Combustion Basics

There is more to a burner than just blowing fire into a boiler or other heating device. Just what is a burner supposed to do?

- ⇒ Provide heat to a boiler
- ⇒ Control the outlet temperature or pressure of a boiler
- ⇒ Provide a high turndown so that it does not shut off over the full range of boiler load demands
- ⇒ Burn the fuel in the most efficient way possible to keep fuel consumption low

The following are some basics about how a burner functions. Natural gas will be used as the basic fuel, but fuel oils follow the same rules. Before we start however, here are a couple of terms and their meaning that you'll need to understand.

Excess Air	The extra amount of air added to the burner above that which is required to completely burn the fuel
Turndown	The ratio of the burner's maximum BTUH firing capability to the burner's minimum BTUH firing capability

The chemistry of combustion:

Natural gas is primarily composed of methane, CH_4. When mixed with the proper amount of air and heated to the combustion temperature, it burns. **Figure 1** shows the process with the amount of air and fuel required for perfect combustion.

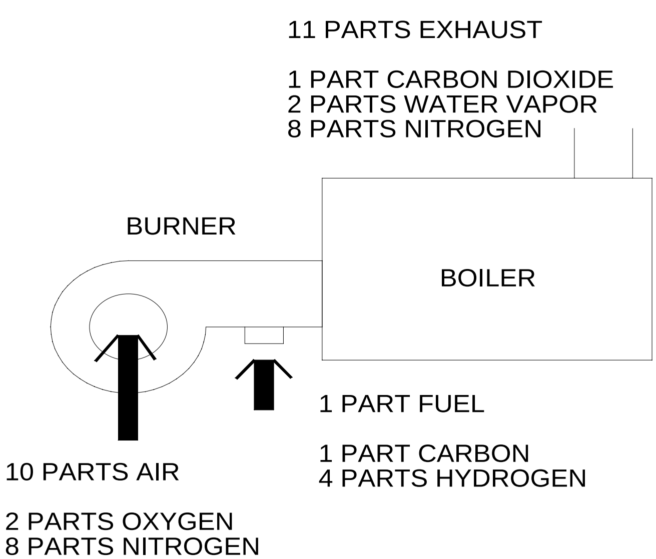


Figure 1

Perfection is absolutely impractical however. Extra, or excess air must be added to assure safe burner operation. Forced draft burners use fans to supply air for combustion. The fan on a burner moves a constant volume of air, not molecules. Any change in temperature or barometric pressure causes a change in the number of air molecules that the fan moves.

The control valves and pressure regulators used to meter the fuel are not perfect devices either so the gas flow cannot be perfectly constant. The gas train is designed to control volume much like the fan, so a change in gas temperature will also change the number of molecules burned.

To insure safe, operation at all temperatures of air and fuel and at all barometric conditions, the gas burner requires that excess air be supplied.

Excess Air and Efficiency

The good news about excess air is that it provides a measure of safety. The bad news is that it wastes fuel. A prominent manufacturer of burners says that "The heat lost in excess air represents waste heat, and proper burner design will help reduce this to a practical minimum." The less excess air used results in the least amount of “waste”. Let's examine just why excess air is a waste of fuel.

The boiler is merely a heat exchanger device designed to absorb heat from combustion products and to transfer that heat into water. When excess air is added to the perfect (stoichiometric) amount of air, obviously more mass is forced through the boiler. In a boiler, there is a modulating control that meters air and fuel so that the proper amount of heat added to maintain the proper pressure or temperature. Because of this control, the same BTU's are absorbed per hour, no matter what the excess air amount supplied is.

The chart below shows various temperatures leaving a heat exchanger when supplied with different amounts of gas at the same temperature.

EFFECT OF FLOW RATE TO EXIT TEMPERATURE			
GAS FLOW (SCFM)	EXCESS AIR (%)	GAS INLET TEMP. (^oF)	GAS OUTLET TEMP (^oF)
5555	0	1400	532
6111	10	1400	610
6666	20	1400	681

As the mass flow is increased through the heat exchanger, the outlet temperature is increased. The mass amount is analogous to the amount of excess air used by a gas burner.

