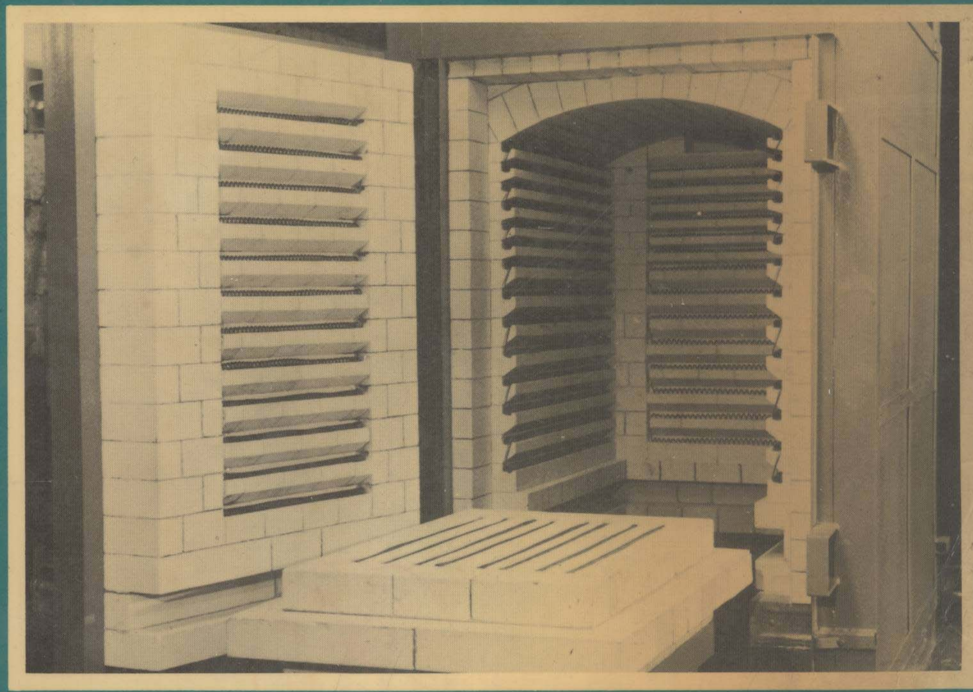
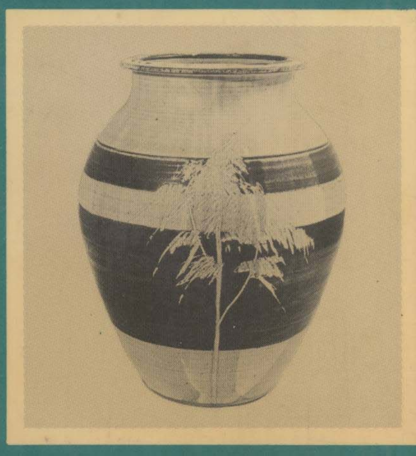
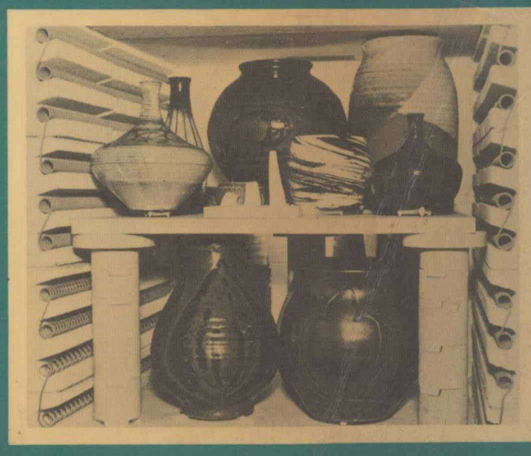
CERAMIC SKILLBOOKS

Electric Kilns and Firing

Harry Fraser







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Electric Kilns and Firing

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This book is dedicated to Helen.

Preface

This coming winter hundreds of evening institutes in towns and villages throughout the country will introduce pottery making into their curriculum and by so doing will swell the ranks of the thousands whose courses are already well established. This is testimony to the considerable growth in recent years of pottery as a craft.

