ART 186 - INTRO TO CERAMICS

KILNS - HISTORY AND BASIC DESIGNS

PIT KILNS

The earliest kilns were certainly no more than the hearths used by primitive peoples for cooking, warmth, light, and protection. In fact, very simple 'pit' kilns are still in use today. Clay was used since prehistory to create figurines and representations of animals and people, but the date of the actual discovery of the firing process is unknown. However, the Neolithic period, when agriculture began, is generally cited as the origin of fired clay objects, approximately 10,000 years ago. These early farmers needed containers for seeds, for harvested foods to be stored, and for water transportation and storage. Fired clay served these needs well, and was locally available and easy to form. The earliest kilns were nothing more than a shallow 'pit' dug in the ground. Pottery was loose stacked on top of each other. Combustible materials were placed around and above the pottery and the fire was allowed to burn down. After cooling, the pots were cleaned of the ash and residue and were then used. Pots fired in this way were very fragile and porous due to the low temperatures possible in such a firing (1000°-1200° Fahrenheit). At this low temperature glazing is not possible and was not discovered until much later. Advantages of this type of firing are its relative ease of 'construction' and low cost. Disadvantages are the low temperature limitations and the fragility of the ware. Also, many pieces break during the firing process due to the erratic nature of the firing and poor insulation.

What are the minimum requirements for a fuel burning kiln?

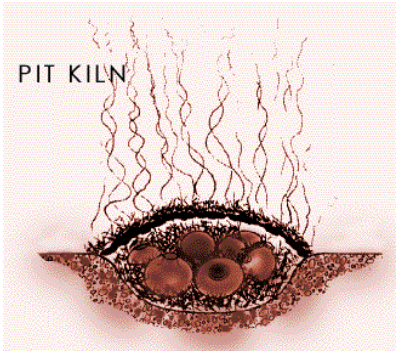
1. INSULATION

2. LOADING AREA

3. FUEL

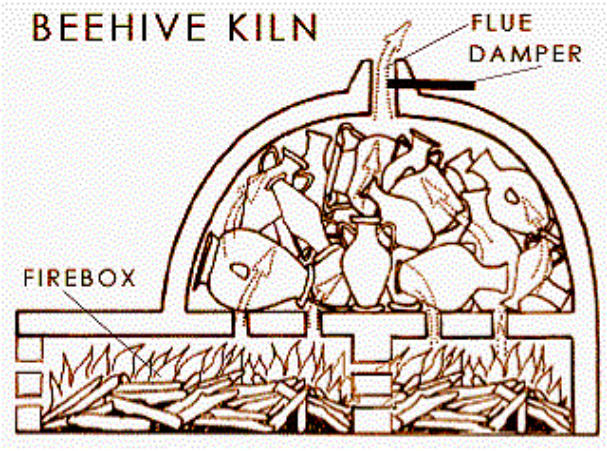
4. OXYGEN

Although the 'pit' kiln does not appear to be much of a kiln, it is nonetheless considered one. Refer to the diagram at right and notice that this kiln does have insulation-the earth itself. Earth is a decent insulator, is not flammable, and is certainly abundant. The loading area is the pit itself; the fuel is any flammable organic material such as wood, straw, or manure; and the oxygen is available in the air surrounding the kiln. So, basic as it is, this kiln meets the requirements.



However, the design defects of this kiln are quite obvious: primarily that the kiln is upside down! The insulation should be on top, and the fuel should be on the bottom. The pit kiln looses most of its heat out the top. Early potters tried putting the fuel at the bottom of the firing, but found that as the fire burned down, the logs would fall, and so would the pottery, breaking everything. So, for this reason, they had to put the fuel on top. They had no architectural technology enabling them to construct an arch. With the rise of settled agricultural communities, however, construction techniques improved and better kilns were built.

