FURNACE CONSTRUCTION IV
David Gruenig West Barnet, Vermont

FIGURE 1 KEY:
A: Insulation, roof or crown insulation
B: Outside Wall
C: Roof or crown
D: Burner Block
E: Burner
F: Inside liner, above glass liner, hardface
G: Insulation, walls and floor
H: Inside liner, hardface, glass tank liner
I: Hot Glass, Glass Tank
J: Base Plate
K: Legs, supports

The purpose of Figure 1 is to provide information about materials and placement of materials. It is not a diagram of an actual furnace, although some furnaces may look like this.

We will conclude discussions of aspects of A to K that are common to all types of glass furnaces.

F: INSIDE LINER The inner liner must be durable. Most hard, durable, glass resistant refractories are poor heat insulators. The purpose of the liner is to protect softer, highly insulating refractories from degradation.

If you are building a day tank this liner can be inexpensive, hard fire brick. The goal is to resist thermal shock and corrosion from glass contact. For invested crucibles, and free standing crucibles, hard fire brick is also a good choice. It should be as thin as possible, while maintaining structural integrity. It should be thin for cost reasons, and because its’ only function is protection. Most furnaces use hard bricks on edge (2.5 inches thick) or splits (1.5 to 2 inches thick). These can be mortared in place or held by compression (day tank).

Some furnaces use cast refractory. This means using a dense 3000F castable, and this is considered to be poorly insulating. Mizzou is useful for cast liner above the glass line.

H: GLASS TANK LINER

1. BRICK This is used for brick day tanks. The bricks holding liquid glass are usually full thickness, not splits. Liquid glass slowly dissolves refractories.

A small inexpensive day-tank for the back yard can use the same inexpensive firebricks for F and H. Maximum firebricks worked well for me. If the day tank is larger and used for long term serious production, people try to find a longer lasting tank liner brick that will dissolve slowly and give higher quality glass. The object is to extend the life of the day tank by using expensive specialized bricks. I used crystalite bricks, and found that they lasted about the same as the cheap maximum bricks, but they did give a slightly cleaner glass. I concluded that the crystalite bricks were not cost effective.

New glass tank refractories are available. They are usually expensive, but they may be well worth the expense. The best way to evaluate them is through information exchange with other day tank users. Now is a good time for day tank people to send in letters about their wonderful new bricks, and their favorite disintegrated bricks from hell.

2. CAST GLASS TANK LINER:

This is made by casting mizzou around a crucible, preferably a crucible made for glass making. Some people have had success with inexpensive crucibles made for melting metals. If the crucible cracks a little, it still works because the mizzou prevents the crucible from leaking.
The advantage is fuel savings gained by using more insulation around the glass tank. If the glass tank is made of bricks, the glass leaks out through the bricks, then at a cooler place it freezes, thus preventing further leakage. Adding more insulation causes the glass to leak further before freezing and it does not save money. Therefore, some people cast around a pot in order to allow for increased insulation to be used. Can you cast around brick liners? Yes, but it starts to get expensive and it becomes a heavy load to heat.

G: INSULATION WALLS AND FLOOR

If you are using The Independent Glassblower to learn about furnace construction, then you will be well advised to obtain a copy of Recuperation and Insulation in Glassmaking: An Overview by Charles M. Correll [The Glass Art Society Journal, 1988, p.79-81] The Glass Art Society, 1305 Fourth Avenue, Suite 711, Seattle, WA 98101-2401, USA. There is also an abridged version [The Correll Furnace, Glass Gazette, Spring 1994, p.3-5] Glass Art Association of Canada, P.O. Box 653, Station 'P', Toronto, Ontario, M5S 2Y4, Canada. This article gives a very helpful perspective on furnace walls, insulation values, and recuperation. Charles explains how to use A.P. Green’s manual for "Calculating Heat Transfer Through Refractory Walls" and he explains his choices for materials. It is important to calculate EIF (Equivalent Inches of Firebrick) for each layer of material. The EIF number for a material, multiplied by inches of thickness gives you a number. Calculate the numbers for different materials in the furnace wall and add these to get a total EIF. This total can be converted into loss of BTUs per hour per square foot. The BTU figure can be converted to loss of dollars of fuel per day. The furnace maker has to find materials that do not disintegrate, are affordable, and give the lowest heat loss per square foot. Here are a few numbers for EIF or Equivalent Inches of hard Firebrick:

