Building a 20-Cubic-Foot Cross-Draft Soda Kiln

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This is a tried-and-true design for a simple LPG-fired crossdraft soda kiln of approximately 20 cubic feet displacement and approximately 16 cubic feet of stacking space, designed for two 12" by 24" silicon carbide shelves on each level. The narrative and accompanying plans include most of the information you need to build this kiln, but they also assume a general knowledge of kiln construction. Unless you have that knowledge and experience, get a copy of my book, *Clay: A Studio Handbook* and/or Fred Olson's *The Kiln Book* to provide necessary supplemental information about kiln-building.

Note Regarding the Kiln Plans:

The plans in this handout were done in Microsoft Paint, which does not allow for much adjustment of size, thus the scale is only approximate - one inch on the drawing equals approximately one foot on the actual kiln. Everything is otherwise to scale, but the indications of individual brick placement are generalized. It is important to consult the section on kiln construction in the books mentioned above, specifically in regards to stretcher and header courses in constructing the kiln walls. Adjustments must always be made when placing bricks at the corners and around the burner ports and flue in order to minimize the alignment of seams in each layer, giving a "locked wall" without the use of mortar. This kiln is all dry-stacked. No mortar is used anywhere in the construction except in laying the chimney bricks in order to minimize air leakage and maximize draft.

Note that there is the option to use IFB (insulating firebrick) on the outside layer wherever possible – everywhere except the header courses (which pass all the way through the wall and therefore must be hardbrick) and the bricks that surround the burner ports, charging ports, accessory ports, door jambs, and flue, which are all hardbrick. I must admit some skepticism as to whether it is really worthwhile to use IFB on the outer layer, especially if you are purchasing new brick. For the cost of IFB compared to hardbrick and the minimal effect once the heat passes through the hotface layer of hardbrick, I doubt that it's worth it.

The Hotface: Hard Brick versus IFB

After working with a series of soda kilns that were at least partially IFB on the interior, I have come to building salt and soda kilns with all hardbrick on the hotface, especially on any soda kiln that is going to receive fairly heavy use. I am concerned about the environmental footprint, but it is questionable whether the perceived fuel savings are really worthwhile. In several soda kilns at the Appalachian Center for Craft we experimented with an IFB hotface sprayed with ITC-100 thermal coating, and those kilns lasted less than 100 firings before needing a rebuild. With the frequency of our soda firings at ACC, that wasn't nearly enough. Rebuilding a kiln is expensive and time-consuming, especially considering the cost of IFB and thermal coatings like ITC. In the academic setting I needed for our soda kilns to last at least five years before rebuild. We got that kind of life with a hardbrick hotface, and the accompanying plans are for such a kiln. IFB kilns also cool much faster than hardbrick, often necessitating down-firing to get the desired glaze results, thus eliminating some of the fuel savings.

Building This Kiln with an IFB Hotface
Considering the price of fuel, especially LPG, if you will only be firing your soda kiln once or twice a month, you may wish to use 2600-degree IFB for the hotface except for high-duty hardbrick in the high-stress areas like the floor, firebox, bag wall, and the ports, flue, door jambs and sill, and door. If you are confident of your ability to treat IFB gently in loading the kiln and stacking the door, and in removing and replacing spyhole plugs, you can use IFB in some of those areas as well. The floor, bagwall, and firebox walls up to the top of the bagwall must be hardbrick, and the burner ports, charging ports, and flue must be hardbrick for the full thickness of the kiln walls.

The brick list at the end of this narrative is for a hardbrick hotface. If you decide on an IFB hotface you will have to extrapolate from the plans and brick list in order to figure how many 2600-degree IFB to substitute for hardbrick. If you do choose to use IFB on the outside layer, they should be the lowest duty and least expensive IFB you can find.

Spraying the Hotface with a Vapor Barrier
If you build this kiln with IFB, spray the entire interior with a saturating coat of ITC-100. Don't build it up at all – just soak the surface. On the IFB-hotface kilns at the Craft Center, we used ITC-100, but with an all-hardbrick salt or soda kiln I have come to believe that it is just as effective to spray the hotface with a thin saturating coat of any cone 10 shino glaze, which will help seal the surface from the start to reduce sodium vapor penetration into the brick. Most shino glazes are similar in composition to what will accumulate on the hotface with time anyway.

The Foundation
The kiln is built on a concrete slab, and is elevated on a single layer of cinderblock (with holes facing upwards) to reduce back-strain during loading and unloading. In order to get the configuration of block you need, use any combination of available cinderblock sizes, including standard block, half block, narrow block, and solid cap-blocks standing on edge. You can also leave spaces between the blocks to fine-tune the outer dimensions of the block base. I like to have the block base exactly the dimensions of the kiln footprint in order to allow the steel frame to extend all the way down to the concrete slab. A layer of fiberglass-reinforced cement board atop the blocks provides a smooth surface upon which to lay the brick. The cement board can be cut with an abrasive blade on a Skillsaw. Be sure to wear appropriate safety goggles and respirator when cutting the cement board.

The Kiln Floor
If you have scrap IFB available, use them for the bottom two layers of the kiln floor, followed by a layer of high-duty hardbrick as the hotface floor to withstand abrasion and soda attack and support the weight of the set. If no IFB, use hardbrick for all three layers. Alter the direction of the brick on each layer to minimize alignment of seams.

IMPORTANT NOTE: When laying the floor of the kiln, flue, and chimney, be sure to leave a ½" space front to back in the bottom layer of brick where the kiln floor meets the exhaust flue floor to allow a piece of ¼” by 2” steel flat-bar to be slipped through flush with the outside wall of the kiln as the lower left cross-member on the steel kiln frame.

The Walls

As mentioned, except for the chimney, this kiln is dry-stacked with no mortar. The walls are 9"-thick (a standard brick is 9" long by 4 ½” wide by 2 ½” high), and are built from a mix of header and stretcher courses of bricks, with a header course generally occurring after every third stretcher course. Each header course begins and ends with a soap (a brick that is as long as a standard brick but half as wide – 9” by 2 ¼” by 2 ½”) on each wall in order to minimize alignment of seams with the layers below and above. Adjustments must be made in laying bricks at the corners and over the burner ports and flue, and alignment of seams should be minimized at all times in order to get the strongest locked wall.

The Burner Ports and Flue Opening

The burner ports and flue opening must be accommodated as soon as you start laying bricks on top of the floor level. On my current soda kiln, I placed the burner ports one brick (2½”) above floor level so that molten soda pooling over time cannot flow into the burner ports. I suggest you do the same. The burner ports are 4.5” wide (½ brick) and 5” high (2 bricks). Remember that the flue opening and burner ports are all lined with hardbrick through the full 9" thickness of the walls.

You will need to cut a lot of hardbrick to produce half-bricks and various custom shapes. Borrow or rent a water-irrigated brick saw for this and save yourself a great deal of time and aggravation. I am not generally a fan of Harbor Freight power tools, but a friend loaned me their “CHICAGO ELECTRIC 10-in. 2.5 HP Tile/Brick Saw” and it worked like a champ. It’s a bargain for $300, considering that renting a brick saw will cost you at least $75 per day. It is wonderful to have the brick saw available throughout the kiln construction project.