This awakening of latent interest in pottery making has been precipitated by several factors but one of the most important of these has been the development of a range of studio electric kilns specially designed to meet the needs of the craft — and at prices within the reach of all. Nevertheless, despite the tremendous appeal and convenience of the modern studio kiln, it still tends to be regarded with awe by most potters and teachers faced with a need to use a kiln for the first time. For some reason its correct operation is thought to result only from years of training and experience — and a measure of inspired intuition.

Pottery firing is not quite so simple as some experts would have us believe but, on the other hand, there is no 'magic' in the process and certainly, there is nothing that should daunt anyone given a little knowledge of the procedures involved. Successful firing mainly comes from an understanding of what happens when ceramic materials are heated, a knowledge of the firing requirements of the products to be fired, and an ability to control the temperature, time-cycle and kiln atmosphere by regulation of a few simple controls.

I hope that this book assists in supplying this basic knowledge and thus enables the novice to fire a kiln with complete assurance and satisfaction.

There should be much here, too, for the teacher or more advanced potter who may find those chapters on kiln instrumentation, effect of heat on clays and glazes, etc., of particular interest.

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1 Kiln Construction and Design

The design and construction of studio pottery kilns has entailed a great deal of careful planning. Perfection can seldom be achieved without simplicity but this apparent simplicity of the craft pottery kiln is very misleading. The basic structure of each kiln — particularly of those offered by reputable suppliers — is generally carefully designed to give adequate strength to withstand movement and knocks without being clumsy and excessively heavy. The type of refractory insulation brickwork used in kiln construction is carefully selected and may vary from one size of kiln to another, depending upon the type and thickness of brickwork necessary to reduce heat losses to acceptable limits. The position and optimum size of vent holes, etc., is determined only after careful research and calculation, in order that the firing performance remains quite satisfactory. The bricks themselves have to be well fitted together if the kiln is to give long service, and carefully shaped around the door if the door is to give a snug fit so as to prevent excessive heat losses. Element design and layout is likewise very much a part of the technology of kiln construction if optimum results are to be obtained. A very great deal of thought, calculation and research, as well as a considerable amount of trial and error, have gone into the construction of the modern efficient craft pottery kiln and it is this careful attention to detail that has produced kilns that provide efficiency and long life with freedom from continual maintenance.

In kiln construction the framework is built first and then the brickwork is built within the frame, the electrical fitments and elements being added afterwards.

Framework

This is normally built of angle-section steel, although in smaller kilns the framework may be made from strip steel or pressed steel panels. Angle-section steel is, however, particularly useful as a basis for building in the brickwork as this section gives support on two sides. All joints are normally welded together but the sheet panelling can be fixed with screws or bolts. A photograph of a typical framework assembly is given in Fig. 1.

Brickwork

The two types of bricks used generally for the construction of kilns are refractory bricks and refractory insulation bricks and

