNITURE PACKING

The delivery of Kiln Furniture Pack will be pack and wrapped on a pallet (as shown below)



Shelves

Props

KILN FURNITURE WITH ROOF MOUNT VENT SYSTEM PACKING

The delivery of Kiln Furniture and Roof Mount Vent System will be packed and wrapped on a pallet (as shown below)



Props

Roof Mount Vent System

Shelves

HOW TO MOVE THE KILN WITH A PALLET JACK OR FORK LIFT

When moving or relocating of kiln with a pallet jack or a fork lift, always remember to make sure the fork can be seen through the other side of the kiln. (**Note:** If the fork cannot be seen through the other side of the kiln and lifting has proceeded, kiln can be damaged and the tipping of kiln can occur.)



POSITIONING FOR ELECTRIC KILNS

There are no specific rules for positioning of an electric kiln, however there should be adequate room around a kiln.

It is recommended a minimum of 150mm of wall on the non-control box sides and 600mm of wall on the control box side. The 150mm is only when the wall is non-combustible. If it is a combustible type material, standard plaster etc., a minimum of 300mm is recommended or a cover by a non-combustible panel. If the area has high combustible materials, the kiln should not be positioned in that area.

Below the kiln should be a non-combustible material, in particular if the kiln is a top loader.

It is recommended a minimum of 1m from the ceiling, but this will vary depending on the type of kiln and ceiling. If the ceiling is combustible, i.e. woven straw, the kiln should not be positioned below that type of material.

Some of the above recommendations may be excessive but it is in consideration to potential insufficient clearways due to materials being stacked up against the kiln which could create a problem. Kilns are very safe piece of equipment.

POSITIONING OF KILNS OUTSIDE

If the kiln is to be positioned outside of a building, it is important to put a structure around the kiln that will shield it from adverse weather conditions, such as heavy rain and very high humidity. If kilns are exposed to excessive moisture, the bricks will absorb the moisture, and when firing the kiln, the moisture will disperse from the brickwork causing future problems. It is a preferred option to have the kiln inside a structure, but still allowing adequate ventilation around the kiln.

POSITIONING OF KILNS IN A SCHOOL ROOM

It is recommended that the kiln has a barrier around the outside to stop inquisitive children from touching the kiln during operations.

VENTILATION OF ELECTRIC KILNS

It is recommended that kilns be fitted with a powered ventilation system, which can be provided by Tetlow. Adequate ventilation in the room must be allowed for the system to work effectively, i.e. air flow.

Tetlow Kilns and Furnaces can visit sites to recommend positioning and ventilation system of electric kilns. This would be charged at out standard rate including travel time, on-site time and preparation of report.

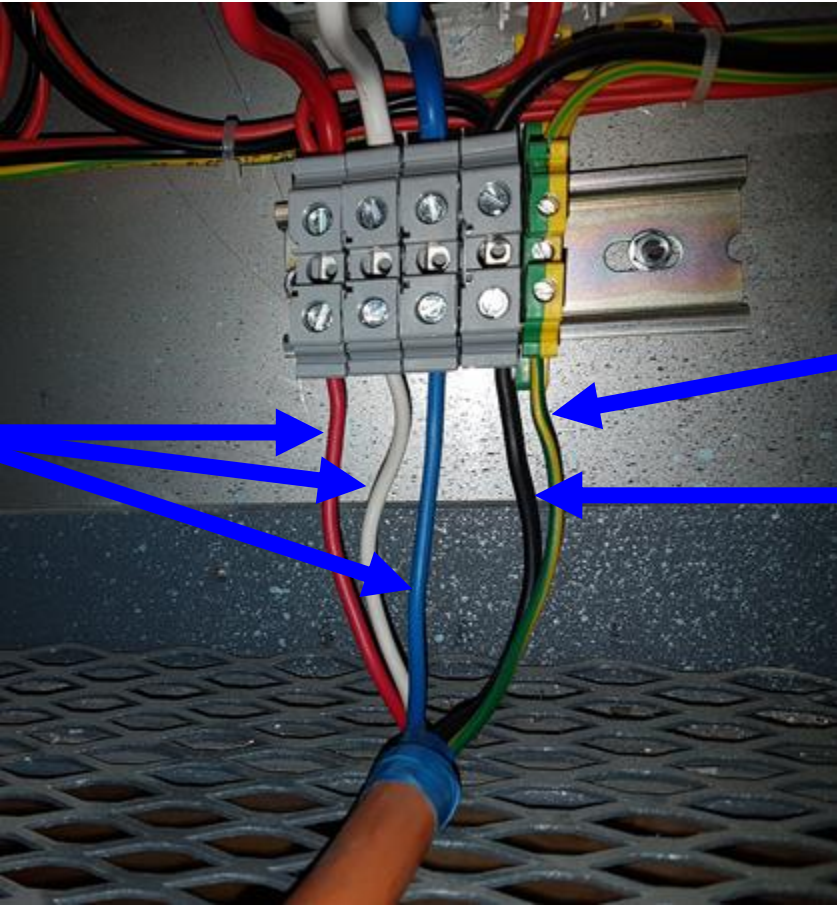
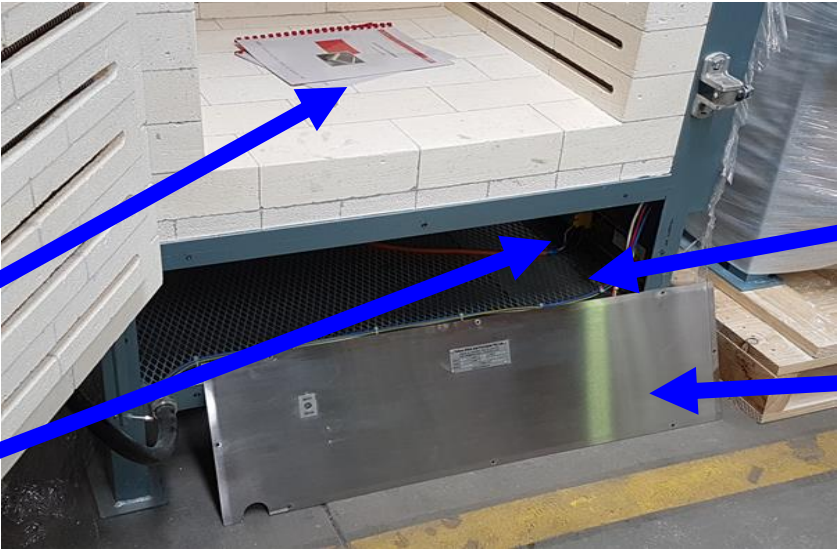
ELECTRICAL CONNECTION FOR KILNS