If you do decide to use a brick chisel, plan your cuts so that they are not exposed within the flue and burner ports. Whether using a brick saw or chisel, always wear appropriate safety goggles and respirator.

As shown on the plans, the flue opening leading to the chimney is 9" wide by 7 1/2" high (three bricks). The best design to span the roof of this flue is a corbeled arch. As you lay the third course of bricks adjacent to the opening, have them extend 2” into what would otherwise be a square opening, providing a ledge to support straight bricks spanning the opening above, providing the roof over the flue This design very slightly diminishes the cross-section of the flue, but not enough to make any difference on such a short flue. Another option is to cast a slab with Mizzou castable to span the opening, retaining the full 9” by 7 ½” cross-section.

The Spyholes

All spyholes are 2 ½” high and 2 ¼” wide (the height and width of a quarter brick). This kiln has a stacked brick door, and I like stacked doors specifically because you can determine the placement of your front spyholes with each firing. That can be a significant advantage. You still need spyholes in the back wall in order to place cone packs and draw rings front and rear. Your bottom shelf will be standing 2 ½" off the kiln floor on small brick posts (1/8 of one brick). Depending on the thickness of the shelves you are using, place your bottom spyhole so that it is just above the bottom shelf. Figure out exactly where the rear center shelf posts will be and place all spyholes just off to the side so that they will not interfere with those posts. Place a second spyhole about midway up, and a third spyhole about the level of the bottom of the arch. In general terms, do the same when you are stacking the door.

Spyhole plugs can easily be fashioned from scrap IFB or cut from hardbrick. I prefer IFB spyhole plugs because they don't get as hot and are easily fashioned to any shape. If you use hardbrick and don't have access to a brick saw, get a diamond cup wheel for your angle grinder and grind down one end of a quarter brick to a taper to fit the spyhole.

The Charging Ports

Be sure to note the placement of charging ports in the front and back walls of the firebox. The charging ports are one brick (4 ½" x 2 ½") wide and high in the outside layer, and two bricks (5") high on the inside layer in order to allow maximum spray angle with the metal spray-wand of a garden sprayer. The single brick opening in the outside layer of bricks must be the upper level of the two-brick opening in the inside layer in order to allow spraying downwards towards the firebox floor. As mentioned earlier, the charging ports must be lined with hardbrick through the entire thickness of the kiln wall.

All charging of soda solution is normally done through the main charging ports directly into the firebox, although some people choose to charge some soda directly onto the wares through the spyholes in the back wall or the door. A note of caution – you must never spray soda solution through the spyholes if you are using Advancer shelves, because it can cause them to crack.

Never charge soda through the burner ports under any circumstance because it will result in rapid deterioration of the burner ports and serious corrosion of the burner system. The charging ports are provided specifically to introduce soda solution directly into the firebox. These ports are located low down, so that the direct impact of soda solution is confined to the hardbrick hotface surfaces of the firebox floor and adjacent wall.

Completing the Walls

When building the walls, keep going right up to the level of the skew bricks on the side walls, but leave the back wall and the partial front wall one brick lower until after installing the arch. You need the space on top of the back wall and partial front wall to install shims and wedges to partially support the arch form.

The Steel Frame

Once the walls are completed up to the level of the skews, it is time to build the steel frame, since the arch cannot be sprung until the frame is in place to absorb the outward thrust of the arch. You will need to refer to Olson's *The Kiln Book* or to *Clay: A Studio Handbook* for specifics about building kiln frames.

A steel frame is essential on any sprung-arch kiln to absorb the outward thrust of the arch. On a salt or soda kiln, a very sturdy welded frame is important because with time, such kilns start to shift in interesting ways. In the high-stress areas, bricks can become saturated with flux and expand, and a frame helps to keep everything in place. The frame is all standard mild-steel stock arc-welded at all joints. The corner verticals, front upper and lower cross-members, the arch-buttressing cross-members, the right lower crossmember that supports the burners, and the front vertical to the right of the door are all ¼" by 2" by 2" angle iron. The other cross members are ¼" by 2" flat bar.

Note that on the sides there are three crossmembers, because of the inclusion of the arch-buttressing cross-members. I believe in having continuous cross-members all the way around the top of the frame to help stabilize everything. Those members are flat-bar on the sides and back, but angle iron on the front, because it needs that rigidity to support the angle-iron vertical to the right of the door. The bottom cross member on the front is also angle-iron, to serve as a door-sill reinforcement, and because it requires rigidity for the same reason as the upper front cross-member.

The angle-iron cross-member beneath the door and the one that supports the burners serve as lower cross-members on those two sides.

NOTE: On the left side, the lower cross-member (flat-bar) must be placed below the floor level to get it away from the hotface where the flue passes into the chimney. When laying the first layer of brick on top of the cement board, be sure to leave a ½" gap front to back (only on the first layer) where the kiln floor meets the flue floor to accommodate the left lower cross-member. When you build the steel frame, you will need to slip a piece of ¼" by 2" flat bar through this gap so that it lays on edge flush against the outside wall of the kiln to serve as a cross-member on that side, connecting the left-front and left-rear vertical corner angle-iron members.

The vertical angle-iron member to the right of the kiln door is very important. This is a high stress area, and without that vertical, the stub-wall will often warp or lean outwards with time.

Note that the plans show placement of the burner-support cross-member so that its upper surface is one brick below the burner ports, in order to protect it from excessive heat-exposure. On my current soda kiln, I placed it a brick and a half (about 4") below the burner ports.

The Arch

This kiln features a 4 1/2" hard brick arch plus a 4" layer of castable insulating refractory. The arch extends the full distance from the outside front face to the outside back face of the kiln, and the kiln is five bricks deep front to back on the outside.

This kiln is four bricks wide inside, which is 36". Using the specifications in the *A.P. Green Pocket Refractory Handbook* (or the "A.P. Green Arch Chart" on my website) an ideal 36"-span arch for this kiln has a rise of 2.3" per foot, a center rise of 6 15/16", and an inside radius of 2' 15/16". This arch requires 18 #1 arch bricks and one straight brick from one side to the other to get the appropriate curvature and span. That means 18 front-to-back rows of #1 arch bricks and 1 row of straight bricks. With this configuration, the straight brick would always be placed as the key-brick row at the top, but it never fits perfectly. A preferable solution is to omit the straight bricks and cast the key-brick row at the top with Harbison-Walker A. P. Green Mizzou castable or another super-duty hard castable.

The arch tables provided in Olsen, in a refractory supplier's literature, or in the "A.P. Green Arch Chart" on my website are always just a generalized guideline, and sometimes when you are laying the arch you will find that adjustments must be made. There is often a little discrepancy in the size of bricks, and it is logical to assume that this is also true of the arch brick taper. The slightest discrepancy in angle can make a big difference in how many rows of straight bricks are needed in the arch. Always watch the joints between bricks and make sure that each one represents a true radius of the curve. In building this arch from the #1 arch bricks I have been using, I've have found that the arch bricks start tilting off-radius about four or five rows up from either side unless we add a row of straight bricks at that point on either side. At the top of this arch the key-brick row ends up being about 1 ¼" wide, and we always cast it with Mizzou castable. This gives us an arch composed of sixteen rows of #1 arch bricks, two rows of straights, and the cast key-row at the top. Things may turn out different for you depending on the bricks you use, and the important thing is to be sensitive to how the arch is laying, and make adjustments in the choice of arch versus straight bricks when necessary.

