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Boilers: Back to Basics

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Presentation Outline

- Basics of Natural Gas
- Heating Value
- Types of Boilers
- Translates to Heat in the System
- Loss Mechanisms
- Conclusions/Summary

Natural Gas Basics

- Caloric Value: ~1,000 BTU/ft^3

Typical Composition of Natural Gas

Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	A, He, Ne, Xe	trace

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Heating Value

Amount of heat released during the combustion of a specified amount fuel

- Higher Heating Value (HHV)
- Lower Heating Value (LHV)

$$HHV = LHV + h_v \times (n_{H2O,out} / n_{fuel,in})$$

h_v = heat of vaporization

$n_{H2O,out}$ = moles of water vaporized

$n_{fuel,in}$ = moles of fuel combusted

Types of Boilers

Description	Thermal Efficiency	Working Temp
Std. Hot Water Boiler	80 – 88%	130 – 200 ºF
Condensing Hot Water	88 – 98%	? - 130 ºF
Direct Contact Water Heater	Up to 99%	? - 185 ºF
Steam ≤ 15 psi.	78 – 84%	212 - 250 ºF
Steam > 15 psi.	78 – 84%	> 250 ºF

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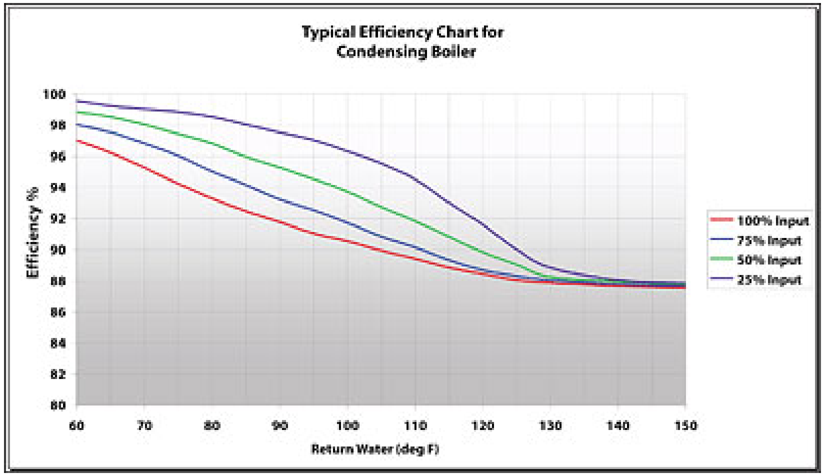
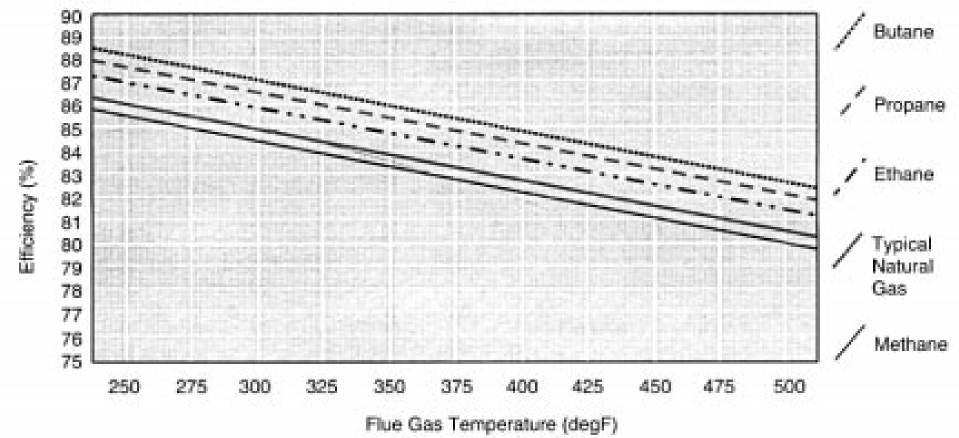
How Temperature and Pressure Relates to Boiler Efficiency



