Condensing Boiler Operation and Appropriate Use

What causes boilers to condense?

All boilers under certain conditions will condense. The difference between a condensing and non-condensing boiler is that a condensing boiler is designed to operate and survive long term in a condensing environment. A non-condensing boiler will not last, because condensate is corrosive.

The condition that causes a boiler to condense is reduced flue gas temperature. The point at which condensing will occur, also called the dew point of the products of natural gas combustion, is about 130°F. Above this temperature, the moisture entrained in flue products as water vapor will remain vaporized. Below this temperature, the water vapor will change phase and condense out of the flue products as liquid. When this phase change occurs, additional energy is released that is beyond the sensible heat of the flue products. In a boiler, this phase change occurs on a heating surface and the released energy transfers through the heating surface into the boiler water on the other side. By capturing this energy, which is lost out the exhaust stack on a typical boiler, a condensing boiler gains in efficiency.

Naturally, the products of combustion cannot be reduced in temperature to 130°F unless some of the heating surfaces in the boiler are also less than or equal to 130°F. The only way to accomplish this is to have an entering boiler water temperature of less than or equal to 130°F. Simply stated, if return water to the boiler is higher than 130°F, condensing cannot occur; even if the boiler modulates and is at its lowest firing rate. This is determined by the laws of physics. The highest achievable efficiency that can occur without condensation forming inside the boiler is approximately 87%. *At this efficiency, condensation will almost certainly occur in the vent.*

The highest efficiency numbers occur when very cold return temperatures are combined with the ability of the boiler to reduce its firing rate by modulating or staging. Under optimum conditions, reduced firing rate efficiency of condensing boilers can exceed 95%.

Will an Installation Benefit from Condensing Boilers?

As indicated above, the decision to use condensing boilers should center around the availability of entering water temperatures that are low enough for the boiler to condense. Otherwise, a good deal of money might be spent on technology that isn't utilized in the installation. In an installation with set point operation at 160°F return temperature or outdoor reset with return water limit of 140°F, for example, a condensing boiler will operate more efficiently than a non-condensing boiler, but only marginally and it may take many years for the investment in higher priced condensing boilers to pay off.

Condensing boilers are better suited for installations with an outdoor reset control system that reduces return water temperature to at least 120°F. This provides some opportunity to condense during the milder days of the heating season. With typical outdoor reset control schemes, there is the opportunity to employ hybrid boiler systems where condensing boilers are combined with non-condensing boilers to take advantage of both the higher efficiency when loop temperatures allow it and the lower initial cost of non-condensing boilers when loop temperatures are too high for condensing to occur.

The prime candidates for condensing boilers are low temperature systems, such as snow melt and supplemental heating for water source heat pump loops, where entering water temperatures are commonly at or below 100°F and the boiler will have frequent opportunity to operate at reduced firing rates with these lower water temperatures.