Building the Arch Form

The arch form is a temporary structure that supports the arch while the bricks are laid. Be sure to save your arch form. Generally, by the time a soda kiln needs to be rebuilt, the arch bricks cannot be re-used for other than landfill, and the arch can be knocked down without using the arch form. But you will use the arch form again if/when you rebuild the kiln or build another like it.

Arch Form Tools and Materials

- 1 – 4x8 sheet of ¾" plywood,
- 1 – 8' 2x4
- 1 – 4x8 sheet of 1/8" Masonite, cheap thin paneling, or some other similar, flexible sheet material
- Several dozen 3" drywall screws
- A box of 100 1" drywall screws
- A yardstick.
- Two electric drills – one for drilling pilot holes and the other for driving the drywall screws.

The flexible sheet provides a smooth, sturdy curved surface over the plywood ribs, and before proceeding you must subtract the thickness of this material from the radius given above, so that your finished arch form will come out with the correct radius. Assuming you are using 1/8" Masonite, the corrected radius for making the ribs would be 2' 2 13/16".

You can easily adapt the yardstick to serve as a compass to make the initial rib for your arch form. Drill a pencil-size hole near one end and affix a pencil with some duct tape. Measure exactly 2' 2 13/16" and install a drywall screw protruding from the same side as the point of the pencil.

Near one edge of the plywood sheet, draw an arc at least 36" wide with this compass. Lay the yardstick across the wide edge of the arc and move it up and down until you find the point that is exactly 35 ½" wide. Draw a line at that point. The width is only 35 ½" to give clearance for easy placement and removal of the arch form. This initial measurement gives you an idea of the size of each rib, and you can now reposition if necessary to make the best use of the plywood. Cut out the first rib and use it as a template to trace and cut four more ribs.

Six inches in from either end of the straight edge of each rib, cut a notch the size of the cross section of a 2x4 (remember that the standard 2x4 is actually 1 ½" by 3 ½", but measure yours to be sure).

One rib is placed right at the front edge of the arch form, one right at the rear. The others are equally spaced between. The arch is five bricks deep from front to back, which is 45". Cut two 45" pieces of 2x4, and fasten them in the notches of the ribs with 3" drywall screws. Drill a pilot hole in each case to reduce the chance of splitting the plywood and the 2x4s. When this assembly is done and sitting upright on the ground, the two 2x4s will be laying parallel flat on the ground, inset into the notches in the plywood ribs, and the ribs will be standing vertically, one placed right at each end of the 2x4s, and the other three ribs evenly spaced between, creating a parallel series of curves corresponding to the underside of the arch.

Carefully measure the length of the curved edge of one rib, and cut a piece of Masonite to this length and 45" wide. Masonite is quite hard, and you will probably need to drill a pilot hole for each screw as you proceed. Starting at one edge of the curve, attach the Masonite to the ribs with 1" drywall screws. This will require two people, one bending the Masonite tightly against the curve while the other drills holes and installs the screws.

With good quality plywood and with screws installed as close as possible to the ends of each rib, it is possible to hold the Masonite tightly against the ribs even at the ends. If this proves problematic, a solution is to inset a piece of 2x2 stock parallel to the 2x4s in notches at each end of each rib and trim one edge to conform to the curve of the ribs in order to provide a front-to back support to attach the edge of the Masonite with row of 1" drywall screws.

Placing the Arch Form and Laying the Arch

The arch form is supported by the back wall of the kiln and the front stub-wall on the right, but on the left you will build up a temporary support with cinderblocks, bricks, and wood shims. In all cases, you will achieve the final level of the arch form by using wood shims and a set of four tapered wood wedges. The wedges should be approximately six inches long with a taper from 1" to ¼" over that length. Do not taper the wedges down to a knife edge, because you need a flat surface to drive them out in order to "spring the arch." Set the arch form in place, and raise it up with a combination of shims and wedges to visually get the outer edges of the arch form level with the lower leading edge of the skew bricks. Place arch bricks in the correct position at the front and back ends of the first row on either side of the arch form. Adjust the height of the arch form with the shims and wedges until the outside lower edges of these arch bricks line up perfectly with the lower edge of the skew bricks at all four corners of the arch.

Once you are sure the arch form is in exactly the right position, start laying the arch. Lay the bricks in full rows front to back from both sides simultaneously, working towards the center. Begin and end every other course with a half-brick in order to stagger the seams and produced a locked arch. If any of the arch brick are trimmed, be sure to brush or blow off all dust, preferably with compressed air. If you neglect this, the dust will inevitably sift down on wares being fired.

If you were building with IFB, you would lay up the necessary rows of arch bricks on either side right to the top, and then trim some IFB to size to form the final row of key bricks. As mentioned earlier, with a hardbrick arch it only makes sense to cast the key-row with a hard high-duty castable like Mizzou. Before casting the gap, fasten small scrap pieces of wood to the front and back ends of the gap, screwing them to the arch form, using shims if necessary to get them to lay flat against the brick and seal the gap.

IMPORTANT NOTE: Line the gap with plastic wrap, pushing it into place with a stick so that it covers the sides and bottoms of the gap. This will prevent the adjacent bricks from absorbing moisture from the castable refractory. Castable refractory mixtures must air-set while still wet, just as the case with Portland cement. If the key row is cast directly against bricks, the bricks will immediately suck the liquid out of the castable, preventing proper setting, and the refractory will fail very quickly. That is true to a lesser extent even if the adjacent bricks are dampened, and the easiest sure-fire solution is to line the gap with plastic wrap.

Cut several dozen 1” x 5” shims from scrap Masonite or thin paneling. Every four or five inches along the gap, place two of these shims vertically against the plastic wrap on either side inside the gap. Roughly measure the width of the gap inside the shims just above the midpoint in the height of the adjacent arch bricks. Cut about a dozen 5”-long 1”-wide wood sticks of a thickness that will wedge against the shims and press outwards on the bricks at that point. Hammer these sticks into the gap between every pair of shims. The reason for the shims is that without them, hammering the sticks in place would rupture the plastic wrap. The purpose of this system is to forcibly press outwards on the bricks along the gap, tightening up the arch and closing up any gaps.

Go to the “Documents and Handouts” page of my website and study the PDF handouts on preparing and using A.P. Green Mizzou castable, and mix it exactly according to the instructions. The best way to do that is in a five-gallon bucket with a drill impeller mixer. It will not hurt to add very slightly more water than specified, but no more than that! The more water, the weaker the castable. When you add the water and start mixing, you will think it’s not nearly enough water, but be patient until all the particles are moistened. That takes time.

Work the castable into the gap with a mason's trowel a little at a time, tamping it in place with gentle blows of a hammer against a thin wood stick, carefully avoiding damage to the plastic wrap. Build the castable up just above the top of the brick and gently pound it with a rubber mallet until the upper surface is shiny with moisture. Remove the sticks and shims and fill all the spaces they occupied, once again applying a little castable at a time and tamping it in place repeatedly. Once all the holes are filled just above the adjacent bricks, gently pound again with the rubber mallet until the surface is shiny with moisture for the whole length of the key row. Don't try any shortcuts here if you want a strong, long-lasting arch.

