



Interested PAABA Members at John Groll's in February 2012.

**PAABA Hammer-In at John Groll's Shop
Pittsburgh, PA
February 18, 2012
Presenter: Jay Hayes,
"Burner and Forge Design"
Article & Drawings by: Henry Sibenthaler**

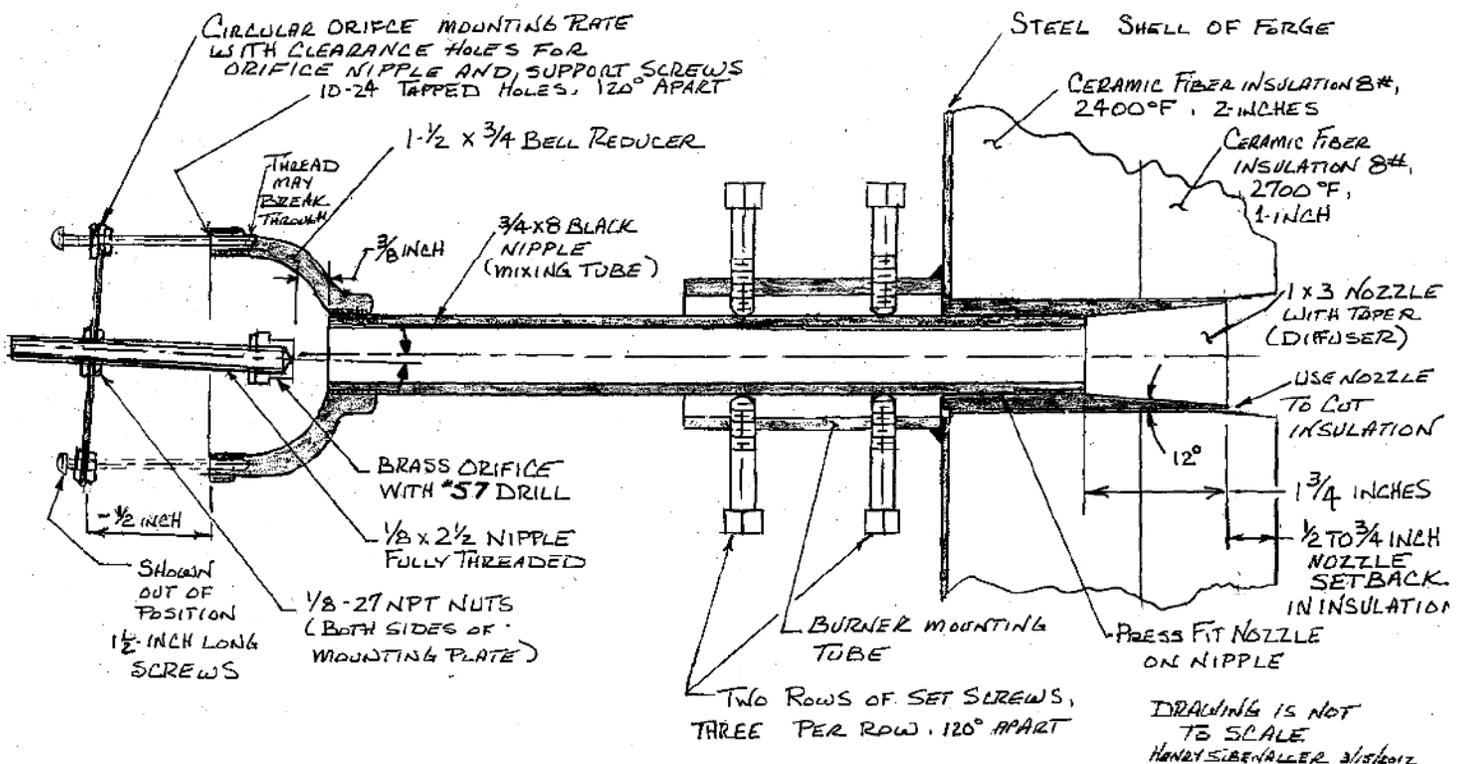
If you are interested in building efficient, cost effective, naturally aspirated forge burners, a complete gas forge, or looking for a ready to use forge this article may interest you.

