

Boiling Down BOILER EFFICIENCY

Understanding some of the factors that come into play when determining boiler efficiency can help with boiler selection.

BY JOHN KOPF

Images courtesy of Weil-McLain.

Boiler efficiency is an important factor in selecting a space-heating boiler, but what does “boiler efficiency” really mean? When selecting the right boiler for the commercial application, it is important to understand the difference between the various types of efficiencies:

- **Combustion efficiency** determines the ability of the boiler to burn fuel. It can be calculated using the heating input of fuel minus the stack losses due to incomplete combustion and heat-exchanger inefficiency.
- **Thermal efficiency** is best described as combustion efficiency minus radiation and convection losses (jacket losses). It is a measure of the heat-exchanger efficiency to transfer heat from fuel to the water or steam.
- **Steady-state efficiency** is how efficiently the boiler uses the heat from combustion when operating under full load continuously under the same conditions. All variables, such as fuel composition, fuel and air mix, entering and leaving water temperatures and so on, must be kept unchanged. These conditions seldom exist and therefore the seasonal efficiency is a more useful measurement in typical space-heating applications.
- **Seasonal efficiency** is how well the boiler uses fuel over the entire heating season. It is the ratio of the total seasonal heat output used by the facility to the total seasonal fuel input. The seasonal efficiency depends on the boiler's steady-state efficiency, standby losses, and cycling losses.
- **Annual Fuel Utilization Efficiency (AFUE)** is similar to seasonal efficiency, however, this is a standard established by the U.S. Department of Energy specifically for residential and light-commercial boilers with input rates up to 300,000 Btuh.



⚡ **Wall-mounted boiler systems offer efficient heating in a more compact design for easy installation and maintenance.**

While each type is important, seasonal efficiency is one of the most important measurements because it determines how much the commercial building owner will pay for fuel over the course of the heating season.

Increasing efficiency of commercial boilers

Potential to overstate boiler efficiency exists when the manufacturer determines the combustion or thermal efficiency under unrealistic conditions. These can include extremely low return-water temperatures, excess air, unusual ambient temperatures and other abnormal conditions. In cases like these, the efficiency is often stated as “up to 99%” while the actual certified efficiency is significantly lower. The following are some general considerations when evaluating efficiency improvement measures.



»A condensing boiler and indirect-fired water-heater installation offers heating comfort and energy efficiencies.

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The longer a boiler operates continuously, without cycling, the higher the seasonal efficiency. Therefore, a boiler that is smaller than required will more closely match the heating load of the building for a larger part of the season because of fewer on and off cycles. When the first boiler can no longer keep up with the heat loss, a second, and then a third boiler, if necessary, picks up the extra load.

Therefore, instead of just one boiler for a job, two boilers with one-half the required capacity—or even three boilers each with one-third the required capacity—should be used. Each boiler will cycle one-half to one-third less than a single boiler, thus significantly increasing seasonal efficiency.

However, the key to maximizing efficiency with two or three commercial boilers is to be sure that each boiler is completely isolated from the others so that non-operating boilers will not be hot with system water. This will eliminate most of the jacket heat losses from the non-operating boilers.

Another method of increasing efficiency of non-condensing commercial boilers is to use lo-hi-lo burners rather than on-off models. With a lo-hi-lo burner, you have the equivalent of a half-size boiler on lo-fire and full-size boiler on hi-fire. The operating efficiency gain with one boiler with lo-hi-lo burner would be similar to using two on-off boilers. And with two boilers, it would be similar to using four on-off boilers.

Modulating boiler controls offer yet another opportunity to significantly improve boiler system efficiencies. In simple terms, the modulating controls will adjust the boiler heat output in response to changes in demand for heat and therefore will

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maximize its operating efficiency. Since the boiler operates most efficiently at the low fire and least efficiently at the full fire, the longer the operation at the low fire, the more efficient the boiler. By being able to run at the low firing rates, the modulating boiler controls reduce the cycling rates, further improving the overall boiler efficiency.

Primary-secondary piping

The key to maximizing efficiency with two or more boilers, either residential or commercial, is use of a primary-secondary piping system. With this system, the primary piping circuit runs continuously to supply the radiation; each boiler has its own secondary circuit to add incremental amounts of heat into the primary piping. A primary-secondary piping system will:

- Assure precise water temperature control;
- Isolate non-operating boilers to eliminate wasteful jacket heat losses;
- Return the coolest water to each operating boiler to maximize efficiency; and
- Reduce installation costs through the use of manifolds.

It should be noted that the variable primary-only piping systems are becoming more and more popular and can provide additional benefits over more traditional primary-secondary systems. When properly designed and implemented, the variable primary piping system can provide lower first cost (less piping, less pumps, fewer valves) and will use less energy (bigger pumps are typically more efficient than smaller pumps) than the conventional primary-secondary system. On the other hand, the primary-only system will result in more complexity of the bypass and will require more sophisticated controls.

Energy-management control systems

An option to consider is installation of an energy-management control system that will automatically sequence the boilers

to match heating load requirements for increased efficiency and reduced fuel usage. Control packages and prewired panels are available for both commercial boiler systems and other multiple boiler systems. In addition, there are control systems for zoning with zone valves or circulators, as well as for combined space heating and service water heating.

Hybrid systems

When an old, inefficient boiler still has many years of service left, and the building owner does not want to invest in a complete boiler replacement, two or three smaller high-efficiency condensing modulating boilers can be installed to supplement the existing boiler. This is called a “hybrid system.”

Using primary-secondary piping, the new boilers handle the load in milder weather at seasonal efficiencies as high as 95%; the old boiler fires in only the coldest weather. Even in a northern city, such as New York, the average winter temperatures are 43°F, so the small boilers can handle the demand during most of the heating season.

The best operating practices to increase seasonal efficiency in an existing system include:

1. Eliminating boiler and system leaks—Replacement water is usually colder than the system return water requiring additional amount of heat. Also, replacement water costs money.

2. Using water treatment—The lime that is deposited when the water is heated can coat the boiler surfaces, reducing the heat-transfer efficiency. Proper water treatment does not just protect the boiler against scale and corrosion, it also protects the entire system, including pumps, valves and heat emitters.

3. Using outdoor air-temperature reset and programmable thermostats—These control methods adjust water temperature in the system loop in response to lower building demand for heat. Because boilers operate at the maximum design capacity only a fraction of the time, these controllers can be very effective and save significant amounts of money.



» A multiple boiler and indirect-fired water-heater system provides efficient heating for larger facilities.

4. Widening the operating and limit control differentials—

This method will reduce the number of burner firing cycles. The fewer the cycles, the higher the efficiency.

5. **Performing annual boiler maintenance**—Cleaning heat exchangers, replacing worn out components, adjusting air/fuel mixture and maintaining the water pH balance will improve the boiler seasonal efficiency, prevent costly failures and will extend the useful lifecycle.

In summary, a number of factors come into play when determining boiler effectiveness including system features and configuration, climate, equipment sizing and manufacturer support. Whether it is today's new condensing boilers and hybrid systems or noncondensing boilers, contractors and engineers have a number of options when choosing the most efficient water-heating system for the application. ☁

John Kopf is the Senior Product Manager with Weil-McLain, a leading North American designer and manufacturer of hydronic comfort heating systems for residential, commercial and institutional buildings. Founded in 1881, Weil-McLain is based in the Chicago

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suburb of Burr Ridge, IL, with manufacturing facilities in Michigan City, IN and Eden, NC, and regional sales offices throughout the United States. For more information, visit www.weil-mclain.com.