

# COMMERCIAL BOILERS: OPTIMIZE EFFICIENCY WITH CONDENSING BOILERS AND LOW RETURN WATER TEMPS

The simple choice for energy efficiency.



MAY 2020

## CONDENSING BOILERS DOMINATE THE MARKET AND SAVE THOUSANDS PER YEAR IN ENERGY COSTS

If you are a facility manager looking to upgrade your heating system, you probably already know that condensing boiler installations are common. Condensing boiler sales rose from 30% of the commercial boiler market in 2012 to 60% in 2016, and are expected to continue growing.<sup>1</sup> While condensing boilers do have a higher upfront cost, proper system design and installation can deliver energy savings that make it worthwhile.

### HOW DO THEY WORK?

As shown in Figure 1, a non-condensing boiler's hot exhaust gases leave the combustion chamber through a chimney (1). In a condensing boiler, the exhaust gases flow through an extra heat exchanger (2) which uses the additional exhaust heat to preheat the cold water returning from the radiators. The cooler exhaust gases exit through a sideways-oriented PVC flue (3) and produce an acidic condensate drip (4).

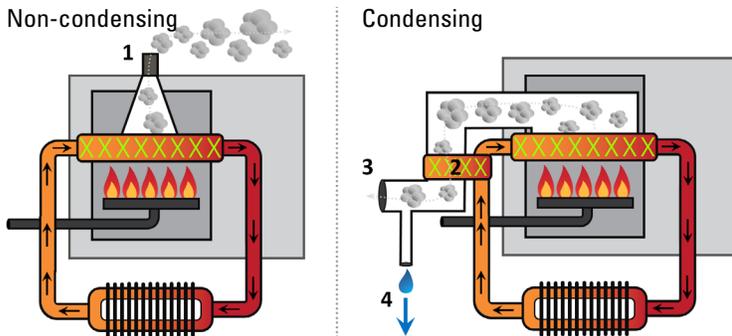


Figure 1: Non-Condensing Versus Condensing Boiler<sup>2</sup>

**Tens of Thousands in Annual Savings!**

- A pharmaceutical company in San Francisco replaced half of their old boilers with condensing boilers, installed a hybrid boiler management system, and saved 30% on fuel costs. In one of the four buildings, savings were \$90,000 per year with a return on investment (ROI) of less than two years.
- Developers of a new 32-story, 900,000 square foot, mixed-use high-rise in Boston installed a hybrid configuration of six condensing boilers and two conventional boilers. The system saves approximately \$16,000 per year and reduces greenhouse gas emissions by 80 metrics tons annually, equivalent to 66 acres of forest sequestered annually!

## LOW RETURN TEMPS: YOUR SECRET WEAPON IN THE FIGHT AGAINST WASTE

Commercial condensing boilers need a low return water temperature, typically between 80°F and 120°F, to condense the hot flue gas and operate efficiently. As the return water temperature rises, the Thermal Efficiency (TE) drops as less of the exhaust gas condenses (see Figure 2 below). If operated with high return temperatures, condensing boilers lose much of their efficiency gain over conventional boilers.

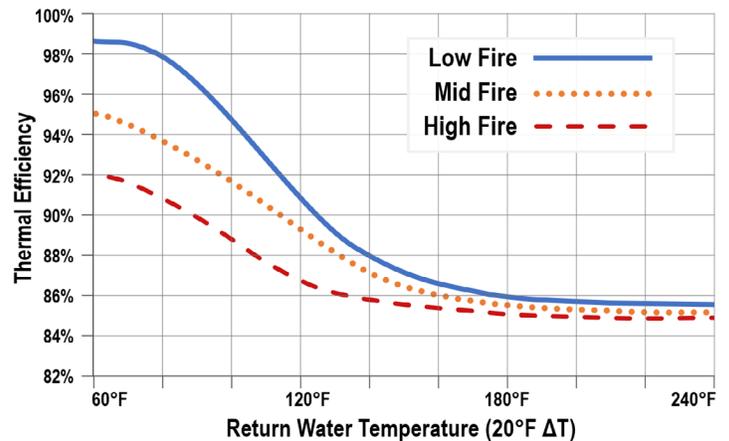


Figure 2: Thermal Efficiency vs. Return Water Temperature<sup>3</sup>

When older non-condensing boilers are replaced with new condensing boilers, they are often simply swapped in without any adjustments to the system. One industry expert estimated that 90% of commercial condensing boilers never operate in the condensing range.<sup>4</sup> Before condensing boilers emerged, hot water systems were typically designed to a 160°F return temperature, to prevent the formation of corrosive acidic condensate. If you install a new condensing boiler but continue to operate with the higher return water temperatures designed for older boilers, the flue gas will not condense, and you will lose the efficiency advantage of your purchase.

