Heating Systems Best Practices II
Alternative Systems & Approaches for Low Heat Load Homes

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Better Buildings by Design 2008
Burlington, VT
February 2008
Objectives

• Discuss what constitutes a “low heat load” home
• See how certain oil-fired systems can function efficiently in low load homes, in spite of burner limitations
• Appreciate new gas burner technology, and the implications for low load homes
• See the good and the bad of combination systems
• Appreciate the new integrated eKoComfort space/water/ventilating systems now appearing in the marketplace, and how these have particular application in energy efficient homes
• Get a glimpse of the next generation of integrated systems, leading towards the “net zero” homes of the near future
What are you looking for?
Oil-Fired Systems
Most **crucial** element to achieve good performance and high efficiency in low load homes is the **oil burner**
Retention Head Burner
Retention Head Oil Burner

- Better fuel-air mixing (EA - 50%)
- Fair resistance to stack and house pressure fluctuations/depressurization
- Resists off-cycle flow loss
- Firing rate down to 70kBtu with good EA
- Efficiency should be 80-83%
- Should have delayed action solenoid valve to reduce soot/degradation from cycling operation
High Static Burners
Hi Static Burner
High-Static Oil Burner

- Excellent fuel-air mixing (ExcessAir - 25%)
- Stable under stack (exhaust) pressure fluctuations due to wind/turbulence
- High resistance to house depressurization, which can be a char of low energy housing
- More suited to sealed combustion operation
- Zero off-cycle flow loss (ex post-purge)
- Firing rate down to 70kBtu with good excess air control
- Efficiency should be 82-86+%
- Minimal sooting/degradation
- Should be burner of choice for low energy homes
Air Requirements

- Cast iron head burner 100% excess air
- Retention head burner 50% excess air
- High static burner 25% excess air
- Barometric damper 1-5 times air for combustion
- Combustion air related to air change for 1500 ft² two storey + 750 ft² basement, 1 air change = 18000 ft³/hr
Air Requirements of Conventional & High Static Oil Burners

Air Changes/hour

- Conv Oil Burner
- Conv Bnr + Dilution
- Hi-Static Burner
- Hi-Static Bnr + Dilution

Graph showing air requirements for different types of oil burners.
Oil in an Energy-Efficient Home?
Problems with Oil Nozzles at Low Firing Rates
Oil
House Demand vs Heat Output

• Potential problem with oil and energy-efficient housing, with minimum firing rate ~ 70k Btu/h
• This results in a minimum heat output = 60 000 Btu/h, and many feel more comfortable at 67 000 Btu/h
• Canadian houses are now being designed at a Heat Load ~ 40 000 Btu/h
• Means over-design of 1.7
• Becomes more/less significant depending on how heating load is distributed re design temperature (Flat vs triangle)
Other Possibilities

- Nozzles of 0.4 gph, although many find they clog or their spray pattern deteriorates quickly, leading to sooting, coking, failure.

- Using a lighter fuel might help this problem, although I have a difficult time recommending keosene.
However, well-conceived combined systems for space and water heating can be an effective way around the technical limitation of oversizing with oil-fired equipment in energy efficient housing.
Tankless Coil Boiler or Tank-within-Tank Boilers not Recommended!
Oil-Fired Technologies That Can Work in Low Energy Homes

- Must be able to divert load, rather than just short cycle
- Must be able to withstand depressurization, or operate as sealed combustion
- Typically will use an external storage tank and water-to-water exchanger for service water
Efficient Oil-Fired Space/Water Heating Systems
Condensing for Part of the Season

Part of heating season boiler can operate in condensing mode (%)

Baseboard oversize factor

- Gas - Minneapolis
- Gas - Long Island
- Oil - Minneapolis
- Oil - Long Island
Gas-Fired Systems
High Efficiency Condensing Furnace

********
Dewpoints for Gaseous Fuels

Excess Air, %

°F

- Natural Gas
- Propane
High-Efficiency Gas Furnace

• Powered exhaust
• Electronic ignition
• No dilution air
• High resistance to depressurization
• Excellent side-wall vent - plastic!
• Should be well above 90%
• Efficiency improves with slight oversizing
• Units are available at 40 000 Btu/h, suiting low energy housing
What about two-stage furnaces?
Lower speed in ducts can result in “better” heat exchange to duct, resulting in greater heat loss, less heat to registers & increased t/s & furnace operation.
What about two-stage condensing furnaces?

