A Closer Look At Condensing Boiler Efficiency PART-III

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Dew Point Temperature Of Flue Gas

One of the key concepts that needs to be clearly understood when discussing boiler efficiency is the concept of the Dew Point Temperature of the Flue Gases. (Or more specifically the Dew Point of the water vapor in the flue gas.) If you are going to design a HW Boiler installation, you must be aware of what the Flue Gas Dew Point is going to be. In fact, flue gas dew point becomes even more important if your boiler is of the Non-Condensing type. Ignoring this critical piece of design information can be very costly.

Flue Gas Dew Point is the temperature at which water vapor in the flue gases *begins* to condense. There are two popular misconceptions about Flue Gas Dew Point. The first is that the Flue Gas Dew Point is a fixed number and if the boiler return water is below this fixed number all vapor in the flue gas will condense. A popular number thrown around is 130°F. So it is believed that if the return water temperature to the boiler is less than 130°F all the vapor will condense. The second misconception is that this dew point has some chemical dependency on CO_2 or O_2 levels in the flue gas. Both are incorrect as the following discussion will make clear.

The first thing to understand is that the dew point of water vapor is dependent on the "VOLUME FRACTION" (or "MOLE FRACTION") of water vapor in the flue gas. It has no (chemical) dependency on the CO_2 or O_2 percentages in the flue gas. We simply use CO_2 and O_2 percentages because they indirectly indicate the amount of Excess Air and therefore help calculate the water "Vapor Volume Fraction". It is really very simple and the following illustrates how it is done:

Instead of pounds, let us re-write the 15% excess equation with respect to moles (or volumes):

1 MOLE NATURAL GAS + 2.3 MOLE O_2 + 8.65 MOLE N_2
→ 1 MOLE CO_2 + 2 MOLE H_2O + 0.3 MOLE O_2 + 8.65 MOLE N_2 .....[7]

Total moles in the product of combustion are (1 + 2 + 0.3 + 8.65) = 11.95 moles

Molar %age (Volume Fraction) of H_2O = 2 ÷ 11.95 = 16.73%

To find the Dew Point we proceed as follows:

Assume the flue gas is at atmospheric pressure (14.7 psia). (If this assumption bothers you, remember that every psi equals about 407 inches of WC, and so even ± 1" WC does not make any appreciable difference.)

We know that the partial pressure of a gas or superheated vapor is equal to its Volume Fraction times the Total Pressure, therefore:

Vapor Pressure of water should be 16.73 percent of 14.7 psia which equals 2.46 psia.

Now it is a simple matter of looking up the saturated steam table to find the saturation temperature (dew point) for this vapor. Using my handy smart-phone app this comes out to 134°F.

The dew point for zero Excess Air for Natural Gas (Methane) is 139°F, and as above the dew point for 15% Excess Air is 134°F. The dew point DECREASES as the percentage Excess Air INCREASES. And so as we would expect the dew point for 50% Excess Air is 125°F. (This inverse relationship can be a problem if your boiler burner is using extra air to help in turn-down.)

But here is the catch. For our particular example, even if we were able to supply 125°F water back to the boiler above, we would condense only approximately 22% of the moisture. This is because the vapor fraction of the moisture keeps going down as

water is removed from the flue gas and consequently the dew point also goes down. After initial contact with 125 °F the dew point is lowered below 125°F and requires even colder water to condense any further. This is why for Condensing boilers to really work at their best we need the return water temperature quite a bit below the Flue Gas Dew Point.

Keep in mind that condensation of flue gas is a double-edged sword. It is great for condensing boilers because they are designed to handle the acidic liquid on the heat exchanger surface. However, any condensation on the surface of a non-condensing boiler will ruin it in a very short time. This is why the knowledge of Dew Point temperature of the flue gas is so important. For the condensing boiler it tells you if you can extract the latent heat of flue gas vapor; and for the non-condensing boilers it tells you the lower limit below which you must not allow your return water temperature to drop. In fact for non-condensing boilers, not only should you not condense on the heat exchanger, but always have enough safety margin to not condense inside the stack. This is the reason behind all those "cold start" kits they sell with the boilers. Be careful though, all the factory temperature settings for the cold start kits are to protect the boiler. Your chimney rotting is not their business – you should know better!

Continued in Part IV