Jay Hayes, a blacksmith and engineer who designs and builds gas furnaces for a living is the president of C.J. Products, Inc. At the hammer-in Jay discussed and demonstrated how his naturally aspirated burners and

forge designs work. The burners are powerful, relatively easy to make, cost effective, and don't use a blower, which means you can use them almost anywhere.

Jay explained the basic design principles for his 3/4-inch size naturally aspirated burner. He also demonstrated making some of the burner components, assembled one of the burners and then demonstrated how to tune the burner. The design of the propane supply manifold and some interesting features of his forges were also discussed. The 3/4-inch size burner(s), in a well designed forge, achieves both forge welding temperature and conditions inside the forge that are favorable for forge welding.

Burner Design: A typical burner is shown in Figure 1. It has a converging inlet section, a mixing tube, diverging diffuser section, and a burner mounting tube. The various parts of the burner are identified and critical parts are dimensioned.



This burner has a low-end output of about 20,000 BTUs/hour and a high end of up to 200,000 BTUs per hour, and it doesn't use an external air blower.

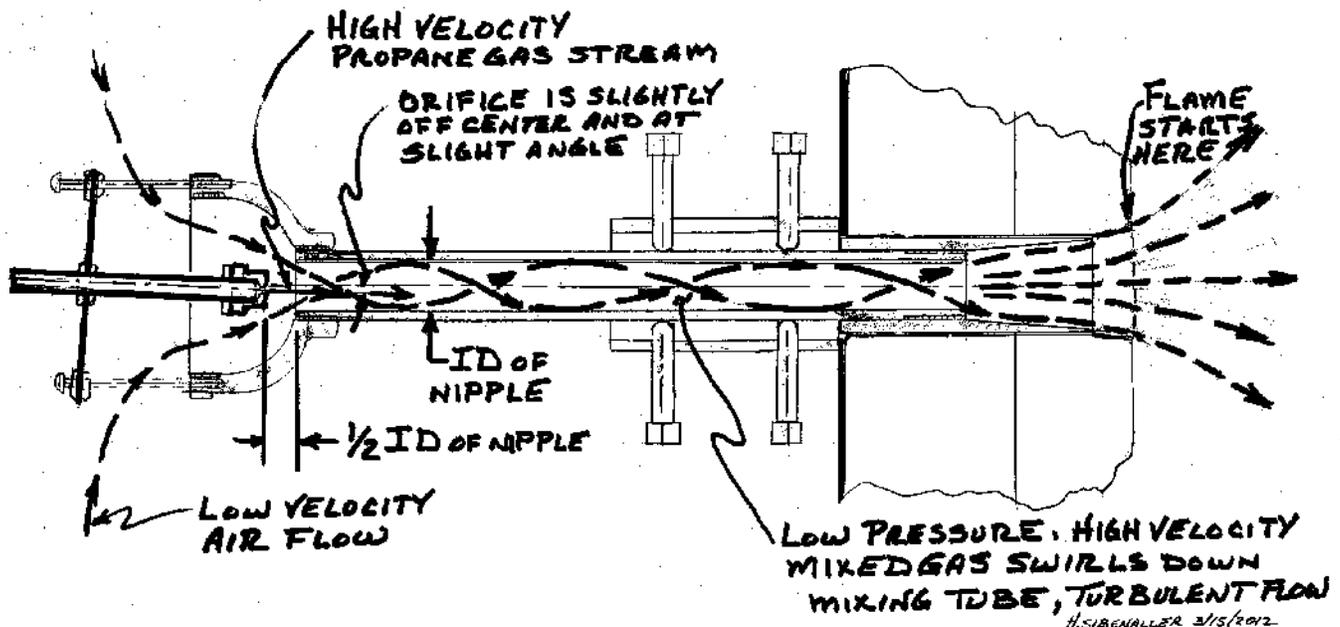
The orifice support plate and the adjusting screws position the burner orifice assembly inside the bell reducer. The orifice is located $\frac{3}{8}$ -inch upstream from the inlet end of the $\frac{3}{4}$ -inch inside diameter mixing tube. This offset is a critical dimension and is equal to $\frac{1}{2}$ times the inside diameter of the mixing tube. The relatively high velocity stream of gas exiting the orifice induces air to flow down the mixing tube, where the two gasses become well mixed.

