Economical Refractory Shape and Composition for Kilns

High Temperature Ceramic Furnace Linings, or Refractories, as they are commonly known, are a necessary component in the production of pottery.

Although there are hundreds of compositions and shapes available to construct a kiln, most potters can construct virtually any type of kiln with just a few of them.

In order to achieve the most economical kiln lining, both from an initial cost standpoint and a continuing operational standpoint, one must have a basic understanding of refractory composition, shape types, and refractory construction techniques.

Compositions:

Fireclay based refractories are the most common and least expensive dense compositions used for floors, chimneys, and salt/soda kiln construction.

Fireclays are available in several grades. Starting from the lowest (low duty), then intermediate duty, high duty, super duty, and finishing with high fired super duty at the top end of the fireclay spectrum. The vast majority of dense refractory kilns used in firing pottery are constructed of high duty or super duty fire clay based refractories and performs quite well.

High alumina compositions start at 50% alumina and increase in alumina content to 98% for the highest purity and most expensive. It is extremely rare that a potter would require an alumina content exceeding 70%.

Insulating compositions range from 1600°F to 3300°F and are used primarily in reduction kilns or as backup layer(s) to dense refractory hot face linings to help reduce energy losses through the lining.

A point to remember is the higher the density of the refractory (excluding fiber based products) the more energy it takes to heat it up, and the greater the thermal losses can be if not appropriately insulated.

Each composition can be made into a variety of shaped and unshaped refractories.

Bricks : Most bricks are pressed or extruded. Common shapes are straights, arches, wedges, keys, rotary kiln blocks (RKB's) and square edge tiles. Larger pieces are typically produced by air hammering the brick mix into wooden or steel molds sized for the desired shape dimensions.

The standard refractory brick size is 9" x 4 ½" x 2 ½" series or one brick equivalent (beq). This size is the most common used in pottery kiln construction. However, an equally popular standard size used in industrial furnace construction is the 9" x 4 ½" x 3" series. 3" series brick reduces the number of joints in the kiln. For sprung arch and barrel arch crowns the use of 3" series eliminates the use of straights except for very large kilns. Remember, straights do not have a taper and can slip and or fall out in a crown that does not stay in compression.

Monolithics: Commonly referred to as unshaped or specialty refractories, monolithics are available in several forms and bonding systems.

Mortars – air set, heat set, and phosphate bonded

Castable and gunning mixes (both dense and light weight) – cement, chemically and no cement bonded

Plastics – air set, heat set, phosphate bonded

Ramming mixes (wet and dry) – air set, heat set, phosphate and ceramic bonded

The use of mortar when bricking a kiln is highly recommended. Although a lot of pottery kilns are constructed without mortar, using mortar serves several purposes. First it helps the bricklayer to keep walls square and level by evening out the minor variations in brick sizing that occur during manufacture. Secondly, mortar helps reduce heat loss in the lining, thereby conserving energy and reducing uneven temperature in the kiln. Mortars can be thinned with water to desired consistencies and further diluted so that they can be sprayed or brushed as protective coatings.

Castables are used to make precast shapes of various sizes, bases or floors of kilns, cover the outside of a kiln (like a stucco) and sometimes to pour the "key" in roof construction to avoid cutting brick.

Plastics can be used to construct an entire kiln just as they are used in large industrial furnace linings. They can also be used to patch worn kiln linings and seal up large cracks.

Fiber Based Products: Mineral wool and ceramic fiber based products are used to produce insulating blankets and vacuum formed boards and shapes. Additionally ceramic fiber materials are available in papers of thickness ranging from 1/32 to 1/2 inch, ropes of various diameters and shapes (tadpole type), woven tapes for gaskets and cloth for heat resisting curtains, and moldable and pumpable compositions. Service temperatures range from 1200°F to 3000°F.

A point to remember is that typically the higher the density of the fiber based products, the more insulating they become. This is the reverse of denser brick and monolithic materials.

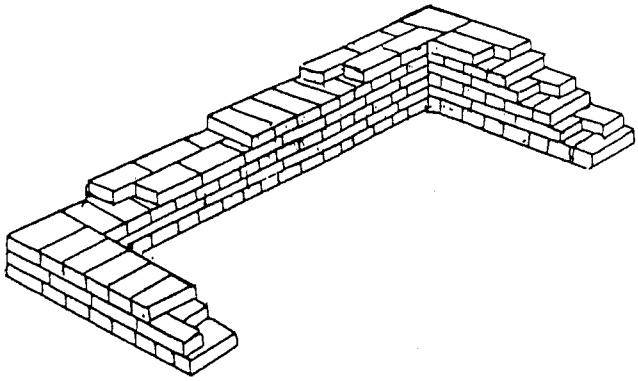
Construction: The following illustrations show recommended methods of wall and arch construction.