<table>
<thead>
<tr>
<th>Material</th>
<th>EIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Firebrick</td>
<td>1.00</td>
</tr>
<tr>
<td>Heavy Castable</td>
<td>1.00</td>
</tr>
<tr>
<td>3000 F Insulating Castable</td>
<td>2.92</td>
</tr>
<tr>
<td>2500 F Insulating Castable</td>
<td>2.92</td>
</tr>
<tr>
<td>2200 F Insulating Castable</td>
<td>4.80</td>
</tr>
</tbody>
</table>

2000 F Softbrick          4.30
2600 F Softbrick          3.70
2800 F Softbrick          3.15
1900 F Block Insulation    12.00
1600 F Vermiculite Castable 12.00
2400 F Ceramic Fiber      12.00

Materials are rated for use temperature. This means a 2000F brick is good to 2000 degrees Farenheit, and it will fall apart at temperatures above 2000F. Therefore, it becomes practical to make your wall with a series of materials that are rated for higher temperatures on the fire side, and lower temperatures on the cold side. For example, it would not be good to back up a 3000F wall with 2000F brick, but it might be good to back it up with 2800 F brick, then 2600F brick, then 2000F brick. There are many variations, but the EIF chart, and refractory prices, can give you some choices.

WALLS FOR DAY TANKS: Some people back up the hard brick with a full brick thickness of 2600F IFB (Insulating Fire Brick) and stop there. Some people add another layer one brick wide of 2000F IFB. There are many variations on this and other materials can be used. The glass leaks into the soft brick and freezes. Eventually there will be too much frozen glass in the soft brick and the liner will be corroded. When that condition is reached, the furnace will use extra fuel and refuse to heat good. The usual procedure is to remove the angle iron tie rods, remove any good refractories that can be saved for rebuilding, and fix the rest of it with a sledgehammer. The glass/brick rubble is good for fill when pouring a cement floor for your shop. Then you rebuild and repeat. Some day you will have to find a new way to dispose of the rubble.

WALLS FOR CORRELL FURNACE: (Free standing crucible).

Start with a 3000F mizzou hardbrick liner (splits mortared and stacked on edge). Back that up with 2 inches of 3000 insulating castable. Finish with 7 inches of vermiculite castable.

2" Hard Splits, EIF=1.0 = Total EIF 2.00. 2" 3000F castable, EIF=2.92 = Total EIF 5.84. 7" vermiculite cast, EIF=12.00, total EIF=84.00. Add the EIF
totals, and the entire total is EIF=91.84. This gives a heat loss through the walls of 200 BTU/Hour/square foot when the glass tank is at 2400F. If you do calculations on some of the "standard" or "common" glass furnaces of past years, you will find a saving of 76% in heat loss over the older models.

The Correll furnace is one example of what works and is efficient. When you design a furnace, see if you can approach a total EIF of 91.84 or higher, at the lowest cost for materials that will survive. Some old furnace designs have a total EIF of 20 to 40. The Correll furnace construction is recommended for tough work of all kinds and it is resistant to abuse because of the quality hard brick liner.

WALLS FOR GRUENIG FURNACE: (Free standing crucible).

Start with an inner liner of 2800F IFB mortered and stacked on edge. Then 8.5 inches of vermiculite, cast.

2.5" 2800 IFB, EIF=3.15, total EIF=7.88. 8.5" vermiculite, EIF=12, total EIF=102. Add these up for a total EIF=109.88.

This furnace has lasted for years, melting batch up to 2350F, and it is still good for a long time. The softbrick inner liner can be coated with Dudley Giberson's Zircon wash. If you cannot afford Zircon wash, use kiln wash (Kaolin and Silica). After a number of years, a thin 1/4" layer of siliconized liner can be peeled away by hand, and then apply a new layer of zircon or kiln wash.

This is not recommended for beginners, teaching situations, or melting cullet. This is because cullet can pop when loaded and get glass on the furnace walls. Use hard brick walls for cullet. Expert glass blowers do not get glass on anything, especially the inside of the furnace, but beginners and students do it all the time at first, and some of the time later. (Use hard bricks.)

The reason for using this system was a shortage of $ when it was constructed, and I wanted to find out if a lightweight, insulated box would work for batch. The only commercial refractories in the wall are 2800F soft bricks and refractory cement. The vermiculite mix was made according to Roland Butlers' formula in issue #9. I did purchase agricultural vermiculite and perlite, but it is very cheap. It has held up extremely well. This vermiculite mix is an example of something that might be rated for 1600 to 1900F but it works just fine against only 2.5" of 2800F IFB. Perhaps it has a higher use rating in this case because it is not a structural material. Maybe the perlite increases the temperature rating. Roland, you may have saved hundreds of starving glass artists from extinction, and we thank you very much.

