IMPROVING THE BUILT ENVIRONMENT

CARB

Condensing Boilers: Optimization of System Performance in Cold Climates

August 2011

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Building AMERICA
U.S. Department of Energy

Overview of Presentation

- Previous Research – 3 Phases:
  - Monitoring and Evaluation of 6 Existing Homes
  - Bench top Research from Thomas Butcher at BNL
  - Design, Monitoring & Evaluation of 3 New Homes
- Next Round:
  - Close collaboration w/ Industry Partners
  - 3 New Homes, 3 Different Systems

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Phase I Existing Homes – Objectives

- Analyze the frequency of condensing
- Determine factors most likely to affect the overall performance
- Identify typical operating conditions in existing installations
- Analyze how the boilers were functioning: cycling frequency; typical flow rates; etc.
- Make recommendations for the design and operating conditions of several new systems.
- Evaluate the monitoring plan and make revisions and refinements where necessary for Phase III.

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Phase I Existing Homes – Key Findings

- Primary/secondary loop plumbing configuration contributes to higher than optimal return water temperatures to the boiler
- Flow rates are higher than recommended, contributing to higher than optimal return water temperatures.
- Baseboard lengths being installed in these homes are consistent with the lengths needed for a low temperature, low flow system.
- Maximum boiler output temperature is typically set to 180°F or higher.
- Boiler supply temps to the domestic hot water tank were set at 180°F or higher for 5 of the 6 homes.

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Phase II Bench top – Objective

- Blow up the boiler!

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Phase II Bench top – Key Findings

- Particularly difficult to blow up the boiler!
- Low mass boiler tested can be operated with:
  - flow rates significantly lower, and
  - temperature rises significantly higher than the manufacturer's recommendations.
- The boiler pressure should be maintained at the high end of its allowable range.

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Phase III New Homes - Objectives

- Design systems for optimal performance
- Verify installed performance
- Develop guidelines for installers outlining key factors for optimizing efficiency:
  - Best control settings
  - Pump selection/sizing
  - Plumbing configurations

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Phase III New Homes - Recommendations

- Maximum boiler supply temperature should be set to 160°F;
- Flow rate through each zone should be 1 gpm;
- Baseboard sizing was based on an average water temperature of 150°F;
- 30 gallon, indirect storage tanks controlled by boiler's controller;
- The primary loop should be removed.

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Phase III – Bin Analysis: 150°F, 2.5 GPM

Bin mean	Hrs	Supply	Load	Return	Dt	
62	738	100.3	1065.8	99.4	0.9	11.1%
57	715	104.7	1731.8	103.3	1.4	10.7%
52	691	109.0	2397.9	107.1	1.9	10.4%
47	643	113.4	3064.0	110.9	2.5	9.7%
42	686	117.8	3730.1	114.8	3.0	10.3%
37	776	122.1	4396.2	118.6	3.5	11.7%
32	767	126.5	5062.3	122.4	4.1	11.5%
27	507	130.9	5728.4	126.3	4.6	7.6%
22	381	135.2	6394.5	130.1	5.1	5.7%
17	297	139.6	7060.6	133.9	5.7	4.5%
12	209	144.0	7726.7	137.8	6.2	3.1%
7	119	148.3	8392.8	141.6	6.7	1.8%
2	68	150.0	9058.9	142.7	7.3	1.0%
-3	28	150.0	9725.0	142.2	7.8	0.4%
-8	20	150.0	10391.1	141.7	8.3	0.3%
-13	8	150.0	11057.2	141.2	8.8	0.1%
-18	2	150.0	11723.3	140.6	9.4	0.0%
			Percent annual heating load met in a condensing mode			89.1%

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Phase III New Homes – Key Findings

- Recovery from setback
  - Extremely slow in all homes monitored
  - Location of outdoor reset sensor is important to system performance
  - Appears to get worse with increasing outdoor temperatures
  - Differential setting can affect recovery time
  - 2-story configuration may be contributing to lag on first floor

