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Maximizing Heating System Gains with Hybrid Boiler Plants

What is a hybrid plant?

A hybrid boiler plant is defined as a hydronic heating plant combining condensing and non-condensing boilers. This system is designed to take advantage of the best properties of both boilers. Through the proper design and selection, 100% of the potential energy savings can be realized with a possible installed cost savings of one third to one half of the cost compared to an all condensing plant.

Hybrid boiler plants may also include alternative fuel boilers such as electric/electrode boilers. In these cases the use of one over the other may be driven by the instantaneous cost of the fuel, triggering the use of the least expensive. Monitoring of the cost of delivered fuel can drive the switch-over between operating boilers, and should be part of the operating procedure.

Where to use hybrid systems?

One of the main stumbling blocks in using non-condensing boilers in higher efficiency designs has been the higher return water temperature requirements. In most applications, water has to be returned to the boiler at or above 130-140F in order to prevent flue gas condensation from occurring. The dew point of exhaust gases is normally in the range of 135F.

Hybrid plants can be utilized in legacy/existing plants or new designs. Depending on the condition of existing boilers, older, non-condensing boilers could be incorporated into the design and significantly reduce the overall project budget.

The ideal combination of condensing and non-condensing can lead to reduced fuel consumption in excess of 40% when compared to existing systems or new all non-condensing systems. The main benefit leading to this savings is the reduction of boiler cycling.

Why use them?

The heating profile of many buildings looks very similar to fig 1. Within this profile, the maximum heating load occurs in the winter months. However, when you look at the fuel consumed normalized against a unit of consumption such as heating degree days, it becomes evident that we consume more heat per heating degree day in the off-peak months such as October and April. The leading contributor to this is the on-off cycling of boilers as the PID loop cannot be maintained within acceptable parameters resulting in what is often referred to as “short cycling.”.

Two control concepts lead to the ultimate savings within a boiler system. See the green theoretical curve in fig 2. The first area to consider is that of flow intelligence (patent pending).

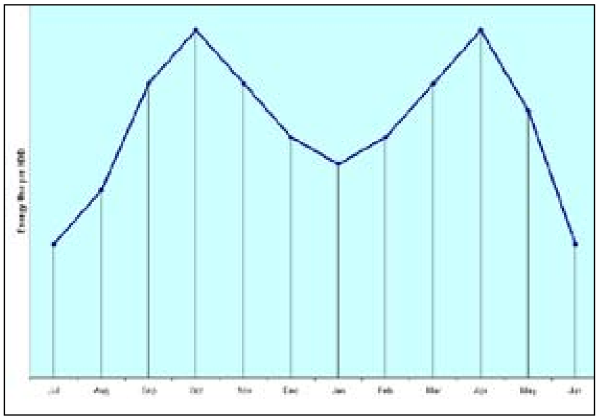

Figure 1

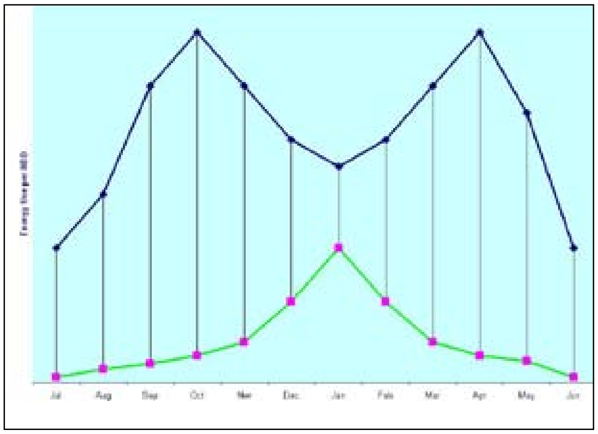

Figure 2

Current control schemes are based on PID temperature controls. This was a great improvement over older systems, but with the leap forward of software processing power, calculated BTU heating load consumption is lending itself to matching the exact heat profile needed instead of chasing the temperature change. In other words, as Btu's are used in the heating system, they are immediately recognized through mass flow balancing and the boiler system responds.

