

# BOILER EFFICIENCY DEFINITIONS

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There are many different terms to describe heating system efficiency, and some of those terms have more than one definition. "Combustion efficiency," "thermal efficiency," and "boiler efficiency" can all have different meanings, and it is important to understand what definition is intended.

For the purpose of NYSERDA's Multifamily Performance Program, the critical distinction is between descriptions of steady state efficiency and descriptions of seasonal or annual efficiency.

Combustion efficiency and thermal efficiency describe steady state efficiency. Annual Fuel Utilization Efficiency (AFUE) and other measures of seasonal or annual efficiency are non-steady state measures that include a boiler's performance when it is operating at part load and idling between calls for heat.

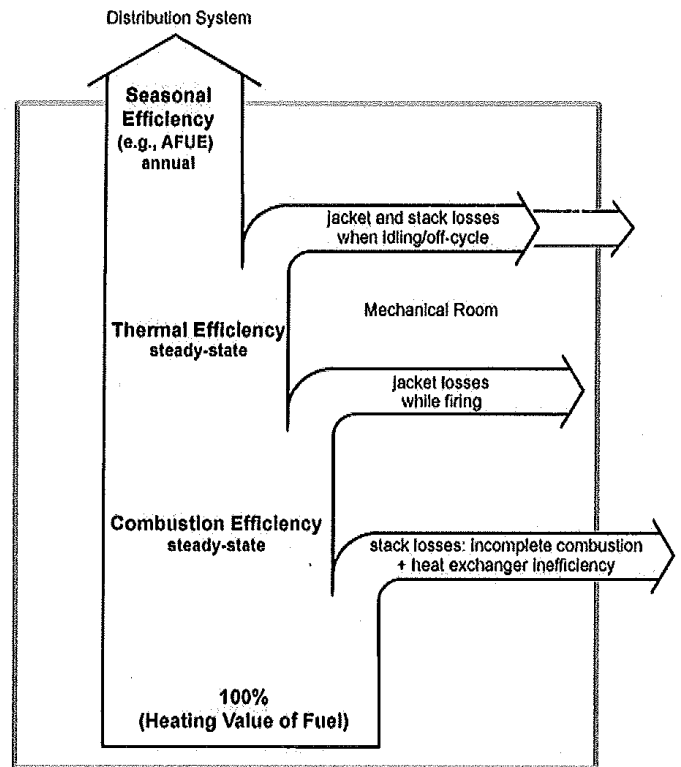


Fig. 1 Boiler Efficiency Losses

## WORKING WITH EFFICIENCY RATINGS

ASHRAE Standard 90.1-2007 describes the minimum acceptable ratings for new boilers:

Boiler Btu/hour	Standard Used for Minimum Rating
<300,000	AFUE
300,000—2,500,000	Thermal Efficiency ( $E_t$ )
>2,500,000	Combustion Efficiency ( $E_c$ )

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) publishes Certified Product Directories for commercial and residential boilers.

## COMBUSTION EFFICIENCY

$$\text{Combustion Efficiency \%} = \frac{\text{Fuel Input} - \text{Stack Losses}}{\text{Fuel Input}} \times 100$$

Combustion efficiency describes the results of a combustion efficiency field test on an existing combustion appliance. The test estimates the heat lost up the stack once the combustion appliance has been firing long enough to reach equilibrium. Combustion efficiency does not account for jacket losses or off-cycle losses.

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Stack heat loss is assessed by measuring:

- Net stack temperature, the difference between the temperature in the flue and the temperature in the mechanical room
- Carbon dioxide concentration or oxygen concentration in the flue gas (%)

Carbon monoxide is also often measured as an indication of unburned flue gases.

Combustion efficiency measurements account for inefficiency of the heat exchanger due to soot, scale, or poor maintenance because heat that fails to transfer through the heat exchanger goes up the stack.

The Hydronics Institute *Testing Standard BTS-2000* provides a test procedure for rating the combustion efficiency of new boilers. The *BTS-2000* combustion efficiency test is a more precise version of the combustion efficiency field test. Values for combustion efficiency measured using this standard are given in the AHRI boiler directories referenced above.

The Building Performance Institute's *Technical*

“Combustion efficiency does not account for jacket losses or off-cycle losses.”



Fig. 2 Cast Iron Sectional Boilers

*Standards for Multifamily Building Analysts* also address combustion efficiency testing as part of the building analysis process. Section 4.2 requires that “combustion efficiency tests shall be completed at steady-state conditions and interpreted based on observed operating conditions to establish overall boiler efficiency.”

## THERMAL EFFICIENCY

$$\text{Thermal Efficiency \%} = \frac{\text{Output}}{\text{Input}} \times 100$$

Thermal efficiency is the ratio of boiler input and output. These values are found on the boiler nameplate or manufacturer's data. The definition of thermal efficiency shown above is also from *BTS-2000*.

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Thermal efficiency cannot be tested in the field; it requires metering the fuel input and measuring the pounds of steam, rate of hot water production, and condensate produced (for steam boilers or condensing boilers). The biggest difference between combustion efficiency and thermal efficiency is that thermal efficiency accounts for the heat lost through the boiler jacket during boiler firing.

## ANNUAL OR SEASONAL EFFICIENCY

Seasonal efficiency cannot be tested in the field or described with a simple equation. In addition to stack losses and jacket losses, seasonal efficiency accounts for heat loss during periods that the boiler is "idling" to maintain its internal temperature while the building is not calling for heat.

The AFUE rating system applies to boilers up to 300,000 Btu per hour input. ASHRAE is working on Standard 155P, a similar rating system for larger boilers and boiler systems. The AHRI *Certified Product Directories* provide AFUE values for larger boilers and boiler systems.

*ASHRAE/ANSI Standard 103-1997* describes the procedure used to calculate AFUE, which includes assumptions such as:

- Varying outdoor temperatures in order to simulate a "typical" winter. While this is a typical winter for the entire United States (not NYS), it does model boiler performance at part load

- An oversizing factor, which means the boiler does not run at full capacity, even on the coldest day.

Seasonal efficiency is the closest approximation of the boiler's actual performance in a particular building. The AFUE rating system makes simplifying assumptions that may not apply to a particular installation. However, as a single number to represent seasonal efficiency, it comes closer than any other rating system currently available.



Fig. 3 New condensing boiler

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## SOURCES AND STANDARDS

*ASHRAE 90.1-2007 Energy Standard for Buildings except Low-rise Residential Buildings.* Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2007.

*ASHRAE/ANSI 103-1997 Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers.* Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1997.

*BTS-2000 Efficiency of Commercial Space Heating Boilers.* Berkeley Heights, NJ: Hydronics Institute Division of AHRI, 2007.

*Certified Product Directory: Boilers, Baseboard Radiation, Finned Tube (Commercial) Radiation, Indirect-fired Water heaters.* Berkeley Heights, NJ: Air-Conditioning, Heating, and Refrigeration Institute, April 2009.

*Technical Standards for the Multifamily Building Analyst Professional.* Malta, NY: Building Performance Institute, 2008.

## WEB RESOURCES

[www.ahrinet.org](http://www.ahrinet.org)

[www.ashrae.org](http://www.ashrae.org)

[www.bpi.org](http://www.bpi.org)