Let the Mizzou castable air-set for at least 36 hours until it is rock-hard before springing the arch.

Springing the Arch

Once the arch is constructed and the castable key row has thoroughly cured, drive out the tapered wedges with a hammer and punch or a hammer and a thin piece of wood. Drive the out a little at a time, alternating between the four corners, so that the arch form is lowered evenly. This is the most important ceremonial moment in the construction of a kiln, when the arch form drops, "springing" the arch, leaving it standing on its own. Once the arch is sprung, the arch form can be removed. Note that with the vertical angle iron member adjacent to the door in front of the door jamb, the arch form can only be removed to the rear.

The Insulation Layer Over the Arch

Since the arch is hardbrick, the insulating layer helps with heat retention. Heat naturally rises, so while an insulating layer on the outside of the walls is of questionable value, the insulating layer atop the arch is proven to be of great benefit. That layer also provides rigidity, lessening the flexing of the arch. That reduces the amount of material sifting down on the wares, and makes the arch last longer. I always do a single-thickness brick sprung arch, and then add a 4" rigid insulating layer atop the arch.

If you have a source of scrap IFB, that makes a good insulating layer, laid with a mortar of sand and fireclay. I have done that a few times when scrap brick were abundant. Otherwise, I use a homemade insulating castable refractory. It would be a complete waste of money to pay for commercial insulating castable refractory for an external layer over an arch. To get insulating properties, there must be voids in the castable. That can be achieved by using something like sawdust or crushed walnut shells that burn out when the kiln is fired (leaving voids), or with a refractory material that contains air pockets and thus introduces voids. The disadvantage of sawdust or other organic inclusions is that they produce volumes of smoke for many firings, and it can take years for all of the organics to burn away. The two most readily available insulating refractory materials are vermiculite, which is expanded mica, and Perlite, which is expanded silica. Both can be purchased from garden/landscaping suppliers. Vermiculite has been popular for this use in the past, but I find that it partially disintegrates and collapses in the mixing process, losing much of its insulating properties. I have settled on Perlite, which is available from garden and landscape suppliers in reasonably-priced four-cubic-foot bags. For my 30-cubic-foot soda kiln, four bags were more than enough.

I have always known that a small addition of Portland cement will make a homemade insulating castable weatherproof. Recently I realized that the addition of cement causes the insulating layer to air-set hard overnight, minimizing any subsequent cracking during drying and firing. Without the Portland cement, the castable will shrink and crack badly, and the cracks must be filled with more of the same insulating mixture. It will also be much more subject to damage, and will deteriorate quickly if the overhead roof is leaky.

Homemade Insulating Castable Recipe (***not for hotface use*** – use only outside a layer of brick. This recipe is parts by volume, not by weight.

- 6 parts Perlite
- 2 parts fireclay
- 1 part cheap builder's sand or play sand
- 1 part Portland cement

In the past I've used a regular cement mixer to blend the insulation castable ingredients, but then a neighbor loaned me a proper mortar mixer, which works far better for any homemade castable. A mortar mixer has rotating paddles mounted on a horizontal shaft, and will produce castable with far less water than would be possible with a conventional cement mixer with a rotating barrel.

The insulating layer cures very hard in about 36 hours and no cracks will appear initially. After several firings a few hairline cracks will appear, but they in no way negatively affect the performance or durability of the insulating layer.

The Chimney and Damper Slot
The flue leading out to the chimney is a single layer of hardbrick (4 ½") in the walls, and two layers of hardbrick (5") in the roof. Earlier I mentioned either using a corbel arch or a custom-cast refractory piece, and either should continue through the kiln wall and the chimney wall. The chimney is 9" by 9" inside, built of a single thickness of hardbrick. A tight chimney with no leaks makes for a better-firing kiln, so use a thin fireclay mortar when building the chimney, Don't add any sand. Trowel in a thin layer of mortar on all contact brick surfaces as you build the chimney, and as always, stagger the bricks in each layer to avoid vertical alignment of seams.

I generally place the damper slot about a foot above the top of the flue, and you can choose whether to place the damper slot on the front, side, or back of the chimney – whichever is more convenient for your situation. For a damper, purchase an 11" x 26" mullite or cordierite 1" kiln shelf. Cut bricks lengthwise so that they are still 9" long and 2½" high but only 3" wide. Use those to lay the back and side walls of the damper slot. That will give a slot 12" wide and one brick high (2½"). For a kiln that is not salt, soda, or wood, you could use thinner shims to make a damper slot that fits the damper more tightly, but in salt or soda firing, the damper can occasionally get badly stuck with salt/soda slag. With a 2½" damper slot you can always work it loose. With the damper in place, during firing, keep a soap and quarter brick end-to-end laid against the opening atop the damper in order to seal off the opening.

To cast the lintel block to span the damper slot, build a wood-box casting form with interior dimensions exactly 18" long, 4½" wide, and 5" high. Fill it with Mizzou or some other super-duty hard castable, tamping and vibrating to make sure the castable fills the corners. As with the key row, tamp it on top with a rubber mallet until the entire upper surface is shiny, and then strike it off even with the top, smoothing with the trowel. This block will replace two courses of bricks across one side of the chimney, spanning the damper slot. Build up the adjacent walls with two courses of bricks and then return to building with bricks all the way around.

A kiln with power burners requires a chimney only as high as the kiln, but any kiln with atmospheric (natural-draft) burners needs a chimney extending quite a way above the kiln in order to introduce sufficient draft. I used to advocate transitioning to 10"-inside-diameter corrugated steel culvert pipe above the top of the kiln. But it has become very difficult to find 10" inside-diameter corrugated steel culvert pipe, and other types of 10" I.D. steel pipe are very expensive. I think that the disappearance of small-diameter steel culvert pipe is due to the available and effectiveness of flexible plastic culvert. You can use insulated chimney pipe such as would be used for a wood stove or fireplace, but that stuff is also very expensive.

In any case, with a salt or soda kiln, all of the pipe options will corrode through in three to five years and require replacement, whereas a brick chimney is permanent. On my latest soda kiln, the chimney is mortared hardbrick all the way up. The interior height of the chimney is approximately twice that of the ware chamber, and this chimney works great.

I used to advocate a chimney extending a minimum of eight feet above the top of the arch, but that's unnecessary and in fact counterproductive unless you need a tall chimney to clear an overhead roof. A chimney that tall creates a lot more draft than you need, and while we can always regulate draft with the damper, the convection tower effect of a tall chimney sucks gases past the damper at a much higher velocity, which has a significant effect on the way the flue pulls gases out of the kiln. It's a workable situation, but requires changes in the bagwall design and firing protocol including burner pressure. In my experience, a chimney that is just high enough to provide adequate convection vacuum results in a kiln that is a easier to control. As explained below, it requires a bagwall a little lower with more openings in order to heat the kiln evenly from top to bottom. My chimney is still adequate to give plenty of draft to pull the soda vapors through the kiln during charging if I want asymmetrical soda effects.

