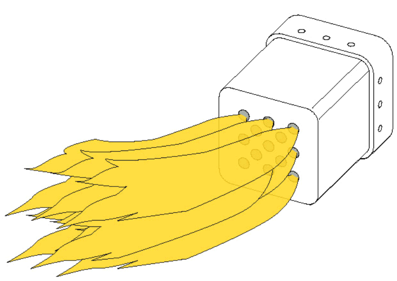
BLOG 12: Importance of the Orifice in Your Gas Burner System

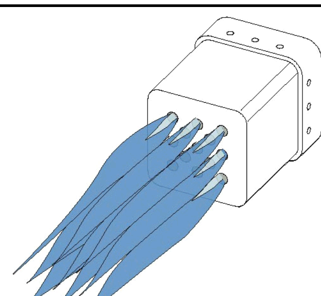
For good combustion you need a very specific ratio of gas to air to produce a neutral flame. The actual term is stricometric: a.k.a. right on the nose..

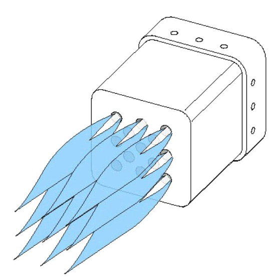
Stoichiometric is the perfect mix. How much air do you need to properly combust one cubic foot of natural gas? Answer is 10 cubic feet of air. For propane what is the ratio of air to gas? Answer is 15.6:1 and 15.8:1. This ratio varies because Propane is sometimes a mix of Butane and Propane which can cause this difference. This idea of the perfect burn, the perfect combustion ratio is a laboratory idea and as such it gives us a target to shoot for and the scientific approach gives us a method to measure this business of complete combustion. The flue gas analyzer is the laboratory answer. This devise costs many hundreds of dollars and it requires continual maintenance of its parts for top performance, but you will be glad to know in actual use in a glass shop it is pretty ineffective. The problem is you measure the mix in your glory hole with the doors closed, but you use the glory with the doors open. The same with your furnace. Most glassmakers know with their eyes what condition the furnace atmosphere is in.

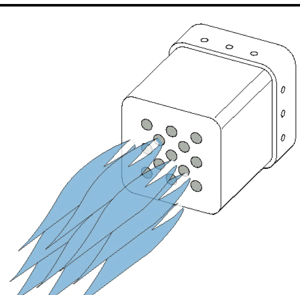
But having the idea of the right mix, the stricometric burn, is very useful. It will help you get the right amount of BTUs per gallon of propane or per cubic foot of natural gas by tuning the flame: with a lean burn you are cooling the flame because you have extra air and with a rich flame you are wasting your gas as some of it is leaving the combustion chamber as unburned potential. For me the hottest fire is a neutral flame with a very slight lick.

So how do we properly meter the gas to get our money's worth? It would be helpful to see what these conditions look like. Here is an illustration of the three different conditions of combustion: A..Flame in heavy reduction, B., Flame in a neutral burn, and C., Flame in oxidation.


