Gas Forge Burner Construction & Comparisons

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It's getting time for me to repair/retrofit some of my shop gas forges, so I've been doing a bit of research. There are a number of designs out there and many claims about efficiency with precious little comparative data. I've listened to folks expound on the "obvious" superiority of blown forges since the gas pressure is far less than venturi systems - ignoring the fact that gas consumption is both a function of pressure and orifice size. Since I'm a fan of venturi systems (no dependency on continued electricity to maintain a safe burn), I decided to play with a couple of standard designs. The idea is to run them side-by-side in the same forge while doing the same work and while monitoring actual fuel consumption.

The burner types are all venturi (or atmospheric) burners. The first is based on the burner design used in the Sandia forges (Fig.1). There is a bell that connects to a narrower delivery pipe and the gas is injected from a delivery tube running perpendicular to the overall burner. The second type is a "T" burner (often referred to as a "T-Rex" burner). It is composed of a pipe T fitting with the delivery pipe as the stem of the "T" (Fig.2) and with the gas delivery tube inserted through the top of the "T" and centered over the delivery pipe. The third design is the sidearm design (Fig.3) with a gas delivery tube equivalent to the "T" unit but with a single lateral air opening.

Figure 1: A "Bell" burner

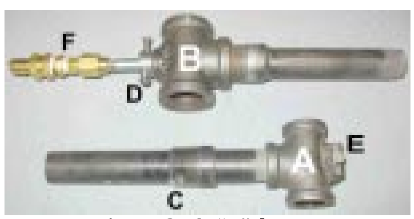

Figure 2: A "T" burner

Figure 3: A Sidearm burner

Before launching into the actual comparison, I'm going to indulge myself with a blow-by-blow account of the fabrication of the units. The Bell-type can be made using pipe-reduction fittings, but that's no fun if you're a smith.

I've equipped my 50lb Little Giant power hammer with a lower die block with two "ears" (Fig.4). The ears are simply 1" square blocks of steel welded to the sides of the die with 5/8" holes drilled down their centers. There is a 3/8" threaded hole in the outer surface for a lock bolt (not needed) and a 1/2" hole at the base for scale removal (*really* needed). In the best of all worlds, the ears would be positioned outboard of the bottom of the die cavity but, for now, those 1/2" holes will have to do. The swage is shown in Fig.5. Note that the left post is fixed while the right post can slip back and forth -- makes getting the unit mounted a lot easier. Fig.6 shows the unit in operation. Block the end of the pipe with a wet rag (otherwise, it's a chimney), heat the pipe to yellow, slip it (ok - force it) into the swage and start hammering while rotating the pipe. This is, of course, precisely the same operation for making candle sockets when applied to smaller pipe. When you've got a neck forged (and thus two bells), cool the pipe. Saw off the neck close to the bottom of the bells and saw off the bell that is still part of the pipe. Repeat for as many pairs of burners you want. I have made burners out of 1.65 and 2" pipe (ID measurement) welded to 3/4" pipe (more on why one might be better than the other later in this article). Fig. 7 shows the result - a bell.

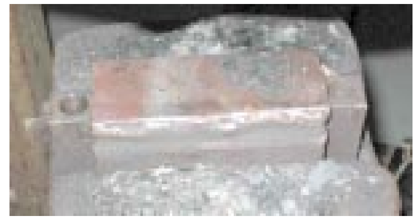

Figure 4: Lower die with hardy holes

Figure 5: "Bell" former swage

Figure 6: Swage in action

Figure 7: "Bell" in progress

The next step is to drill a large hole (~3/4") centered in the bell - not an easy task unless you make a quick tool - a chunk of round stock that will sleeve into the bell that has been drilled to accommodate 3/4" round stock (a lathe or a friend with

Fig. 8: Center drill

Figure 9: Gas delivery tubes

a lathe helps here)(Fig.8). I usually smooth out the lip of the hole in the bell by beveling with a 7/8” bit.

Insert a piece of 3/4” round stock to produce what is shown in the lower left of Fig.1. The rod acts as an alignment device for the 3/4” pipe forming the business end of the burner. Slip an appropriate length of pipe over the rod, butt it against the bottom of the bell and weld it around the entire junction of the two pieces. I’ve made burners with lengths of 3/4” pipe as little as 4” and as long as 8” and have put a 45 degree bend in some - and all worked fine.