An unreinforced chimney is a death-trap in an earthquake. Measure, cut, and place angle-iron verticals on all four corners of the chimney and temporarily hold them in place with a strap clamp. Weld horizontal flat bar crossmembers at the bottom, midpoint, and top on all four sides. Weld several connectors to tie in the chimney frame with the kiln frame.

The Bagwall

In some gas kilns, bagwalls are not necessary, but they are almost always present in salt and soda kilns in order to provide a specific firebox area of maximum heat and turbulence to encourage effective vaporization of the salt or soda before it affects the wares, and to prevent the sodium vapors from hitting the wares too directly. Bagwalls are always necessary in gas kilns with side-mounted burners, in order to keep the flames from impinging directly upon the wares. In a salt kiln, the bagwalls must be constructed from hardbrick laid flat, giving a 4½" thickness. Soda is less corrosive, and the bagwalls may be constructed from hardbrick laid on edge, giving a 2½" thickness. The first course of bricks should be laid with no gaps in the areas directly in front of the burners except for a small gap at the ends of the first course of bricks, and a gap in front of each of the two pillars between burner ports. Stagger the openings slightly in the second layer, but once again do not place them directly in front of the burner ports. The third layer should be constructed of half and quarter bricks with quite a few gaps. Expect to cut bricks to get the desired spacing, and do not try to build a bagwall without cutting bricks wherever needed.

When building the bagwall, all contact surfaces between bricks and where they touch the kiln walls and floor should be coated with appropriate salt-soda shelf wash (40% EPK, 10% ball clay, 50% alumina). This will greatly simplify the inevitable occasional reconstruction of the bagwall. As your kiln becomes well-used and the floor of the firebox becomes saturated with soda, the bag wall naturally will tend to tilt quickly towards the burner ports. When you see that happened, rebuild the bagwall as described above. If the floor surface has become slightly uneven but is still in reasonable condition, you can level the contact points with wadding mixture (same as the shelf wash mixture but mixed to plastic clay consistency). If necessary, level the corresponding floor surface with a diamond cup stone on your angle grinder. If you don't tend to this as soon as the bagwall starts leaning, it will slump against the firebox wall in the middle of a firing, completely stalling the firing.

The Stacked Door

This kiln is designed to have a loose stacked door 9" thick. Hinged doors are great, but can be problematic on salt and soda kilns, especially as the kiln shifts a bit over time. Personally, I enjoy the "building with bricks" ritual of stacking the door, and I can change the placement of the spyhole whenever it is advantageous. Also, with a stacked door, after the kiln has cooled below red heat, you can remove a few bricks from the top of the door to hasten further cooling. That's especially advantageous on a hardbrick kiln. With a hinged door, as soon as you crack the door, convection will aggressively pull cold air in at the bottom of the door, which will crack your wares. I also enjoy the "slow reveal" that takes place as you unstack the door after a firing. I've built hinged doors that functioned very well, but I really do prefer stacked doors on salt and soda kilns.

When stacking the door, the inside and outside courses should be laid simultaneously, staggering the bricks to minimize alignment of seams and give a stronger monolithic door. About two-thirds of the way up, lay a header course to tie the two layers together. When the kiln is otherwise complete, stack the door up to the arch, and then cut custom brick shapes to fill the space beneath the arch. The easiest way to do that is with IFB. When the bricks eventually start to slag and break down, replace them. If you want to make the custom shapes out of hardbrick, either cast shapes with Mizzou, or else cut and shape them with the brick saw and an angle grinder equipped with a diamond cup stone.

In either case, store those special shapes stacked in sequence atop the arch, while the rest of the door bricks can be stacked to the side. Whether IFB or hardbrick, don't worry about making these bricks fit tightly, because that will just make them difficult to remove.

Coat the contact surfaces on the door bricks with the salt-soda shelf-wash described above. With repeated firings they should be recoated as soon as they start to stick together or show any soda accumulation. As mentioned above, incorporate spy holes as you construct the door. I generally have cone packs in the top and bottom spy holes and draw-rings in the middle spy hole. Remember to place the spy holes so that they are not directly in front of the middle kiln post. As you are stacking the kiln, you will need to determine the spacing of shelves to accommodate the rear spy holes. While stacking the door, you can place the spyholes as needed to correspond to the shelf spacing. Also, if you are not using Advancer shelves and are planning to spray soda directly on certain pots, you may wish to incorporate additional spyholes for that purpose.

Once the stacked door is in place, all larger cracks or gaps in the exterior face should be sealed with a mortar mixture containing four parts by volume recycle slurry or cheap fireclay to six parts cheap builder's sand or play sand. Some people add sawdust, which makes the mortar crumbly and easier to remove. If you mix a batch of mortar that seems too fluid to stay in place, just stiffen it with some dry crushed scrap clay to get the appropriate consistency.

Burner Systems

This kiln uses a burner system with three GACO MR-100 venturi burners, available from Ward Burner Systems and other suppliers. The MR-100 is a very reasonably-priced and reliable venturi burner, and on high-pressure LPG with a pressure regulator at the kiln, this system produces plenty of BTUs for a hardbrick kiln up to 30 cubic feet. The system is equipped with a Baso safety valve and a Ransome B-1 pilot burner, both also available from Ward Burner. Complete information on the burner system is provided in a separate handout, "Soda Kiln Burner System," available on the "Documents and Handouts" page of my website. That handout includes several photos of the burner system, but extensive photos including detail shots can be found on my website. Go to www.vincepitelka.com and on the drop-down menu beneath "Gallery," click on "Studio and Soda Kiln." Scroll to the bottom of the page to find the photos of the burner system.

Brick List

This list includes all of the brick needed plus extras. If you are planning to incorporate clean used brick that you already have, subtract accordingly from these amounts. You will soaps (bricks that are 9" by 2 ½" by 2 ¼") for the burner port spacing and at the ends of all the header courses to minimize alignment of seams with bricks above and below. They are also ideal 9" kiln posts for salt and soda firing, so I have included plenty of extras. Cut standard hardbrick into fourths for 4 ½" posts and into eighths for 2 ½" posts, and cut scrap kiln shelves into shims for fine adjustment of shelf height.

As mentioned earlier, this list is for an all-hardbrick hotface. If you choose to build your kiln with a hotface that is partially IFB, you will need to extrapolate from the plans to determine how many IFB to substitute for hardbrick. These brick are all the standard 2.5” series, which refers to the height of the brick when it is laid in place, or to the maximum thickness (not width) of the arch bricks.