I am not surprised that this furnace is very efficient, but I am surprised at how well it holds up. Every year that goes by makes it that much more cost effective. Rebuilding will consist of one layer of new soft brick--a very small job.

J: BASE PLATE

This is usually a steel plate. If a steel plate is not available, it may consist of sufficient angle iron support to hold the load. Cover the angle iron with a piece of sheet metal.

K: LEGS, SUPPORTS

Use cement blocks or an angle iron frame. The angle iron frame makes it convenient to add wheels which make it easy to move and position the furnace if you have a cement floor. Plan the height for the glass worker, for easy gathering.

Conclusion: This concludes aspects of A to K in figure 1 that are common to all glass furnaces. Selecting materials is accomplished by examining price and availability, durability, temperature ratings, and insulating qualities. The only secret to building a good furnace is proper selection of materials, proper cementing and casting of materials, and solid construction. There is no "best" blueprint because you must design the furnace to meet your own personal requirements. You can use anything that happens to be available at the right price if it will stand up to the requirements.

Members are encouraged to send in designs that work. It is also beneficial for people to send in designs that fail, especially if you have discovered the reason why.

Trade-offs are important to consider. Compressed brick day tanks may be a poor choice for a glass
producer, but they may be exactly right for a small
down furnace that is fired only on weekends
or when time permits. A simple backyard day tank
(all brick) trades fuel efficiency and glass quality
for the advantage of very low construction cost
and very fast heat up from cold start without
destroying the furnace. Castables and crucibles
must be heated slowly to avoid cracking.

Electric furnaces follow the same principals for
refractory construction. The only differences are
power supply considerations and elimination of
exhaust ports, combustion space and recuperation.

INVESTED POT FURNACE & VENTURI
OPERATING TIPS

Art Allison Pottsboro, Texas

I use a Giberson burner head with a ransome
venturi on a "serious" setup. I really enjoy the
quietness and dependability.

I have worked with "Alfred" type burners with
blowers using low pressure natural gas. I lived
also, close to Kent Fiske for a while working with
low pressure propane and a blower. I have also
worked with low pressure natural gas, blowers,
and Giberson heads. I prefer the venturi setup for
the furnace. For the glory hole I use a Giberson
head, high pressure propane, and a blower.

When you are trying out the venturi set-up you
really do need to stay close by, in case of backfire.
Match the orifice size and venturi and burner head
as per Dudley Giberson's book. However, have on
hand 6 orifices: 3 smaller and 3 larger than what
you think you will need. With the Ransome
venturi/Giberson head it is very simple to change
the orifice if needed.

1. PRE-BURN. If you have problems with pre-
burn, decrease the orifice by one size. Make sure
you have room for the furnace to "breathe". Open
the flue, build a larger flue, or open the door a
little. If you are getting monstrous stingers out the
door, or the flue, the gas is being combusted in the
burning chamber.

2. POPS OFF. If the flame is popping off the
burner head, then choke the air to the venturi
(make the adjustment on the venturi burner, do not
close completely). If this is still a problem increase
the orifice by one size and try again.

LIGHTING THE VENTURI: When you
initially light the venturi burner, choke the air way
down to prevent pop-off. I typically take 8 to 12
hours to fire up the furnace. Stay close by until
equilibrium is reached.

I have achieved success and manganese dioxide
melts (oxidizing) and cadmium/selenium melts
(reducing) in my furnace setup, so I do not agree
with your dismissal of the "Simple Venturi". No,
Kent Fiske is at 6,500 feet above sea level. I am
at 560 feet above sea level. So, due to slightly
rarified air, it is possible that a venturi will not
work at that altitude. When I lived at 6500 feet, I
did not try a venturi setup. But hell, Kent can go
skiing practically anytime he wants. Surely this is
an even trade-off.

Currently, I live in an area plagued by power
outages, short, and not so short. When the power
goes off in the middle of the night, I do not need
to go down to the studio and tear my hair out
waiting, waiting. I usually say "sure hope that stuff
annealed good", then I roll over and go back to
sleep. The furnace is fine, puttering merrily along.
I built a furnace in Ohio and saw it destroyed by
3 separate 8-20 hour long power outages in less
than 1 month. There was nothing I could do, it
operated on a blower and low pressure natural gas.

Using a venturi setup is a lot like using a Coleman
lanset. Once you get the flame going the way you
want it, you can just go away and forget it. I am
regularly away from "checking on the furnace" for
8 to 12 hours. No problems so far. But please be
aware of this: This is not a suggested mode of
operation. This is simply what I do. I live out in
the country and do not have a multitude of codes
to follow. Thus if the place burns to the foundation
it is only my responsibility. If I blow myself to
boogers tomorrow, then it is my problem.