**READ ON FOR 9 TIPS TO KEEP RETURN WATER TEMPERATURE LOW AND EFFICIENCY HIGH!**

<sup>1</sup> <https://www.weil-mclain.com/news/commercial-market-embraces-condensing-boilers>  
<sup>2</sup> <https://www.explainthatstuff.com/gasboilers.html>

<sup>3</sup> <http://www.revisionenergy.com/pdfs/condensing-boiler-article.pdf>  
<sup>4</sup> <https://www.group14eng.com/wp-content/uploads/2017/01/Condensing-Boiler-System-Design-Tool.pdf>

## TOP 9 TIPS TO ENSURE CONDENSING BOILER ENERGY SAVINGS

Review these tips with your engineer or designer to see how they may inform your equipment selection, system design, and cost-benefit analysis.

### TIP #1: LOOK FOR ENERGY STAR CERTIFIED COMMERCIAL BOILERS

In addition to a 94% minimum thermal efficiency (TE), ENERGY STAR certified condensing boilers must have a turndown ratio<sup>5</sup> of at least 5 to 1, meaning a 1 million BTU per hour (MBTU/hr) rated boiler must be able run as low as 0.2 MBTU/hr. As shown in Figure 2, condensing boilers run more efficiently at lower loads (i.e., low-fire) versus higher loads (i.e., high-fire). A boiler with a higher turndown ratio can provide heating continuously at lower loads rather than cycling on and off, which leads to inefficient operation. Finally, higher turndown models that don't cycle as often benefit from reduced maintenance cost (e.g., replacing gas valves, ignition transformers, etc.) and longer boiler life due to reduced expansion and contraction of metal components. ENERGY STAR certified commercial boilers are appropriately sized for smaller buildings, or for use in a modular system (see tip 9).



### TIP #2: CHECK YOUR BOILER MINIMUM WATER FLOW RATE

Boilers often have a minimum allowable water flow rate that must be maintained during operation to avoid damage to the boiler, and operating below this limit can void the warranty. When the building demand for hot water is lower than this minimum flow, a bypass valve will allow excess hot water from the supply side to flow directly back into the boiler return – greatly increasing the return water temperature and taking the boiler out of the condensing range. When selecting a boiler, the design engineer should consider the building load during shoulder seasons when less heat is demanded and ensure that this demand is above the boiler minimum flow rate. High-mass condensing boilers (50 gals per MBTU/hr or more of water volume) generally have lower minimum flow rates than low-mass boilers (20 gals per MBTU/hr or less of water volume), which often require constant flow rates.<sup>6</sup> The minimum flow rate will be provided by the manufacturer during the selection process and included in product documentation.<sup>7</sup>

### TIP #3: UPGRADE TO LOW TEMPERATURE EMITTERS

Many older commercial heating systems in operation today use fin-tube baseboard emitters from as early as the 1930s that were

inexpensive, lightweight, compact, and easier to install than cast-iron radiators.<sup>8</sup> Unfortunately, designed to operate between 140°F to 200°F, these emitters do not allow a condensing boiler to operate efficiently. As shown in Figure 3, low temperature emitters (e.g. heated floors, radiant walls and ceilings, high performance radiators, high performance fin-tube baseboards) can meet load requirements with a water supply temperature of 120°F. High-performance panel radiators and fin-tube baseboard emitters are easily retrofitted in existing facilities. Low temperature fin-tube emitters, shown in Figure 4, can supply almost double the heat of their conventional counterparts at the same water temperature and flow rate by using high capacity two-pipe design and enhanced folded fin structure to provide more surface area.<sup>9</sup>