Please ensure that you do not install a kiln on an electrical connection with an EARTH LEAKAGE SYSTEM (RCD or RESIDUAL CURRENT DEVISE BREAKER). These systems will often cause the kiln to trip out (as with stoves or ovens). A simple circuit breaker is more suitable. Should an Electrician have an issue with not installing an RCD then the kiln may need to be hardwired to the connection.

Small kilns up to 20amp, single phase come complete with 3-pin plug. All kilns above 20amp, single phase or multi-phase require direct wiring. All kilns require neutral.

All kilns require neutral. All active and neutral connections are to ceramic terminal blocks mounted in the control area along with a screwed terminal for earth.

1phase:	3wires	1active	1neutral	1earth
2phase:	4wires	2active	1neutral	1earth
3phase:	5wires	3active	1neutral	1earth



ELECTRICAL ISOLATORS

An electrical isolating switch should be fitted adjacent to the kiln, so the kiln can be isolated when not in use.

It is recommended that circuit breakers or fuses and electrical cables are rated at a minimum of 20% above the required amperage of the unit.

Important: Before electrical connections are made, check and secure all terminal screws and nuts on factory fitted cables (contactor, etc). These may have become loose in transport and associated handling.

FIRING OF ELECTRIC CRAFT KILN

BRICKS

The bricks used for manufacturing of electrical kilns are of the refractory insulation type. These have all the heat-resisting qualities of refractory bricks but are very porous.

These allow for air, a good insulator, to use the huge number of air pockets inside these bricks, so that if one face of the brick is exposed to heat it takes a considerable time before this heat is transmitted through the brick to the opposite face. The pore structures also make the bricks very light in weight.

ELECTRICAL WIRING AND FITMENTS

The electrical wiring and fitments are installed into the control box of the kiln, allowing access to them via removing the control panel side plate.

Electrical kilns, especially the larger sizes, take quite a considerable amount of current, therefore when the kilns are switched on and off, the switching device must be robust to withstand the sparking which may occur. The switching is therefore often done via a contactor, which is merely a robust relay that enables the kiln to be switched on and off without burning any of the connections etc.

Most kilns are fitted as standard with an energy regulator complete with a pilot light which is switched automatically on and off as the energy regulator switches the current to the elements on and off. Kilns are fitted with a door safety switch which turns off the element power when the door is open.

ELEMENTS

There are a various types of elements that can be fitted to kilns, but the most popular type is known as Kanthal A1 and is the element type used on all kilns.

These are made from alloys of iron, aluminium, chromium and cobalt. The alloys do not contain nickel and the great disadvantage is that once they have been fired they become very brittle and have to be well supported in the kiln. Take care in ensuring that minimal knocks or shakes occur as they can easily broken at this stage. A1 elements will allow a maximum operating temperature of 1300°C.

An important feature of Kanthal wire is that after firing the wire becomes coated with aluminium oxide, which protects the wire from attack by most of the harmful gases. Exposure to reducing atmospheres will, however, very quickly remove this coating and the elements will then deteriorate very quickly unless the coating is restored by an oxidizing fire. Alkali vapors and halogen vapors – for example, fluorine, iodine, etc. – are harmful to elements and so is lead vapor. Kanthal wire has chemical resistant properties built into its substructure.

Elements of the Kanthal type are wound into a continuous spiral, which is usually formed into a hairpin shape, i.e. two rows of element coils joined at one end. The last nine inches of each end of the element is not coiled but is left as a straight wire so that the element “tails”, as they are called, can be pushed through the holes drilled through the wall of the kiln and connected to brass connectors in the connection chamber of the kiln.

Electric craft kilns are of the exposed element type. This means that the elements are supported in the grooves or channels cut into the walls of the kiln leaving the elements clearly visible. This method is much cheaper, more efficient, and lends itself to easier maintenance.

If ever it is necessary to replace a burnt-out element, always quote the model number of your kiln, indicating which particular element has failed and always ensure that EVERY trace of the burnt-out element has been removed from the element grooves before fitting the replacement. THIS IS OF HIGH IMPORTANCE.

THE FIRST FIRING

Before any kiln is put into use, it should be fired slowly, preferably over 2 or 3 days, to a temperature no higher than 100°C or 200°C below the maximum firing temperature for which it was designed. This gentle firing drives away any moisture present in the brickwork, after which the kiln is ready to be put into full service.