You must follow all applicable safety regulations
and codes. You should use each and every safety
device available. You should know what you are
doing before you start.

The design from which my best furnace to date
was built, was by Peter Andres (Trumansburg, New York). He had a flue which I eliminated. I wrap the whole construction with sheet metal and top with about 6" to 8" of fiberglass insulation.

I always keep the venturi OUTSIDE of the vent hood to get 100% of available oxygen.

The door is very loose fitting. (Big honking gaps! East and West! Probably 8-10 square inches of free space.) No Flue.

Make the combustion chamber 1.5 times the volume of the pot. I do not know where I got this information but it works.

I melt at 18 psi with the venturi wide open (unless it is for a heavy reduction melt). I work at 10 psi with the venturi wide open. I am using a Giberson 250S head with a #58 or #59 orifice. The pot is an Ipsen 125 pound pot made of 1-Mul. This works for me. It may not work for you. However, if you keep trying you will find what works for you.

Dear Nani,

Thank you for the invitation to visit Kitengela glass. If it becomes possible to leave here, I will.

That is quite a list, and it is my wish that we will find all the answers so that you can continue with your wonderful work. I thank Anselm for sending photos of beautiful Kenya. Your panel "Visage de Verre" of cast glass pieces, glass masks, and cement in recent exhibition is most impressive and that photo has a special place on my desk because it is so enjoyable.

I tried to get the A.P.GREEN handbook but no luck. The distributor offered to give me some numbers, but I am trying to get the handbook. I will try again. Meanwhile if any members would like to send a copy to Nani at the above address please do so soon.

There is information on iridizing. We have not covered information on your other questions, but there are enough of us around to get you all the answers. You will have to experiment.

I am asking members to send letters concerning these questions, and you can watch for responses in the letters section of each upcoming issue.

Can you obtain something from the ground, that is like vermiculite, or perlite (calcium silicate)? The land provides everything we need, you may be standing on the answer. If you put a small amount of cement with a found insulating material and cast it as mentioned in this issue, there may
be ways to use it to make a good fusing kiln. If you can make an angle iron lid or lids, perhaps this material will make a cast insulating top. You would have to experiment with the insulating material first before going ahead with a top that large. Another way is to make bricks of found materials, clay and straw, or vermiculite and clay and cement. (You have to experiment). Make the bricks with a hole in one end. Stack up a long row of bricks and put a metal pipe through the holes. Use the pipe for handles to pick up the entire row and set it on top of the kiln. Make enough stacks to cover the top. The only drawback is that it takes a length of pipe for each stack and two people to put the stacks on and take them off, but it works. Just make sure that you create a brick that is strong enough to hang without breaking loose and falling into the kiln. Try to make it insulating, because solid clay hard bricks would be hard on the fuel bill.

Can anyone out there help with good tips and tricks for operating a fusing kiln on oil using home-made parts? It is possible to melt or fuse glass with anything that burns, the question is how to build burners with found parts. Most people find a way to have forced air. It may be more practical (because of sporadic power) to get a venturi effect with pressurized liquid fuel and a nozzle. Pressurizing with a hand pump is reasonable for kiln firing, but it would be a bit much for a constantly running glass furnace. Perhaps the method used by Anselm (the monotube steam generator heated by the glass furnace, which atomizes and injects the gravity fed diesel fuel at the nozzle) could be modified for the fusing kiln. If you find someone with a gasoline fueled blowtorch it would give you clues about construction for pressurized injection. Blow torches are hand-pumped and give a hot blue flame used to heat soldering irons for soldering sheet metal work. The flame can also melt glass. No blower needed.

I bet there are enough Independent Glassblowers out there to figure out some great tricks for you Nani. It will get even better when we find out what kind of materials you can get. For example, ceramic fiber in an angle iron frame makes a great lid for a kiln. But if you cannot get it, or if it costs too much to consider, then we will find something else. Maybe vermiculite.

Let us know what kind of cheap materials you can find, especially things similar to vermiculite and perlite. Is clay easy to get?

Most people make beads in a torch flame but I wonder why. Before there were torches, people made beads. Dudley Giberson put a cone of ceramic fiber over a small charcoal fire. He arranged a port hole in the top for exhaust and for working. No blower or power needed. He then proceeded to make beads, using the cone like a mini-glory hole. Anything that burns will do, if you can get it to burn right. Any refractory will do. Try a clay cone with an insulating jacket. Make the beads on a metal rod dipped in a release material (like kiln wash). Anneal the beads on the rod (a rod can have a number of beads--keep them hot). Then slide the beads off and clean the hole. People in this country are able to purchase stainless steel welding rod at a welding supply. It works. It will work just like Anselms'glass shop on a very small scale. You can iridize the beads, you can roll the hot bead in silver nitrate and get
a silver glass. Do not breathe any of the fumes. You can mix colored glasses on the beads if they have the same coefficient of expansion. When you do beads, you will be doing the same things Anselm is doing, take your clues from the glass shop and all will go well.