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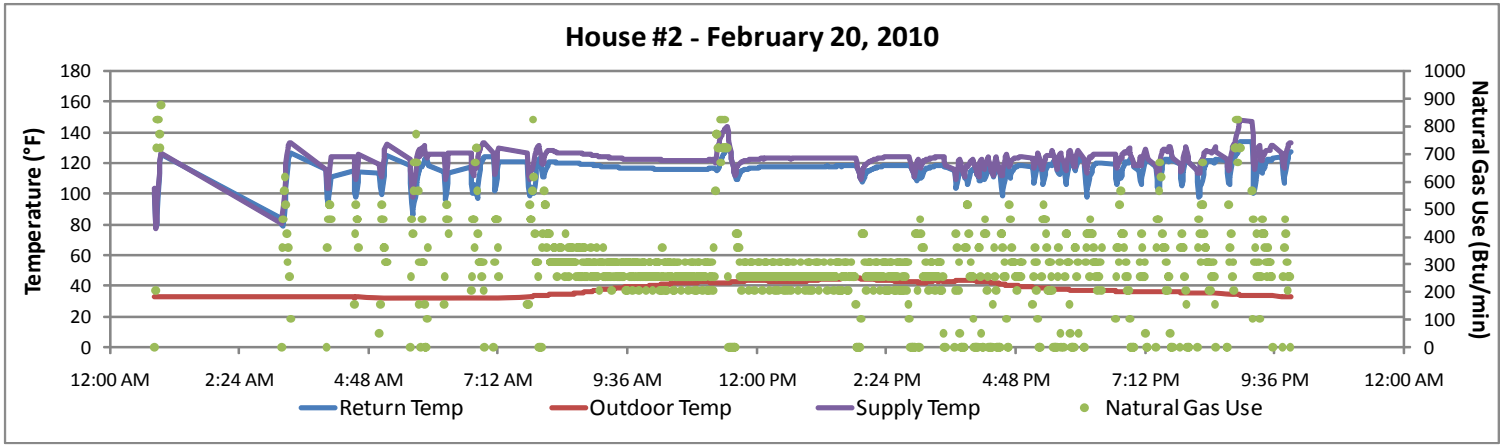
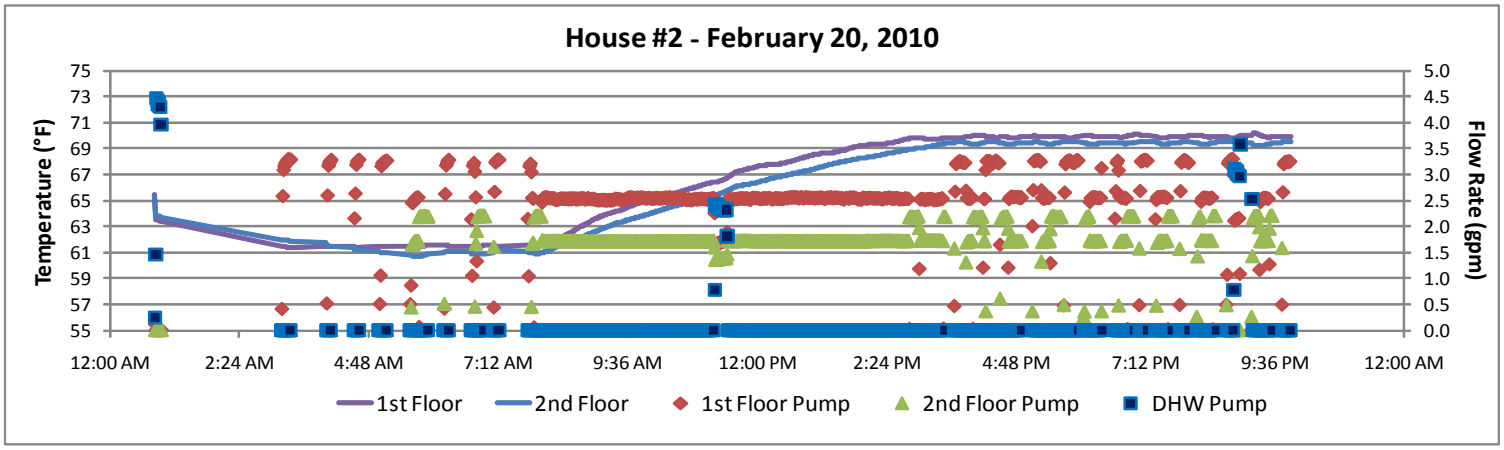
Phase III –Warm Outdoor Temps