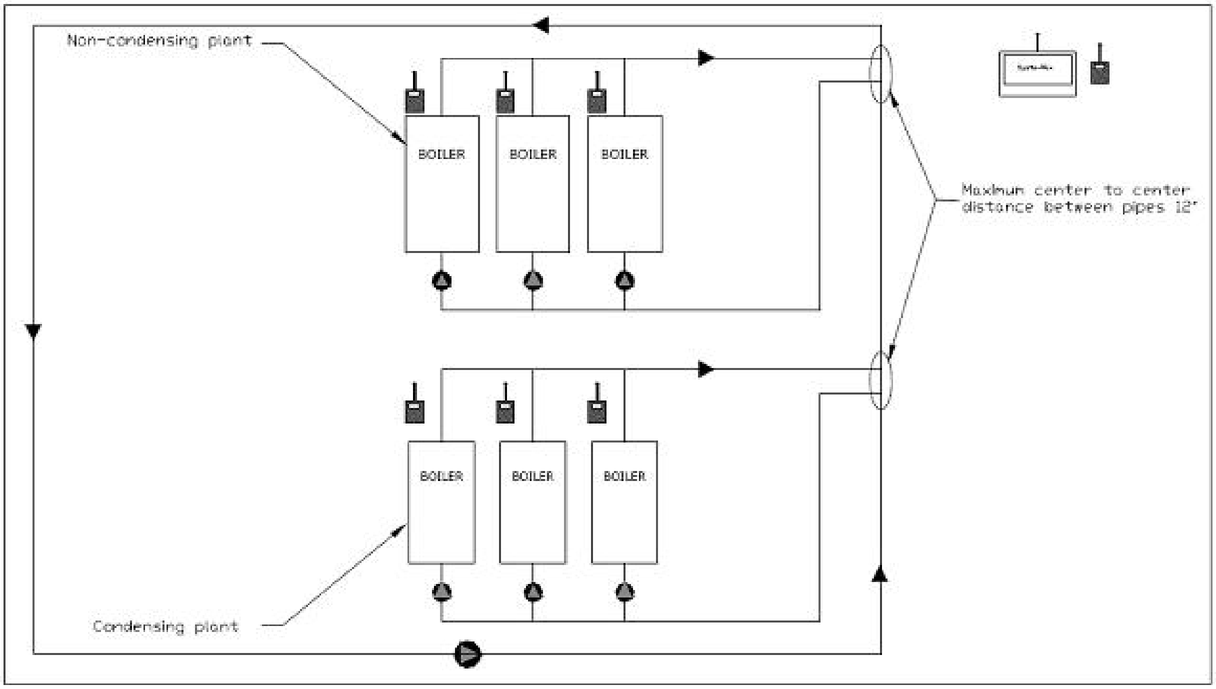

Figure 3

With the use of this applied control, needless cycling of the boiler(s) is greatly reduced if not eliminated. Under current control scenarios, on-off cycling of boilers at low load conditions, chasing PID loop temperatures can reduce boiler efficiency by 20-30%. Even with a condensing boiler at low return temperatures, theoretical efficiencies of 95% can drop to as low as 65% under these high cycling conditions. Through the use of system delta T and flow rate, the actual consumed heating load can be calculated. Theoretical energy savings; therefore, is the difference between the curves in fig 1 and fig 2.

The second concept to consider is that of intelligent load sharing. With a properly sized boiler, run cycles can be limited to two (2) cycles an hour (or less) under no-load conditions. To accomplish this, a small boiler is sized to allow 30 minutes of run time under no load conditions. Given the system volume and the delta T of the boiler operating set point, the minimum firing rate can be calculated. With this minimum firing rate, a boiler with appropriate turndown can be selected to achieve this outcome.

