Summer 2009

Thermal Notes

A publication of Fluid Handling Inc.

FLUID HANDLING

Condensing Boilers: What, When, Why and Where?

Though condensing hot water boilers have existed for years, confusion abounds as to what they really are, when and why they reduce operating costs, where they should be applied and when they are economically viable. This article attempts to shed some light on these questions.

What Is A Condensing Boiler?

A little background helps to understand the answer to this question. Hot water boilers normally utilize either natural gas (which consists mostly of methane – chemical formula CH_4), or propane (C_3H_8). ***During the combustion process, the hydrogen (H) atoms and the carbon (C) atoms from the fuel combine with oxygen (O) from the combustion air to form water vapor (H_20) and carbon dioxide (CO_2) respectively.*** In addition, some nitrogen (N) from the combustion air combines at high temperature with oxygen to form NO, NO_2 and NO_3 called the "NOx" products. Trace amounts of sulfur in the fuel form SO_2 during combustion. A little carbon monoxide also forms (CO) due to incomplete combustion.

In non-condensing boilers, water in the flue gas leaves the boiler as vapor. Condensing boilers cool the water to below its dewpoint, meaning that some fraction of the water vapor condenses to liquid. Each pound of condensed water results in about 1,000 additional BTU's of useful heat transferred to the heating system. In the condensing process, water absorbs some of the CO_2 gas, causing carbonic acid formation. Similarly, NOx's combine with water to form nitric acid and SO_2 forms sulfuric acid. These corrosive acids form on the outer surface of the heat exchanger, so condensing boiler manufacturers use corrosion resistant heat exchanger materials to prevent early boiler failure.

What System Conditions Cause Condensing to Occur?

The actual water dewpoint depends on many factors, including the amount of excess combustion air and the amount of moisture in the combustion air. However, in most cases as the flue gas approaches 130-140 degrees ***or so*** condensing starts to occur. Cooling the flue gasses to this extent requires that the system provides return water to the boiler at a temperature somewhat below this (the exact return temperature causing condensing varies with the design of the boiler itself).

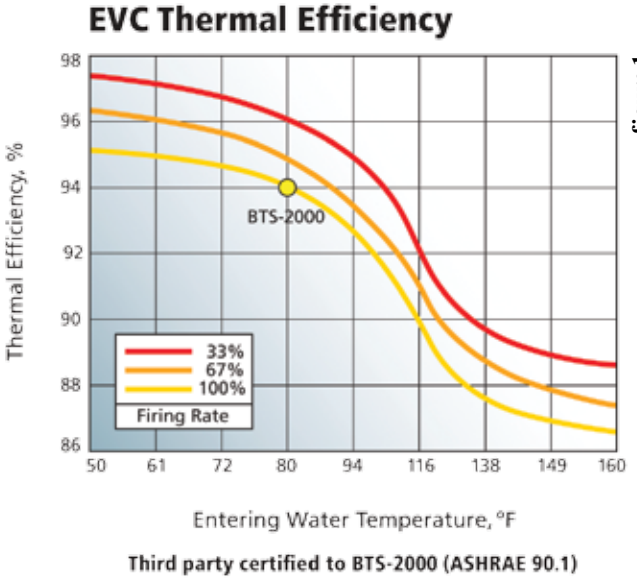


figure 1

Figure 1 shows the efficiency curve of a typical condensing boiler, the Thermal Solutions model EVCA. Note that regardless of

firing rate, the efficiency increases rapidly at return water temperatures below about 138 degrees. ***Failure to realize that condensing requires low return water temperature results in the misapplication of condensing boilers in systems that never allow condensing to occur.*** In a too-typical situation, someone specifies or purchases a "Condensing Boiler Rated Up to 98% Efficiency" failing to realize that 98% efficiency occurs at 80 degree return water temperature. The boiler ends up serving a system in which the return water temperature never falls below 140 degrees. The result is a boiler that costs 50% more than necessary and achieves no additional performance compared to a high efficiency non-condensing boiler.

Some internet references still promote the myth that says, "condensing boilers will always be more efficient than non-condensing boilers." But after many years, this thinking is being recognized as an over simplification! For example, **Focus on Energy** for the first time recently formally recognized that return water is a key element in predicting boiler efficiency (see www.focusonenergy.com/Incentives/Business/Heating_Cooling.aspx and click on "Tips to determine thermal efficiency)."