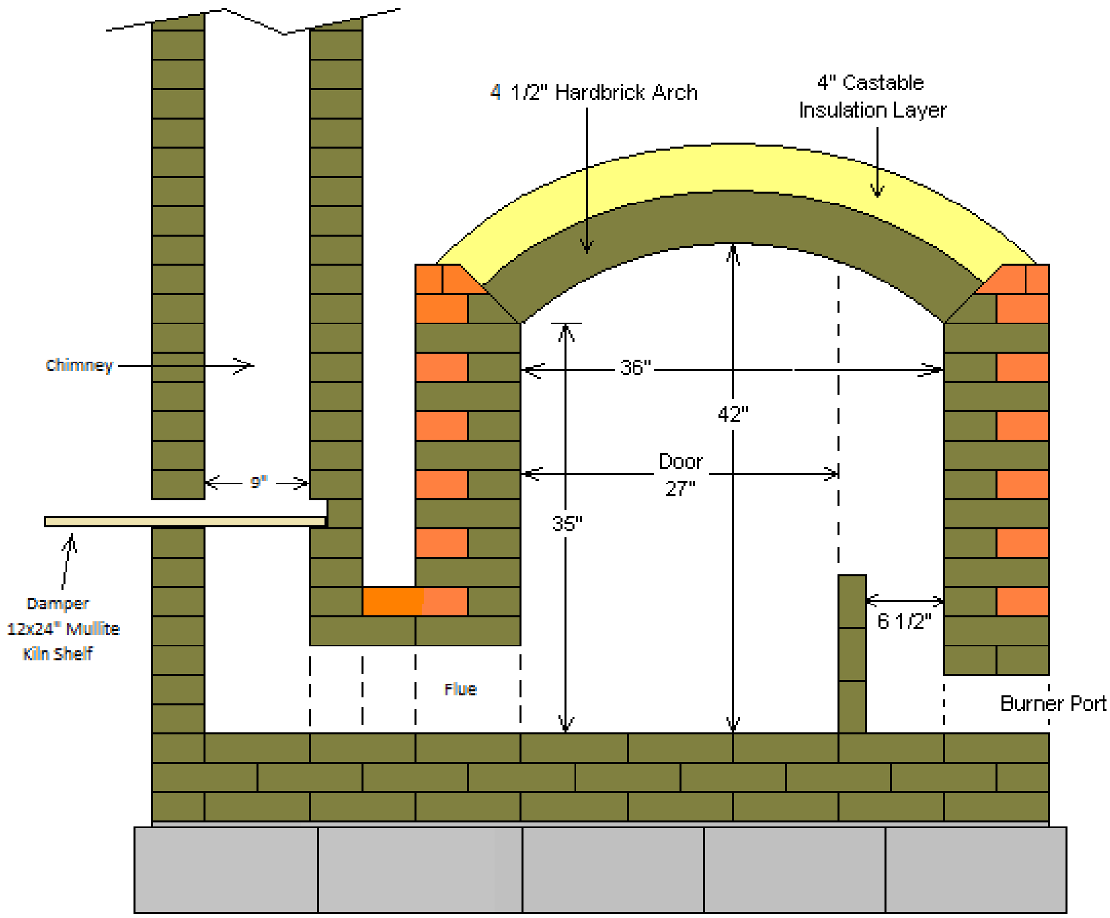
There is some disagreement as to whether an outer layer of IFB really makes much difference by the time the heat penetrates the inner layer of hardbrick. IFB are twice as expensive as high-duty hardbrick, so if you are on a tight budget, substitute more hardbrick in place of the IFB.

Type of Brick	Quantity
High-duty hard firebrick - #1 arch, 2.5” series	100 pieces
High-duty hard fir brick - straights, 9"x4.5"x2.5"	650 pieces
High-duty hard firebrick - soaps, 9"x2.5"x2.25"	70 pieces
High-duty hard firebrick - 45-degree skew bricks, 2.5” series	12 pieces
Insulating firebrick, 2300-degree (or lower), 9"x4.5"x2.5	425 pieces
High-Duty Castable Refractory (for casting the key at top of arch and for damper-slot lintel in chimney). My go-to high-duty hard castable has always been Harbison-Walker A.P. Green Mizzou Castable.	200# dry-mix (mix strictly according to manufacturer’s instructions)

Steel List

This list includes the steel needed for the welded frame on the kiln and the chimney. There is extra to facilitate cutting whole pieces rather than splicing scraps together. This is all standard mild steel.

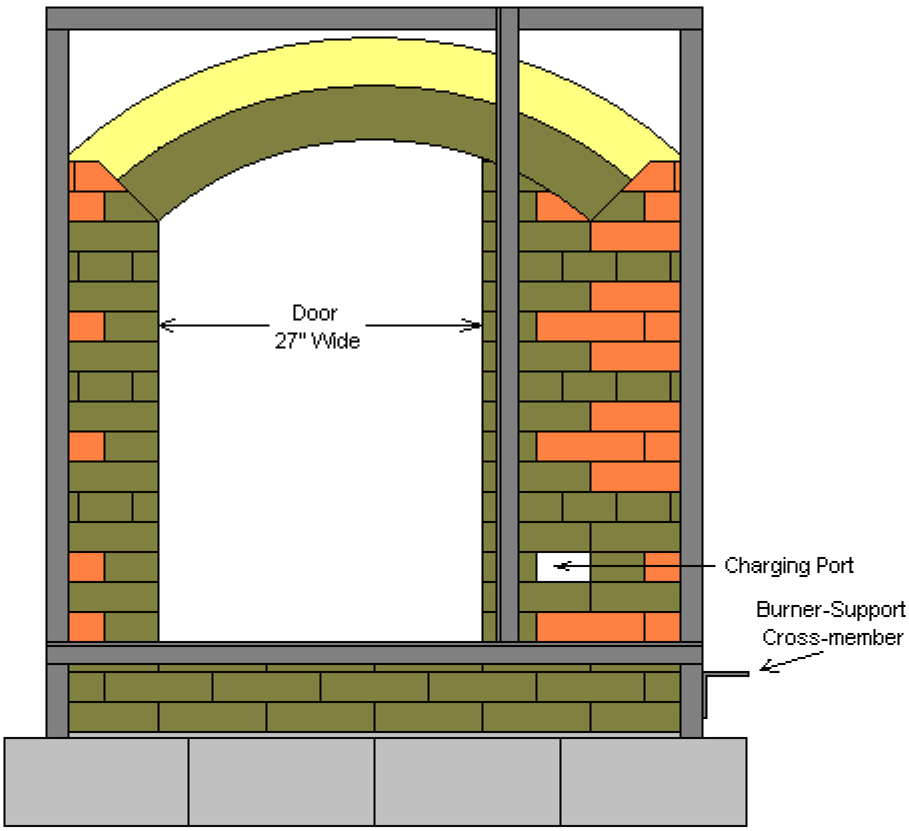
Steel Stock Type and Size	Amount	Application
¼” by 2” by 2” angle iron	80’	Corner verticals, chimney frame, front upper and lower cross-members, door sill vertical, arch buttressing crossmembers, lower right (burner mount) crossmember
¼” by 2” flat bar	50’	Rear upper and lower crossmembers, left side upper and lower crossmembers, right side upper crossmember, burner support frame, chimney crossmembers



Downdraft, Crossdraft Soda Kiln
Gas Fired, 21 Cu. Ft.
16 Cu. Ft. Stacking Space
Vince Pitelka, 2005
Appalachian Center for Craft
Scale - Approx. 12:1

Front Cross-Section View,
With Dimensions, Showing
Burner Port, Flue, Chimney,
Bag Wall, and Damper