To finish the basic design, drill a hole slightly larger than the gas delivery pipe at right angles to the long axis of the burner somewhere in the bell (more on that later). A 1/4” pipe nipple (2nd from the top in Fig.9) requires a hole a bit larger than 1/2”. A mechanism needs to be added to lock the gas pipe in place. For a 1/4 pipe, a 1/2 x 13 hex nut drilled out to slip over the pipe, drilled and taped for a set screw on one of the flats, and welded to the bell makes a decent lock mechanism.

The “T” design is simple - start with a “T” and weld a block of steel opposite the stem opening or use an “X” fitting with a plug (Fig.2), screw in a section of pipe as the stem, chuck the assembly up in a lathe (you *do* have a lathe, no?), and drill a close tolerance hole for the gas delivery pipe. For a 1/4” pipe, I drilled a 1/2” hole and bored it out to a couple thousands over the pipe diameter. Drill and tap a set screw at right angles to the gas pipe to make a lock mechanism. The sidearm burner is essentially the same with the exception of the major pipe fitting (Fig.3) which ought to have the smooth sweep to the “stem” opening.

A series of gas delivery tubes are shown in Fig.9. For the bell burner, you’ll need an orifice somewhere around 0.040” diameter (#60 drill). Cap one end of the pipe, slip it through burner and mark the pipe midway across the bell. You can then: (1) drill a 0.040 or 0.035” hole in the pipe (a collet drill chuck helps here) (top pipe labeled “D”); (2) drill and tap a hole to accept a MIG tip (lower pipe labeled “D”), or (C) drill a 0.150” hole, press fit a TIG tip and drill it. Miller tips are 1/4x28, Lincoln tips are 12x24 and all are ~1/4” soft copper, so it’s easy to cut them in half, rethread to 1/4x20 or 1/4x28 (Fig.9 C), and deburr the orifice. For a “T” burner, you can use a 1/8” pipe with a connection fitting and a plug (top pipe, Fig.9 B) or a cap (lower pipe, Fig.9 B) or use a 1/4” pipe (Fig.9 A) - here using a cap and a shortened MIG tip. In all these cases, the orifice has to be located at the center of the cap or plug, so it’s back to the lathe again.

The other end of the system is the connection to the gas

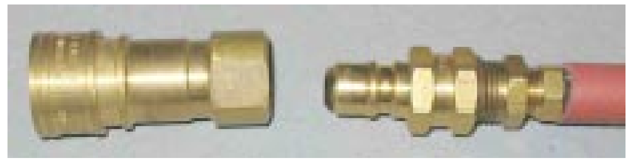

Figure 10: Propane quick connects

supply. Your friendly propane/AC retailer (in my case, Tempaco) stocks gas quick connects (Fig.10) which work just like the ones on your compressed air lines. The costs are not too bad and they make the plumbing a lot easier. They typically are 3/8” NPT so a bushing or two may be needed to hook to the gas delivery pipe. If you don’t already have one (or two or three), get an adjustable LP regulator with gauge (ran about $25 last one I bought).

The “T” burner design does not have (nor needs) adjustment

Figure 11: Tuning a bell burner

while the bell burners need tuning. Secure the burner and slip a scrap of fire brick over the end of the burner. The tip ought to be an inch or so inside the brick. Position the orifice in the center of the bell and pointing down the delivery tube. Light off the burner and observe the flame and listen to the burner. If there is a lot of yellow and sputtering (top , Fig.11), you loosen the set screw and move the gas pipe back and forth and rotate it until the flame is blue and the sound resembles a little jet engine (lower, Fig.11). There will be a sweet spot and it’s pretty obvious when you find it. When satisfied, lock down the set screw.