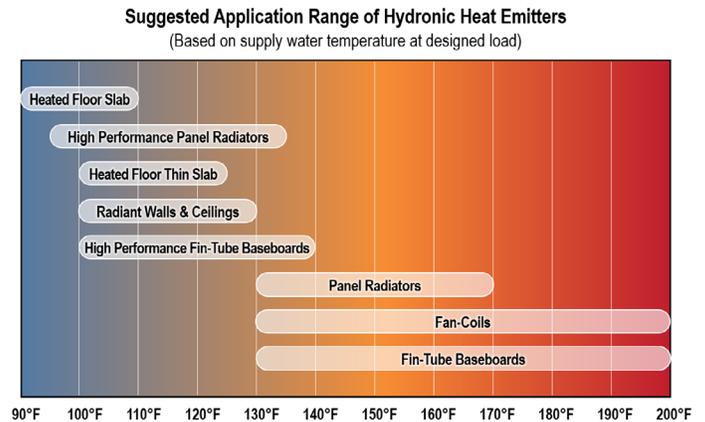


Figure 3: Suggested Supply Water Temperature Range for Hydronic Heat Emitters



Figure 4: Low Temperature, High Efficiency Fin and Tube Emitter

<sup>5</sup> The ratio of the boiler's maximum nameplate firing rate (MBTU/hr) to the lowest nameplate firing rate (MBTU/hr)

<sup>6</sup> [http://cleaverbrooks.com/about-us/news/articles/2017/practical-strategies-for-condensing-boiler-retrofits\(1\).html](http://cleaverbrooks.com/about-us/news/articles/2017/practical-strategies-for-condensing-boiler-retrofits(1).html)

<sup>7</sup> <https://www.group14eng.com/wp-content/uploads/2017/01/Condensing-Boiler-System-Design-Tool.pdf>

<sup>8</sup> Siegenthaler, John. A Sampling of Low Temperature Heat Emitters. PM Engineer. 2014. [www.pengineer.com](http://www.pengineer.com)

<sup>9</sup> <http://www.h-mac.com/product-catalogs/smiths-environmental-products/Smiths-Heating-Edge-Brochure.pdf>

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#### TIP #4: DIAL BACK BASED ON OUTDOOR AIR TEMPERATURE

Outdoor air temperature reset controls reduce the boiler supply water temperature when outdoor temperatures are higher (see Figure 5). In the Spring and Fall, warmer outdoor temperatures mean that less heat is needed to keep indoor spaces comfortable. Rather than inefficiently cycling the boiler on and off, emitters can use lower supply water temperatures to continuously provide heating at a reduced rate. In addition, the lower supply temperature leads to a lower return temperature and more efficient condensing boiler operation.

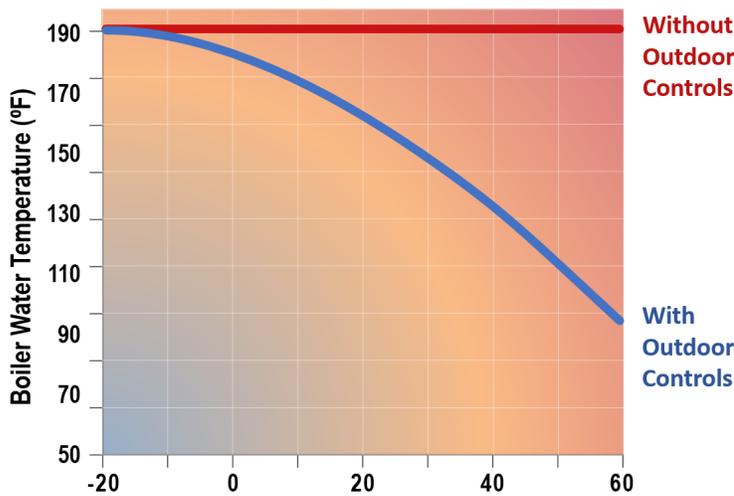


Figure 5: Variability in Outdoor and Boiler Water Temperatures

#### TIP #5: REDUCE ENERGY USE BY RAISING DELTA T

A system's "Delta T" is the difference in temperature of the hot water as it enters an emitter and the cooler water as it exits an emitter. The amount of heat an emitter gives off depends on both the delta T and the amount of water flowing. Many older systems are designed to a 20°F difference, with supply at 180°F and return at 160°F. By raising the delta T, an emitter can produce the same space heating with a lower water flow rate, which will reduce the required pumping power. Ensuring that your heating distribution system has a large difference across supply and return temperatures will also keep the return water temperature low and allow the boiler to maintain condensing operation.

