Efficiency Killers... (Waste Not, Want Not)

By George R. Carey

This expression dates back to around 1772 and it basically means if you don't waste something, you will never have a want for it…those who waste will want…waste and want or save and have. When it comes to heating systems, you don't want to create a system that uses the fuel source inefficiently. Waste not, want not!

Over the years I have seen several systems that violate this principle. With energy costs on everybody's radar screen, it is in your best interest to provide or improve your customer's existing hot water to minimize their waste! And there are several steps that you can take to eliminate wasted energy in a heating system. (Two very obvious ones which have little to do with the actual heating system are 1) increase the insulation in a home and 2) upgrade the windows. Whatever heat the system produces, keep it inside the building for as long as possible!)

Regarding the heating system, short cycling is a major efficiency killer. And it strikes in multiple areas, mechanically and economically.

The mechanical problems occur because of the rapid cycling on and off of the boiler. All of the various components found on an oil-fired boiler have an expected life cycle. When a boiler is short cycling, the components are seeing all these cycles in a very short time span. This leads to premature control failures, nuisance lock-outs, service calls and frustrated customers. If you want to kill a brand new boiler in less than five years and frustrate you and your customer along the way…short cycle it!

The economical problem is often unknown and certainly under-appreciated. There is an old rule of thumb that states: "a short cycling boiler will operate at least 15% points below its rated efficiency when said boiler is not short cycling." The loss of fuel efficiency can be staggering. Which means the wasted fuel consumption is paid for by the unsuspecting homeowner with the new high efficiency boiler.

So if you want to prevent short cycling, what can you do? The first step is ensuring that the boiler is not oversized! When a boiler is too big, it will always produce more energy (BTUs) than the system can receive/use (without over heating the space). And by being too big, it reaches its high limit very fast, not allowing the boiler/burner to operate in a "steady state fashion." And the best way to make sure that a new boiler is not too big is to perform an accurate heat loss on the house. There are several software heat loss programs available that will help you establish the heat loss of any building. By using this information, you can then select the right size boiler for the house instead of relying on someone that came before you and who had installed the previous boiler.

Unfortunately, as the expression goes, "no good deed goes unpunished." A boiler can still short cycle even when it is sized properly. Do you know why? Load and zoning are the reasons. A properly sized boiler is sized for design conditions. This means when it is very cold outside (design outdoor temperatures), the boiler is capable of keeping the occupants at design indoor temperature, which is usually around 70°F. But these design outdoor conditions exist for less than 5% of the total heating season. That means for the remainder of the heating season, even the properly sized boiler is too big and can lead to short cycling.

One of the many advantages and/or selling features of hydronic systems is the fact that they can be zoned very easily. Most homeowners like the idea of being able to control sections of their house, even right down to a room by room control. This, unfortunately, can also lead to short cycling.

If one or two small zones are calling and the boiler fires in response, the energy output of the boiler is too great compared to the needs of the smaller zones—the high limit is reached very rapidly and the boiler shuts off. The zones continue to call and the water temperature drops, the limit control responds and the boiler fires up again. Of course, the high limit is reached quickly and the boiler turns off. So even though the hydronics industry promotes it and homeowners enjoy the comfort and control offered by zoning, it can really foul up the boiler's potential efficiency rating.

If you were to ask any boiler manufacturer what would be an acceptable firing on-time that would eliminate short cycling and all its downfalls, a minimum of 10 minutes of firing is the industry standard. So what can we do to achieve this minimum 10 minute firing on-time? I think the answer lies with one or two options— or perhaps even both.

One would be to improve the controlling operation of the system. And a system it is…for a long time we have allowed the individual zones to operate independently and therefore randomly. The net result is inconsistent and very uneven loading of the boiler, which often leads to severe boiler short cycling. Granted, the occupants upstairs are still relatively comfortable, but at what expense? There are controls/thermostats available on the market today that synchronize with each other (i.e., talk to each other).

By synchronizing with each other, they all call for heat at the same time at the beginning of each new heating cycle. Naturally, how long each one runs for is determined by that particular zone's needs. The benefit of this is the boiler is seeing a reasonable load/flow rate that it can work with, thus minimizing the short cycling. Another benefit of these "new thermostats" is they also can request a water temperature back to the boiler control (the "brains"). The control receives these requests from all the various zones and makes a decision based upon the zone with the highest temperature requirement. The other "lower temperature" zones then calculate their own on-time with the higher temperature water to maintain their desired setpoint.

The other option would be to provide some mass to the system so each time the boiler fired, it would have to raise the temperature of this mass X number of degrees. If the added mass is calculated correctly, the boiler would not short cycle! This added mass is known as a "Buffer Tank." So how much mass is needed? How big should this Buffer Tank be? It is actually a rather easy number to establish. It is based upon a couple of conditions: 1) the minimum firing on-time of the boiler (usually 10 minutes); 2) Btu/h output of the boiler; 3) the minimum Btu/h load of the smallest zone calling and 4) the desired/acceptable temperature rise (delta T) of the tank (usually 20-40°F). When you plug in all the necessary numbers, the answer will be the suggested size of the buffer tank in gallons. The formula looks like this…

$$V = \frac{T \times (\text{Q heat input} - \text{Q min. heat load})}{\text{Tank temp. rise} \times 500}$$

So for example, if we had a boiler with a Btu/h input of 150,000 and the smallest zone load was 5000 Btu/h, and the system could accept a 40°F rise, what size buffer tank would be needed?

$$V = \frac{10\ (150{,}000-5000)}{40 \times 500} = 72.5 \text{ gallons}$$

In this particular system, if you installed a 72.5 gallon buffer tank and only the smallest load was calling, the boiler would run for a minimum of 10 minutes, thus eliminating short cycling from occurring.

Some might say that the additional cost of the tank would be prohibitive, but weighed against the life of the system, the cost of energy and the additional efficiency points gained by the longer run-times of the boiler would outweigh the additional equipment costs. A few notes regarding buffer tanks:

* They MUST be well insulated;
* Ideally they should have a minimum of 4 pipe connections;
* With a vent installed at the top of the tank, you now have a system air separator;
* Because of the size of the tank relative to the pipe sizes, the tank becomes a hydraulic separator (low loss header), thus acting like a Primary/Secondary connection between the boiler(s) and the system piping.

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