Walls – Figure 1 illustrates a recommended wall construction utilizing alternate header and stretcher course construction. Another acceptable method uses 4 or 5 stretcher courses plus one header course. This construction is typically used for dense hot face and insulating backup layer. The header course is of the dense material. The 4 and 1 construction is more energy efficient than the alternating method.

The level and square are your best friends in properly constructing walls. Mortar joints should be very thin (no more than 1/8" thick) and applied just like putting peanut butter on a slice of bread.

WALL

NINE INCHES THICK

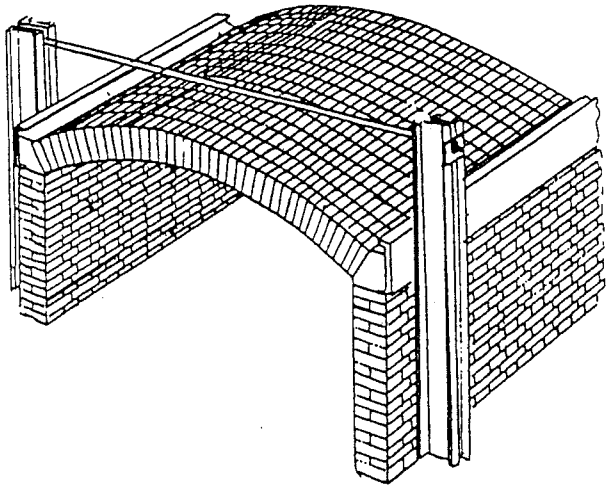


Alternate header and stretcher courses

FIG. 1

Since bricks are available in sizes other than the typical 9" x 4 ½" x 2 ½" or 3", do not limit yourself to the standard series format. Just design the kiln for sizes and shapes you can obtain to minimize brick cutting and to obtain adequate bonding.

RING ARCH ROOF



Using 9 inch Wedges

FIG. 2

Arches: Figure 2 illustrates typical sprung arch construction. Each row (or ring) is the same depth. For additional stability a bonded arch type construction utilizes different width (or length) brick as shown in Figure 3.

The construction of the arch begins by fixing the steel supporting structure to the kiln walls and the skew retainer steel to the vertical supports connected by tie rods. Caution: Do not forget this important first step as the arch will likely collapse if you wait until the end to install your steelwork.

Next, lay out one ring on a flat surface marked with a chalk line for squareness. This establishes the combination of arches or wedges you will use to obtain the desired rise of the arch and to assist you in cutting your skews (in lieu of preshaped skew backs).

BONDED ARCH ROOF

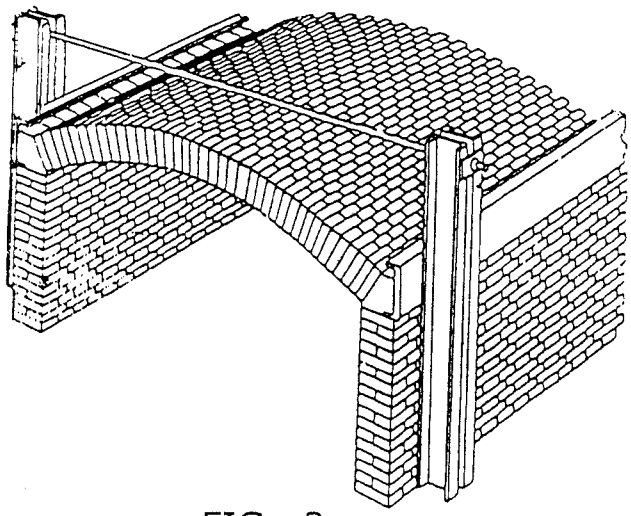


FIG. 3

Arch Form Construction: Carefully transfer the measurements to a sheet of ¾" plywood and draw the shape of the inside of the ring on the plywood. Then cut the plywood so that the outer edge corresponds to the inside dimension of the walls and the curvature of the arch. Cut a second piece of plywood to the same shape using the first piece as a pattern.

Next, separate the two pieces with short lengths of 2 x 4's. The length of the 2 x 4's is determined by the length of the brick plus 3 inches. A minimum length should be 12 inches. Attach sufficient 2 x 4's around the radius to adequately support a thin cover of flexible masonite or luan sheeting over the top of the form.