BEEHIVE KILNS

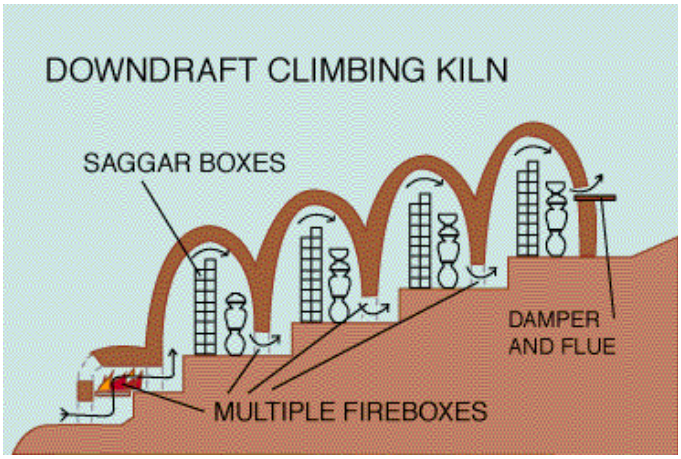


The BEEHIVE kiln was the first kiln constructed that looks like what we consider a kiln.

See the cross sectional diagram at left, and notice that now the fuel and fire are below the ware, the insulation, in the form of an arch is on top, retaining the heat better. The pots are stacked within this chamber allowing greater retention of heat. The enclosing of the kiln presents a problem. Oxygen access is restricted, and, without ventilation, this kiln will not burn properly. Therefore, a hole at the top of the kiln, known as a FLUE, must be included in the beehive design. The DAMPER is the device that regulates the size of the opening of the flue. Oxygen does not enter the flue. Rather, it exits the flue by nature of the tendency of heat to rise. As the fire burns, and the kiln gets hotter, the hot air rises and leaves the kiln through the flue. Meanwhile, cool air enters the bottom at the FIREBOX.

CLIMBING KILNS

An interesting variation on the beehive design was first built in China around 500 A. D. This is called the CLIMBING KILN (or a stepped kiln, or a hillside kiln). This kiln utilized the basic format of the beehive, but multiplied the chambers so that total kiln capacity could be increased. This modification worked well in villages where pottery making was the primary activity, and where a large volume of pottery needed to be fired at once. Notice in the diagram below how each chamber has the arch construction typical of the beehive, but that the chambers are joined so that the draft passes through from one chamber to the next. After the kiln is loaded, the fire is lit in the bottom chamber's firebox. The heat rises through the first chamber, and rather than passing out the flue at the top of this chamber, notice how the heat is cycled down and into the opening at the base of chamber number two. After the first chamber has been fired to its ultimate temperature, the potters begin stoking firewood into the firebox at the base of chamber two. The heat follows the same circuitous path as before, rising, then falling, and entering the base of chamber three.



This process is continued until all chambers have reached temperature. Notice that the draft of the kiln is eventually up, even though along the way it has taken several downwards turns. Such a kiln is referred to as a DOWNDRAFT kiln, even though the ultimate draft is UP. It is the observation that the draft is DOWN during part of the cycle that causes this kiln to be called a DOWNDRAFT.

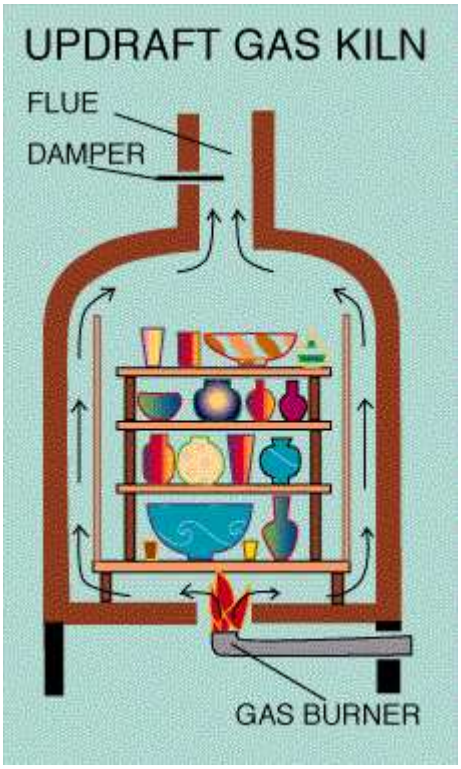
The biggest disadvantage of this kiln design is that large quantities of pottery are required to fill these huge kilns, making it an impracticable design for the individual potter. This is, of course, its big advantage also: large quantities of work can be processed at once, making it ideal for pottery communities. As mentioned earlier, this kiln was first built in China, probably to increase the volume of pottery available for trade. However, a significant difference in these kilns is that they were able to reach higher temperatures than any kilns before. The recycling of waste heat, the increased thickness of the walls necessary to reinforce these huge chambers, and the multiple fireboxes all combined to cause higher temperatures to result.