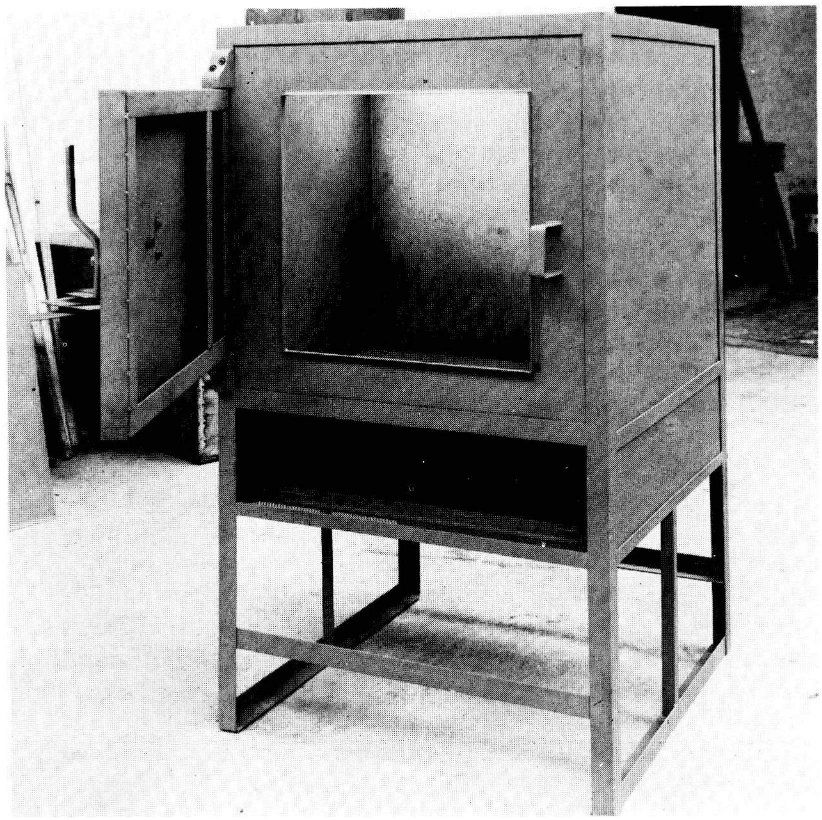


Fig. 1 Typical steel cabinet used as a base structure for craft pottery kiln. *Courtesy of Kilns and Furnaces Ltd.*

they should not be confused. Refractory bricks are normally fairly dense bricks and are, therefore, comparatively heavy in weight. They absorb heat fairly quickly and if one face of the brick is exposed to heat the other side of the brick will very soon become warm as the heat is conducted through the brick.

