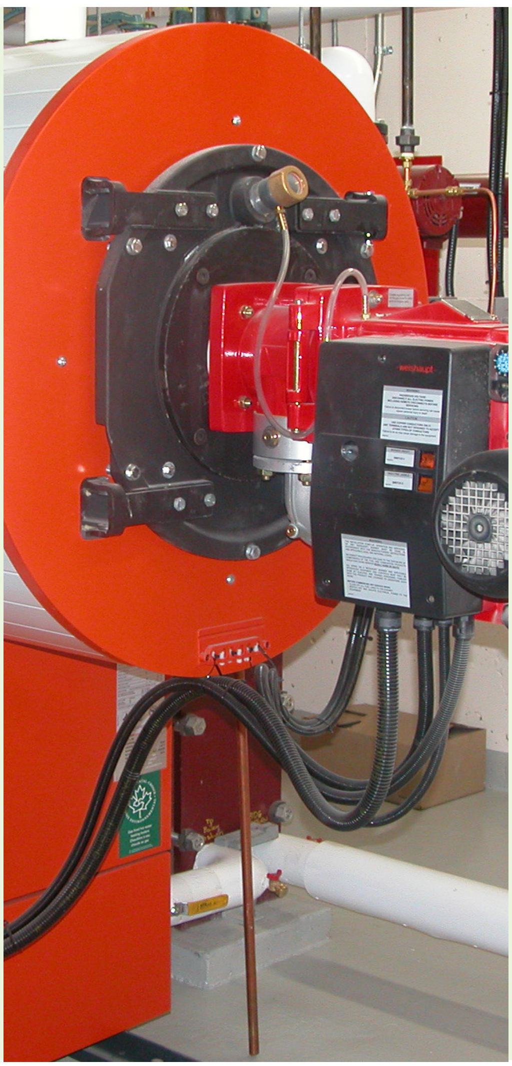
GSA Public Buildings Service

GPG FINDINGS 05, UPDATED JUNE 2014

CONDENSING BOILERS



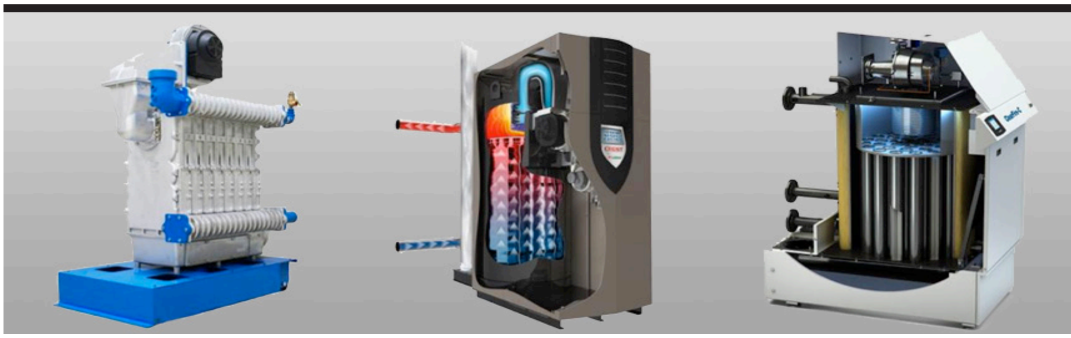
Condensing Boilers Reduce Heating Energy Consumption

Heating accounts for roughly a third of total energy consumption in U.S. commercial buildings, with boilers supplying heat to 34.5% of total floor space.[1] Considering GSA's own reliance on boilers for heating, GSA's Green Proving Ground (GPG) program recently assessed the performance of condensing boilers at six federal facilities—one at the Peachtree Summit Federal Building, in Atlanta, Georgia, and five at the Denver Federal Center (DFC) in Lakewood, Colorado. Condensing boilers perform more efficiently than conventional boilers by extracting more of the heat energy released in the combustion process. For maximum efficiency condensing boilers must operate under the right conditions—the most important of which is return water temperature (RWT). For "condensing mode" to be achieved, RWT must be below 130°F. In the six facilities studied, only three were able to achieve condensing mode more than 30% of the time. Still, all facilities experienced significant reductions in natural gas consumption, with savings greater than 14% when compared to conventional boilers.

GPG
Green Proving Ground Program

The Green Proving Ground program leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies. The program aims to drive innovation in environmental performance in federal buildings and help lead market transformation through deployment of new technologies.

INTRODUCTION



Cut-Away View of Three Different Condensing Boilers[2]

"Condensing boilers reduced our natural gas consumption by 14%, putting us that much closer to meeting our EISA mandate."

Roderick Grant,
Property Manager
Peachtree Summit Federal Building
Atlanta, Georgia
GSA

PERFORMANCE SPECIFICATIONS
Energy Efficiency

RATED	
High-efficiency, near-condensing	**85-88%**
Condensing	**86-98%**
DFC	**98%**
Peachtree	**95%**
MEASURED	
DFC	**88-90%**
Peachtree	**94%**
FEMP GUIDELINES	
Boilers, new & replacement	**94%**

What Is This Technology?