In fact, some high efficiency non-condensing boilers operate at higher efficiencies than condensing boilers when operating with warmer return water temperatures. ***Remember, the heating system must allow operation at low return temperatures for condensing boilers to provide an advantage.***

What Types of Systems Allow Condensing to Occur?

Two immediately come to mind: 1) radiant floor systems and 2) water source heat pump systems. Both utilize low water temperatures at all times, ensuring condensing operation.

In addition, a designer can modify any type of heating system by over-sizing heating coils to allow successful operation with low temperature water – at added expense, of course.

Finally, many conventional heating systems operate using an aggressive hot water reset schedule that allows reduced return water temperature operation during late spring, in summer, and in early fall (the shoulder seasons). Hybrid systems fit this strategy well. A hybrid consists of a mix of condensing and non-condensing boilers. With a hybrid system, all boilers operate in the non-condensing mode in the heart of the heating season. As the load decreases during the shoulder seasons, the non-condensing boilers turn off and the condensing boilers operate with reduced water temperatures at increased efficiency.

Options for Corrosion Resistant Heat Exchangers

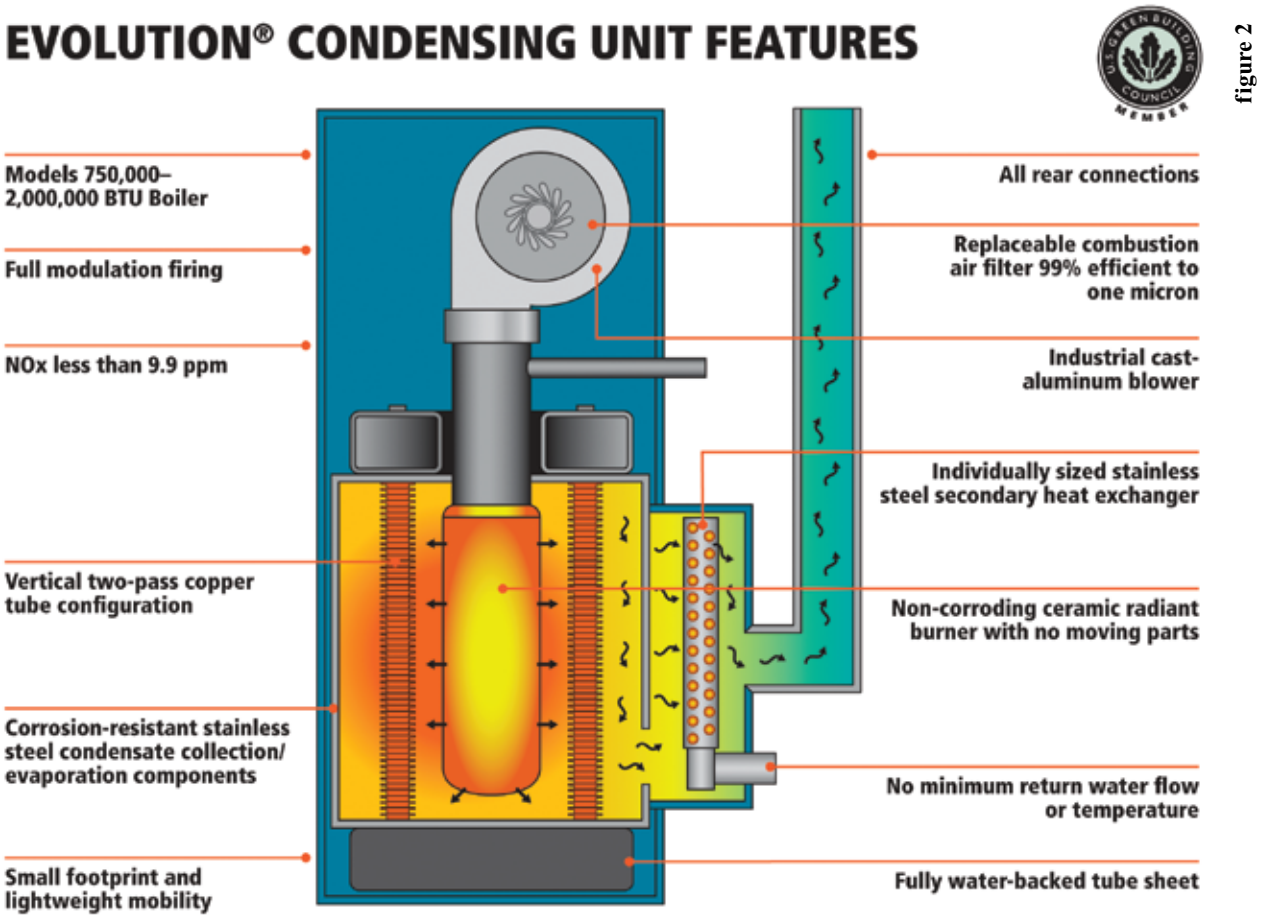
Condensing boiler manufacturers commonly use one of the following options for heat exchanger corrosion protection.