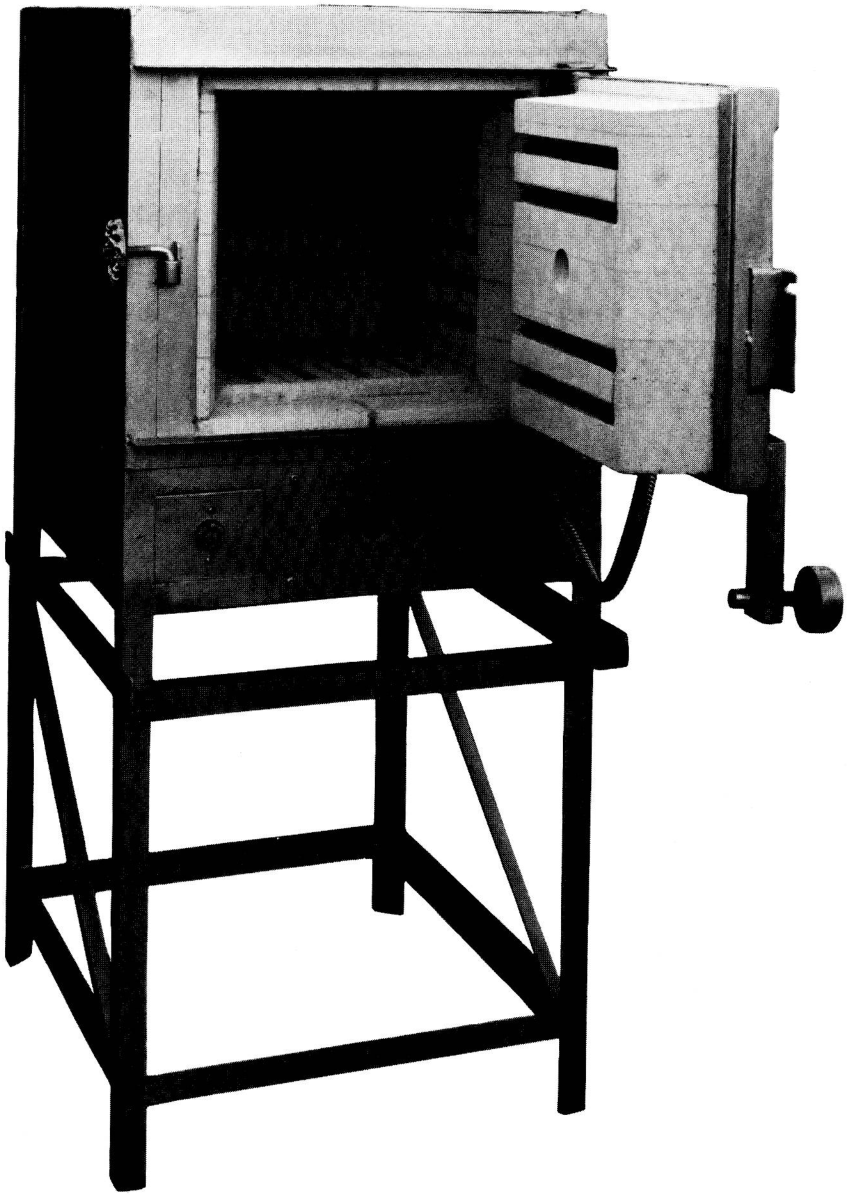


Fig. 2 Kiln and stand utilising angle-iron frame. The handwheel on the door is a power interlock device to isolate power whenever the door is open.
Courtesy of Cromartie Kilns Ltd.

Refractory bricks, therefore, tend to be used in those positions where heat loss is not quite so important — for example, for the building of chimneys or for the exterior brickwork of oil or gas fired kilns. This type of brick is seldom used in the manufacture of electric kilns, due to this high heat conductivity and the considerable weight which would make carriage charges more expensive and movement of the kiln more difficult.

Instead, bricks of the refractory insulation type are used: these have all the heat-resisting qualities of refractory bricks but are very porous indeed. Air, as we all know, is a good insulator and the huge number of air pockets inside these bricks makes them good insulators of heat 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. This pore structure makes the bricks very light in weight.

The very high porosity (i.e. pore structure) gives another very useful property to these bricks; i.e. it makes them comparatively soft and easy to cut with a normal hacksaw. They can therefore be very easily shaped so that cutting a groove to take elements, or boring holes in them, presents no problem.

The brickwork is built into the framework using a heat-resisting compound of a similar composition to the bricks themselves. Care is taken to make the joints as fine as possible since large gaps between bricks filled with jointing compound are unsightly in appearance and a possible source of weakness.

Ceramic fibre

This remarkable material has become an increasingly common kiln insulant in the last ten years or so because of its combination of refractoriness, low weight and phenomenal insulation properties. Kilns incorporating ceramic fibre insulation — often referred to as 'low thermal mass' kilns — use up much less of the generated heat thus resulting in low firing costs and permitting larger kiln capacities for the same electrical loading. Since less thickness of insulation is needed, the kiln weight can be reduced. A problem, however, is that it has poor strength and abrasion resistance and so it is often used as a hot-face insulant with conventional refractory insulation bricks used as back-up insulation and as corner posts. The elements are generally supported by rods passed through them or by some other means to prevent the ceramic fibre from bearing the weight.

Durability and structural problems tend to restrict significant economies to semi-industrial kilns and particularly where fast turn-round times are needed (for low thermal mass kilns tend to cool very rapidly). It is not unusual for decorating kilns utilising ceramic fibre to be fired three times per day.

Electrical wiring and fitments

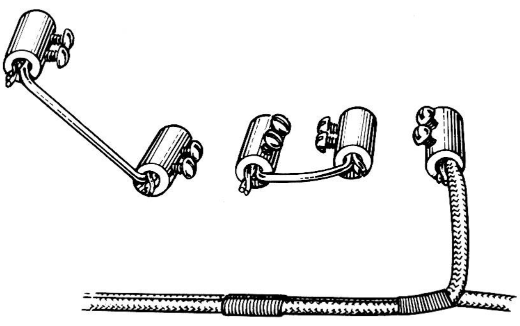
With most designs of kilns the 'works' such as junction boxes, terminals, etc., are fitted at the back of the kiln and access to them can normally be gained by removing a panel from the kiln. Electric kilns, of course, take quite a considerable current — especially the larger sizes — and when the kilns are switched on and off the switching device must be robust to withstand the sparking which may occur. The switching is therefore often done through a contactor, which is merely a robust relay enabling the kiln to be switched on and off without burning away any of the connexions, etc. Smaller kilns may not be fitted with a contactor and this is why one is normally required if any form of energy regulator is subsequently fitted to the kiln, for these energy regulators operate by continually switching the kiln on and off.