A MATURE TECHNOLOGY WIDELY DEPLOYED

The condensing boiler is a system of technologies, consisting of the boiler itself, the flue stack, and the condensate collection system. Condensing boilers have been manufactured since the 1980s, and are now a fully mature technology deployed throughout the world. They achieve higher efficiencies by condensing the water vapor that is produced during combustion and trapped in the flue gases. In traditional boiler technologies, the latent heat contained in the water vapor is allowed to escape through the flue. Condensing boilers reclaim that latent heat by condensing the water vapor and transferring its heat back into the return water, which increases boiler efficiency from 80% for traditional boilers to between 88% and 98%. These potential efficiency gains can be attained only if the boiler is operating in "condensing mode," which requires the temperature of the water returning from the building to the boiler (aka: return water) to be below the dew point of the water vapor in the flue gas. The dew point is determined by several variables, among them altitude, outdoor air temperature, and the type of fuel the boiler consumes. The critical variable, however, is combustion efficiency: excess oxygen in the combustion process leads to lower efficiency and requires a lower dew point before condensation can begin. In general, with efficient combustion, return water temperatures (RWT) should be below 130°F, with lower RWT creating more condensation and greater efficiency.

What We Did

CONDENSING BOILERS REPLACED CONVENTIONAL BOILERS IN SIX FEDERAL FACILITIES

In 2010, conventional natural-gas-fired boilers were replaced with condensing boilers in six federal facilities. To assess performance of the new boilers, GPG engaged two U.S. Department of Energy (DOE) laboratories to perform measurement and verification (M&V). Pacific Northwest National Laboratory (PNNL) assessed four condensing boilers at the Peachtree Summit Federal Building heating plant; the National Renewable Energy Laboratory (NREL) assessed twenty-two condensing boilers distributed throughout five Denver Federal Center (DFC) facilities. Peachtree's condensing boiler plant was monitored for approximately six months, from December to May. The DFC buildings were evaluated through numerous site visits during the 2011-2012 heating season.

FINDINGS

REDUCTION IN ENERGY CONSUMPTION On a weather-normalized basis, condensing boilers reduced Peachtree's natural gas consumption by 13,019 therms/yr, or 14%, and DFC's by 101,000 therms/yr, averaging 24%. Assuming a reduction of only 14%, the application of condensing boilers throughout GSA's portfolio would result in a savings of between 0.7% and 1.0% of GSA's FY2007 total energy consumption.

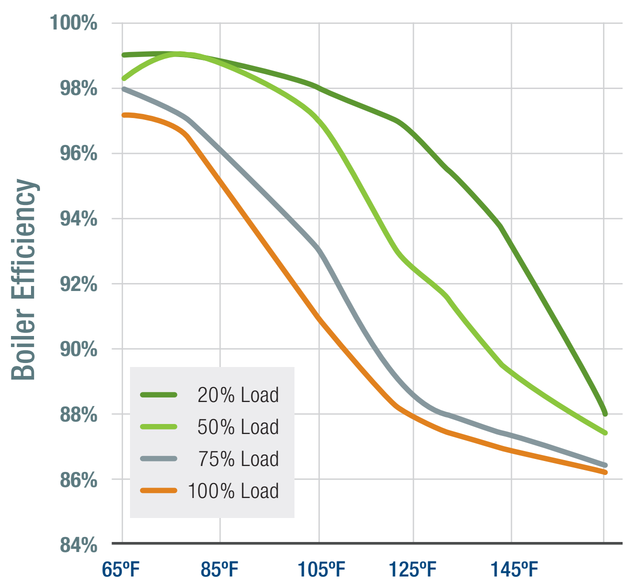
LIFE-CYCLE COST EFFECTIVE AS END-OF-LIFE RETROFIT Using installed costs, some of which were high because they reflected work that would not be part of a typical installation, simple payback for the Peachtree and DFC boiler retrofits varied widely. Using GSA average fuel costs and typical boiler costs, however, payback ranged between 4 and 7 years. When compared to high-efficiency boilers, condensing boilers were found to be life-cycle cost-effective even when only 3%-5% more efficient.