Source: Engineered Systems, 2006



Source: Cleaver Brooks, 1996

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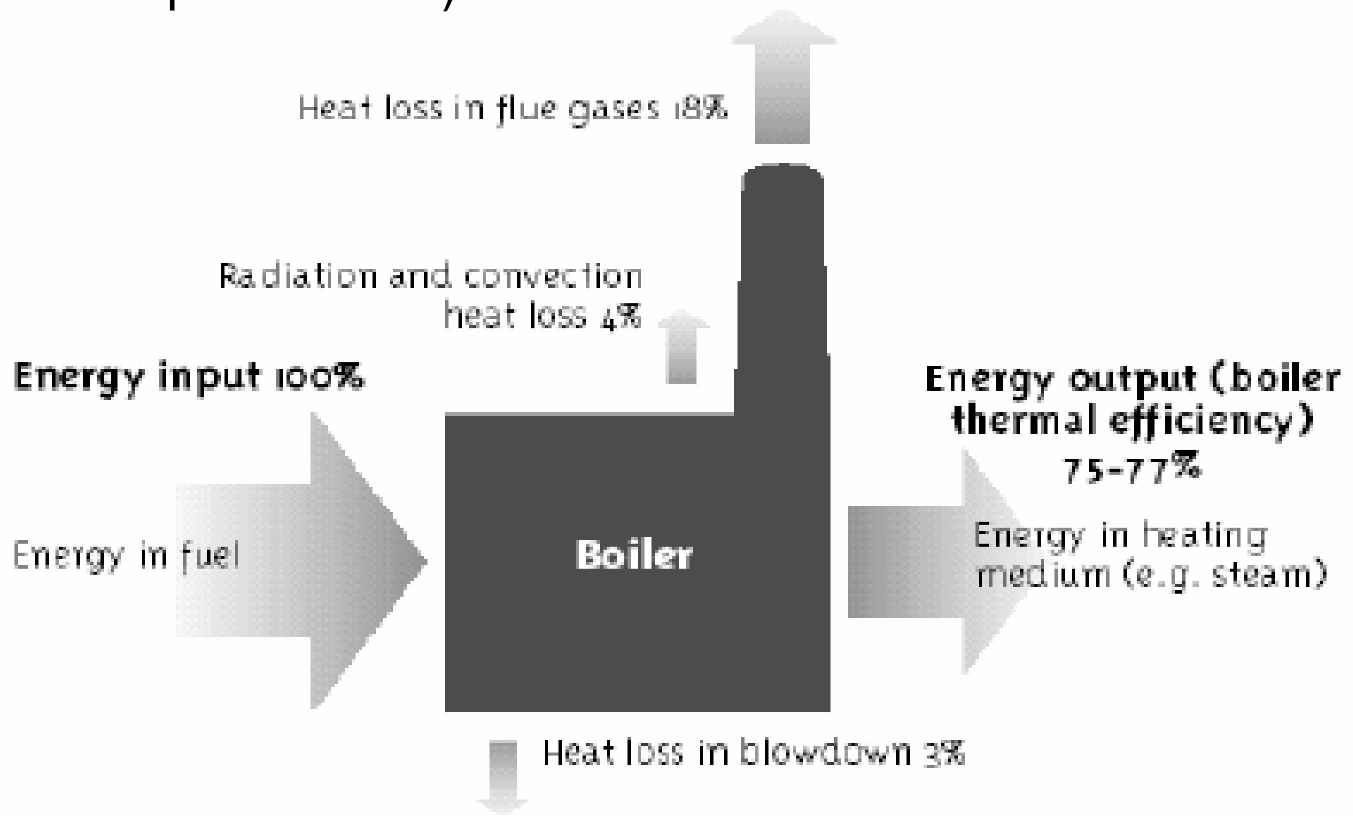
System Heat Losses

Typical Energy Balance of a Boiler/Heater
(before improvements)



Source: *Boilers and Heaters: Energy Efficiency Improvements*, Natural Resources Canada, 2001

Boiler

- Flue Gas Loss (5-15%)
  - Waste Heat Recovery
- Blowdown (3%)
  - Necessary to reduce scale and deposits that can reduce efficiency
  - Too much blowdown can also lead to efficiency losses
- Convection and Radiation (5%)
  - Insulation
- Latent Heat (10%)
- Burner Control Method (5-30%)

Burner (1-5%)

- Air/Fuel Ratio
  - Minimum O_2 for Natural Gas is 1.5%
  - Techniques
    - O_2 trim system
    - Modulating Burner
  - More precise control of O_2 is recommended for higher flue gas temperatures

The **higher** the flue temperature, the **lower** the efficiency.

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O2, Temp and Efficiency

Combustion Efficiency for Natural Gas						
Excess, %		Combustion Efficiency				
		Flue Gas Temperature Minus Combustion Air Temperature, °F				
Air	Oxygen	200	300	400	500	600
9.5	2.0	85.4	83.1	80.8	78.4	76.0
15.0	3.0	85.2	82.8	80.4	77.9	75.4
28.1	5.0	84.7	82.1	79.5	76.7	74.0
44.9	7.0	84.1	81.2	78.2	75/2	72.1
81.6	10.0	82.8	79.3	75.6	71.9	68.2

Assumes complete combustion with no water vapor in the combustion air.

Source: *Steam Tip Sheet #4*, U.S. DOE, 2006

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Distribution (25-30%)

- Piping Leaks (15-20%)
  - Rate is a function of orifice size and pressure of steam
- Standby Radiant Loop Loss (10%)
  - Insulation
- Steam Trap Loss (5%)
  - Sizing steam trap is key
  - Requires maintenance
- Flash Steam Loss (depends on pressure)

Lower pressure and temperature to meet the system needs.

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Operation and Maintenance (10-15%)

- Water Treatment (2-5%)
  - Case by case basis
- Condensate Return
- Load Control (10-25%)
- Blowdown (3-5%)

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Boiler Sizing/Controls

- Can improve efficiency by 10-25%
- Match the load to the size of boiler and the temperature/pressure
- Consider outdoor air temperature setback
- Consider hot water demand priority
- Consider modulating burner technology

Summary

- Select boiler type based on end use temperatures. Lower is more efficient.
- Seek to minimize system complexities.
- Integrate into the overall building controls if possible.
- Trend toward minimizing the use of steam systems.
- Post-install commissioning is important.

Contact Info

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