Now you are ready to install the form in your kiln. Using 4 vertical supports boards of either 2 x 4's or 4 x 4's in the corners, cut them to length to hold the arch in correct height position. It is easier to cut the vertical supports ½ to ¾" shorter and then use wooden wedges under the supports for final leveling of the form. Wedges are more readily removed for repositioning of the form as you work your way from one end to the other.

SPECIAL SKEWBACK

Recommended Construction

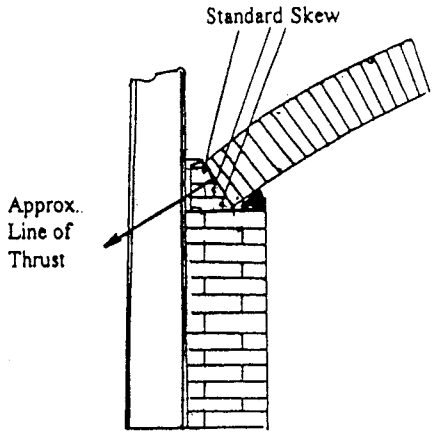


FIG. 4

Installing the Arch: Using either preformed skews or built up ones you cut from straight brick (Figures 4 & 5) install the skew line. Then begin laying your arch or wedge brick according to the combination you determined by laying out your first course on the flat surface. Note: your brick supplier should be able to provide you with a close approximation of quantities if you tell them the desired span, rise and length of arch for your kiln.

In some cases the center brick or "key" brick may have to be cut to achieve a tight arch. Never cut a brick less than ½ of its original thickness for the "key" brick in order to maintain sufficient strength.

After completing each ring, reposition the form and continue as before until completion.

