Installed Performance of High-Efficiency Gas Furnaces

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Test Plan

- Problem Statement
- Experiment
- Analysis
- Expected Results and Follow-on Work

Expected Conclusions

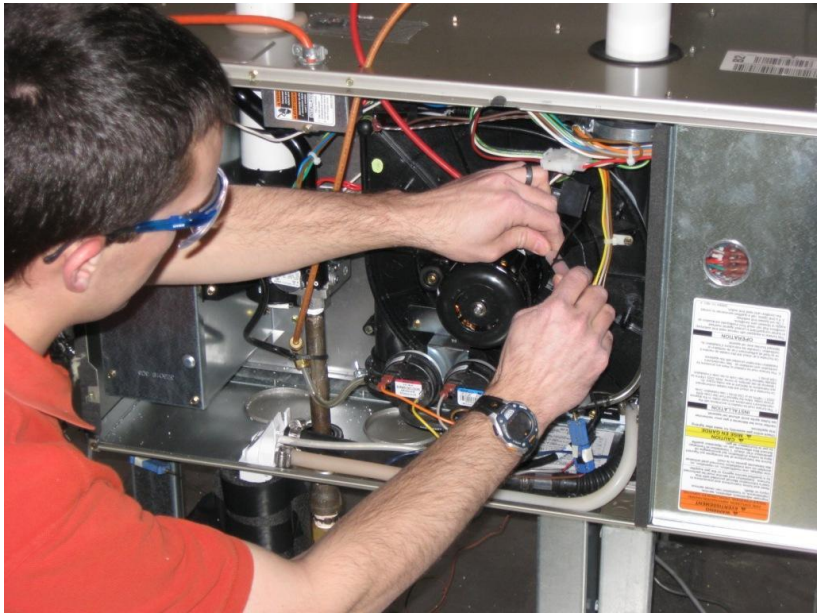
Research Question

How do we get the rated furnace performance in the field?

Problem Statement

Installed performance of gas furnace and AFUE measurement can be quite different

- Uncontrolled environment vs. controlled environment
- Typical residential distribution systems and filters vs. lab ductwork tuned for the test
- Field measurement accuracy vs. laboratory measurement techniques



Problem Statement

Background

- ASHRAE Standard 103 – 2007 current method of test for AFUE
  - Prescribed accuracy of test devices
  - External static pressure guidelines
  - Jacket loss analysis
  - Latent and sensible heat transfer analysis
  - Tests under 3 modes

Problem Statement

Cost-effectiveness

- Three common options:
  - Single stage furnace with single speed motor at 90% AFUE
  - Two stage furnace with multi-speed motor up to 96% AFUE
  - Step modulating furnace with variable speed ECM or multi-tap permanent split capacitance blower motor up to 98% AFUE

Replacing Furnace (AFUE)	With Furnace (AFUE)	Installed Cost (80,000 Btu/hr Capacity)	Incremental Cost from 78% AFUE
78%	78%	$1040	$0
78%	90%	$2400	$1360
78%	92%	$2640	$1600
78%	94%	$2880	$1840
78%	96%	$3120	$2080

Source: NREL National Residential Efficiency Measures Database

Problem Statement

Cost-effectiveness

- Cost/benefit:
  For $1000 annual heating cost
  - 78% AFUE to 90% AFUE has a 9 year payback
  - $500 utility rebate and 25% tax credit reduces payback to 5 years

Economics look good for cold climates.

But how can we get the rated AFUE in the field?

Annual Estimated Savings for Every $100 of Fuel Costs by Increasing Your Heating Equipment Efficiency

Existing System AFUE	New/Upgraded System AFUE								
	55%	60%	65%	70%	75%	80%	85%	90%	95%
50%	$9.09	$16.76	$23.07	$28.57	$33.33	$37.50	$41.24	$44.24	$47.36
55%	----	$8.33	$15.38	$21.42	$26.66	$31.20	$35.29	$38.88	$42.10
60%	----	----	$7.69	$14.28	$20.00	$25.00	$29.41	$33.33	$37.80
65%	----	----	----	$7.14	$13.33	$18.75	$23.52	$27.77	$31.57
70%	----	----	----	----	$6.66	$12.50	$17.64	$22.22	$26.32
75%	----	----	----	----	----	$6.50	$11.76	$16.66	$21.10
80%	----	----	----	----	----	----	$5.88	$11.11	$15.80
85%	----	----	----	----	----	----	----	$5.55	$10.50
90%	----	----	----	----	----	----	----	----	$5.30