How about it glassblowers--any big tips for Nani?
More later, David Gruenig

Dear David,
Here is my renewal check for another year of 'Hot Glass Information'. It is always a joy to find another issue of The Independent Glassblower in my mailbox.
Currently I have been building my hotshop, the furnace being built concurrent with the key topics of the last few issues, which was nice as it seems I'm flying by the seat of my pants.
For example, when I was assembling my daytank which consists of refractory, tank liner and insulating bricks, each of a different size. As I had no plans, I began assembling and disassembling the bricks, my only limitation being the amount of bricks.
At first it was frustrating then something clicked in my head and I was able to come up with a box with two openings for the door and burner port. Of course my wife said it came to me from all the hours I've spent playing Tetris on the Nintendo.

Wishing you the best, sincerely
Michael Mangiafico Pittsburgh PA

Dear Mike,
Thanks for writing. Welcome to the ancient game of stackem and restackem. This should encourage others to go ahead and do it. Glassblowers always fly by the seat of their pants, it's the only way to go. Hardly anyone uses blueprints because it pays to understand your refractories, find what you can find, then stackem and restackem. Be sure to overlap joints, and if you have the right bricks, this will work fine.
Congratulations and best of luck,
DG
TO: People building their furnaces for the first time:
FROM: Art Allison
1. Look at as many set-ups as you can, take notes. LOOK and see what is there. ASK questions. LISTEN
2. Read and plan. Read lots. Plan lots. Throw away a bunch of plans. Keep 1 or 2, or better yet--5 plans.
3. Pick One. Do It. It will either work or not. Probably it will work, but probably not as good as you want it to.
5. If you suddenly find that you have gotten disgustingly rich, via glass, then please set up trust funds for David and me. David has my social security # on file. Thanks!

P.S. Anyone traveling in my area is welcome. I'll give you a tape measure and scrap paper to take notes. There are much better furnaces than mine, but mine works for me. If I asked for more I would be greedy.
Art Allison Pottsboro, Texas

Dear Art,
Thanks for writing and sending so much experience. Thanks for the trust fund request, I like that a lot. I will hold my breath waiting. If that happens, we can take a break and visit Kitengela glass.
Meanwhile, back at the ranch, I like your outfit a lot. I used to have a set up like that. My present setup is good, because of the fuel savings. But people have to think about how much fuel they must save before paying for all the trouble of nozzle mix burners, recuperators, electric gizmos for safety system (like the one outlined in earlier issues), blowers, and the electric standby generator. It takes a lot of glass to pay for that stuff. It makes a lot of sense at a high level of production, which I never reached. You guessed it, I did it because no one can stop a mad tinkerer. I did it and I'm glad.

Seriously, anyone starting out with a venturi will be well advised to pay a lot of attention to your tips. Most of my venturi work was done at around 1200 or more feet above sea level. I think they are good, but I liked the blower better. [Beginners Note: Venturi burners can be trouble when you try to see how efficient they can get, and you push them to the limit for damping down. You can damp them down and have them running sort of OK, but hours later the head can get hot enough to pre-burn. They must be tuned up correctly and they must not be trusted until you know them well.]

**Please be sure to do what Art said about orifice size and enough exhaust]. I use them when I do not want to get involved with a bunch of complicated stuff. My present "complicated" recuperated system with blowers has performed well with no trouble. Luckily, the power has been pretty good here except for short outages (which the system takes care of automatically). Nobody knows about tomorrow though. I do not worry because I keep my venturi right handy, ready for instant use. It is a lot cheaper to stick a venturi in the door than it is to run a generator for 3 days. My recuperated system has paid for itself in fuel savings over the years, and paid back more than that, so it is just another kind of trade-off. It also helps when sales are down, money is short, and you can light up with 1/2 to 1/3 the fuel bill (relative to earlier furnaces). Even if you have a generator, and even if it comes on automatically, you still have to get up in the middle of the night, because who can guarantee that all these gadgets will work all the time? I still get up and check everything if the power goes out. You are one up on us there. DG

Dear David,
A thought occurred to me this morning which I want to share with you as an idea for furthering the spirit of this