Residential Boiler Controls

May, 2006

Summary

Definition	Integrated and stand-alone controls for residential boilers that estimate changes in heat demand under part-load conditions and control maximum boiler water temperature, firing time, and/or circulating pump cycling and speed in response				
Basecase	Residential gas-fired non-condensing boiler (heat only) with standard safety and operating controls (alarms for high temperature limit, low water cut-off, high pressure cut-off, etc.) Standby/idle loss typically 2–3% of input energy				
New Measure:	Gas-fired boiler equipped with a control system, either direct or indirect, that reduces idle losses to ~0.3%	Percent Savings	2020 Savings TBtu (Source)	2020 Cost of Saved Energy	Success Rating (1-5)
		11%	310	$3.39/MMBtu	4

Background and Description

Conventional non-condensing boilers fire at a single fuel-burning rate. They turn on when the thermostat calls for heat, and turn off when the heat call is satisfied or when over-ride controls (high temperature limit, etc.) cut the cycle short. Typically, the high temperature limit is set at about 180ºF. This is designed to be hot enough to meet heating demand on the coldest day of the year. For most days during the heating season, maintaining this water temperature results in relatively high off-cycle heat losses. Several available control strategies are able to judge the current load on the system and lower the water temperature setpoint and/or delay burner firing accordingly. Depending on the system, they estimate load from indoor and outdoor temperatures, supply and return water temperatures, and/or the rates of change of these parameters.

The most common approach is the outdoor reset control. This uses outdoor temperature as a proxy for heat demand: when outdoor conditions are relatively warm, it changes the supply water temperature setpoint to an appropriate cooler supply temperature. All gas boilers can be controlled to a minimum temperature with light loads down to 140ºF, the point at which significant condensation can begin. Most gas boilers are "cold start," and will allow short operating periods below that temperature. Condensing boilers can be controlled to arbitrarily low temperatures. "Keep-warm" boilers, primarily oil-fired, must be maintained above the condensing temperature (ASHRAE 1993; Table 7). Otherwise, boiler corrosion rates may accelerate, and condensate may leak from the system.

Other strategies for harvesting residual heat include controls that "purge" the residual heat at the end of a firing cycle, and controls that delay burner firing until all residual heat from the previous cycle is harvested. Two-stage thermostats and time-delay relays are examples of the latter, using warm water circulation to meet an initial call for heat before firing the burner.

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Data Summary

Basecase: Residential gas-fired non-condensing boiler (heat only) with standard safety and operating controls (alarms for high temperature limit, low water cut-off, high pressure cut-off, etc.) Standby/idle loss typically 2–3% of input energy. Thermal efficiency is 82% (Butcher, 2006)

New Measure: Gas-fired boiler equipped with a control system, either direct or indirect, that reduces idle losses to ~0.3%.

Application and Status			
Market Sector(s)	**Application(s)**	**End Use(s)**	**Fuel Type(s)**
Residential	New Construction Retrofit	Space Heating	Oil Gas
Market Segment	**National/Regional**	**Region(s)**	**State(s)**
	Regional	Northeast MidAtlantic Midwest	
Current Status	**Date of Commercialization**	***Notes***	
Commercialized	1980	approximate	
Life			
15 years			

Basecase Information			***Notes (Source)***
Efficiency	69	%	Annual Efficiency with 3% idle losses
Electric Use	0	kWh/yr	
Summer Peak Demand	0	kW	
Winter Peak Demand	0	kW	
Gas/Fuel Use	86.7	MMBtu/yr	
New Measure Information			***Notes (Source)***
Efficiency	77.3	%	Annual Efficiency with 0.3% idle losses
Electric Use	0	kWh/yr	
Summer Peak Demand	0	kW	
Winter Peak Demand	0	kW	
Gas/Fuel Use	77.1	MMBtu/yr	
Savings Information			***Notes (Source)***
Electric Savings	0	kWh/yr	Electricity use of boilers is poorly understood and thus left out of this analysis.
Summer Peak Demand Savings	0	kW	
Winter Peak Demand Savings	0	kW	
Gas/Fuel Savings	9.6	MMBtu/yr	
Percent Savings	11	%	
Feasible Applications (%)	70	%	30% of existing systems deemed too old to retrofit. Feasibility is 100% on new systems.
Industrial Savings Potential (>25%)	NO		
2020 Savings Potential	**0**	**GWH**	
2020 Savings Potential (Source)	**310**	**TBtu**	
Cost of Saved Energy	**$3.39**	**$/MMBtu**	Lower CSE if installed on new systems ($2.88/MMBtu) based on a longer life expectancy and lower labor cost.
Cost Information			***Notes (Source)***
Incremental Cost	$350	2006 $	
Other Costs / (Savings)	0	$/yr	