After the first firing has taken place, it may be noted that a few fine cracks will have formed in the interior brickwork of the kiln. These cracks will close up when the kiln is next heated and open again when the kiln is subsequently cooled. They therefore serve as expansion joints and are in no way detrimental to the operation of the kiln.

KILN ACCESSORIES AND INSTRUMENTATION

ENERGY REGULATOR

This is purely a medium that controls the rate of temperature increase through control of the heat input to the kiln. It comprises of an automatic switching device, with the switch contactors opening and closing being infinitely variable. The delay of power to the elements will alter the length of time it takes the kiln to heat to temperature required, and contactors are used to regulate the process. The calibration is 0 to 100 percent, with 100 percent being when the contactors are closed and the kiln is heating at maximum rate normalcy. A small red indicator light is incorporated in the regulator, which illuminates when the kiln is heating up.

An energy regulator is a very useful piece of equipment to easily control the rate of temperature control. Thus, if thick-walled pots are being fired, the rate of temperature increase can very easily be reduced. If a pyrometer is fitted to the kiln and there is a need to maintain the kiln at a certain temperature, the energy regulator setting can be adjusted until a position is found where the elements would switch on and off at a rate slow enough to prevent further temperature rise, but fast enough to prevent the temperature dropping. This procedure should only be done for short periods of time to ensure minimal temperature drifts.



DOOR SAFETY SWITCH

This device is designed to isolate the electrical supplies to the kiln elements when the kiln door is open. The usual door safety switch consists of a metal bracket that is fixed to the lower edge of the kiln door and depresses a plunger fitted to the front or underside of the kiln, this in turn operates the contactor relay, thus allowing current to flow to the kiln elements. When the door is opened the plunger is released, which switches the contactor relay to an "off" position,

cutting off the electric supply to the elements. The door safety switch is a hard wired control shut off, tempering with this device could cause electric shock and electrocution.



PYROSCOPES AND TEMPERATURE CONTROL

Before the intensive study of pyrotetric practice the sense organs were the only means of determining temperatures and kiln firemen estimated the temperature of a kiln by reference to the degree and colour of the glow inside it. The determination of temperature by sight and feel, however, can only be an approximation and it is quite inadequate.

There are basically two methods of controlling a kiln firing: by the use of pyrometers and by the use of pyroscopes. Pyrometers and Pyroscopes are, however, often used in conjunction as they measure two completely different functions. Pyrometers measure temperature and pyroscopes measure heat work.

PYROSCOPES

Pyroscopes are indicators made of ceramic mixtures based on silicates. The chemical nature of silicate mixtures is such that they do not have definite melting points, but they have a temperature range in which part of the mixture is melted and the remainder is solid. In this temperature range the process of glass formation (vitrification) takes place. When sufficient degree of vitrification occurs, the pyroscope can no longer support itself and bends or collapses, thus giving a visible indication. There are two ways of attaining this result. The first is to heat the pyroscope to a temperature high enough to produce this effect quickly and the second is to slightly lower the temperature but to hold this temperature for a longer time.

Since pyroscopes tend to be of a similar composition to pottery bodies, they offer a very good means of controlling the finishing point of a kiln firing. Pyroscope is like pottery and is correctly fired when the correct degree of vitrification has taken place. If a kiln firing is done slowly this will be reached at a lower temperature than when the firing is done very quickly, therefore the reliance on pyroscope alone to determine the finishing point of a kiln firing can be misleading.

CONES

Cones are possibly the most important and useful way of controlling a kiln firing. They are commonly classified as pyroscopes; Buller rings and Holdcroft bars fall into the same category.

Staffordshire cones come generally in two sizes, standard cones are 2½ inches tall and miniature cones are 1 inch tall. The cones are three-sided conical shape and made of a carefully controlled mixture of ceramic materials, which is designed to give a graduated scale of fusing temperatures at approximately 20°C intervals.

The cones, which melt at the lower temperature, contain a higher proportion of fluxes than those melting at the higher temperatures, which contain increasingly larger proportions of refractory oxides. This melting or fusing temperature is denoted by a number which is stamped into the back of the cone and by reference to the Staffordshire cone chart, which can obtain an approximate melting point for each of the different numbers. Although it is commonly assumed that the Staffordshire cones melt at indicated temperatures on the chart, the cones can also melt and collapse when they have been subjected to a certain temperature, or rate of temperature increase, for a certain length of time.

Time factor is important because it is usually assumed that when a kiln fires to 1000°C over a period of 8 to 10 hours, the ware has been fired to its recommended temperature and therefore fired correctly. However, if firing is controlled solely by a pyrometer, then the kiln would have switched off when the temperature reached 1000°C and the ware fired in 3 to 4 hours would not have been properly fired and would probably be underfired when withdrawn from the kiln. This is where the time factor of Staffordshire cone becomes useful.

Staffordshire cones will only collapse when subjected to heat for a certain length of time and will not collapse if they are fired too rapidly until a temperature is reached which is considerably higher than the indicated number stamped on the back. Similarly, if the cones are fired too slowly, they will probably collapse at a temperature earlier than that indicated by the cone number. In this way Staffordshire cones give an indication of the amount of heat work applied to the ware and not merely the temperature to which the ware is subjected.

It should also be noted that other factors can influence the temperature in which the Staffordshire cones collapse, such as usage in a strongly reducing atmosphere where chemical reactions may take place, causing the cone to withstand higher temperatures than usual. There are also other potential various affects that could cause misleading. Sulphur gases can also attack the Staffordshire cones, resulting in bloating and grey discolouration, which could distort collapsing temperatures.