A. Flame in heavy reduction

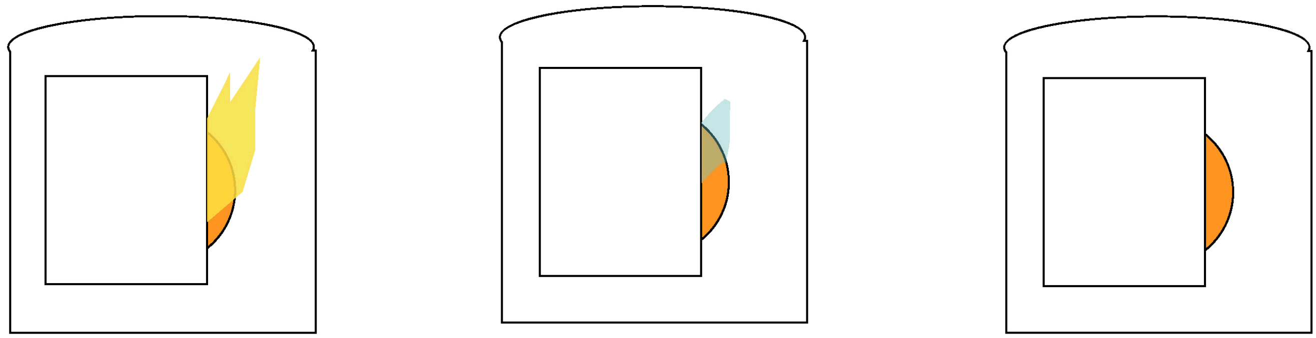

B. Flame in neutral burn


C. Flame in oxidation


D. Flame in High Oxidation

d., And if we go further into oxidation the flame will blow off the face of the burner. I try to keep most of my burners in a neutral burn as shown in "B" above and really a slight tweak to a very slight softer flame is generally my target. Keep in mind there is also some extra oxygen in the atmosphere of the combustion chamber which will convert this slight richness to heat.

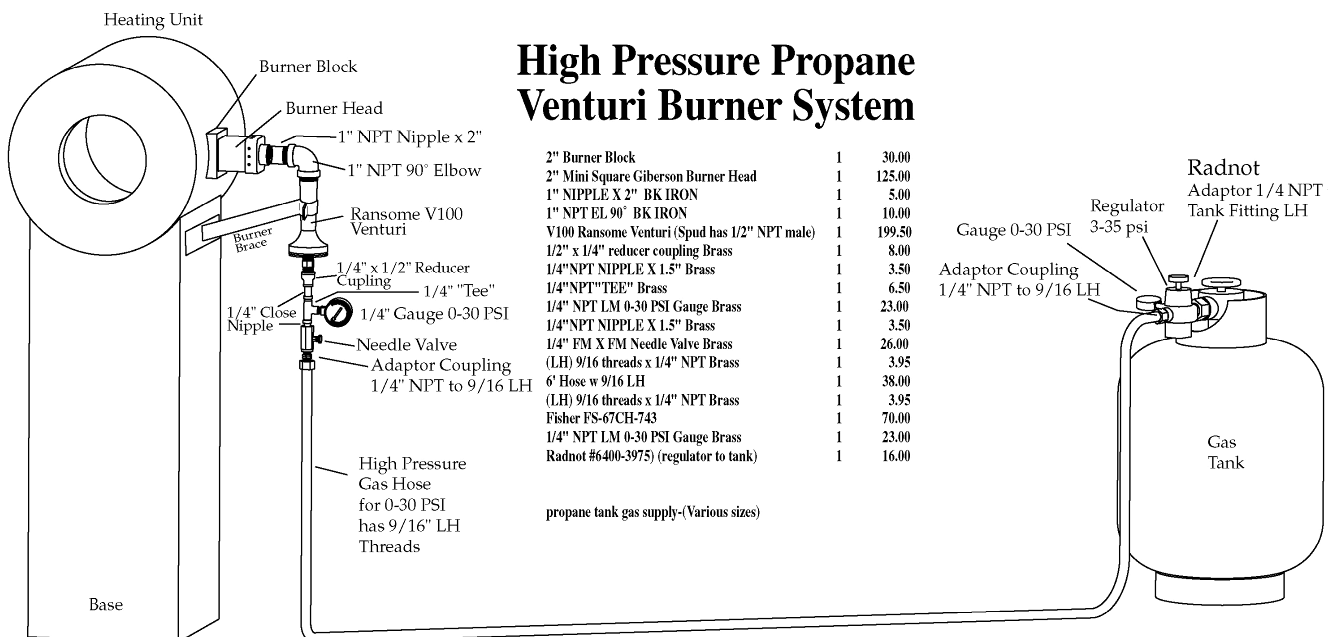
During operation of the glory hole or furnace some minimum opening is required to let the flue gasses escape. This can be either a formal flue or, as in this case the door. It is here where you can observe these three conditions:



Reduced Atmosphere — Neutral Atmosphere with a "Lick at the Door" — An OxidizedAtmosphere

So how do we control these mixes of gas and air to achieve a correct burn? Well, it is a matter of putting valves and gauges on the component gasses with numerical indices so you can dial in a particular mix. We use specific sized holes that deliver just a very specific amount of gas into the burner system. Not only do we have a specific gas orifice size but we also need to control the gas pressure in the delivery pipe.