Success Factors			
Market Barriers	**Non-Energy Benefits**	**Current Promotional Activity**	**Next Steps**
- Public awareness - Contractor/Builder Training	- Cleaner boiler operations - Longer boiler life - Increased occupant comfort	- Advertising	- Utility Promotion/Incentives - Testing - Marketing
Priority (1-5)	**Likelihood of Success (1-5)**	**Success Rationale**	
5	4	Feasibility is high and valuable non-energy benefits exist. Market barriers are surmountable, but overcoming them will take extensive effort.	
Data Quality Assessment (A-D)	**Data Explanation**		
B	Based on manufacturer data and reports by and discussions with boiler experts at the national laboratories		

Current Status of Measure

Some of today's high-efficiency condensing boilers include temperature reset and load monitoring controls as standard features. These features are important for lowering water temperature enough to realize the full condensing function of these boilers. Several manufacturers (Weil McLain, Veissmann, Buderus, Lochinvar, and Munchkin, to name some of the larger) have introduced these systems on the U.S. market within the last 10 years. Other condensing boilers on the U.S. market provide outdoor reset as an option. The condensing boiler market share is not known but is fairly small (probably less than 5% of sales).

Controls can also be purchased separately and added to an existing conventional system. Honeywell, Tekmar, and several boiler manufacturers produce a wide range of controls of varying levels of sophistication and features. Altogether, these controls are present on no more than 1-2% of the existing boiler stock.

Savings Potential and Cost-Effectiveness

The savings potential of boiler controls is a measure of how effectively they cut out idle losses, regardless of system oversizing issues. For conventional boilers, adequate add-on controls may cost from $150 (time-delay relay) to over $1,000 (reset with automatic post purge) and save up to 6–8% or more of the fuel used. In most cases, the costs and fuel savings depend heavily on the existing system and plumbing. Add-on controls that can claim around 10% savings for most existing systems are roughly $300-$400. In contrast, a new condensing boiler equipped with sophisticated controls will incur a similar incremental cost of $500-$1,000, but will save 20% of fuel use compared to standard gas boilers based on reduction of idle losses to between 0.15 and 0.3%.

Market Barriers

Residential boiler controls that modulate supply water temperature have been available on the market for at least 30 years but have remained uncommon due to high up-front costs and a lack of aggressive promotional activity and marketing. With higher fuel costs, manufacturers are increasingly showcasing their most efficient systems, most of which are condensing models with controls that come as standard or optional features. For existing boilers, however, stand-alone controls have not been actively marketed to consumers. Public acceptance is likely hindered by the lack of a one-size-fits-all solution. Depending on the size, age, and type of boiler; plumbing configuration; and burner sophistication, the cost of purchasing and installing the components that are necessary to achieve significant energy savings can vary dramatically and be expensive.

Next Steps

Condensing boilers that are integrated with more advanced load measurement and response controls are now mainstream in the U.K. and Germany due to strict residential codes and standards. These products are increasingly popular in the U.S. But for the non-condensing boilers that dominate the U.S. market, consumers could be given greater access to information that helps them understand what controls would be appropriate and cost-effective for their existing systems. New field demonstrations and documentation of the clear fuel savings that modern controls provide would strengthen the case for such incentive programs. Utility promotions would be an appropriate channel for wider adoption by both consumers and manufacturers.

Key Assumptions Used in Analysis

See Field Notes for specific assumptions.

Average Price of Electricity	$0.083/kWh
Percent New Res. Construction in 2020 (EIA 2006)	14.8%
Average Price of Natural Gas	$10.16/MMBtu
Projected 2020 End Use Electricity Consumption (EIA 2006)	0.39 quads
Real Discount Rate	4.53%
Projected 2020 End Use Gas Consumption (EIA 2006)	1.25 quads
Heat Rate	10.42 kBtu/kWh

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