- Compared to condensing furnace with PSC circ fan motor, 2-stage furnace with ECM gave increased gas use.
- Increased operation time (~ doubled) may lead to sig. increase in electrical use, esp if PSC motor used with ID fan.
- Loss of heat to distribution system may give less heat to some registers and result in homeowner upping the thermostat.
- No evidence of gas savings, in spite of claims.
- May give increased comfort.
- May be only way of getting ECM fan motor.
Gas Boilers
“Antique” Conventional Boilers (natural draft) are still available!

(at low **real** efficiencies and subject to depressurization)
Newer Gas-Fired Boilers
Major Advances in Gas Burners
- High modulation
- Power Burners
It’s a New Gas Burner World

- Power burners (mainly forced draft)
- Gun, metal matrix or ceramic (cylinder, cone, plate)
- Low excess air (EA)
- Many have good modulation with excellent excess air control over operational range
- Ultra-Low NOx
- Usually on boilers
- Provide a more assured pathway to high efficiency condensing and turn-down suitable for a range of house heat load demands
Recent Major Advances in Gas Boilers
Can a condensing boiler condense in low energy housing?

- Yes, if radiant floor
- Likely, if fan coil
- Difficult but possible if conventional hydronic, by integrating outdoor reset, reduced flowrate/increased heat exchange, service water preheat, preheat ventilation air, as with . . .
Dewpoints for Different Fuels

Excess Air, %

°F

- Natural Gas
- Propane
- No. 2 Oil
Enhancing Condensing Boiler Operation

- **Outdoor reset** lowers supply temp.
- **Increased heat exchange**
- **Preheat service water**
- **Ventilation air preheat with boiler return**

Get return water below flue gas dewpoint!
Condensing boiler with good modulation ideally suited to radiant floors and low energy housing
Air Requirements of Conventional Gas Boilers & High Efficiency Condensing Gas Furnaces

![Bar chart showing air requirements for different types of gas systems.](chart.png)
Gas Water Heaters
Natural draft – continuous pilot gas water heaters do not belong in today’s tighter, energy efficient housing.
Power-Vented Water Heaters

- Pilot light or not
- Draft hood
- High on- and off-cycle losses
- High resistance to depressurization
- Most use a lot of house air, and have low efficiencies
Condensing Tank Water Heater

> 90% efficient, as mains water provides driving force for condensing
Tankless Water Heaters

Wide range of technologies and efficiencies

ACT examining performance in lab and field, as well as hot water use trial, to optimize performance and develop appropriate seasonal efficiency test procedure
Natural Gas vs Propane

• Natural gas has a higher hydrogen content, so produces more water vapour
• Higher dewpoint with natural gas, so easier to condense than propane
• Propane condensing furnaces less efficient than NG
• Propane mid-efficiency furnaces or boilers more efficient than natural gas
• Propane boilers even more difficult to condense than natural gas
Combined Space-Water Heating Systems
Performance of Combo Systems in “almost” real-life conditions
Efficiency of Tank-Based Combo’s vs Outdoor Temperature
Efficiency with Tankless Combo

Figure 9: Combo1, Combo2, Combo3 and Combo4 efficiencies vs. outdoor temperature
Inefficient “Instantaneous” Segregated, Non-Condensing Boiler with Modulation