During most evaluations this usually turns out to be a smaller boiler than the rest of the units attached to the heating plant. This smaller boiler then becomes similar to the "pony boiler" concept used in steam plants. In those cases, the small steam boiler is used to carry light loads such as when the heating load is removed in the summer leaving a small process load. An example could be the steam used for sterilization, and/or humidification in a hospital.

To accomplish the intelligent load sharing, the heating plant control must be able to calculate the load consumed and recognize the maximum and minimum capacity of each boiler attached to the heating plant. With this knowledge, the controller must also be able to further turn on and off modulating boilers to exactly match the load.

With current designs, the sizing and control schemes using temperature variation only (without mass flow calculating/selection) usually employ multiple boilers of equal size resulting in considerable on-off cycling as the load drops below the minimum turndown of these similarly sized units. This is extremely inefficient due to the frequent pre and post purge losses; saying nothing about the stresses on the mechanical equipment leading to higher incidences of (costly) repair and downtime.

How does it work?

In hybrid systems, the use of condensing boilers is usually sized to provide the heating loads down to around 32-35F degrees outside air temperature. In the northern climates, this will account for approximately 75-80% of the heating season, and around 1/3 of the heating load. Actual loads will need to be verified using load calculation software or existing load profiles.

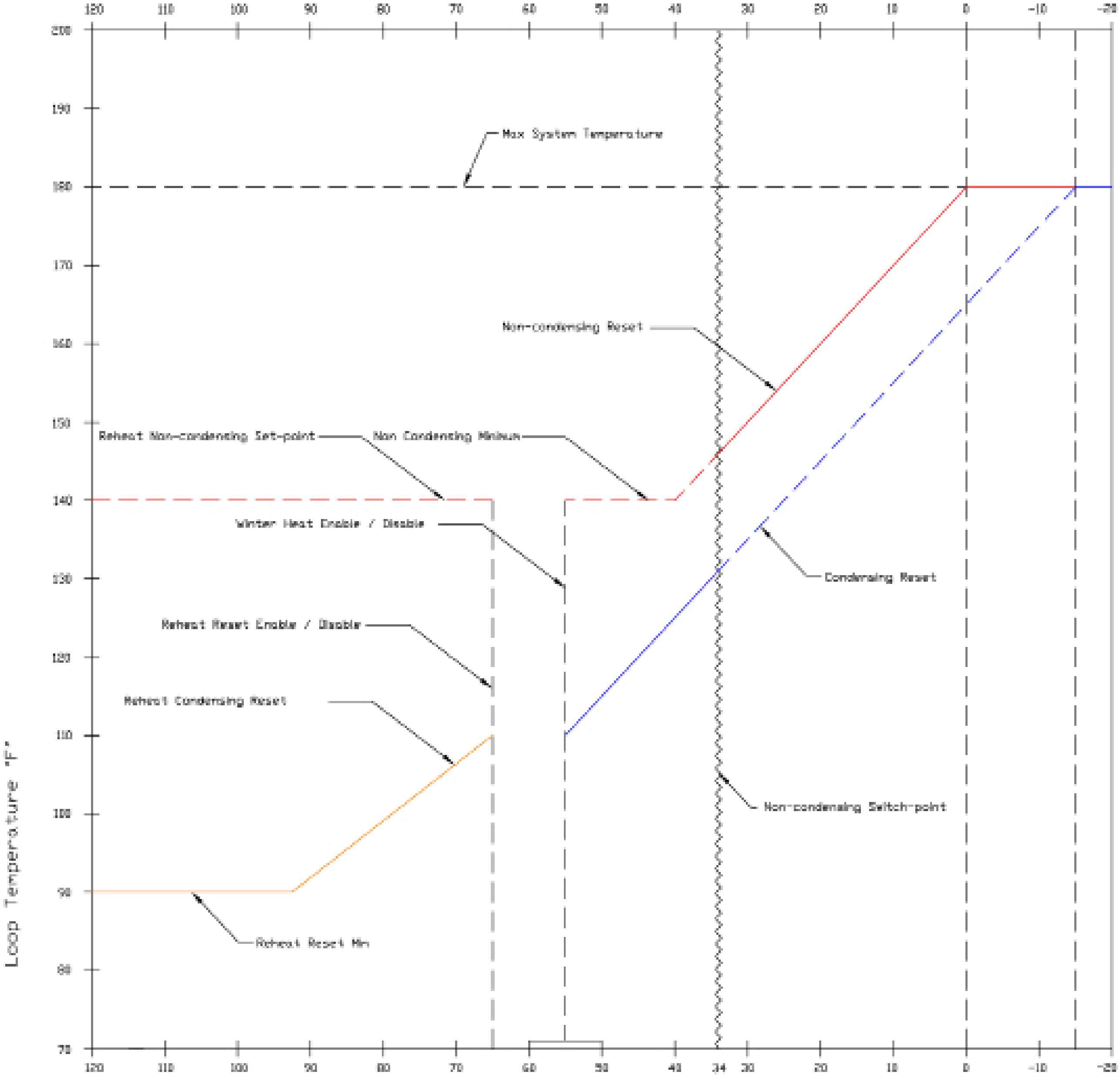

Figure 4

As the heating load increases with an outside air temperature drop, a change over to the non-condensing boiler(s) will provide heat for the incremental increase in demand. Built-in algorithms will enable the transition from condensing to non-condensing units. See fig 3 for possible piping. Under this configuration, the outputs of the condensing boilers are driven up to at or above 140F. This will ensure that the inlet to the non-condensing boiler(s) is adequate to prevent condensing from occurring in the unit. See fig 4 (reset curves).