It should be noted that other factors could influence the temperature at which Staffordshire cones collapse. If they are used in a strongly reducing atmosphere then it is possible for a chemical reaction to take place which results in a hard refractory skin being formed on the outside of the cone. The cone may then stand quite upright and the temperature of the kiln continue to increase considerably beyond the point at which the cone was supposed to have collapsed. It is even possible for this hard skin to be formed and yet for the inside of the cone to melt and run away, with the result that the refractory shell of the cone which may be still standing upright misleads the operator. Sulphur gases can also attack Staffordshire cones, resulting in bloating and a grey discolouration which, again, tends to distort the collapsing temperature.

One of the most important considerations in the use of pyroscopes is the way in which they are mounted. This is generally done by inserting the base of the cones either into special cone holders or into a pad of plastic clay, but regardless of the type of mounting it is important that all the cones be embedded to the same depth. It is necessary for the cones to be placed at an angle of about 15° to the vertical, and to ensure that the manufacturer slants the base of the cone so that this inclination is automatically brought about when the cone is stood upright.

It is standard to use a series of three cones for each firing, one cone indicating a temperature of about 20°C below the temperature to which the ware is to be fired, one cone indicating the required temperature and one cone indicating a temperature 20°C above the required one. In this way the collapse of the lower cone serves as a warning that the temperature is rising to the point at which the second cone will collapse (at which time the kiln should be switched off). The third cone serves as a guard to show potential overfiring.

It is important to place the cones in some definite order, which is usually done by placing the cones from left to right in order of increasing fusion point so that the cone on the extreme right will be the last to go down. The correct firing of any cone will be indicated when the cone bends over so that its tip bends down and touches the base on which the cone is mounted. This is referred to as the end-point of the cone. If the temperature continues to increase the cone will collapse further and eventually melt completely.

TEMPERATURE MEASURING INSTRUMENTS (PYROMETERS)

There are different types of temperature-measuring instruments, but the ones generally used consists of a thermocouple attached by compensating cables to an instrument, which transforms the voltage fed into it from the thermocouple into degrees of temperature indicated on a scale. The standard pyrometer generally has a simple galvanometer as the recording instrument whereas the more sophisticated recording instruments generally have potentiometric systems or a combination of the two.

POTENTIOMETERS

The word “potentiometric” occurs frequently in temperature measurement systems and describes merely the system used inside the recording instrument to measure accurately and to convert into degrees of temperature the very small voltages fed into it from the thermocouple.

Important “Do’s” and “Don’ts” when installing pyrometers

- ♦ DON'T connect electric mains supply to pyrometer/thermocouple terminals.
- ♦ DON'T run the compensating cables near or parallel to electric mains as otherwise the compensating cables will have an electric current induced in them from the main cables, which will result in inaccurate readings on the instrument.
- ♦ DON'T use ordinary copper cable for connecting the thermocouple to the pyrometer, as this will not compensate for temperature changes.
- ♦ DON'T shorten or lengthen the cable or thermocouple as the pyrometer has been calibrated for external resistance.
- ♦ OTHER IMPORTANT POINTS: The temperature inside the kiln is indicated on the pyrometer dial at all times. DON'T adjust the instrument to read zero if the kiln is at room temperature.

THE STANDARD PYROMETER

This consists of a galvanometer fitted with a temperature scale, a thermocouple housed inside a porcelain sheath, and two pieces of compensating cable for connecting the two.

Installation is simple – the metal framework of the kiln is drilled by the manufacturer at a position suitable for the installation of a thermocouple. All that is necessary is to push the thermocouple into the hole provided in the kiln wall and keep the cold junction about 1 inch away from the kiln wall. Place pyrometer in suitable position and a screw fitted to the front or just underneath the front of the instrument can be adjusted to set the instrument reading to the room temperature, i.e. normally about 18°C.

THERMOCOUPLES

Thermocouples are the “working end” of the pyrometer that projects inside the kiln and generates the current, which is measured by the instrument fixed outside the kiln.

If two different metals are drawn into wires and they are joined together at one end, a small electric current is generated when this joint of the two wires is heated. The greater the amount of heat applied to the junction, the greater will be the voltage generated in the wires. By measuring this voltage one can therefore get some indication of the amount of heat being applied to the junction of the wires.

Chromel-Alumel

Chromel (a nickel chromium alloy) for one wire. Alumel (an alloy of nickel, aluminium, manganese and silicon) for the other. Used for temperatures up to 2000°F (1150°C).

Platinum – 10 percent Rhodium

An alloy of 10 percent rhodium and 87 percent of platinum for one wire and pure platinum for the other. Used for temperatures up to 2700°F (1480°C).

Platinum is a very expensive metal, and for this reason, the thermocouples based on platinum are very much more expensive than the Chromel-Alumel types.

The cold end of the thermocouple is generally referred to as the “cold junction”, the end of the thermocouple projecting into the firing chamber being referred to as the “hot junction”.

It should be noted that the voltage generated by a thermocouple is dependent upon the difference in temperature between the hot and cold junctions and to register temperature accurately, the cold junction must be kept as cool as possible.



THE MINI TEMPERATURE CONTROLLER

The thermocouple section is identical with those used for the other pyrometric instruments, but the instrument is not fitted with a temperature-indicating pointer and is therefore much more robust in its ability to withstand knocks and jolts.

The face of the instrument is fitted with a control knob, which can be rotated within a scale graduated up to 1400°C. When the kiln is switched on, no matter how quickly the temperature rises. It will never exceed the temperature indicated on the scale by the control knob. The temperature regulator therefore functions exactly like a thermostat fitted into the oven of an electric cooker and is fitted with a relay to switch the electric supply on and off.

