FURNACE CONSTRUCTION I
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Introduction:
This is the first of a series of articles on glass furnace construction. We will start with basics and work through enough details to assist a beginner with making decisions about what type of furnace to build and how to build it. There are as many kinds of furnaces as there are glassblowers, and beginners will have to make their own decisions and their own design. Although this may seem intimidating, you will soon realize that given an explanation of the basics, it is a simple process.

We will then proceed to more advanced discussions and get into the nuts and bolts of furnace construction as it exists in studios today.

Membership participation in this series is encouraged, as always, and now is a good time to think about comments, notes and sketches that you wish to send in. Feel comfortable sending any kind of information, it is the concept that counts, with no concern for formal writing.

Members have sent in lots of furnace tips that are very helpful and are available in back issues:

As we progress I will make some recommendations for back-yard furnaces for beginners or for demonstrating at fairs.

Glass furnaces, gas and burners are dangerous. Examples and designs presented are for your information, to help you learn. The designs do not make a furnace safe or guaranteed to work, they merely show you how others have arranged the materials and burners, and help you to avoid disasters. It is up to you, the operator, to make the furnace safe and make it work. Get all the help you can from people with furnace construction experience in your area, or try to travel out to see how it is done.

Furnace building is a decision making process. The only rules that absolutely must be followed are the rules of physics. The configuration that you decide to build will be a function of your personal requirements and your budget.

Before examining the possibilities of A to K in Figure I, look at the Main Areas of Consideration. Keep these in mind as you examine aspects of A to K. Then you will know what kind of furnace to build, and why.

MAIN AREAS OF CONSIDERATION
1. TYPE OF FURNACE
A: Day Tank
B: Crucible
In early factory hand-working times, furnaces made of bricks, holding about one ton of glass were used. These were referred to as Day Tanks because the workers would use all the glass in one day and the night shift would charge the furnace and have a new load of glass ready to work the next morning. Dominick Labino and Harvey Littleton brought mini-versions of this into use in small art studio situations. A mini day-tank might hold 50 pounds to 500 pounds of glass.

A crucible furnace is also a kind of day tank in terms of method of operation, but the glass is contained in a free standing pot or crucible. It is normally referred to as a pot furnace or a crucible furnace.

The brick day tank contains glass in a brick chamber. The molten glass leaks through the cracks between the liner bricks and as it gets cooler it freezes, thus the brick liner appears not to leak.
Another variation is the invested pot furnace, which is like a brick day tank because there is no free standing, replaceable crucible. A container or crucible is cast in place by surrounding it with a dense castable refractory cement. There is no leakage through bricks and if the pot should crack it is still good to use because the casting around it prevents leakage.

During discussion of materials and placement, we will examine each type of furnace, with variations, and the reasons for each type.

2. MATERIALS

Sometimes cheaper is better, sometimes it is worse. We will find out why. Some materials are known to work, some are known to fail, and these tips will help you avoid early furnace death. There is a trade-off between durability and price. Local availability may indicate that you can save a lot of money by substituting with an available material. Some supply yards charge so much for a special order that it becomes unreasonable and you have to find a substitution. Always be ready to substitute but watch out when it comes to inner liners and crowns.

3. SIZE

When you start your plan, you must first know how much glass you wish to melt. In general, 1 cubic foot of molten glass weighs about 150 pounds.

For a backyard or weekend furnace, less glass means a lot less furnace and bricks, therefore it is less expensive to heat up from a cold start. Bringing a furnace up to over 2000 degrees F from a cold start repeatedly (every weekend) will result in destruction of the furnace sooner, as opposed to a furnace that stays on for long periods and has few cold starts. A smaller weekend furnace will be a less expensive to rebuild and you are more likely to do the rebuilding job rather than put it off.

Small melts use more fuel per pound of glass than large melts. This is because of furnace mass to glass ratio and increased melting frequency. If you want your furnace to produce enough glass for steady, long term use, determine how many pounds of glass you need for one day, and build a furnace that holds at least three times that amount. Melting every three days is more efficient, and glass keeps well for short periods of time. I have found three days to work well.

If you use a large amount of glass, then it is time to examine continuous melt.

4. BURNER

A. PREMIX In a pre-mix burner, air and gas are mixed and forced through a tube and burn coming out the end of the tube. It is common practice, and best, to put a flame retention head (burner head) on the end of the tube. This can be made of metal or ceramic. Ceramic is recommended. Two types of burners are common:

1. VENTURI High pressure gas passing through a small orifice draws in enough air to premix the gas and air. No electricity needed. Very Simple. Requires precise sizing of orifice and burner head in order to get the correct BTU output with enough air.