A) Aluminum Heat Exchangers

This is the least expensive option, so it is popular. Acid actually does attack aluminum. Manufacturers subtly admit this by requiring that the water or glycol inside the heat exchanger be maintained at an alkaline pH level of 8 to 9. But the boiler manufacturers build aluminum heat exchangers sufficiently thick so they theoretically last long enough to satisfy the market, in spite of flue gas acid attack.

B) Stainless Steel Heat Exchangers

Metallurgists know that stainless steel offers good resistance to corrosion – not total resistance. The science of corrosion covers many modes of attack, including direct pitting, under deposit pitting, MIC attack, crevice corrosion and stress corrosion cracking. Trace elements and even low water temperatures have an effect on what occurs in a given application and with a given grade of stainless steel (low water temperature makes MIC – microbial-induced corrosion – more likely for example). One could safely state that during the years of condensing boiler development, many stainless steel heat exchangers failed earlier than the expected life of non-condensing heat exchangers built of cast iron or copper. Yet, stainless remains the "better" material for protection in condensing boilers, with higher grade stainless alloys providing the best protection of all.



C) The Secondary or "Economizer" Heat Exchanger Approach

This style of boiler, (figure 2), utilizes two heat exchangers. A conventional-construction primary exchanger operates in the non-condensing temperature range. After the flue gas exits the primary heat exchanger it enters a secondary stainless steel heat exchange coil, in which condensing takes place. Controls and a warm water injection pump ensure that no condensing occurs in the primary exchanger. This arrangement is similar to the "boiler economizer" approach of extracting additional heat from steam boiler flue gas. The Thermal Solutions EVCA is a condensing boiler in all respects, as all components are factory mounted, tested, and certified (beware, as some manufacturer furnish only the secondary exchanger and leave everything else up to the installer). We feel that the possibility of acid corrosion actually favors the secondary heat exchanger approach. With condensing occurring only in the relatively small and accessible secondary exchanger, replacement of condensing surface is less expensive than replacing an entire condensing heat exchanger.

Should I Specify or Purchase Condensing Boilers?

Clearly it wastes money to use condensing boilers in systems that never operate with low return temperatures. Condensing boilers probably should be ***considered*** for all radiant floor systems, water source heat pump applications and systems where oversized airside components compensate for low water temperatures.

For conventional systems utilizing multiple boilers and an aggressive reset schedule, a hybrid system generally provides the best return.

Fluid Handling has developed a bin method/degree day spread sheet that allows the comparison of condensing vs. non-condensing boilers. The input to the spreadsheet includes the design heat load, the reduction in heat load with response to outdoor air temperature, (the building's heating curve), predicting future fuel costs and estimating the water temperature required to match various building

loads. With that information, the spread sheet provides a reasonably accurate comparison of various boilers. We welcome the opportunity to run comparisons for you.

Condensing boilers may fail more quickly than non-condensing boilers, so if the economic analysis reveals no strong winner, perhaps high efficiency non-condensing boilers with temperature mixing provide the best solution.

If you would like us to do a quick comparison using our Bin method/ degree day analysis, please contact one of our sales engineers at 414-358-2646 or visit our website and send a question through our contact us page.

www.fluidh.com

What Fluid Handling Offers

Fluid Handling Inc. offers a complete line of condensing and non-condensing hot water boilers, from small wall-mounted models to units with ratings of tens of millions of BTUH. We are always happy to provide budget pricing and help our customers evaluate which boilers offer the best economics for given applications. Feel free to visit our website at **www.fluidh.com** to see the many boiler manufacturers we represent. Give us a call to help you pick the right boiler for your next project.

FLUID HANDLING INC.
12130 W. Carmen Ave • Milwaukee, WI 53225-2135
Phone: 414-358-2646 • Fax: 414-358-8388
email: fluidh@fluidh.com