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## Condensing Natural Gas Water Heaters

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*This is the 12th article covering one of several energy-saving technologies evaluated in a recent U.S. Department of Energy report. The complete report is at [www.eren.doe.gov/buildings/documents](http://www.eren.doe.gov/buildings/documents).*

**W**ater heating accounts for about 17% of primary energy consumed in residential buildings and 7% of commercial.<sup>1</sup> Overall, natural gas-fired units account for nearly half of all water heater energy consumption. Current mass-marketed storage-type gas-fired water heaters have efficiencies that lie well below thermodynamic limits.

Standard water heater efficiencies, as measured by an energy factor (EF), typically lie between 0.55 and 0.60. This minimal efficiency level reflects two primary factors.

First, gas-fired units suffer from flue standby losses. During periods of burner inactivity, the hot water tank heats the air in the flue. The heated air rises up the flue and leaves the hot water heater, which increases the amount of energy required to maintain hot water set points.

Second, most gas-fired appliances are designed to operate outside the condensing regime. Natural gas contains small quantities of sulfur that react with the water produced in the combustion process to generate sulfuric acid vapor. If the temperature of the flue gases falls below the dew point of the sulfuric acid vapor under operating conditions, the sulfuric acid can condense on colder surfaces. The cyclical accumulation of sulfuric acid and subsequent dry out corrodes many common materials, including conventional steels.

Most gas-fired appliances, including water heaters, avoid condensation by ensuring that the flue gas temperature leaving the appliance exceeds the condensing regime by a sufficient margin. The appliance, however, can extract only a limited portion of the combustion energy, about 80% of the heat in the case of natural gas.

Commercial and residential condensing gas water heaters do exist. Typically, they use stainless steel heat exchangers that resist corrosion, which allows them to operate in the condensation regime. Consequently, they achieve significantly higher EFs, up to as high as 0.86. The need for special

materials, however, also increases the cost of the products. As a result, condensing units have captured only a few percent of the commercial water heater market and less than 1% of the residential market.

### Energy Savings Potential

New NAECA energy standards that come into effect in 2004 mandate that standard storage type natural gas water heaters must have a minimum energy factors of 0.594 (for a 40-gallon [151 L] water heater). A condensing water heater that achieves an energy factor of 0.86 consumes about 30% less energy than a conventional unit at the 2004 NAECA level.<sup>2</sup> Commercial water heaters typically have higher duty cycles than residential units, in which case thermal efficiency becomes the relevant metric. Condensing designs achieve thermal efficiencies in excess of 90% as compared to the ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, minimum of 80%, which decreases unit energy consumption by at least 11%. On a national scale, this translates into an annual energy savings potential of greater than 0.5 quad.

### Market Factors

The high cost of existing condensing water heaters has clearly had an adverse effect on their market share. Higher-efficiency water heaters incorporate items such as stainless steel tanks and heat exchangers as well as expensive burner systems to achieve the higher efficiencies. In addition to the direct cost impact of these components, stainless steel tanks also increase the difficulty of welding the tank and assembling the unit.

The increased cost of current high-efficiency water heaters make them less than desirable for many consumers. For example, a conventional water heater may cost between \$200 and \$400 (uninstalled). In contrast, one manufacturer's condensing natural gas residential water heater with an energy factor of 0.86 costs approximately \$1,500 (uninstalled). Similarly, a high-efficiency model for commercial buildings typically will cost more than \$2,000 as compared to around \$1,000 for a conventional model.<sup>3</sup>

Alternate approaches exist for condensing water heaters that result in somewhat lower energy factors than the highest-

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efficiency units but that could realize greater market penetration due to significantly lower first cost.

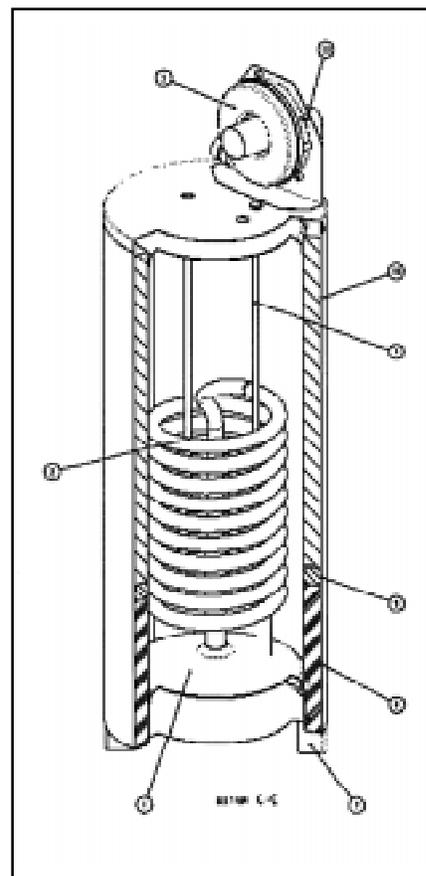
The Department of Energy has funded a development program to develop a market-optimized residential condensing water heater.<sup>3</sup> This approach incorporates as many standard water heater components as possible, including tanks, combustion chambers, burners, igniters, gas valves, and controls. Furthermore, the unit uses a heat exchanger with enameled surfaces to provide corrosion resistance instead of a more costly stainless steel heat exchanger; this becomes the primary difference — and cost increase — relative to conventional units (*Figure 1*). The net result is a condensing water heater design with an EF of around 0.78 that could cost less than \$1,000 (compared to ~\$1,500 or more for existing condensing water heaters).

Additional analyses suggest that the market attractiveness of the unit would increase if applied as part of a combination heat and hot water system. The higher energy usage levels associated with this type of heating system results in much shorter payback periods. Long-term accelerated life testing of the design approach will be needed to confirm that the product meets the desired level of reliability.

Other potential concerns include the need to drain condensate from condensing water heaters and the greater height of condensing water heaters (due to a draft induction fan on the top of the unit). Both issues have been successfully overcome in condensing furnace and induced-draft water heaters, respectively, and should not pose major barriers to commercialization of condensing water heaters.

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**Figure 1: Condensing water heater.<sup>3</sup>**

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