In the illustration below we have a high pressure venturi system for Propane. There is a tank of propane with a regulator that delivers 25 psi propane into the high pressure rubber hose



High Pressure Propane Venturi Burner System

2" Burner Block	1	30.00
2" Mini Square Giberson Burner Head	1	125.00
1" NIPPLE X 2" BK IRON	1	5.00
1" NPT EL 90˚ BK IRON	1	10.00
V100 Ransome Venturi (Spud has 1/2" NPT male)	1	199.50
1/2" x 1/4" reducer coupling Brass	1	8.00
1/4"NPT NIPPLE X 1.5" Brass	1	3.50
1/4"NPT"TEE" Brass	1	6.50
1/4" NPT LM 0-30 PSI Gauge Brass	1	23.00
1/4"NPT NIPPLE X 1.5" Brass	1	3.50
1/4" FM X FM Needle Valve Brass	1	26.00
(LH) 9/16 threads x 1/4" NPT Brass	1	3.95
6' Hose w 9/16 LH	1	38.00
(LH) 9/16 threads x 1/4" NPT Brass	1	3.95
Fisher FS-67CH-743	1	70.00
1/4" NPT LM 0-30 PSI Gauge Brass	1	23.00
Radnot #6400-3975) (regulator to tank)	1	16.00

propane tank gas supply-(Various sizes)

which connects to a needle valve. The needle valve controls the amount of gas which flows through to the orifice which resides in the base of the venturi. It is the size of this orifice which determines the maximum amount of fuel which shoots down the venturi tube to mix with a specific amount of air which is metered into the venturi by rotating a metal disc upon the threaded spud. This makes for a repeatable setting, meaning 3 turns lets in “X” amount of air into the mix and tomorrow it will do the same. Maybe you have discovered that 4 turns on the air disc and 15 psi against the orifice make the ideal burner flame. A week from now or a year from now it will do the same. Just keep good notes.

Below is the Joppa Glassworks, Inc. Burner Head chart that lists the various burner heads we make with their BTU outputs. This is a rough estimate of the values because it is hard to compare apples and oranges so to speak. The venturi system and the forced air mixers are together in "BTUs Range" though the venturi system is a less powerful injection system. The Blower/Mixer system most often used for low pressure gasses are good at forcing the combustibles through the burner head. A forced air system can be likened to a turbocharged carburetor whereas the venturi is more like a standard carburetor. The forced air unit produces greater gusto but it also uses more fuel.

Burner Head Size	Btu Range (1000'S)	Low Pressure Natural Gas (6-8″w.c.) Drill Size (inches)	Low Pressure Propane Gas (6-8″w.c.) Machinist Drill Size	High Pressure Propane Gas (0-25 psi) Machinist Drill Size
B-650	50-195	5/16″ orifice	#30 orifice	#56 orifice
B-255	40-150	17/64″ orifice	#36 orifice	#57 orifice
B-250	36-120	1/4″ orifice	#38 orifice	#58 orifice
B-250S	25-95	15/64″ orifice	#41 orifice	#59-60 orifice
B-7/32	20-70	7/32″ orifice	#43 orifice	#62-65 orifice
B-3/16	10-45	3/16″ orifice	#46 orifice	#65-72 orifice
Sq. 2.5-7/32	13-52	#32-30 orifice	#43 orifice	#69 orifice
Sq. 2-7/32	10-40	#39-37 orifice	#48 orifice	#72 orifice