The orifice has a hole in it that is the diameter of a #57 drill. The nozzle diameter is critical and one drill size larger or smaller will adversely affect overall burner performance. The orifice shape is also important, and it creates a high velocity flow at its exit, which helps to promote entrainment and mixing of the air in the mixing section of the burner. The general orifice cross-section is shown in Figure 1. A burner tip made from a gas welding torch tip will not work nearly as well because the gas that exits from it does not have the same optimal flow characteristics. The combination of orifice design, orifice diameter, and fuel gas pressure determines the velocity of the gas exiting the orifice. If the velocity is too high the gas will blow through the mixing tube with little mixing and if it is too low insufficient air will be mixed with the fuel gas.

The mixing tube is purposely made from a "lower quality" welded pipe nipple that has a rough weld seam along its inside diameter. The rough and protruding weld helps to promote turbulent flow and thus mixing inside the tube. An excessively long tube causes undesirable pressure drop and one that is too short won't provide adequate mixing.

The nozzle at the end of the mixing tube slows down the gas flow to maintain a stable flame over a wide range of operating pressures. The nozzle angle is important, and it is about 12 degrees as shown in Figure 1.

Burner Tuning: Figure 2 illustrates the airflow condition inside the burner. The orifice centerline is slightly at an angle and offset from the centerline of mixing tube. This is done to obtain a swirling condition as the gas starts its way down the mixing tube. Three burner support plate adjustment screws position the nozzle to the desired attitude relative to the centerline of the mixing tube, and the nozzle assembly is moved axially in the support plate to obtain the desired axial position relative to the upper end of the mixing tube.



Burner, Continued...

Jay cautioned that propane is heavier than air and will accumulate on the ground in a closed space. So store your tank(s) outside, not in your closed shop, garage or house. Also, be sure to have a carbon monoxide detector in your shop so that you can take corrective action if there is an elevated reading. Always properly ventilate your work space.

You want to tune the burner to achieve a teal blue inner flame and a faint blue outer flame. It should not be orange, except possibly initially while pipe coatings and oil are being burned off. The tuning should be done outside the forge, with the burner clamped in a vise, where the flame and sound can be easily observed and heard. A relatively smooth, not rough, sound is desired.

Use a hand held propane torch to light, and relight, the burner and later to light the forge once the burner(s) are installed. Don't use matches, cigarette lighters or paper for safety and cleanliness reasons. Always have a lit starting torch present before turning on the manifold gas and, of course, keep all body parts away from the path of the flame. NEVER put your face in front of a burner or forge when lighting off.

Tune the burner to work best at low output and it will most likely work well at high output. Work with the orifice position to achieve the final tuning. With this particular burner design the orifice support palate is not choking or controlling the amount of air that is entering the burner, the overall design plus the orifice position and fuel gas flow control the air flow.

Start with a low gas pressure around 3 psig. Increase the pressure until the flame blows off the end of the nozzle. Adjust one or two of the orifice support plate screws to improve the burn. The orifice tube can also be adjusted in and out. Just remember to only adjust one thing at a time and reverse the procedure if there is no improvement or the flame gets worse. The flame should remain stable up to 25 psig.

Now drop the pressure as low as possible and tweak the adjustments until the flame remains stable at 1 psig or less. Cycle and adjust between the high and low range to achieve the widest operating range.