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Phase III New Homes – Key Findings

- No heat in swing seasons if outdoor temperatures exceed $T_{out,max}$ but Tstat is calling for heat.

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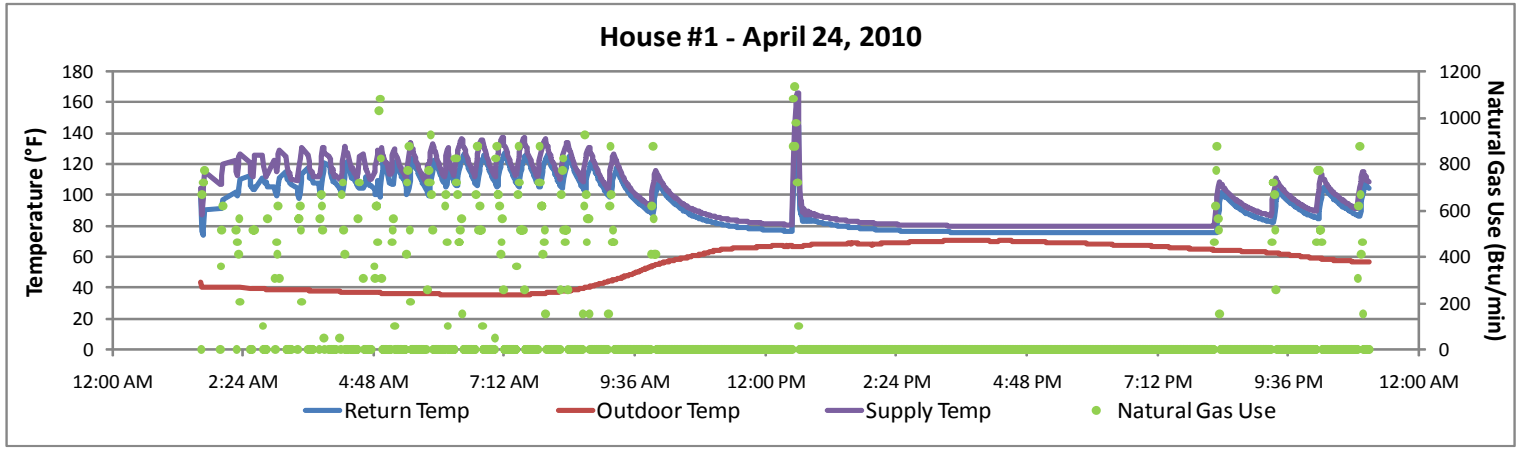
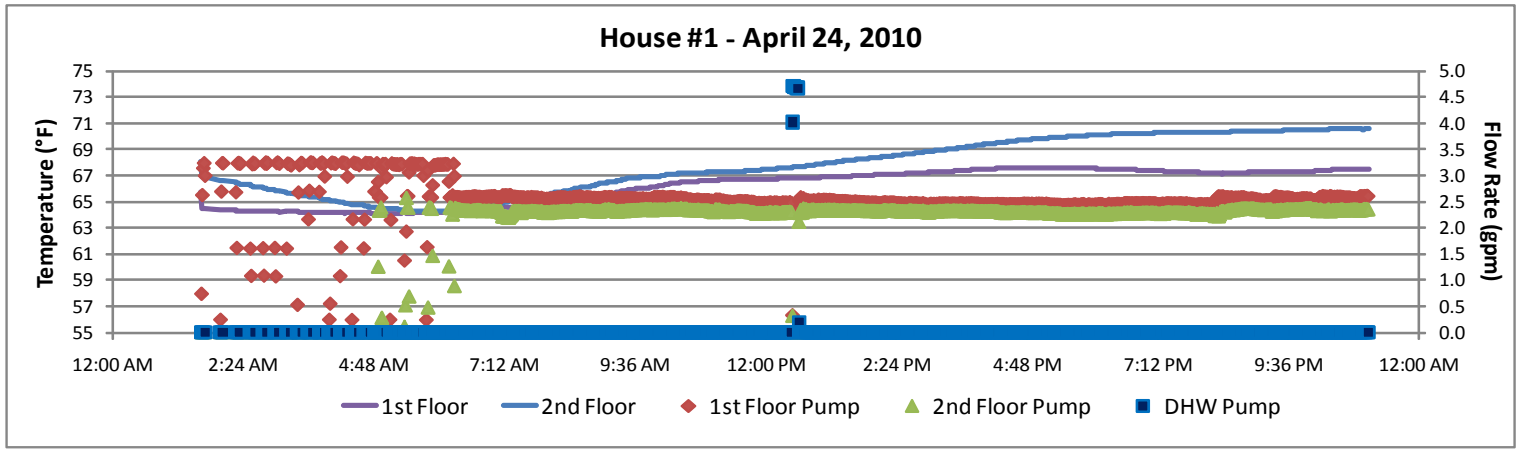
Phase III – No Heat in Swing Seasons