To compute the BTUs of any given burner you need the size of the gas orifice and the pressure of the gas going through that orifice. Joppa Glassworks provides a small set of charts:

For Low Pressure: www.joppaglass.com/burner/lowp_chrt.html

For High Pressure: www.joppaglass.com/burner/highp_chart.html

A good resource book for working with this material is Olsen, Frederick L., The Kiln Book , Third Ed. Krause Publications, 2001. He has a very complete set of charts for Propane and Natural gas with pressure functions and orifice functions for each gas as they are quite different. These were provided to him by Marc Ward of Ward Burner Systems for publication.

An example of how to use this chart to perform a calculation:

> We have a high pressure propane burner with a #60 orifice. It runs at 15 PSI.
> How many BTUs are we using? The solution:
> The #60 orifice function is 4160 and the propane function at 15 PSI is 16.522.
> Total BTUs coming through the system is 4160 x 16.522 = 68,640 BTUs.

These ideas will get you started to calculate the energy use of the burners in your shop. It might be a bit complicated for some of you, but perhaps a more simple approach would be to take notes on what is being used in the shop over a certain time period. When the gas bill arrives, divide it by the number of days you were working and that will give you a pretty good idea of your daily fuel use. But you will still need to use some math. I will give an example of this:

> Say you have a BBQ tank and a small glory and you want to know how long your fuel will last. Use your Toledo scale and weigh the tank. Propane weighs 4.24 pounds per gallon and there will be a TARE weight on the tank, about 17 lbs. Weigh the full propane tank and use it for two hours. Weigh it again. Subtract the present weight from the initial weight to find out how many pounds of propane you used. Say it was 3.5 pounds used in the 2 hours. So divide 3.5/4.24 = 0.82547 gallons in 2 hours or .412735 gal/hour. There are 92,000 BTUs per gallon for propane so we multiply .412735 x 92000 = 37972 BTUs/ hour. A full BBQ tank holds 4.6 gallons so it would last 11.15 hours.

The usefulness of having a specific orifice size and knowing the amount of pressure against the orifice and the type of gas being used is paramount to understanding and improving your combustion issues.

> Another example: Lets take the same calculation we did 4 paragraphs above only we are going to change the fuel type to Natural Gas and the line pressure to 6” water column which is typical for Natural Gas. We will keep the orifice the same of #60. The Natural Gas orifice function for the #60 is 1664 and the pressure function of Natural Gas at 6”w.c. is 3.0619. This combination produces a burn of 1664 x 3.0619 = 5095 BTUs. This is barely enough energy to boil a cup of water.

To develop the same 68,000 BTUs in Natural Gas we need to use a bigger orifice. We need an orifice function of near 22,208. The #26 orifice has a function of 22468 so if we use this drill in our orifice we have a burner that will deliver 68,794 BTUs. However, we now have a different problem, we have a soft fluffy rich flame where all the gas is coming through but the air is not doing much. A high pressure stream of a small size can excite a great deal of air moving through a venturi system, but this is not the case. So this is the switch-over place. If we had a 2 psi Natural Gas pressure line we could make this work:

Natural Gas pressure function at 2 psi is 9.304 and the orifice that most closely fits the need of 68,000 Btus is the #44 at 7692. This would produce a burner BTU output of 71566. or we could use the #45 at 6990 and have a burner output of 65,034 BTUs.

We could consider using a blower with a low pressure Natural Gas mixer and get just what we want, say a burn close to 68,000 BTUs. Here we could use the low pressure of 6”wc Natural Gas. The pressure function at 6”wc is 3.0619 and use the #26 orifice with a function of 22468 to produce an output of 68794 BTUs. And the blower would provide plenty of air.

In Summary: The orifice is the most important part of the burner train as it defines the maximum amount of heat output for your burner system. If you know the orifice size, gas type, and pressure of your gas source you can calculate this number.

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