Electricity supply to each element is normally made through a small brass connector. Steel connectors tend to oxidise too readily.

Some kilns are fitted as standard with an energy regulator complete with a little pilot light which is switched automatically on and off as the energy regulator switches the current to the elements on and off. A few kilns are fitted with a door switch as a standard item — particularly where the kiln is to be used for metal enamelling. The majority of kilns used by the craft and school potter are, however, merely fitted with a rotary switch which normally has four settings marked upon it, denoted 'Off', 'Low', 'Medium' and 'High'. These settings refer to the amount of current which is allowed to flow to the elements and thus the rate at which the kiln increases its temperature.

Usually the kiln is fitted with a control panel — rather like the dashboard of a motor car — on which the electrical accessories mentioned above are fitted. Some kilns, however, are supplied

Fig. 3 Brass connectors used for element connection.



with a separate control panel which has to be mounted on an adjacent wall or other convenient surface.

Following the Health and Safety at Work Act, it is now demanded that a kiln be fitted with a 'power interlock'. This can be either a captive key type interlock (such as the Castell type) using an isolator for the mains input, or a 'fail to safety' door switch can be used provided the switch positively isolates the mains power rather than with a contactor. The latter is common practice on kilns up to 3kw rating, single phase (i.e. will operate off a 13 or 15 amp socket). These devices ensure that once a firing is commenced the kiln door cannot be opened without the electricity supply being switched off.

Additionally, some manufacturers make provision for a padlock to be fitted to the door so that the door cannot be opened without removing the padlock.

Elements

There are several types of elements which can be fitted to kilns, but the most popular types are those known as Kanthal A and Kanthal A1 elements; Kanthal DSD is widely used up to 1200°C. Other types of elements, such as Nichrome, Super Kanthal or silicon carbide, can also be fitted. Let us now look at each of these element types in turn.

Nichrome elements

These, as the name implies, are made basically from an alloy of nickel and chromium and are fitted to kilns which are not required to operate at temperatures above about 1050°C. The fitting of these elements may enable a kiln to attain temperatures up to 1150°C but at temperatures as high as this the elements would very quickly burn away and so for all practical purposes the maximum temperature is normally kept down to 1000°C or thereabouts. This temperature, however, is quite sufficient for enamelling, biscuiting and low-temperature glazes. Nichrome wire is comparatively cheap and is, incidentally, the wire used for domestic electric fires. One cannot, however, use the wire from a domestic fire in one of these kilns for within the enclosed kiln such wire would very quickly burn away. A free flow of air around electric-fire elements helps to keep the actual element temperature within reasonable limits. This would not happen inside a kiln.

Kanthal A and A1 elements
These are made from alloys of iron, aluminium, chromium and cobalt and it is claimed that these alloys will give three times the life of the Nichrome types at similar temperatures. These 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. Any knocks or shaking can easily break them at this stage. Kanthal A or Kanthal DSD elements will allow the kiln to reach maximum temperatures of about 1200°C but Kanthal A1 elements will allow a maximum operating temperature of 1300°C. These are the types of elements most commonly used in electric kilns. 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 oxidising fire. Alkali vapours and halogen vapours — for example, fluorine, iodine, etc. — are harmful to elements and so is lead vapour. Kanthal wire is not attacked by sulphur compounds as is Nichrome wire.

Super Kanthal and silicon carbide elements
These are used only for very high-temperature work beyond the temperatures used in pottery production. Temperatures of 1600°C can be attained with Super Kanthal and 1500°C with silicon carbide. Both types of elements are very expensive and as the resistance of the silicon carbide elements increases with each firing, voltage regulators have to be fitted. Both types are normally used only for industrial applications.