As the load increases (increasing heat loss), the non-condensing boiler will assume the load. If the non-condensing unit(s) is sized for 2/3 of the load, the condensing boiler(s) can supplement when at the design day or most severe condition. If more than one non-condensing unit is used, the control can also change or sequence the operating units in a lead/lag setting to equalize run time. The use of non-condensing boilers thereby allows higher temperature (more Btu's) for colder, design day temperatures of the legacy building. Incorporating this concept into new designs also allows higher supply temperatures to keep the heating coil surface to a minimum.

What is a good hybrid candidate for existing systems?

A ready source of determining a good candidate for a hybrid system is the flame safeguard system. Many units keep track of the cycles and run hours. If it can be determined that units are cycling excessively the system is a good prospect for a hybrid system. Many boiler rooms can be shown to have cycles upwards of 10-40 per hour. This is indicative of an over sized heating plant during small loads. This may show up as customer complaints of excessive cycles. Other indicators can be complaints of excessive maintenance requirements, frequent downtime, and customer perceptions of general frustration, either in fuel bills or performance of the system.

What is potential savings?

From above fig 1 and 2, the potential energy savings are shown as the difference between the blue and green lines. The savings will be greater by capturing the larger difference in the off peak conditions, such as October and April. This savings will be driven by the amount of operating hours in theses ranges. Moderate or mid range climates will have a higher potential for savings. Warmer climates will still have the potential for savings by taking advantage of the summer reheat schedule (fig 4).

Average Seasonal Efficiency (ASE) for a traditional non-condensing boiler plant has been shown to be 65-70%. This is mainly due to the on-off cycling in the off peak design seasons. ASE using condensing boilers exclusively could reach as high as 93%. However, properly designed hybrid system could approach these levels at a lower installed cost compared to an all condensing plant.

Finally, when evaluating systems, savings of 20% should be the minimum expected though savings as high as 40-50% can be realized (. Additionally, these systems can reach these levels without changing the higher supply temperature during design day conditions. The final result is retrofit applications which are more affordable with shorter payback; combining condensing boilers with new (or existing) non-condensing units; achieving the best of both worlds.

References

1. Tom Durkin 2006. "Boiler System Efficiencies" ASHRAE Journal 48(51-57);
2. Martha Hewett 2006 "Inside ASHRAE Standard 155P" Boiler Systems Engineering June 2005 (10-21)