#### TIP #6: USE VARIABLE SPEED PUMPS TO CIRCULATE EFFICIENTLY

A variable speed pump with an electronically commutated motor (ECM) can raise or lower the hot water flow rate through a system to match the demand load. A control system can use a variable speed pump to ensure that hot water is not over delivered, and keep the return water temperature to the boiler low. Pumps also use dramatically less energy when pumping water more slowly - a pump running at one-half the speed uses one-eighth the energy!

#### TIP #7: RETHINK YOUR BOILER ROOM DESIGN WITH A VARIABLE PRIMARY DISTRIBUTION SYSTEM

Many boiler rooms have primary-secondary distribution systems, which were designed for older boilers that required constant water flow. A dedicated set of "primary" pumps circulate water through the boilers, drawing from the supply side when necessary to maintain a constant flow rate, while "secondary" pumps circulate the supply water to the emitters throughout the building. This arrangement leads to mixing of supply and return water and inefficient operation due to higher return water temperatures.<sup>10</sup> Instead, when installing condensing boilers that do not require constant flow, a variable primary distribution system can be deployed that uses variable speed pumps and isolation valves to provide flow through the boilers and emitters in one loop. This eliminates dedicated boiler pumps, mixing manifolds, hydraulic separators, and heat injection loops— and the coldest return water feeds directly to the condensing boiler.<sup>11</sup> See Figure 6 below.

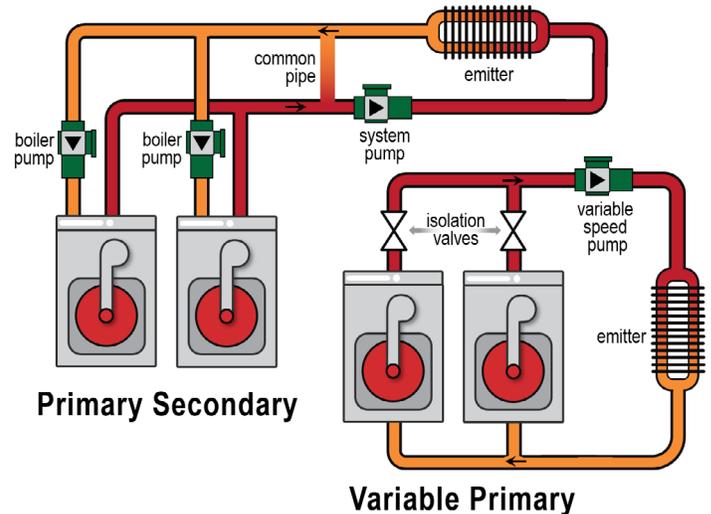


Figure 6: Boiler Room Distribution Systems

<sup>10</sup> <https://www.group14eng.com/wp-content/uploads/2017/01/Condensing-Boiler-System-Design-Tool.pdf>

<sup>11</sup> [http://dallas-ashrae.org/images/downloads/Past\\_Presentations/2014\\_modern\\_hydronic\\_system\\_designs\\_hts\\_ashrae.pdf](http://dallas-ashrae.org/images/downloads/Past_Presentations/2014_modern_hydronic_system_designs_hts_ashrae.pdf)

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## TIP #8: FOR SMALL UPGRADES – HYBRID SYSTEMS PROVIDE ENERGY SAVINGS

If your existing standard boiler still works, you can reduce your annual energy use by adding a small modulating condensing boiler to your system. On the coldest winter days, the standard boiler will operate, and on milder days the more efficient condensing boiler will take over when lower boiler supply and return water temperatures can be initiated by the outdoor reset controls (see Figure 7 and Figure 8 below.) The system controls communicate with the variable-speed pump to lower water flow rates to further reduce return temperatures to maximize condensing operation. Energy savings are possible anytime the system switches to the modulating condensing (MOD/CON) boiler and the unit operates at high turndown for long periods to maintain space conditions.