Two indicating lights are fitted to the instrument; one of the lights come on when the temperature regulator is allowing current to pass to the elements and the other light is for main supply.

This is generally more robust than other types of pyrometers, and enables the kiln operator to maintain the kiln easily at any temperature until it is switched off and it is possible to approximate the temperature of the kiln, if necessary, by moving the knob setting and “searching” until a setting is reached at which the temperature light on the instrument switches off.

LIMIT SWITCH

A switching device can be incorporated into the instrument, which will switch off the instrument at any desired temperature.

CHOOSING YOUR KILN

The choice of the correct kiln is influenced by these major factors:

- (a) The approximate size of the kiln required.
- (b) The maximum temperature to which the kiln will be fired.
- (c) Difficulty of access to the kiln site.
- (d) Whether the electricity consumption of the kiln can be accommodated by the electricity supply.
- (e) The space in which the kiln is to be situated.

BASE EFFECTS OF HEAT ON CLAY

With the exception of some terracottas and a few stoneware clays, most of the clays used are not merely clays dug up from the ground and purified, but are mixtures of different types of clay with other materials mixed in to give desirable properties (i.e. with the consistency of Plasticine). This plastic clay is then passed through a pug mill where the clay is thoroughly sliced and mixed to give it a very homogenous consistency. Prepared clay is generally referred to as a “body” rather than clay, and particularly so once the clay has been fired.

VITRIFICATION AND POROSITY

Some clays are known as being more refractory, and this means that the firing temperature or maturing range is higher for certain clays, for example, stoneware bodies which have to be fired at temperatures of about 1250°C-1300°C are

more refractory than earthenware one which fire at 1100°C-1150°C. Vitrification and porosity are terms used to describe the degree of water retention of the body after firing. A vitrified body is one that is dense and nonporous or low in porosity. The porosity of a body generally decreases as it is fired to a high temperature.

A body is correctly fired when it has been fired to its maximum degree of vitrification without deforming or has been fired to a temperature which has enabled the body to develop a sufficient coefficient of contraction to enable glazes to be used without crazing. The range of temperatures at which this stage is reached varies from one type of body to another and is referred to as the firing range, maturing range, or vitrification point of the clay. Some clay, i.e. stoneware, will be almost completely vitrified when this point has been reached; others will possess an appreciable degree of porosity – such as the earthenware and terracotta types.

The golden rule of pottery is that it should always be dry before firing. If damp pottery is placed in the kiln, there is a great risk of cracking or explosion during the firing operation, with bits being scattered over all adjacent pottery pieces causing damage. A good way of determining whether clayware is dry is to place it against the cheek and if it feels cold then the ware is damp and must be dried further. Thick pieces of pottery take longer to dry and longer to fire than thin pieces. If you place thick and thin pieces of pottery into the same kiln, the kiln should be fired more slowly compared to only firing thin pieces.

When clay is fired, it undergoes several complex changes, therefore even if it is dry when placed into the kiln, a considerable amount of water vapor is still driven off during the firing operation. This volume of water driven off may be about fifty times the volume of the kiln and is not water that can be dried, and they shrink still further during the firing operation. This degree of shrinkage varies with clay and is generally higher in those bodies which have the firing temperatures. The more clay is present in the body, the greater the degree of shrinkage.

THE IMPORTANCE OF SILICA

Silica is sometimes regarded as the basis of pottery industry because it is the most important material used in ceramics and the most important characteristic of silica is its behavior when heated. Silica can be located in many different materials and the silica crystal has several different forms and modifications. When silica is heated, some of it changes from one form to another only to revert to the original form when subsequently cooled. Other modifications of silica can change permanently to another form which remains even after cooling.

MODIFICATIONS OF SILICA

The most important crystal modifications of silica are as follows:

(alpha) quartz	(beta) quartz
(alpha) tridymite	(beta) tridymite
(alpha) cristobalite	(beta) cristobalite

Alpha and beta quartz, and alpha and beta cristobalite modifications are similar and should be cautioned. When these silica are under the influence of heat, it expands and when it is subsequently cooled, beta quartz reverts to its original form of alpha quartz causing a contraction of the silica mass.

When silica is heated, it gradually expands until a temperature of approximately 225°C is reached and then it will expand considerably as the alpha cristobalite content changes to beta cristobalite, which is the same chemical composition but a larger volume. As heating is continued, another sudden expansion occurs at a temperature of approximately 550 - 575°C, when alpha quartz changes to beta quartz.

As heating continues, other forms of silica begin to change into beta cristobalite. This conversion progresses with increasing rapidity as the temperature is raised higher. If silica is heated above 1200°C for example, most of it is converted into beta cristobalite, thus the higher the temperature to which a pottery clay or body is fired, the more cristobalite is developed.

As silica is cooled, it gradually contracts until a temperature of approximately 575 - 550°C is reached, at which point the beta quartz content reverts to its original alpha quartz form accompanied by a sudden contraction. As the silica is cooled still further, the point at which beta cristobalite changes back to alpha cristobalite is reached when the temperature drops to approximately 225°C. This beta to alpha cristobalite change causes another sudden volume contraction.

These sudden expansions and contractions at the certain temperatures occur every time the silica, or a body containing silica, is fired. Therefore, this occurs during glaze firings as well as biscuit firings, and if heating or cooling of the pottery is proceeding too quickly, the stresses set up by the above silica "inversions" can, and often do, result in cracks right through the pottery causing the fault known as "dunting".