BUILT-UP SKEWBACK

Recommended Construction

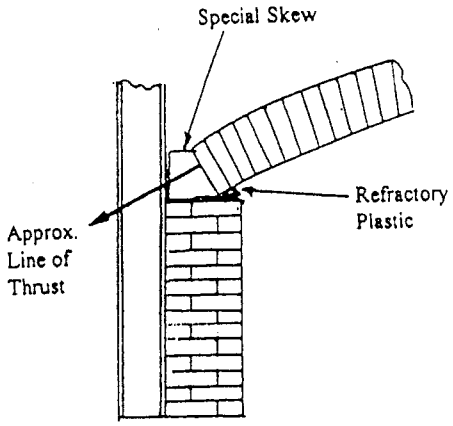


FIG. 5

TYPICAL CIRCULAR CONSTRUCTION ALTERNATIVES
USING ROTARY KILN BLOCKS

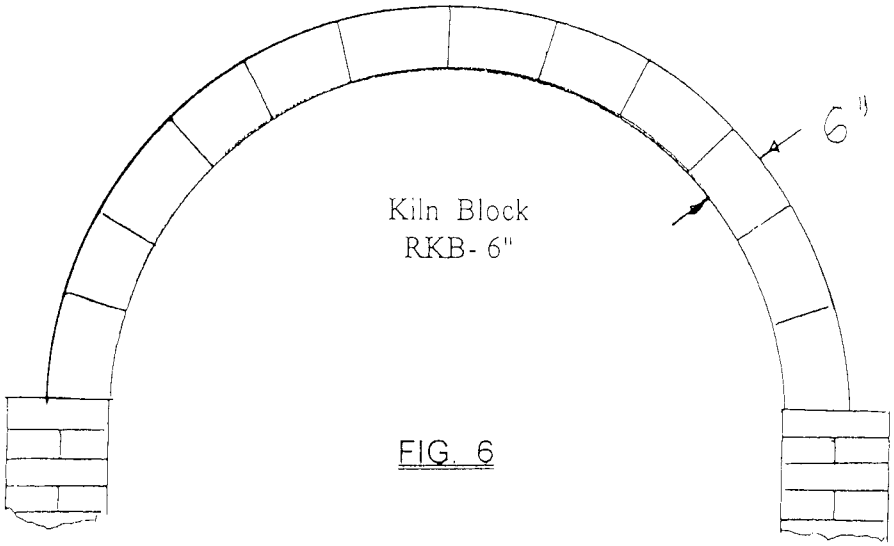


FIG. 6

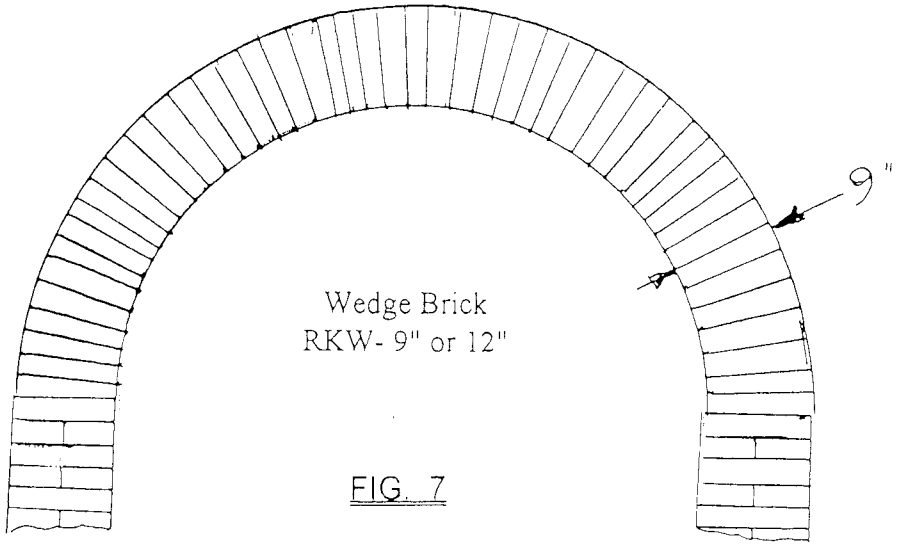


FIG. 7

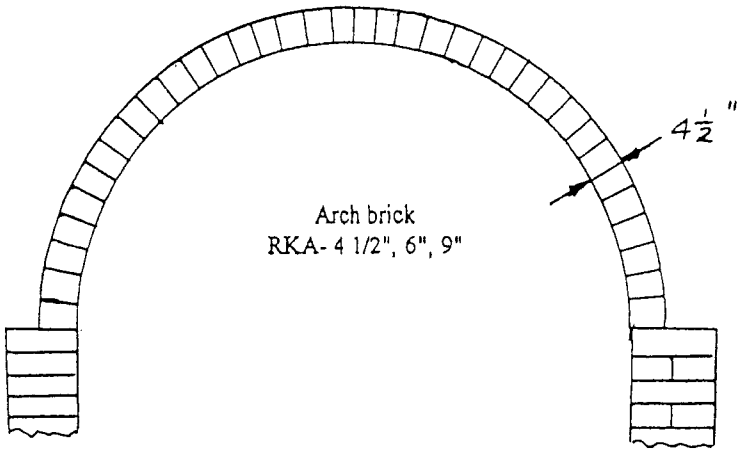


FIG. 8

Figure 8 shows a half circle constructed of arch brick. Again typically 2 sizes are necessary for most arches.

A point to consider is the thicker the arch, the more structurally stable it is. This assumes of course that good bricklaying techniques have been employed throughout the kiln construction.

Many people try to save a few dollars by choosing a 4 ½" arch thickness where a 6" or 9" thick arch will better serve you in the long term.

Final Thoughts:

1. Use extreme care when considering used refractories for building kilns. In most cases, one doesn't know the conditions under which they were exposed. If they have been removed from a furnace, it is usually because the lining failed. Properties of refractories deteriorate with exposure to extreme heat, chemical vapors, mechanical stress, and thermal cycling.

2. Make sure that the flu opening from the kiln to the chimney and the chimney's size and height is sufficient for the volume of the kiln. Error on a larger size and control with dampers.

3. Just as an automobile needs routine maintenance, so does a kiln. If gas or oil fired, disassemble the burners periodically and clean them for maximum performance. Large cracks should be repaired with refractory mortar or plastic. Dipping pieces of ceramic fiber in mortar prior to sealing cracks is also an effective patch.

4. Increasing the amount of insulation on a kiln lining allows it to be more economically fired and reduces the tendency for cold spots in the kiln.

5. Before you purchase an electric or gas kiln, investigate the possibility of building your own. The refractory cost is modest and the reward of building your own kiln is priceless.

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Jim Wunch is the owner of Larkin Refractory Solutions located in Lithonia, GA. A graduate of Clemson University in Ceramic Engineering, he has over 35 years of professional experience with refractory manufacturers and installers worldwide. He has published several technical articles on refractory applications and conducted numerous refractory seminars for customers and professional organizations. His professional affiliations are the American Ceramic Society, NICE, TRI, the Potters Council, NADCA, NCECS, and Glass Arts Society (GAS). Mr. Wunch has traveled extensively worldwide solving refractory problems in nearly every refractory consuming industry.

Larkin Refractory Solutions
P O Box 716
Lithonia, GA 30058

Phone: 678-336-7090
Fax: 678-336-7094

Email: lrs@larkinrefractory.com
Web: www.larkinrefractory.com