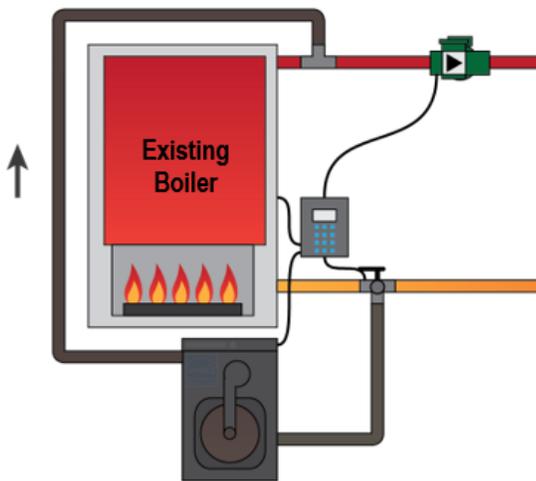


Figure 7: System Operation During Cold Winter Days

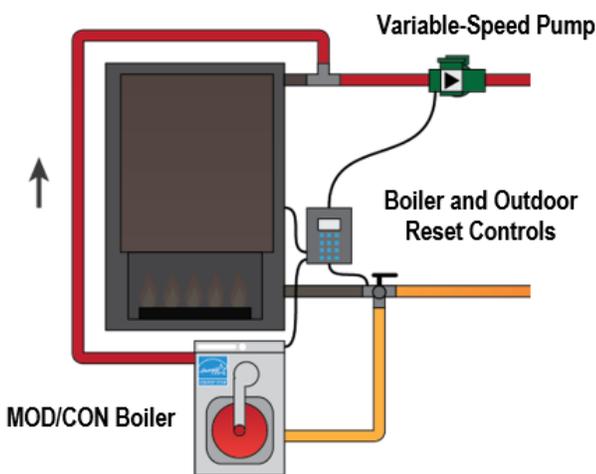


Figure 8: System Operation on Mild Days

## TIP #9: FOR NEW SYSTEMS – CONSIDER A MODULAR SYSTEM

Modular systems deploy multiple smaller condensing boilers to efficiently accommodate a variety of heating load conditions. At the lowest load conditions, one boiler can operate at its minimum capacity, which allows a larger total system turndown ratio. Individual boilers can be shut down for servicing, while the remaining boilers keep working. Modulating condensing boilers are compact and sometimes stackable, so they are ideal for retrofits or projects with space constraints. See Figure 9 below.

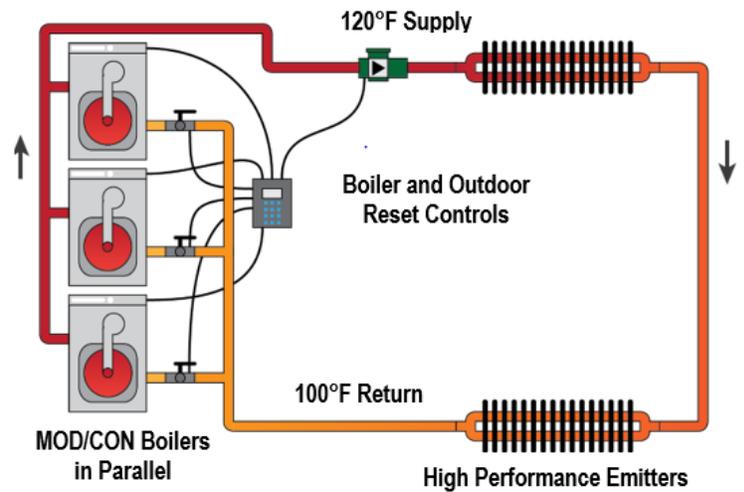


Figure 9: Modular System

## KEY TAKE-AWAYS

If you are considering a new commercial boiler installation:

- Specify [ENERGY STAR certified condensing commercial boilers](#).
- Realize overall heating system design is just as important as boiler selection - condensing boilers require low return water temperatures to operate at their rated efficiency.
- Discuss these 9 key technical tips with your design engineer to see how best to ensure efficient condensing boiler operation for your project.

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