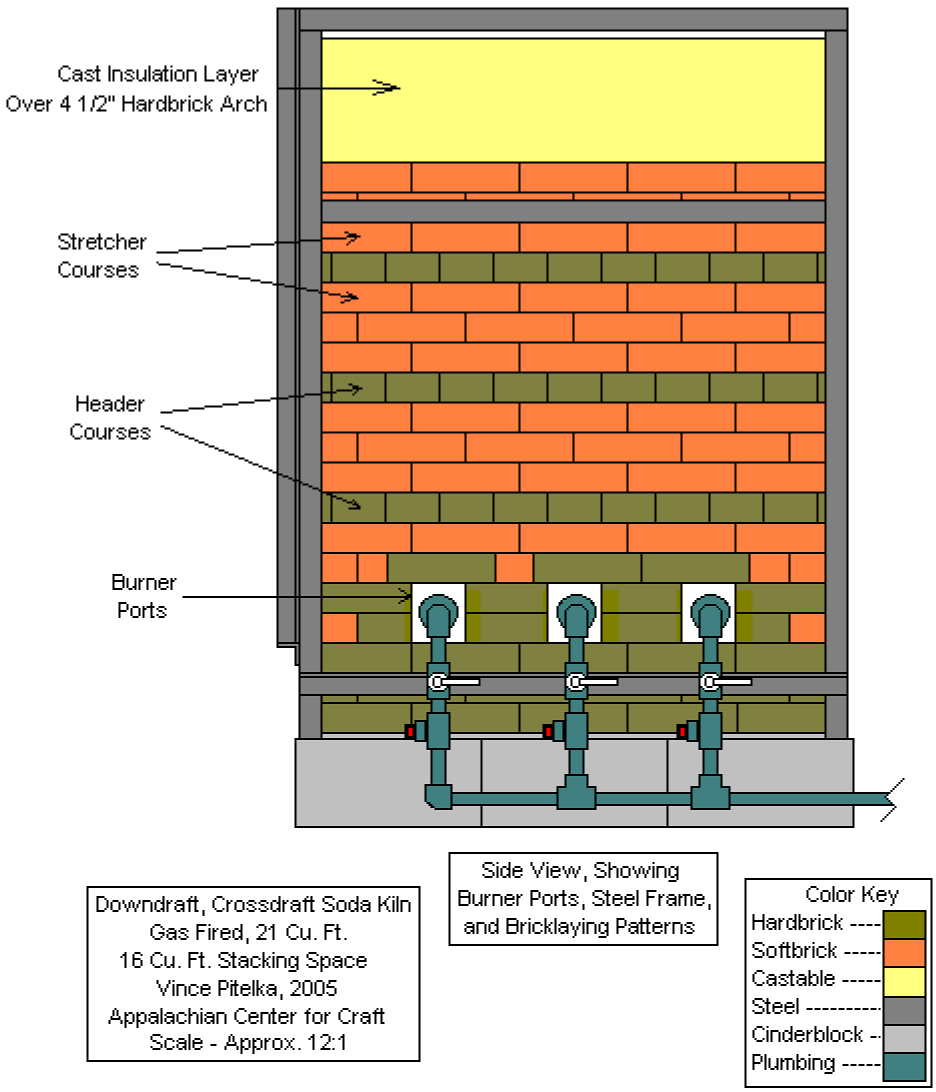
Color Key
Hardbrick ----
Softbrick -----
Castable -----
Steel ----------
Cinderblock --
Plumbing -----

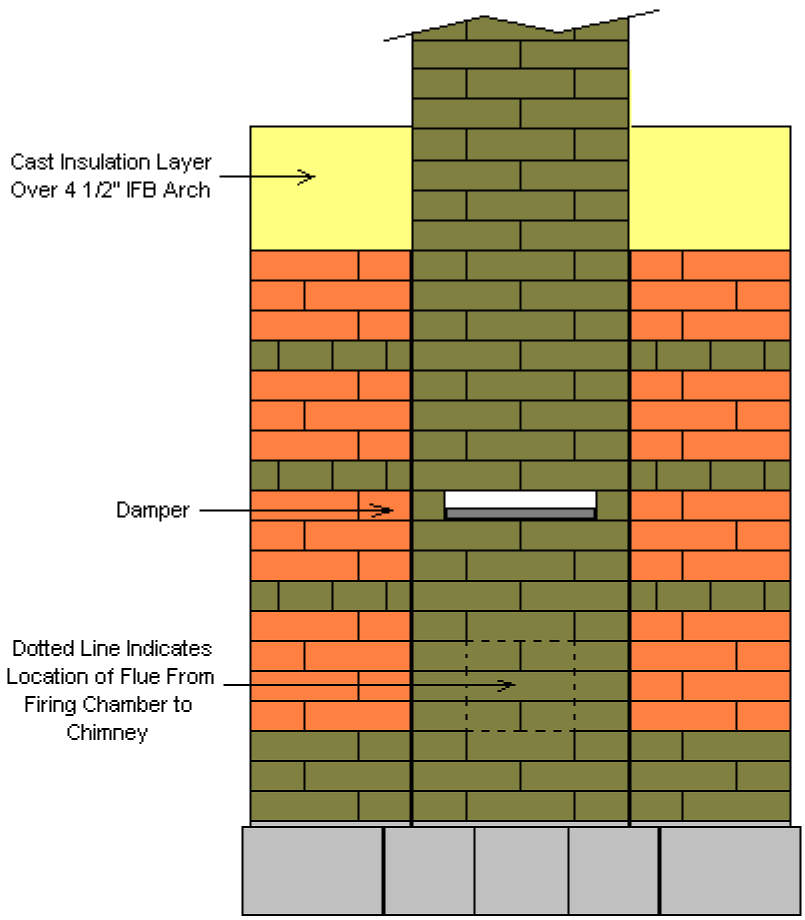


Downdraft, Crossdraft Soda Kiln
Gas Fired, 21 Cu. Ft.
16 Cu. Ft. Stacking Space
Vince Pitelka, 2005
Appalachian Center for Craft
Scale - Approx. 12:1

Front View, Showing Door, Stub Wall, Charging Port, and Steel Frame

Color Key
Hardbrick ----
Softbrick -----
Castable -----
Steel ----------
Cinderblock --
Plumbing -----