The formation of an appreciable amount of cristobalite renders pottery clays and bodies craze-proof. This is because the beta to alpha cristobalite changes as the glaze-fired ware is being cooled suddenly shrinks the biscuit ware, causing the glaze covering it to be placed in a state of compression.

STAGES IN BISCUIT FIRING

1. Water Smoking

This covers the period from the beginning of the firing up to a temperature of about 150°C. During this period any remaining mechanically held water present in the clay is boiled away. Removal occurs in two ways: firstly, the body continues to contract until each particle touches its neighbor and secondly, water is removed from between the particles.

2. Dehydration Period

This covers an approximate temperature range of 150°C to 600°C. The chemically combined water present in the clay mostly leaves the body between a range of 200°C - 460°C up to 600°C but traces are still present up to 900°C. During this period of time the amount of steam given off from the ware will be about fifty times the interior volume of the kiln and this must be allowed to escape easily from the kiln. If the kiln is heated too quickly from the commencement of firing up to the end of the dehydration period, the steam formed inside the body may not be able to get to the surface quickly enough and may build up to such a pressure that the pottery is blown apart. Firing should therefore be at a fairly slow rate over this temperature range.

Incidentally, by 800°C the clay is as porous as a sponge, as at this temperature it has lost all chemically held water and most of the carbon and had no readjustment to the other ingredients. At this stage, the body is lighter in weight and extremely porous compared to when it was first placed in the kiln. If the biscuit is too porous, it has not been fired enough and if it is too vitreous then it has been over fired.

3. Vitrification Period

This period has a temperature range from approximately 900°C to the firing temperature of the clay. The fluxes present in the body begin to react with the clays and tend to soften and melt as the temperature increases. If the temperature is taken beyond the vitrification point of the body, gases would be given off and lead to bloating or blistering. At this point, the fluxes of the body are literally boiling.

BASIC EFFECTS OF HEAT ON GLAZES

Glazes are suspended in water or materials which will subsequently melt together to form a glasslike material.

MATCHING OF GLAZES

Glazes have to be "matched" to the body to which they are applied if good craze-resistance is to be obtained. This means that the rate of expansion and contraction of the glaze must be similar to that of the body otherwise one will crack away from the other if the fired pot is suddenly heated or cooled.

The rate of expansion of a glaze is dependent on the quantity and rate of expansion of each material used in its composition. Various materials have different rates and careful selection process should be used to design a glaze with specified rate of expansion and contraction. When the rate of expansion of the body is known, a matching glaze can be calculated and designed to suit it, thus “matching” to the body. The glaze is designed to have a slightly lower coefficient of expansion to the body so that during the cooling process, the glaze contracts slightly less than the body, which allows for slight compression of the glaze from the body, giving a built-in resistance against crazing.

STRESSES AND STRESS RELEASE

When glaze is molten, some of its components are being vaporized and therefore any unnecessary continuance would make the glossy glaze dull and lack shine. As the glaze cools to the point at which it becomes a solid mass, the rate of vaporization decreases considerably. To obtain a good glossy glaze, the kiln should be cooled fairly quickly down to approximately 750°C, where most glazes become rigid. Any stresses or strains created in the glaze by this rapid rate of cooling can be easily absorbed because the molten glaze will allow the stresses to flow away. However, as the glaze becomes increasingly more rigid, caution must be applied as it is now able to crack and will do so if the stresses and strains are caused by cooling too quickly. It is therefore best to fix an arbitrary point of 750°C and to cool as quickly as possible down to this followed by a slower rate of cooling.

EFFECT OF COOLING

Devitrification can also be caused if the glaze is cooled too slowly while it is molten. This will result in a transparent glaze with a milky appearance, and although there are other causes to this, slow cooling is the most common.

Once the temperature has fallen below 700°C, there are two particularly dangerous temperatures, which is approximately 575°C and 225°C. At these points, the silica in the body undergoes a sudden contraction during its cooling, which results in the body and the fixed glaze layer suddenly contracting. If all of the body and the glaze covering reach these temperature points at the same time, no problem will occur.

However as the above is rarely the case, due to difference of temperature points in different parts of the same pot by 10°C-30°C, cracking often occurs. This can be prevented by allowing the pot to absorb these stresses over as long a period of time as possible, which can only be done by cooling slowly when the temperature of the kiln approaches 575°C and again when temperature reaches 225°C.

KILN PLACING

Each shelf should be supported at three points rather than four points to prevent rocking from occurring. The supports should be arranged in a similar position for each succeeding shelf so that the total weight of the complete set of kiln furniture acts downwards through continuous columns.

The ideal material for putting on the shelves for glaze firing purposes is a mixture of alumina and china clay or zircon and china clay mixed with water and painted on the shelves in the form of a wash so that it adheres quite firmly. Many companies sell a specially prepared mixture known as bat wash.

Kiln shelves and props are usually made from sillimanite or a mixture of refractory materials similar to sillimanite. These materials are very refractory and will easily withstand stoneware temperatures, however if the kiln bats are required to withstand temperatures up to 1300°C without warping, then it is best to select bats either ¾ or 1 inch thick. ½ inch thick kiln shelves are very popular, but these are best reserved for temperatures below 1200°C.

BISCUIT KILN PLACING

Kiln placing for a biscuit fire is simpler than placement for a glaze fire, because the only aim is to get as many pots as possible into the smallest possible space.

Large heavy pieces may need a shrinkage platform under them to prevent warpage. These are smooth slabs of clay made from the same clay as the pot and therefore will shrink to the same extent. A thin layer of bat wash or silica sand

should be placed between the shrinkage platform and the shelf to enable the clay platform to shrink easily without sticking to the shelf.