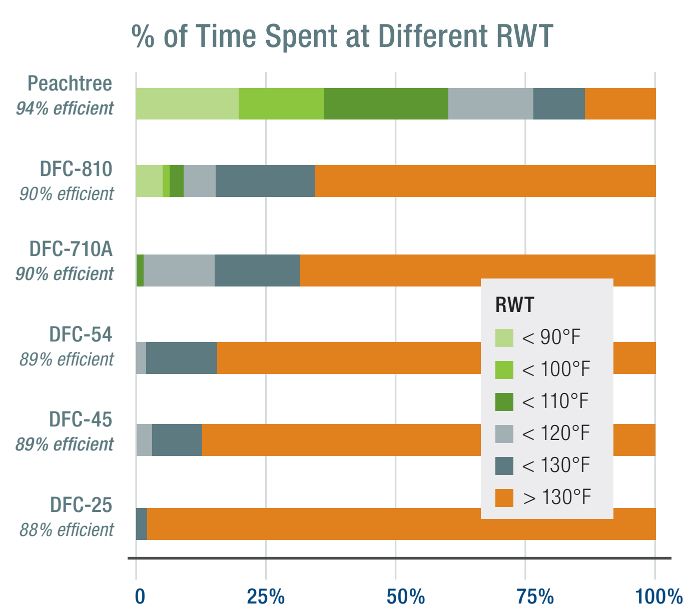
LOW RETURN WATER TEMPERATURES ENSURE CONDENSING BOILER EFFICIENCY To operate in condensing mode, a return water temperature (RWT) below 130°F is required. While the RWT at Peachtree was below 130°F the majority of the time, this was not the case at the DFC. Because the temperature of supply water influences the RWT, a more aggressive approach to lowering the supply water temperature in response to outside air temperature would have decreased the RWT and increased efficiency. Given the same parameters, boilers in mild climates operate in condensing mode for a higher percentage of time than do boilers in more extreme climates.

DEPLOY IN ALL NEW CONSTRUCTION AND AS END-OF-LIFE REPLACEMENT IN RETROFITS Best candidates include, but are not limited to, buildings in moderate climates, buildings with low temperature heating systems (such as in-floor radiant heating), and buildings with hot water loops that can easily be retrofitted to avoid coil bypasses and three-way valves. In buildings where a RWT below 130°F is not possible, high efficiency near-condensing boilers, with thermal efficiencies above 84%, could be more cost-effective.

Return Water Temperature is Key to Efficiency

Lower RWT results in greater efficiencies





CONCLUSIONS

These Findings are based on the reports, "Condensing Boiler Assessment: Peachtree Summit Federal Building, Atlanta, Georgia" and "Condensing Boilers Evaluation: Retrofit and New Construction Applications" which are available from the GPG program website, www.gsa.gov/gpg

To help optimize condensing boiler systems, a Condensing Boiler Design Tool (CBDT) is available upon request from Sue Reilly, sreilly@group14eng.com

For more information, contact Green Proving Ground gpg@gsa.gov

What We Concluded

LIFE-CYCLE COST-EFFECTIVE WHEN COMPARED TO HIGH-EFFICIENCY BOILERS

At both the Peachtree Federal Building and Denver Federal Center, condensing boilers outperformed the incumbent conventional boilers by substantial margins. When compared to high-efficiency boilers, condensing boilers were found to be life-cycle cost-effective even when only 3%-5% more efficient. Efficient boiler operation and a return water temperature below 130°F is key to achieving savings.

NOTE: Recently, the Federal Energy Management Program (FEMP) updated the minimum efficiency requirements for natural gas-fired boilers to 94%[3], which in effect requires all federal agencies to install condensing boilers. This mandate means it is all the more crucial to ensure proper boiler installation and operation in order to maximize efficiency.

Best Practices

FAVORABLE RESULTS DEPEND ON PROPER APPLICATION AND OPERATION

- Conduct a thermal load calculation to select a boiler that meets maximum thermal load without excess capacity. Relying on previous plant sizing is not necessarily reliable because changes might have occurred in building size or operation, and previous sizing methods may have been inaccurate.
- Select boilers with a low turndown ratio and low minimum flow requirement.
- Operate multiple smaller boilers in parallel at low loads.
- Ensure a return water temperature below 130°F by implementing some or all of the following strategies: reduce the supply water temperature in response to outside air temperature or in response to zone temperatures or control valve position; reduce the hot water flow rate, particularly when the building is unoccupied; optimize valves with the use of pressure independent control valves, two-way valves, and variable speed drives on booster pumps; install heating coils that provide temperature drops between 40°F and 60°F; use a primary piping system with one water loop that circulates water through both the boilers and the heating coils.
- Use condensing boilers for 75% of a building's heating load with a conventional boiler as backup during the coldest weather. This strategy has the potential to increase condensing mode operation and lower initial condensing boiler costs.

Reference above to any specific commercial product, process or service does not constitute or imply its endorsement, recommendation or favoring by the United States Government or any agency thereof.

Footnotes

[1]EIA 2003b. Commercial Buildings Energy Consumption Survey: Energy End-Use Consumption Tables, Table E.1. Major Fuel Consumption (Btu) by End Use for Non-Mall Buildings, 2003, U.S. Energy Information Administration, Washington, DC. Accessed 07/05/2012.

[2]Images courtesy of Harsco Industrial Patterson-Kelley, Lochinvar, and Cleaver Brooks, [from left to right, respectively], used with permission.

[3]Federal Energy Management Program Regulations. http://energy.gov/eere/femp/covered-product-category-commercial-boilers Accessed 5/22/14.