In a boiler, as the excess air is increased, the stack temperature rises and the boiler's efficiency drops. It takes fewer BTU's of input to the burner to get the same number of BTU's out of the boiler if lower excess air can be used. Therefore one of the most important functions of a burner is to burn the fuel at the lowest possible excess air to achieve the greatest overall boiler efficiency.

Excess Air, Efficiency and Turndown

Figure 2 shows a simplified burner head. The air is brought into the head by means of a forced draft blower or fan. The gas is metered into the head through a series of valves. In order to get proper combustion, the air molecules must be thoroughly mixed with the gas molecules before they actually burn.

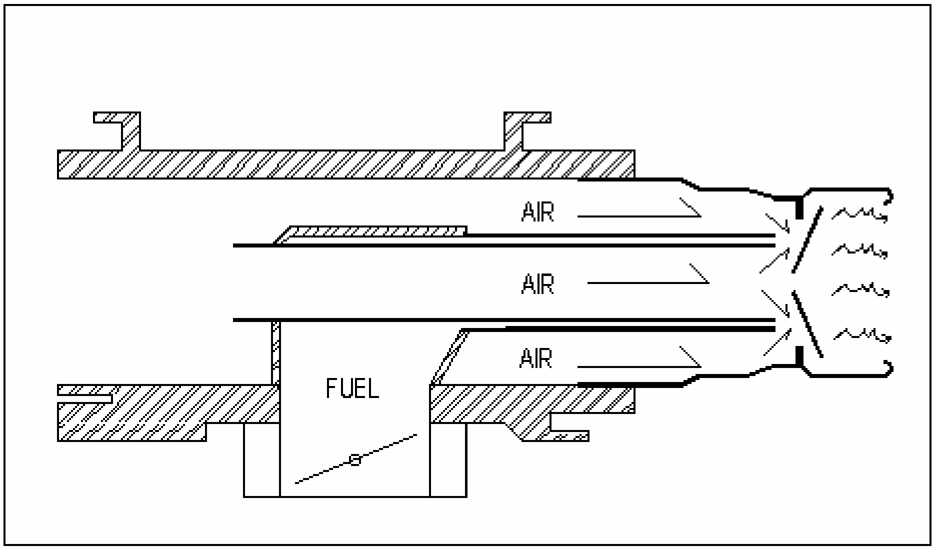


Figure 2

The mixing is achieved by burner parts designed to create high turbulence. If insufficient turbulence is produced by the burner, the combustion will be incomplete and samples taken at the stack will reveal carbon monoxide as evidence.

Since the velocity of air affects the turbulence, it becomes harder and harder to get good fuel and air mixing at higher turndown ratios since the air amount is reduced. Towards the highest turndown ratios of any burner, it becomes necessary to increase the excess air amounts to obtain enough turbulence to get proper mixing. <u>The better burner design will be one that is able to properly mix the air and fuel at the lowest possible air flow or excess air.</u>

Figure 3 shows graphically how excess air affects the efficiency and operating cost of a boiler. The data was compiled on an actual boiler and is not just some theoretical mumo-jumbo.