The cones should be placed in a position and checked to ensure that they are in a position directly in line with the spy-hole in the kiln door.

GLOST KILN PLACING

Care must be ensured in glost firing as the glaze covering the pots will stick them together if allowed to touch. Similarly, should any glaze adhere to the underside of a pot, it will stick the pot firmly to the kiln shelf. Therefore, the glaze is always removed from the base of the pot beforehand by using a sponge. If the removal of the glaze from the underside of a pot is difficult or time-consuming, stilts can be used as reassurance to no sticking. Repetitive usage of the stilts may cause the sharp edges to become blunt after several fires, and should be replaced with a new stilt, which will be less likely to leave a blemish on the base of the pot even when it is covered with a thin layer of glaze.

Stilts are particularly useful in the firing of glazed earthenware and terracotta wares to support the pots clear of the kiln shelf. Further advantage of using a stilt is that the air circulation under the pots helps to reduce the temperature variation between the top and bottom of the pottery article. However, usage of stilts can raise problems when firing stoneware. This is because if these wares are fired to full maturing temperature, the pots may begin to sag or squat over the stilts or any other supporting medium being used. Therefore when firing stoneware, the base is left unglazed and stood directly on the kiln shelf.

When placing for either biscuit or glost firing, leave a gap of at least 1-inch between the pot and the nearest element. Failure to do this may result in one side of the pot being scorched.

It is best to avoid placing differently colored glazed pots in the same firing. This is because the volatilization of glaze from one pot can influence the color of its neighbor to a very noticeable degree. If this cannot be avoided, try to keep white and highly pigmented glazes, such as black, as distant from each other as possible.

FIRING

Firstly, the vent plug should be removed to allow steam to escape more easily and the spy-hole left open, and if there is an energy regulator, this should be set at a fairly low setting. Switch the kiln to its low setting for 1 hour to drive away any surplus of moisture retained from previous firing.

The objective of this procedure is to ensure that during the early stages of firing, the water vapor chemically held inside the clay that converts to steam, is allowed to escape from the kiln easily. The rate of temperature increase should be fairly slow and no greater than 100°C per hour for the thinner pieces of pottery. The thicker pieces will demand a temperature increase that is considerably slower and as low as 50°C-70°C per hour.

When the kiln is set to its medium setting of about 50 to 70 on the energy regulator, leave this setting for 1 hour or so before switching to the highest setting. The vent plug should be in position during this period and remain until the kiln is switched off.

As the kiln is gradually increasing in temperature, large amounts of steam, which may not be visible to the human eye, may be escaping from the vent hole and spy hole of the kiln. After approximately 2-4 hours, the energy regulator can be turned up to a reading of approximately "60" on the scale, and at this point the temperature should be in the region of 150°C – 350°C.

The actual brickwork that lines the interior of the kiln will begin glowing red at a temperature of approximately 600°C and at 650°C - 700°C, the glowing will be very noticeable. At this point, the vents can be closed and the kiln will probably have been on medium setting for approximately 1-3 hours and can now be switched to the high setting to finish off the firing for the terracotta and earthenware types of clay. For stoneware clays, it is normally best to allow the

kiln to remain for an additional hour or so at its medium setting before switching to its high setting, since these clays contain comparatively higher amount of carbon.

Once the energy regulator is switched to 100%, the kiln will begin to increase temperature at its maximum speed. If this rate of temperature increase is too rapid, then switch the energy regulator to 90% or less.

The kiln interior will now glow brightly and after a further 2-3 hours, the temperature should be in the region of 800°C - 1000°C. If a pyrometer is fitted, then it will be easier to determine the point at which the kiln can be checked to see the Staffordshire cones. This procedure should normally begin when the reading on the pyrometer gives an indication of 30°C or so before the collapse of the 1st cone. If a pyrometer is not fitted, rely on glancing into the kiln through the spy hole every 30minutes or so until the collapse of the 1st cone. Once this occurs, look into the kiln every 10minutes and switch the kiln off the moment the cone to which the ware is being fired to has collapsed.

As the kiln temperature approaches the required glaze firing temperature, gas bubbles will still be escaping through the glaze layer and form craters in the glaze, and if firing has progressed very rapidly up to this stage, then there may not be sufficient time for these craters to disappear before kiln is switched off. The best option is to slowdown the rate of temperature increase over the last 50°C - 100°C or so of the kiln firing if the kiln has been fired at a faster rate of about 100°C per hour, and to observe results when kiln has cooled. If the glaze surface is pin-holed or has an "eggshell" or "orange peel" effect, or contains a large number of bubbles, then reduce the rate of temperature increase during the latter stages or heat soak the kiln for 30minutes before switching off, which can be done by turning down the setting of the energy regulator. Do not remove the vent plug to slowdown the rate of temperature increase as this will result in a wide temperature variation within the kiln.

Cooling Down

Once firing is complete, the kiln should be switched off. The rate of kiln cooling varies with different models and depends on the temperature and amount of ware and shelves inside the kiln. It is best to leave the kiln as it is until the interior temperature drops to approximately 100°C - 150°C, before opening the door.

The rate of cooling should vary to conform to the type of ware being fired. Many kilns cool too slowly to allow for the best results to be obtained from a glossy glaze, therefore to speed up cooling cycle in this case, partial or complete removal of the vent plug can be done but should be replaced when the kiln has been dropped to 750°C. Below this temperature, the kiln should be allowed to cool slowly until approximately 130°C. the cooling rate can be sped up after this by removing the vent plug or progressively opening the kiln door, noting that the door should be open in intervals and not be flung open as the cold air entering the kiln may crack the pots or kiln shelves.