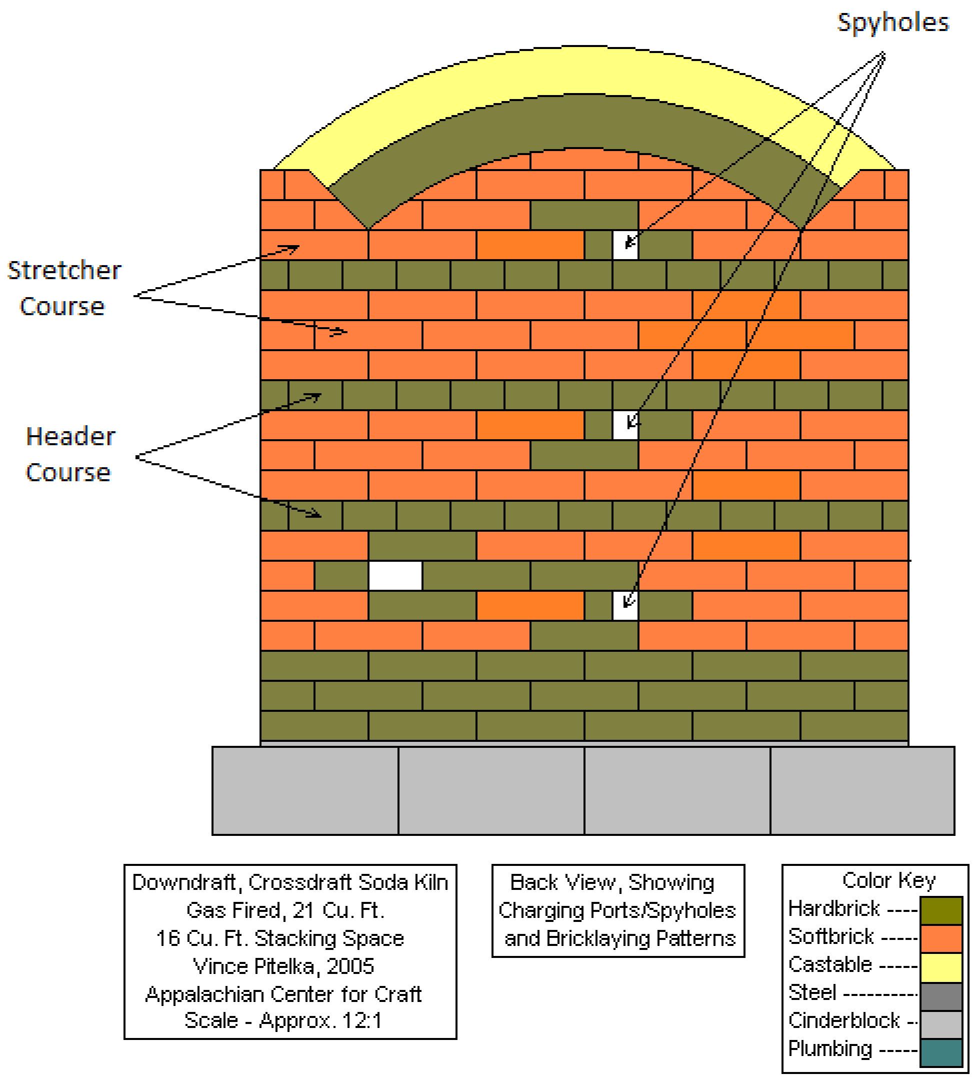

Cast Insulation Layer
Over 4 1/2" Hardbrick Arch
Stretcher
Courses
Header
Courses
Burner
Ports
Downdraft, Crossdraft Soda Kiln
Gas Fired, 21 Cu. Ft.
16 Cu. Ft. Stacking Space
Vince Pitelka, 2005
Appalachian Center for Craft
Scale - Approx. 12:1
Side View, Showing
Burner Ports, Steel Frame,
and Bricklaying Patterns
Color Key
Hardbrick ----
Softbrick -----
Castable -----
Steel ---------
Cinderblock --
Plumbing -----

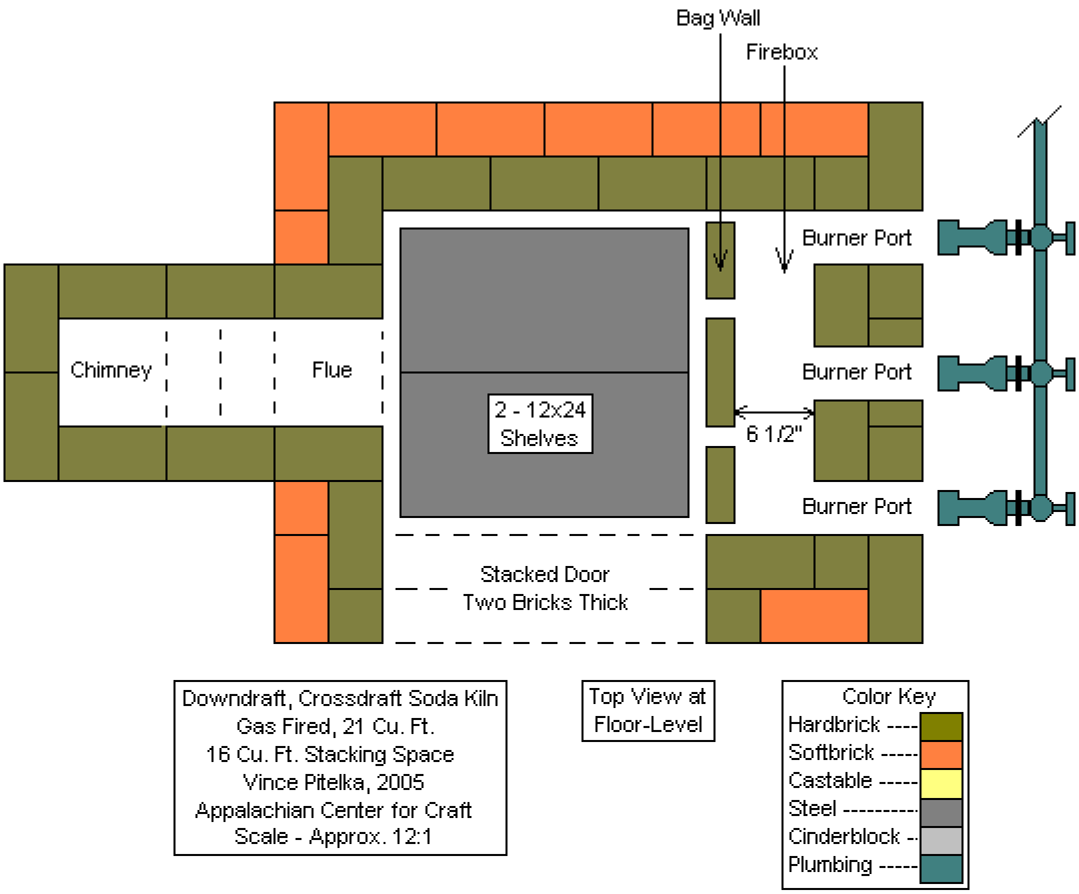


Downdraft, Crossdraft Soda Kiln
Gas Fired, 21 Cu. Ft.
16 Cu. Ft. Stacking Space
Vince Pitelka, 2005
Appalachian Center for Craft
Scale - Approx. 12:1

Side View, Showing Brick Chimney, Steel Chimney Extension, Damper, and Location of Flue

Color Key
Hardbrick ----
Softbrick -----
Castable -----
Steel ----------
Cinderblock --
Plumbing -----


Spyholes
Stretcher Course
Header Course
Downdraft, Crossdraft Soda Kiln
Gas Fired, 21 Cu. Ft.
16 Cu. Ft. Stacking Space
Vince Pitelka, 2005
Appalachian Center for Craft
Scale - Approx. 12:1
Back View, Showing
Charging Ports/Spyholes
and Bricklaying Patterns
Color Key
Hardbrick
Softbrick
Castable
Steel
Cinderblock
Plumbing


Bag Wall
Firebox
Burner Port
Burner Port
Burner Port
Chimney
Flue
2 - 12x24
Shelves
6 1/2"
Stacked Door
Two Bricks Thick
Downdraft, Crossdraft Soda Kiln
Gas Fired, 21 Cu. Ft.
16 Cu. Ft. Stacking Space
Vince Pitelka, 2005
Appalachian Center for Craft
Scale - Approx. 12:1
Top View at
Floor-Level
Color Key
Hardbrick ----
Softbrick -----
Castable -----
Steel ----------
Cinderblock --
Plumbing -----