High Efficiency Gas Boilers

Overview

> Smaller condensing boilers
> High efficiency systems for large boilers
> Heat recovery heat exchanger
> Superboiler
Smaller Condensing Boilers

Smaller Boilers

> Smaller / commercial boilers
> Used for hot water and low pressure steam generation
> Commercial building space heating service
> 0.1-20 MMBH in size
**Smaller Condensing Boilers**

- Generation 1 condensing boilers
  - Boilers with added heat exchangers
- Generation 2 condensing boilers
  - Boilers with air heaters

**Boiler Comparisons**
Non-Condensing Boilers

> Improved efficiency due to new extended heat exchanger layouts taking exhaust temperatures down to lower but still non-condensing levels

> Note addition of the vent fan

Picture Courtesy of Atlantic Boiler
Condensing boilers add another separate heat exchanger to lower exhaust gases further in temperature.

Heating water runs thru condensing heat exchanger and then thru boiler.
Generation 1 Condensing Boilers

> Added heat exchanger is where ALL the condensing take place
> Added heat exchanger is composed of a material that resists corrosion from condensate

The lower the exhaust temperature the higher the efficiency
> Gen 1 condensing boilers CANNOT lower exhaust temperature below the return water temperature of the heating system
> The best application is any system with low return water temperatures
**New High Efficiency Hot Water Boilers**

> Internal layout
  - Compact primary heat exchanger
  - Secondary condensing heat exchanger
    - Corrosion resistant stainless
  - 97% efficient
  - Direct venting

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**New High Efficiency Hot Water Boilers - Even in Oil Systems**

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**New High Efficiency Hot Water Boilers**

![Image of high efficiency hot water boiler](image1)

*Picture Courtesy of Cleaver Brooks Boiler*

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**Larger Condensing Boilers (to 4 MMBH)**

![Image of larger condensing boiler](image2)

*Picture Courtesy of Fulton Boiler*

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1. Fuel and air mix together in the high banddown nozzle into burner.
2. The fuel ignites and the combustion process completes within the generously used furnace.
3. Fuel gases travel through the second heat pass within the primary heat exchanger.
4. The flue gases are gathered in a collection chamber and transfer into the condensing heat exchanger.
5. Flue gases condense along the Duplex stainless steel heat exchanger, maximizing the boiler efficiency.
6. Gases exit through the fire outlet.
7. High density insulating oil-water backed surface extends standby times.
High Efficiency Gas Boilers

Large Condensing Boiler Battery

Five Vantage 3.0MM Btu/hr Condensing Boilers with common HW supply and HW return manifolds, Condensate Drain, single point gas and electrical supply.

Return Water Temp Dependency

Thermal Efficiency vs. Return Water Temperature

- Low Fire
- Mid Fire
- High Fire

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Heating System Return Water Temperatures

<table>
<thead>
<tr>
<th>System</th>
<th>Supply Water Temperature at Design Heating Load (°F)</th>
<th>Return Water Temperature at Design Heating Load (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiator System</td>
<td>180°</td>
<td>160°</td>
</tr>
<tr>
<td>Baseboard Radiation</td>
<td>180°</td>
<td>160°</td>
</tr>
<tr>
<td>In-Floor Heating</td>
<td>110-140°</td>
<td>90-120°</td>
</tr>
<tr>
<td>Fan Coils</td>
<td>140°</td>
<td>120°</td>
</tr>
</tbody>
</table>

Supply and return water temperatures are often set down in warmer weather when much lower than design heating loads occur. Temperatures shown are approximate.

>Unless you can get exhaust down to <50°C (112°F), efficiency <90%

> If the return water temp >100-110°F, this can’t happen

Picture Courtesy of Atlantic Boiler
Smaller Condensing Boilers

> With higher temperature radiant or baseboard systems
  — Temperature setback is needed to achieve efficiency promised in moderate weather
    • Turns down water temps in mild weather
  — Little or no condensing will occur during design (coldest weather) heating operation
  — Result to the gas utility - doesn’t reduce peak gas demand

Smaller Condensing Boilers

> With lower temperature radiant floor systems
  — Low return water temperature at all times
  — More continuous condensing operation

> WILL reduce peak gas load
In this case, the condensing heat exchanger does NOT heat water

Condensing heat exchanger preheats combustion air

That heat recycles into the boiler
**Generation 2 Condensing Boilers**

> With indoor combustion air – air will remain in 70-75°F range  
  — Constant consistent condensing

> With outdoor combustion air  
  — Drops at design conditions  
  — Enhanced condensing in cold weather