Inspection

Once the pots have been removed from the kiln, examine closely for discoloration or flaws. If there is a greyish color, there is usually some organic matter left inside, which means in future biscuit firings, the temperature increase should be delayed, leaving the kiln at medium setting for a longer period of time. If the pots are extensively cracked, a possible reason could be the steam pressure within the pot, and therefore in future, the kiln must be allowed to remain at its low setting for a longer period of time. Clay cracking can however also be caused by a very short, i.e. not very plastic, clay or by working with clay in too dry a condition, by not drying the pots evenly or by drying them too quickly. In such cases, these cracks would be present before being placed in the kiln though invisible to the unaided eye, but the biscuit firing should open them up.

If time is an issue, it is permissible to leave most kilns at its low setting overnight, as the kiln temperature will not rise above 400°C - 500°C at this setting. The following morning, the kiln can be switched directly to its medium or high setting.

BISCUIT FIRING

Earthenware and terracotta clays varies in firing temperatures with different types of these clays. Most earthenware type clay has a firing range of 1100°C - 1150°C, but terracotta types vary more widely. During the period of time when pottery is fired, the complicated chemical reactions need to be taken place unhindered. There are two phases for these reactions: the first phase is being the formation of steam and the second phase being the burning away of all the organic materials.

This is with the assumption that the pots being fired are no thicker than ½ inch, which should cover 90 percent of the pottery produced by school and studio potters. If the pottery is thicker than this, then the rate of temperature increase of the kiln must be slower in order to allow the heat generated inside the kiln really to soak into the ware.

GLOST FIRING

The temperature which the ware should be fired is the firing temperature recommended for the particular glaze being used, and the glost firing should always be taken to this recommended temperature.

SAFETY MEASURES

Kilns should be placed on fireproof base, i.e. concrete slab, and a 3inch or 4inch air space should be left around the kiln to prevent surface temperature of the kiln rising.

No objects should be placed on the kiln or leaned against the kiln as this will increase surface temperature of the kiln and create a fire hazard.

Rubbish should not be allowed to build around the base of the kiln as this will prevent air circulation under the kiln and create a fire hazard.

SERVICING

Tetlow Kilns and Furnaces recommends that you have your kiln serviced yearly by a suitably qualified person to ensure that you get the best possible results from your kiln.

For further information, locate us at our website, www.tetlow.com.au

Do not hesitate to contact us at Tetlow Kilns and Furnaces at 03 8545 8296 or info@tetlow.com.au

JOB SAFETY ANALYSIS/RISK ASSESSMENT FORM (JSA/RA)

ACTIVITY: Tetlow Kilns operation

REFERENCE: Electric kilns firing

DATE: 15 June 2015

RISK SCOPE CALCULATOR

LIKELIHOOD	CONSEQUENCE				
	1	2	3	4	5
A	H	H	E	E	E
B	M	H	H	E	E
C	L	M	H	E	E
D	L	L	M	H	E
E	L	L	M	H	H

TARGET = SHADED AREA

E = Extreme Risk - Immediate action required.
H = High Risk - Senior Mngmt attention required.
M = Moderate Risk - Specify Mngmt responsibility.
L = Low Risk - Manage by routine procedures.

LEGEND

Likelihood

- A. Almost Certain – Is expected to occur in most circumstances
- B. Likely – Will probably occur in most circumstances
- C. Possible – Might occur at some time
- D. Unlikely – Could occur at some time
- E. Rare – May occur only in exceptional circumstances

Consequence

- 1 Insignificant – No Injuries.
- 2 Minor – First Aid treatment, onsite release, immediate containment.
- 3 Moderate – Medical treatment required, onsite release contained with external assistance
- 4 Major – Extensive Injuries, loss of production capability, off-site release with no detrimental effects, major financial loss.
- 5 Death, toxic release off-site with detrimental effect, huge financial loss.

LIST STEPS INVOLVED TO ACHIEVE ACTIVITY	LIST ALL HAZARDS FOR EACH STEP	RATING			LIST EXISTING AND PROPOSED CONTROLS	REVISED RATING			CONTROL ACTIONS	Person Responsible
		C	L	R		C	L	R		
Touching the kiln body when it is running	Burns to body	2	B	H	PPE should always be worn when the kilns is firing	2	C	M	Run the kiln when school is finished, and wear PPE	School
Students in the class room when the kiln is firing	Burns to body	3	B	H	The school should only run the kiln when school is finished, and wear PPE	3	D	M	School should monitor the kilns usage and provide PPE	School
Students in the class room when the kiln is firing	Burns to the body	3	B	H	Patrician off the work kiln area, when running the kiln	3	D	M	School should monitor the kilns usage and provide PPE	School
Touching electrical element wire	Electric shock	3	E	M	Door limit switch isolates electrical circuit	3	E	M	Service kiln at least once a year	School
Opening electrical cabinet	Electric shock	4	E	H	The cabinet sliding door is fastened with screws and must only be opened by a qualified electrician	4	E	H	Service kiln at least once a year	School

LIST STEPS INVOLVED TO ACHIEVE ACTIVITY	LIST ALL HAZARDS FOR EACH STEP	RATING			LIST EXISTING AND PROPOSED CONTROLS	REVISED RATING			CONTROL ACTIONS	Person Responsible
		C	L	R		C	L	R		

FORM COMPLETED BY: _____ DATE: _____

AUTHORISED BY: _____ DATE: _____