Greenhouse Heater Combustion Testing

*by R.A. Parsons, NRAES**

A furnace combustion analysis and tuneup can reduce heating costs by 5% or more. In many northern greenhouses this can mean a saving of 5¢ to 10¢ per square foot, or $2,000 to $4,000 a year for an acre range. Combustion test kits from under $150 to several thousand dollars are available to help do this job.

Any of these test kits are reliable and accurate, but readings can be obtained more quickly and easily with the more expensive units. In most cases it is better to have heaters checked and serviced annually by a reputable heating firm that has the equipment and training to do the job. Then an analyzer can be used to periodically check for possible problems. But to use this equipment effectively it helps to understand how fuel burns.

The Combustion Process

During combustion oxygen combines with carbon and hydrogen in fuel to form carbon dioxide (CO_2) and water (H_2O), as well as heat and light. Air, on a volume basis, is about 21% oxygen, 79% nitrogen and less than 1% other elements. About 14.2 lb of air contains enough oxygen to completely burn 1 lb of fuel oil as shown in Figure 1.

Figure 1. Combustion reaction with no excess air

1 lb fuel oil		1.1 lb water
+	=	+
14.2 lb air		3.2 lb CO_2
		+
		10.9 lb nitrogen

In reality fuel and air can not be perfectly mixed, so some excess air must be added to assure complete combustion. Figure 2 shows the combustion reaction with 50% excess air.

Figure 2. Combustion reaction with 50% excess air

1 lb fuel oil		1.1 lb water
+	=	+
21.3 lb air		3.2 lb CO_2
		+
		10.9 lb nitrogen
		+
		7.1 lb excess air

In effect the excess air reduces the percentage of CO_2 in the flue gas by diluting it. With no excess air, 15.3% (by volume) of dry flue gas is CO_2. When 50% excess air is introduced, the CO_2 amounts to only 10.2% of the flue gas. Less than 8% CO_2 in the flue gas indicates that too much air is entering gas and carrying heat out the chimney.

When too little air is introduced or the air mixes poorly with the fuel smoke and carbon monoxide (CO) are formed because combustion is incomplete. Some of the causes of smoky fires include a nozzle that is worn or is not the correct size or type, delayed ignition or improperly adjusted nozzle or electrodes.

As the fuel burns the hot combustion gases pass through a heat exchanger to warm air or water used to heat the area. If the air goes through too rapidly or if the exchanger surface is dirty, little heat will be transferred and the flue gas temperature will remain high.

A monthly check of this stack temperature can be used as an indicator of possible problems. The furnace should be checked if the temperature increases 50°F.

Draft or the flow of gases up the flue indirectly relates to combustion efficiency. If the draft is too high, air passes too rapidly through the heat exchanger causing high temperatures in the stack, low CO_2 levels, and lowered efficiency. A draft regulator on the stack and near the furnace controls draft to keep it below an acceptable level.

The Combustion Test

A typical test kit includes equipment to measure flue gas temperature, and the amount of carbon dioxide (CO_2), smoke and draft. Some units have equipment to check carbon monoxide (CO) levels. Most test kits include fairly clear instructions on how to use them. A typical test is run as follows:

1. *Measure the temperature of the combustion gas in the stack above the furnace.* Acceptable package unit stack temperatures range from 350°F - 500°F.

2. *Take a smoke sample.* A simple hand pump typically is used to draw a flue gas sample through standard grade filter paper. The color of the resultant smoke stain on the paper is matched to the closest color spot on a standard graduated smoke scale. A stain that is too dark indicates poor combustion.

3. *Measure the CO_2 level.* With the simple test units a flue gas sample is hand pumped into an indicator that contains a CO_2 absorbent. The percent CO_2 in the flue gas is read directly from a scale on the indicator. The unit must be zeroed and a sample taken for each test. More expensive sample equipment can monitor CO_2 or CO continuously. Normal fuel oil CO_2 levels range from 9% to 11%.

4. *Check draft with a manometer.* Draft directly over the fire and below the heat exchanger should be slightly more than 0.02 inches water gauge. In the flue pipe above the heat exchanger a draft of 0.04 to 0.06 inches water is typical.

All tests and any services performed should be recorded in a furnace log book. This record can be a great help to identifying problems and servicing.

*Northeast Regional Agricultural Engineering Service, Cornell University.