> Provides maximum efficiency in the coldest weather

> WILL reduce peak gas load

---

**Generation 2 Condensing Boilers**

> Condensing heat exchanger does NOT heat water

> Condensing heat exchanger preheats combustion air
**Generation 2 Condensing Boilers**

> With indoor combustion air – air will remain in 70-75°F range
   > Constant consistent condensing
> With outdoor combustion air
   > Drops at design conditions
   > Enhanced condensing in cold weather
> Provides maximum efficiency in the coldest weather
> WILL reduce peak gas load

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**Efficiency Comparison**

![Efficiency Graph](image)

- NEW GENERATION BOILER
- CONVENTIONAL CONDENSING
- HIGH EFFICIENCY
- CONVENTIONAL BOILER

*Picture Courtesy of Atlantic Boiler*
Boilers are Scalable to Commercial

> The return temperature of the heating system water only affects the exhaust temperature at the exhaust of water heat exchanger

> Air preheater is not affected
High Efficiency Gas Boilers

Venting

Standard through the wall balanced flue

Picture Courtesy of Atlantic Boiler

Required Service Capacity

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Eff. @ Design Temp</th>
<th>Heating Operation</th>
<th>Maximum Output</th>
<th>Maximum Gas Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>80%</td>
<td></td>
<td>1.0 MMBH</td>
<td>1.25 MMBH</td>
</tr>
<tr>
<td>Condensing – low temp</td>
<td>95%</td>
<td>Low temp in floor heating</td>
<td>1.0 MMBH</td>
<td>1.05 MMBH</td>
</tr>
<tr>
<td>heating system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensing</td>
<td>82%</td>
<td>Baseboards</td>
<td>1.0 MMBH</td>
<td>1.21 MMBH</td>
</tr>
<tr>
<td>2nd Gen Condensing</td>
<td>98%</td>
<td>Baseboards</td>
<td>1.0 MMBH</td>
<td>1.02 MMBH</td>
</tr>
</tbody>
</table>

In evaluating the required gas supply capacity – the efficiency at design (coldest) temperature is the only important point. Efficiencies shown are approximate.
Questions?

High Efficiency Systems for Large Boilers
Terminology

> Economizer
  — Captures exhaust heat to warm feedwater

> Heat Recovery Heat Exchanger
  — Heat exchanger in the flue gas to warm some other load entirely

> Possible loads
  — Domestic hot water
  — Hydronic (hot water) space heating
  — Separate in floor space heating
  — Even outdoor sidewalk ice melting

Efficiency Improvement

> Economizer
  — Improvement for low temperature water boilers only 2-4%
  — Rises for higher pressure steam boilers
    • Function of the return condensate temperature and the boiling point

> Flue Gas Condenser
  — Efficiency improvement depends on finding and isolating a lower temperature load
Economizers

> Additional heat exchanger added onto larger boilers to enhance efficiency
> Newer technology for intermediate sized steam boilers
  — Pressures to 250 Psig (or so)
  — 10-40 MMBH
  — Most commonly fire-tube

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Economizer

![Economizer Diagram](image.png)

Fig. 34.3 A shell boiler with an economizer

Picture Courtesy of Spirex Sarco and Cleaver Brooks
**Generic Economizer**

- Used to preheat feedwater before it enters boiler
- Adds efficiency to the extent feedwater requires pre-heating
- May allow condensation or not

![Generic Economizer Diagram](image)

**Economizers**

- Market development
  - PAST: economizers for smaller boilers were produced by secondary equipment supplier
  - NOW: large boiler manufacturers are now producing their own economizers
  - SHOWN: Cleaver Brooks Economizer on CB Boiler

![Economizers Image](image)
Economizers

**Conventional Layout**

> This economizer will not handle condensation

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Economizer
Condensing

> This CB factory built economizer WILL handle condensation

Economizers

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**Economizer**

*Mounting for Smaller Units*

- Economizer supported by boiler
- Limitation on the weight boiler can support

![Diagram of Economizer Mounting for Smaller Units](Picture Courtesy of Cleaver Brooks)

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**Economizer**

*Mounting for Larger Units*

- Weight of larger economizers will require supports and rigging
- Both horizontal and vertical mounting is possible

![Diagram of Economizer Mounting for Larger Units](Picture Courtesy of Cleaver Brooks)
**Economizer**

*Efficiency with High Make-Up Water Levels*

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**Economizer**

*Efficiency with Non-Condensing Economizer*

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### Table: Economizer Efficiency with Non-Condensing Economizer