2. FORCED AIR Easy to build with pipe fittings and inexpensive squirrel cage blower. Requires electricity. Plenty of control over BTU and air. Can use high or low pressure gas.

B: NOZZLE MIX BURNER

The air and gas mix at the burner input with instant explosion. Requires forced air. Allows for high temperature recuperation thus saving fuel. It can not "burn back" because there is no flame retention burner head or supply of premixed gas and air to burn or explode.

5. SAFETY SYSTEMS AND LOCAL SAFETY REGULATIONS, INSURANCE REQUIREMENTS.

If you plan to insert a thermocouple tube or sight port in your furnace it is easier to provide ports or holes while building the furnace rather than attempting to do this after the furnace is completed.
Frontal Section

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

All glass furnaces are a variation of this basic diagram. All glass furnaces are made by varying the type and placement of material in this diagram, and by varying the type and placement of the burner.

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
You have been given the Main Areas of Consideration with a few brief comments, and Figure 1 with key A to K. Now we will discuss aspects of A to K that are common to all furnaces and important to know. After that we will discuss specific types of furnaces with more details about A to K specific to each furnace type.

First we will start with how to put materials together.

PUTTING BRICKS TOGETHER:

The three following diagrams illustrate how to put bricks together. Bricks can be put together dry, with no mortar, and held in place by compression. The advantage to this is ease of construction, and ease of destruction. You can take the furnace apart easily and salvage a large number of bricks for reuse. The procedure is simple. Imagine a square stack of bricks, and place a vertical piece of angle iron on each corner. The angle irons have metal tabs (with holes) welded on to provide for insertion of threaded rod. When nuts are screwed on to the rods, the bricks are put under tension and stay in place. Brick day tanks are often built this way, using no mortar.

Beginners Tip: Threaded rod is more expensive than plain steel rod. It saves expense to obtain mostly plain steel rod and cut and weld a small length of threaded rod to each end. This is quick and easy to do and it is faster than trying to thread your own rods.

When mortaring bricks together use a high temperature air drying furnace cement. (From your refractory supplier) Mix the cement with a little water using a hand whip or electric mixer so that the consistency is like creamy mashed potatoes. This is easy to spread and work with. When mortaring insulating fire brick, I place the bricks in a pail of water first. They absorb a lot of water. Then stand them on end to allow excess water to run out. Then mortar the damp bricks together using a thin even layer of mortar. Let the assembly air dry before fir-
COMMON ASPECTS OF A TO K
REFER TO FIGURE 1

A: ROOF OR CROWN INSULATION
All types of glass furnaces need up to 12 inches of insulation above the crown. Any refractory insulation can be used, but it is efficient and practical to use a lightweight material that can be removed and re-used. If there is trouble with the crown, the furnace can be shut down, and when it is cold the roof insulation can be removed and replaced after repair.

Insulating firebrick or insulating castable will work fine, but they are not easily removed. Bricks are normally used in areas that require structural strength. Crown insulation does not require strength.

VERMICULITE AND FIBERFRAX
The most common materials used for insulating crowns are refractory ceramic fiber (blanket or loose wool) and vermiculite. Vermiculite is very inexpensive compared to ceramic fiber. It can be re-used many times. Two common sources for vermiculite are building supply places that sell bags of material for pouring into attic spaces or walls, and agricultural supply places that sell very large bags of horticultural vermiculite used for seed starting and soil conditioning. Usually the agricultu-

tural form consists of smaller particles, it works very well, and it is also best for making your own insulating castable mixes. The house insulation vermiculite is usually larger chunks and it also works fine. I prefer the smaller size when making castable mixes.

Vermiculite can be used by pouring it in place. This requires planning walls for your furnace, that extend above the crown. The walls can be made of anything handy that is fireproof. The walls may be an extension of a brick wall, or they may be sheet metal or plate metal held in place by a metal (usually angle iron) framework.

To remove the vermiculite, vacuum it off with a large tank-type shop vacuum cleaner. Make sure it is cold before removing.

The more expensive blanket or refractory ceramic loose wool can also be placed on top and easily removed by hand and re-used.

HAZARD
DO NOT BREATHE REFRACTORY DUST*BRICK*FIBER*CAST*ETC

Sometimes you can get "factory seconds" in bulk blanket rolls or loose, with great savings in expense. The "seconds" work fine. Once in a while there is a notice or ad in The Independent Glassblower for fiber seconds. The last one was good for people in the Kansas area, although it can be trucked anywhere if the trucking fees are not prohibitive.

Although anything can be used for roof insulation, I have had the best results with vermiculite or fiber.

TO BE CONTINUED IN FURNACE II