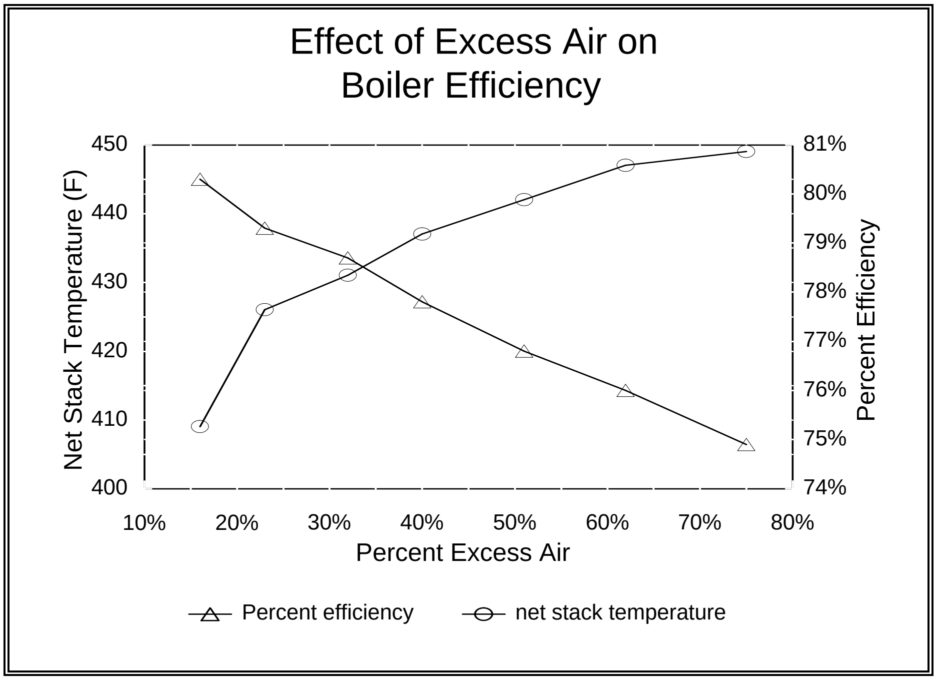


Figure 3

Figure 4 shows the savings realized with a 100 horsepower load at various efficiencies caused by different excess air levels.

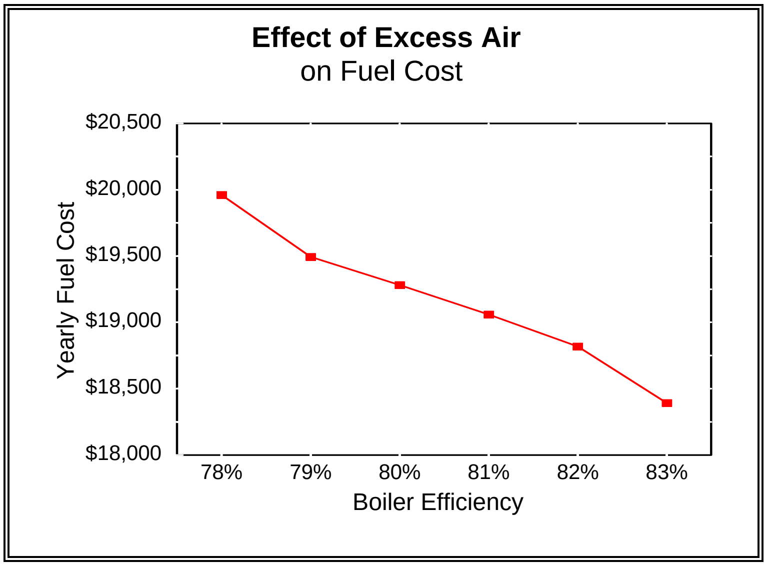


Figure 4

There are several strong reasons why high turndown and low excess air are important. The first is the operating cost of the burner. You've seen how excess air affects the operating cost, but the turndown ratio of a burner has a big affect as well. Every time the burner starts and stops there is a cost associated. Air is always blown through the boiler to assure that there is no unburned fuel remaining. These purges make the boiler work like a chiller because it takes energy out of the system. Two other reasons for having a high turndown relate to lowered maintenance cost and better process or heating control.

Don't confuse turndown to "fully modulating" burners. Having a fully modulating burner with only the typical turndown of 1.7 to 1, is like having a car that can only go between speeds of 59 MPH and 100 MPH. It's a "fully modulating" car all right but try driving it to the grocery store. You'd not only look silly, but think of the how the gas mileage would drop!