Flue Gas Analysis

- Flue Gas T
- O2
- CO2
Non-Segregated Condensing Tank-Based Space/Water “Systems”
Efficient Low Mass Condensing Boilers with Segregated Tap water
In new and renovated housing:

- Space Heating falling
- Water Htg very inefficient
- Need for fresh air - Ventilation
eKOCOMFORT (AIMS) Advanced Integrated Mechanical Systems

A major Canadian initiative to develop and market high efficiency, integrated space-water-ventilating systems

“www.eKOCOMFORT.com”
eKOCOMFORT
Low Mass Condensing Boiler at ACT
eKocomfot
High Mass Boiler
at CCHT
What’s coming in the future?
Renewable Liquid Fuels

- Bio-oils
- Biodiesel
- Blends
- Alcohols
- ...
Since people always seem to want a fireplace,
let’s take the fireplace as the centre of our integrated system
Next Generation Integrated System:
Condensing Fireplace-Based
Characteristics of High Efficiency Condensing Integrated Gas Fireplace

- Efficiency > 90%
- Heats space & tap water + ventilation
- Radiant heat from flame in winter by fire
- Central house heating
- No radiation in summer, but still hot water
- Pleasure of a fire !!
Advanced Technologies to supply both Heat and Electricity
Stirling Engine

• Being an external combustor, how suitable is it to use lower grade or renewable fuels (biomass, etc.)?
• How can its electrical output be increased?
• How should its BOP be optimized?
• Can it be cascaded with another technology to get more electricity?
Fuel Cells
BOP/TUM
Performance & Modelling

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Thermophotovoltaic (TPV)
Heat & Power Research

- Performance of advanced PV cells for combined heat & power
- Investigations into highly-efficient heat-to-radiation conversion materials in our TPV furnace facility
- Novel cascaded radiant burner developed
- Now working on cascaded TPV and TE (thermoelectric) system for higher electric output
Drake Landing Solar Community

- in Okotoks, Alberta
- 52 two-story, R-2000 detached homes
- Heat provided by Solar District Energy System
  - short term: 2 hot water storage tanks
  - long term: borehole thermal energy storage with 144 boreholes
  - backup: natural gas boiler
Drake Landing Solar Community
Drake Landing has won more than 20 National and International Awards, including:

- **United Nations**
  Livable Communities Gold Award,

- **International Solar Association**
  Most Innovative Solar Project Award,
Cogeneration in Energy Efficient Housing with Borehole Storage

- R2000 house (40k btu/h design load)
- Micro-cogen engine with 6 kw electric & 10:1 turndown
- 40% efficient gen.
- Heat not use for space or hot water is put down into boreholes, for seasonal storage & utilization
External Combustion Stirling Engine Cogeneration in EE Housing with Hot Water Phase Change Storage
Micro Cogeneration Units for EE Housing in the Lab
Summary

For low heat load houses:

• With oil, boilers equipped with high static burners, and having external, segregated how water storage, can satisfy low heat loads and comfort at high efficiency
• With gas, the new, highly modulating burners in condensing boilers allow the satisfaction of any heat load. Special effort in installation and control must be made to ensure condensing
• While Vermont has a history of hydronic heating, consideration should be given to eKoCOmfort-type systems, which can supply space and water heating, along with heat recovered ventilation, through a fan coil-based warm air system
• Micro-cogeneration systems, just appearing on the market, offer high efficiency heating, along with at least partial grid independence
Review of Objectives

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Review of Objectives

• Discuss new space & water heating technologies for oil, gas and wood
• Understand what makes heating systems efficient
• Appreciate advantages & disadvantages of various new “high efficiency” systems
• Be better able to assess suitability of newer technologies for comfort and high efficiency operation in new or existing housing
Heating Publications

http://energy-publications.nrcan.gc.ca/index_e.cfm

under Consumers:
Heating, Cooling & Ventilation
Pittsburgh, PA
2008

April 7-11, 2008

affordablecomfort.org
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