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Phase III New Homes – Key Findings

- Flow Rates were higher than specified:
  - Contractors don't have standard, simple methods for measuring and/or setting flow rates.
  - Until recently, low flow residential pumps for which the flow can be set, have been difficult to find.
  - Different boiler manufacturers have different recommendations for minimum flows through the heat exchanger: installers are reluctant to design systems with very low flows

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Conclusions

- Factors affecting efficiency:
  - Primary/secondary loop configuration
  - High flow rates
  - Lack of information for installer – no guidance on best settings
  - House design - 1st floor zones ran approximately 22 - 35% more often than 2nd floor zones in all three homes.

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Conclusions

- Factors affecting comfort:
  - Severe over-sizing
  - Night time setback
  - Outdoor reset and low limit settings on the boiler
  - $T_{out,max}$ on the boiler curve

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Conclusions

- Factors affecting operation:
  - Removing the primary loop leads to control issues such as domestic hot water (DHW) priority set up, and may require wiring diagram changes.
  - Placement of outdoor reset sensor

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Current Recommendations

- Proper sizing of boiler mandatory
- Lower $T_{s,max}$ on boiler curve
- Raise $T_{out,min}$ on boiler curve slightly
- Reduce flows to achieve 20° ΔT at design
- Size baseboard for low-flow & $T_{s,max}$
- Proper placement of outdoor reset sensor
- Eliminate primary loop <u>if</u> OK with manufacturer

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Upcoming Research

- 3 New Homes
- Similar construction to first round of research
- Applicability to retrofit applications
- Industry Sanctioned Designs

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Upcoming Research

- Analyzing 3 different systems w/ baseboard convectors
  - High mass, indirect tank, zone valves, variable speed pump
  - Low mass, indirect tank, variable speed pumps on zones
  - Low mass, integrated DHW, zone valves, delta-T pump

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Upcoming Research

- Working with:
  - Boiler manufacturers
  - Pump manufacturers
  - Project manager for test homes
  - Plumber for test homes
  - Expert hydronic designers

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Questions?

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Thank You.

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