The next step is mounting the burner in a forge. In the past, I’ve welded plates (or big washers) on the burner tip far enough back that when the plate is welded to the forge or bolted to it, the burner tip is recessed in the refractory brick

Figure 12: Burner mounting hardware

Figure 13: Mount installed

approximately 0.75 to 1.0 inches. This makes pulling a burner difficult and thus makes running a two burner forge on a single burner a pain (since you **do not** want to leave a non-burning burner on a forge to act as a chimney!). My ever so clever solution is shown in Fig. 12 & 13. Get a pipe connector that slips over the burner delivery pipe. Saw it at an angle (to allow the burner to enter the forge at that angle so as to produce a swirl effect) and weld it to the forge. A slug of round stock with a centered hole (lower left, Fig.12) lets you drill a pilot hole in the refractory. A pass with a slightly undersized spade bit completes the hole. When the second burner is pulled, just screw in a pipe cap. Voila, problem solved.

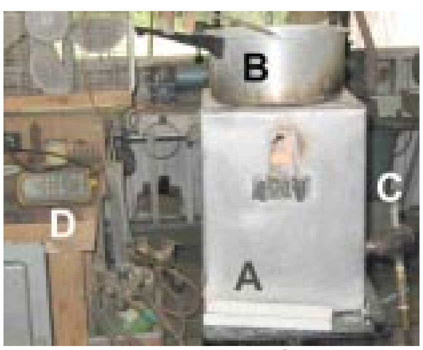

Figure 14: Experimental apparatus

Now to the experiment. The apparatus (Fig 14) consisted of a vertical gas forge (A), a large pot (B), a variety of burners (C) and a digital pyrometer (D). The scheme was to first bring the forge to operating temperature. Four liters of water were placed in the pot and the temperature is recorded). The 20lb propane bottle is weighed and connected to the burner. The burner is lit, the time noted, and the temperature is monitored. When the water temp hits 200 F, the system is shut down and the propane bottle reweighed. As long as the amount of water is constant and the start and end temperatures are consistent from run to run, then the same amount of work is being done in the same forge, hence the gas consumption (the difference in weights) is a reasonable measure of burner efficiency. The variations tested were:

(A) burner designs (Bell vs "T" vs sidearm);
(B) area (in^2)of maximum opening: Bell at 2.0 & 3.55 (1.5 vs 2" pipe); "T" at 1.57 & 2.11 (3/4" vs 1" fitting)
(C) orifice size (0.040 & 0.035) and
(D) location of the orifice relative to the junction of the bell (or "T") to the delivery pipe (Fig.15). Due to the scale used, the precision of weighing was 0.5 ounces.

Figure 15: A "T" burner with tip 1" from junction

Burner Type	Orifice Diameter (in)	Orifice Distance (in)	Gas Used (rel)	Time to 200F (rel)
Bell-large	0.035	2"	1	1.18
Bell-small	0.035	1"	1.14	1.42
T-small	0.045	1"	1.43	1
T-small	0.035	1"	1.43	1.14
T-small	0.035	0"	1.43	1.29
T-large	0.035	0"	1.43	1.14
Bell-large	0.035	1"	1.43	1.34
Bell-large	0.035	1"	1.43	1.28
T-large	0.035	1"	1.71	1.48
Sidearm	0.035	2"	2.14	1.28

Table 1: Experimental results

The results are given in Table 1, where gas used and time were placed on a relative scale. The least gas used was 0.22 lbs (1st row) and the fastest time was 322 sec. (row 3). As you might expect, orifice size controls speed to termination but for the same amount of work, does not affect gas used (compare row 3 and row 4). If you run a forge for a long time, a smaller orifice is indicated. The best gas consumption was acheived by a large bell burner with the orifice 2" from the junction but note that a small bell with a 1" separation was essentially the same (0.5 oz more - right at the limit of the measurement error). At 20 psi, the smaller burner stopped working correctly while the larger one continued burning, so an argument can be made for a larger bell if you're pushing the pressure envelope. Moving the orifice closer to the junction for the bell burner (rows 7 & 8) gave consistent but poorer results. The sidearm burner (as configured here) was definitely the tail-end charlie as was the large "T".

Given the limited amount of replicability and the lack of precision in the gas consumption, the take-home message is that there does not appear to be a head-and-shoulders better burner in the group. Make what is easy to make, A bell allows ease of adding choke plates and/or blower input, so that's the way I'm going with the mount idea shown here.