If the burner doesn't seem to want to tune remove the orifice and check for any dirt that may be blocking the inside of the opening. This is a common problem on new burners. A little pipe dope or a sliver of brass can cause havoc in a burner orifice. Spiders and wasps can also cause problems when a forge has been sitting idle for a while.

A typical manifold piping arrangement for a three-burner forge is shown in Figure 3. This arrangement allows the use of as many burners as needed for a particular job. The manifold includes a gas bypass valve that allows the forge to be put on standby (or in the idle condition) with the burners operating at very low output, which helps to conserve fuel. The fittings are brass and the tubing is 3/8-inch copper with compression fittings. The hose is rated for use with propane. The threaded fittings are assembled with small amounts of pipe dope, not Teflon which can clog the orifices. Check for leaks by brushing inexpensive child's bubble blowing liquid on each of the connections and then look for bubbles.

Forge Design: The burners are typically spaced six inches apart so that one burner's flame's 8-inch diameter will overlap the adjacent one by a couple of inches as shown in Figure 3. The end of one of Jay's typical forges is shown in Figure 4. This forge includes a removable top that is pinned to the flat bottom assembly at the corners, by easily removable pins.

The two halves can be separated and work can be sandwiched between them if large parts need to be heated. Also note the neat and functional door arrangements. A small door in the main doors acts as a viewing port in the front of the forge. A similar arrangement on the rear door allows work to pass completely through the forge. The main doors not only swing open on a hinge, but also can rise vertically and still swing closed. This allows the doors to close on top of wide parts.

Jay cautioned that forge builders should wear a respirator when working with refractory materials. They are known to cause health problems, like cancer, and breathing problems, particularly after the insulation has been heated up to operating temperature.

The recommended thickness of the ceramic insulating blanket is 3-inches, which is necessary for a forge to efficiently achieve forge welding temperature. The bottom of the forge is also lined with high temperature ceramic tiles that protect the insulation from abrasion and also hold up well to welding flux. Ceramic fiber doesn't hold up well to flux, scale, and in particular accidentally melted brass or bronze.

The inside surface of the ceramic refractory blanket needs to be coated with a sealant that helps keep the fibers in place and also reflects the radiant heat back into the furnace, instead of being absorbed by the insulation. The recommended insulation coating is ITC-100, manufactured by International Technical Ceramics, Inc. It is brushed on and is specially formulated for this purpose. The manufacture says one coat is sufficient, but Jay said that two coats are better.

To be fuel efficient you will want to size your forge for the kind of work you plan to do.

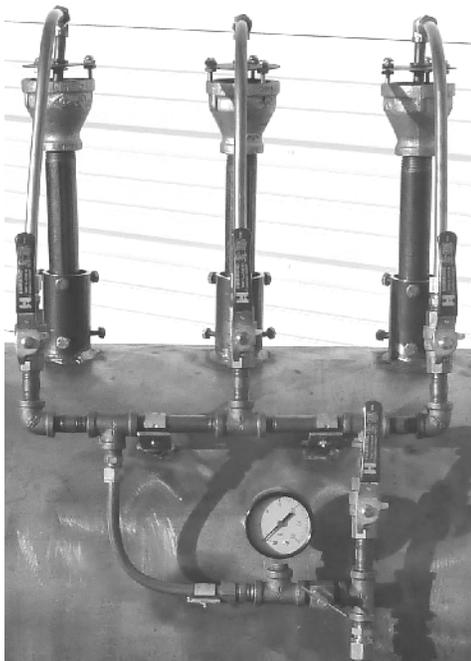


Figure 3. Fully Assembled Manifold



Figure 4. Forge with Doors

Jay sells complete forge kits but also sells burner components to individual forge builders, and sponsors forge building workshops. Jay's complete forge kits, plus individual forge and burner components are available from:

C.J. Products Inc., 100 Christmas Place, Weston, WV, 26452, Phone (304)269-6111, jay@hrea.coop