It was in such kilns that the earliest stonewares and porcelains were developed. Certainly not on purpose initially, but over time the art of porcelain manufacture was perfected by the Chinese potters and held secret for over 700 years. These kilns were huge, often 10-12 chambers, and therefore difficult to conceal. Eventually neighboring villages began to copy the design, and the concept spread out of China to

Korea, Japan and ultimately the West. However, by the time this idea traveled to the United States, pottery villages were all but extinct, their role supplanted by machine-made pottery. One additional interesting feature of this kiln is the use of saggar boxes, which were used to protect the pottery from flying wood ash. These saggar boxes, which were made of clay, are indicated in the diagram as the square boxes stacked in each of the chambers. Without these protective boxes the pottery would have been subject to attack by the wood ash, which at these higher temperatures would form glaze and stick pieces together.

NATURAL GAS KILNS

The most common kiln design utilized by contemporary potters is the natural gas UPDRAFT kiln. Notice in the diagram at right how very similar this kiln design is to the BEEHIVE kiln. Basically, it is the same in all respects. Rather than using firewood, natural gas is the fuel. We now have better quality insulating brick, but otherwise nothing has really changed. Note that the damper and flue are in the same places and have the same function. The updraft design is not the only one used with natural gas however. Many natural gas kilns are based on a variation of the downdraft design described above. Advantages of natural gas as a fuel are that it is environmentally desirable in that it produces very low levels of pollution, and that the fuel is relatively inexpensive compared to electricity.In some parts of the country propane is more commonly used as a fuel, however propane is heavier than air. This means that if the flame should get blown out, then care must be taken to dissipate the gas which will stay at the bottom of the kiln before relighting, otherwise an explosion can result. Natural gas will disperse on its own since it is lighter than air.



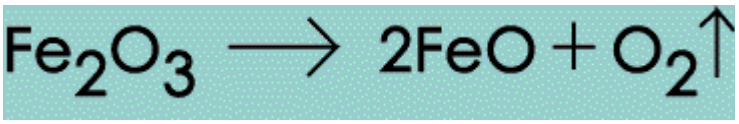
ELECTRIC KILNS

The electric kiln is the only really new kiln technology of the 20th century. Instead of a burning fuel, these operate by radiant heat generated from an electrical current passing through coiled wires. A toaster operates on the same principle. Since these kilns have no fireboxes and no burning inside, they have no need of a damper or flue, since no draft in necessary. Thus electric kilns have no hole at top. They are neither updraft or downdraft,

more like NO DRAFT kilns. What they share with the fuel-burning kilns is insulation and a loading area, but not a fuel or a need for an oxygen draft. Thus OXIDATION firing is the firing of choice in the electric kiln. Most modern electric kilns are equipped with electronic shut off devices, called kiln sitters, to monitor the firing process.

FIRING DIFFERENCES: ELECTRIC vs. FUEL BURNING

These two types of kilns give quite different results in firing. Remember that fuel-burning kilns require oxygen; electric kilns do not. A fuel-burning kiln(fired with its damper open, providing the kiln with adequate draft) will fire with results identical to an electric kiln. However, partially closing the damper during the firing process will have a dramatic effect on glaze colors. Here's how: A FUEL is a material that can combine with OXYGEN to create a fire in a process called COMBUSTION. Generally, the fuel takes the oxygen from the atmosphere during the firing. If the damper is partially closed, the draft is reduced, providing the fuel with not enough oxygen to combust completely. The fuel will then try (chemically) to 'find' the oxygen it 'needs' from any other source in the kiln. What other sources are there? The clay and glaze materials contain oxygen in the form of the metallic oxides such as silicon dioxide, cobalt oxide, iron oxide, copper oxide, etc. A chemical reaction takes place such as:



Note that the original form of iron oxide (which is rust red in color) contains two atoms of iron to every 3 of oxygen. During the firing process, the fuel has reduced two oxygen atoms from the iron, leaving us with a new form of iron oxide (which is jade green in color), in which the ratio is 1:1. The only reason we care about any of this as potters, is that these two forms of iron are different colors. This process results in forms of the metallic oxides that are REDUCED in oxygen. A similar reaction takes place with the other coloring oxides as well, explaining why glaze colors behave so differently in gas and electric kilns. We have come to call this chemical process REDUCTION, and this firing process, REDUCTION FIRING. In an electric kiln, in contrast, there is no draft, no oxygen demand, and no damper. Thus closing it is impossible; it does not exist. So, therefore, reduction firing is impossible in an electric kiln unless the kiln itself is on fire or a combustible material is introduced into the electric kiln. Firings in which the oxygen levels in the oxides are not reduced are termed OXIDATION firings, referring to the observation that the oxygen in not changed. Colors are thus more predictable in an electric kiln (this is good and bad). To summarize, a fuel-burning kiln is capable of REDUCTION or OXIDATION depending of the damper position. An electric kiln is capable of only OXIDATION.

PYROMETERS AND PYROMETRIC CONES

Regardless of what type of kiln is used, the potter needs to be able to accurately determine the temperature inside the kiln. For this we use the pyrometer and pyrometric cones. A pyrometer is an instrument used to measure heat at high temperatures. It consists of a calibrated dial connected to wires which protrude into the kiln. When heated, the welded junction of these wires produces a small electrical current which registers as a temperature reading on an indicator dial. While simple to use, the pyrometer is, unfortunately, not very accurate. It does provide a reasonable guide to whether the temperature in the kiln is rising smoothly and consistently, but does not provide an accurate enough reading to determine the end point of the firing. For this, pyrometric cones are used. Pyrometric cones are commercial produced 'pyramids' of molded glaze, predetermined to melt at specific temperatures. Cones are available at approximately 40° intervals. So the potter puts 3-4 cones in the kiln, arranged in a sequence of increasing melting temperature, so that when the melting temperature of the first cone is reached, it begins to melt, and bend so that by looking through the spy hole in the kiln, this can be seen. This provides a warning to the potter that the kiln is nearing its maturing temperature, and is called the warning cone. About 15-30 minutes later, the second cone's melting point will have been reached, and it begins to bend also. This process continues until the desired temperature has been reached, and the target cone bends. The potter usually places one additional cone in the group, the melting temperature of which is higher than that desired. This cone should remain standing, indicating

that the desired temperature has not been exceeded. This is referred to as the guard cone. Cones are more accurate than a pyrometer since they are made of glaze, just like the glazes on the surfaces of the pottery. So, when the cones melt, one can be assured that the glazes are melting also. Usually, a potter will use both a pyrometer and cones, since each provides information at different phases of the firing process. The pyrometer tells the potter what is happening early in the process, and during the cool down phase. The cones tell what is happening at the exact point of glaze melting. Some kilns come equipped with an automatic kiln sitter, which is a device that uses the melting of the cones to automatically shut down the kiln. While convenient, these devices should never be relied upon 100% because they have been known to fail. There is no substitution for the vigilance of the potter during these crucial firing decisions.

*****Please note that this handout is not a primer on how to fire your kiln, only a brief and selective history of kiln design. Before you attempt to fire any kiln, you should get instruction from an experienced person. In later classes here at GCC, students learn how to load and fire both gas and electric kilns. Firing a kiln without proper instruction is very dangerous and can result in damage to the kiln or fires damaging adjacent structures!**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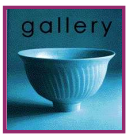
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