Elements of the Nichrome and Kanthal types 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 six to nine inches of each end of the element is not coiled but is left as a straight wire so that these element ‘tails’, as they are called, can be pushed through holes drilled through the rear wall of the kiln and fastened to brass connectors in the connexion chamber at the rear of the kiln.

The determination of the correct amount of element wire to use for the elements is part of the science of kiln technology and is thus one of the more difficult problems which face the 'do-it-yourself' enthusiast. Not only does the kiln technologist calculate how much wire of a certain grade is needed to supply the necessary amount of heat for a given kiln size, he also has to adjust his data to conform to different voltages and he has to calculate the number of coils into which the elements must be made — which must be within certain limits if optimum element life is to be obtained.

Most high-temperature kilns are designed to give a very even temperature distribution at around 1100°C. At temperatures above and below this point there tends to be an increasing degree of temperature variation. In an attempt to obtain the least possible variation over a wide range of temperature, some kiln manufacturers fit graded elements into their kilns. This does have the slight disadvantage that it is not possible to keep one spare element to guard against a risk of element failure since one does not know which element will fail first, but this disadvantage is more than compensated by the more even firing characteristics.

An alternative way to obtain an even temperature distribution over the complete firing cycle is to wire the elements into groups or 'banks' and to fit an independent energy regulator to control each bank of elements. Two or three thermocouples are then fitted to the kiln, so that if the temperature in one part of the kiln shows signs of lagging behind the rest of the kiln, the energy regulator controlling the elements in that region can be turned to a higher setting so that more heat is introduced. This system is often used with large studio and semi-industrial kilns but is not customary with the kilns more commonly used by craft and school potters because of the expense involved.

The vast majority of craft pottery kilns are of the exposed element type. This means that the elements are supported in 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, than the alternative muffle type of kiln in which the elements are completely hidden from sight behind a thin wall of refractory

Fig. 4 36″ high vase by Michael Hawkins, fired in an electric kiln to 1275°C oxidation. Made from Pyropot clay with sgraffito decoration.

material made of sillimanite or, better still, of silicon carbide (Carborundum), through which the heat has to pass to reach the ware.

If ever it is necessary to replace a burnt-out element, always quote the serial number of your kiln to the kiln manufacturer, indicating which particular element has failed, and always make certain that *every* trace of the burnt-out element has been removed from the element grooves before fitting the replacement. This is most important. When fitting a replacement element also ensure that the screws holding the element tails into the connectors are as tight as you can get them, so as to prevent sparking which creates a hot spot which can burn through the element. Once the element tails are secured, the element is then stretched over the grooves and thus fitted into place. Don't stretch the element before fitting the tails into position for if it is overstretched in this way it will not fit into its grooves sufficiently tightly and eventually will lead to part of the element escaping from the groove.

Incidentally, if a Kanthal element burns through at the connector, it is often possible to stretch the element a little so as to be able to reconnect it by strongly heating part of the element inside the kiln (close to the element tail) in a blow-torch flame, whilst pulling the wire gently from the rear connexion chamber. Naturally, any attempt to do this whilst the element is cool would probably result in breakage, since Kanthal wires become brittle after a few firings, but at high temperatures they are always soft.

The first firing

Before any kiln is put into use, it should be fired slowly to a temperature no higher than 100 or 200 degrees 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.

With a kiln capable of firing to 1300°C for example, a good general procedure might be to fire at about 75°C per hour (regulator on 'low' or about 30—50) with the vent hole open up to 450—500°C (black heat) and then to hold temperature at this point for approximately two hours. Increase temperature at 75°C per hour up to about 800—900°C (cherry red) or until a little steam is visibly escaping from the kiln at which point the vent plug can be replaced. The regulator is then set to high or 100 and the temperature taken up to 1100—1150°C (light orange) at which point it is held for one hour and the kiln is then shut off.

As an alternative, one manufacturer recommends a slow firing up to 500°C with the vent open and then holding temperature for about eight hours. Whichever method is adopted, two factors are important:

Firstly, if large volumes of steam are escaping from the kiln it is best to hold the temperature steady until this has been reduced.