Source: DOE EERE

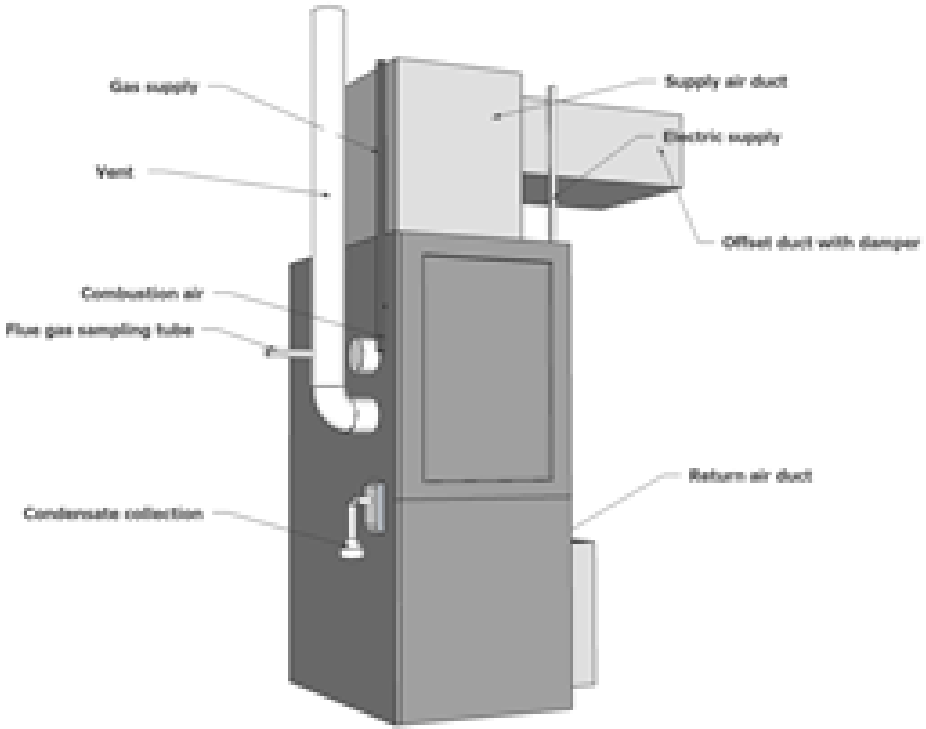
Experiment

Scope

In the lab, test all 3 furnace types under standard conditions and conditions that simulate field installation problems:

1. Oversized furnace
2. Undersized ducts
3. MERV (high performance) filters

Recommend best practices for installation



Experiment

Test detail

- Oversized furnace
  - 70% oversize (standard)
  - 100% oversize
  - 120% oversize
- High external static tests (tight ducts)
  - 0.2 inches water column pressure rise (standard)
  - 0.3 inches WC
  - 0.5 inches WC
- High Efficiency Filter
  - MERV 8 filter

- Four tests in the standard:
  1. Steady-state test
  2. Cool-down test
  3. Heat-up test
  4. Condensate heat loss under cycling conditions test

Equipment needed and required accuracy

Measurement	Equipment Needed
Gas flow rate	Gas flow meter calibrated to be accurate within 1% of flow volume
Electric consumption	Watt meters with an accuracy of 1% of measured energy
Temperatures	Bead thermocouples with an accuracy of ±2°F
Air pressure	Manometer or pressure gage with an accuracy of ± 0.01 inches of water column
Power conditioning	Voltage to be controlled within 1% of nameplate requirement on the furnace
CO_2 concentration	Within ±0.1%
Weight of water	Scale accurate to ±0.5% of quantity
Time	Stopwatch or timer accurate to ±0.5 sec/hr
Tracer gas	Gas Chromatograph accurate to ±2% of measured concentration
Gas heating value	Gas Calorimeter ±1% in Btu/scf
Air flow rate	Pitot tube flow station

Analysis methods prescribed in the Standard

11.4.12 Annual Fuel Utilization Efficiency. The annual fuel utilization efficiency, AFUE, for each $Effy_{HS}$ shall be expressed as a percentage and defined as

$$AFUE = \frac{5200 Effy_{SS,W} Effy_{HS}}{5200 Effy_{SS,W} + 2.5(1+\alpha)(4600) Effy_{HS}(Q_P/Q_{IN})}$$

where

5200	=	annual average heating degree-days,
$Effy_{SS,W}$	=	weighted average steady-state efficiency as defined in 11.4.8.9,
$Effy_{HS}$	=	heating seasonal efficiency as defined in 11.4.11.3,
Q_{IN}	=	maximum fuel input rate as defined in 11.4.8.1.1,
α	=	oversizing factor for furnaces and boilers as defined in 11.4.8.2,
Q_P	=	pilot flame fuel input in Btu/h,
4600	=	average non-heating-season hours per year.

Lab Photos

Installation Photos

Expected Results and Follow On

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Expected results

- AFUE values not expected to vary significantly with ESP changes if proper fan speed adjustments are made
- AFUE values will be lower with at lower part-load associated with oversizing
- Power consumption will increase with increasing ESP

Follow-on tests

- Expand test parameters to include improper field adjustment of burners and blowers, improper vent system design, and leaky ductwork.
- Compare results with field results on the same equipment

Expected Conclusions

- High-efficiency furnaces are cost-effective, especially with rebates and tax credits
- AFUE rating is calculated under controlled laboratory conditions that may vary significantly in the field
- Proper installing contractor adjustments will produce the best field performance
- Blower power may vary significantly with tight ducts, depending on the furnace type chosen
- Training of contractors on the proper installation techniques is critical:
  - Gas valve and fan speed adjustments
  - Vent sizing
  - Furnace capacity
  - Distribution systems adjustments