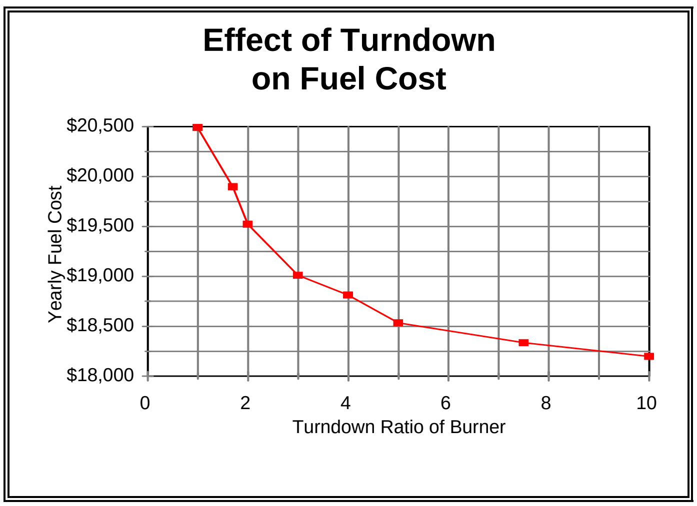


Figure 5

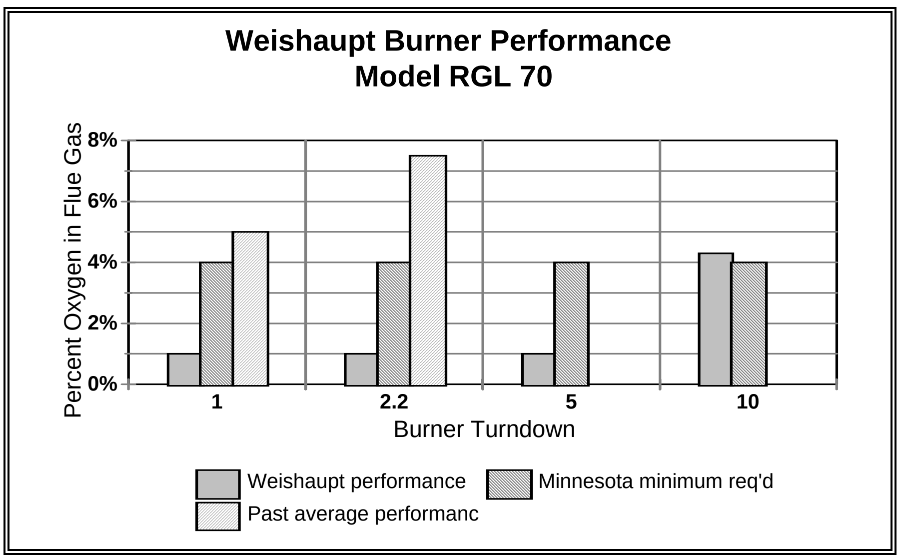
Figure 5 shows how the turndown ratio of a burner impacts the fuel cost needed to run a 100 horsepower boiler for heating. When you combine the effects of low excess air and high turndown, the operating cost savings can range from 10% to 15% below a brand new burner that doesn't have those characteristics.

<u>Process control</u> is enhanced with a high turndown. If the load is smaller than the burner can turn down to, it cycles on and off. When off, the pressure or temperature falls off. On some boilers, we have seen steam pressures drop from 100 psig at burner shut down to about 40 psig before the burner comes on again. That can cause terrific problems in a manufacturing plant that depends on constant steam pressure. Even on hot water heating systems, control problems occur because of low turndown boilers. Valves hunt and temperature control becomes erratic. With a high turndown, those fluctuations are eliminated because the burner tracks the load down to the point where it shuts off only when the load is very slight. There is enough stored energy in the system to take up the small fluctuations at that point.

Maintenance costs are reduced with a high turndown burner because there is much less thermal cycling taking place in the boiler. When a burner cycles, the refractory and metal parts expand and contract. Although those materials are built to take it, their life is prolonged if everything stays the same temperature.   Gas valves, ignition transformers, etc. are all less prone to fail if they never have to cycle. If the burner stays on, they don't have to turn on and off and therefore last longer.

Comparisons

Blesi-Evans Company has been selling boilers with forced draft burners for 40 years. On each system we require that a supervised start up be done and the results sent to us. We have taken a couple of dozen start up data sheets out of our files at random and summarized the results for you in **Figure 6** below.



Weishaupt burners will always have a greater turndown than what we have used in the past. Weishaupt burners will always require less excess air than what we have used in the past. The exact extent of the savings is difficult to predict but there will be significant operating savings realized by using a Weishaupt burner instead of another brand.