<table>
<thead>
<tr>
<th>BOILER HP</th>
<th>LOAD %</th>
<th>ECONOMIZER MODEL NO.</th>
<th>EFF W/O ECON</th>
<th>% FUEL SAVED</th>
<th>EFF WITH ECON</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 hp</td>
<td>100</td>
<td>CCE-16A6AL</td>
<td>82.05</td>
<td>2.50</td>
<td>84.55</td>
</tr>
<tr>
<td>125 hp</td>
<td>100</td>
<td>CCE-18D6AL</td>
<td>80.76</td>
<td>3.84</td>
<td>84.6</td>
</tr>
<tr>
<td>150 hp</td>
<td>100</td>
<td>CCE-18D7AL</td>
<td>81.81</td>
<td>3.04</td>
<td>84.85</td>
</tr>
<tr>
<td>200 hp</td>
<td>100</td>
<td>CCE-18E6AL</td>
<td>82.40</td>
<td>2.34</td>
<td>84.74</td>
</tr>
</tbody>
</table>

NOTES:
1. Feedwater temperature to Economizer 227 °F (Deaerated).
2. Selections are based on best Btu savings per dollar costs.
3. Boiler is firing natural gas.
4. Boiler operating pressure is 125 psig (acceptable tolerance ± 5 psig).
4. Contact your local Cleaver-Brooks representative for sizing detail.
Third-Party Economizers

Direct Contact Economizers
For Larger Boilers

> Very large boilers, high pressure boilers, and boilers built for power generation will come equipped with economizers as standard equipment.

Large Boiler Economizer

> Uses left over heat in the exhaust gases to pre-heat feedwater.
Questions?
Heat Recovery Heat Exchanger

> May be practical to use a heat exchanger in the flue gas to warm some other load entirely
  — Then a “heat recovery heat exchanger”

> Possible loads
  — Domestic hot water
  — Hydronic (hot water) space heating
  — Separate in-floor space heating
  — Even outdoor sidewalk ice melting
Flue Gas Condenser

Condensate

> On larger boilers, condensing economizers and heat recovery heat exchangers produce huge flows of condensate

> May serve a useful purpose
   - Boiler water system make-up
   - Lawn watering and garden maintenance

> Cleanliness of condensate water depends on the fuel
   - Natural gas (or propane) condensate – very clean
   - Condensate from oil burning can be contaminated
Questions?

Superboiler
What Problem Does Superboiler Solve?

> Large number of industrial operations need smaller amounts of steam from 15 to 250 psig
  — Boiling points can be as high as 400°F
  — Lowers standard boiler efficiency
  — If the boiling point is at 400°F – exhaust temperatures from a standard boiler must be higher

What is the Problem Superboiler Solves?

> Industrial steam customers also need:
  — Fire-tube design – simpler to operate
  — Compact boilers
  — Low NOx emissions
  — Open condensate return systems require de-aeration
What is the Problem Superboiler Solves?

> Why not just add an economizer??
> Normal de-aerator uses live steam to heat feedwater to 212°F to drive out air contamination
> Hot feedwater to an economizer limits the improvement in efficiency

Superboiler

> Aggressive use of economizer and air heater technology
> Raise efficiency even for industrial pressure steam generation at elevated pressure
Superboiler

> Two economizers
  ─ One before de-aerator and one after
  ─ Heat for de-aeration comes from exhaust gases

Superboiler

> Final dedicated condensing heat exchanger
> Membrane heat exchanger
> Condensation absorbs thru a porous ceramic into the feedwater
  ─ Recovers heat and water
Superboiler – Low NOₓ Design

> Two stages of combustion with gases cooled between stages – super-low NOₓ formation

Superboiler – Compact Design

> Enhanced heat transfer surfaces in boiler
> Efficiency of a 4-pass in 2 passes
Superboiler Convective Pass Tubes

Enhanced fire-tube heat transfer
- Fire-tubes with extruded aluminum inserts
- Heat transfer 18x higher than rifled tubes
- Deliver 4-pass efficiency in 30 to 50% smaller size

Picture Courtesy of GTI
### Superboiler

#### Condensing membrane heat exchanger

![Diagram of Superboiler with condensing membrane heat exchanger](image)

#### Table: Performance Comparison

<table>
<thead>
<tr>
<th>Case</th>
<th>Plant condensate return</th>
<th>Conventional boiler (no heat recovery)</th>
<th>Super Boiler (with TMG/MAH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Stack temp/ dew point</td>
<td>Boiler efficiency</td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td>440/137</td>
<td>80.2</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>440/137</td>
<td>81.3</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>440/137</td>
<td>81.0</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>440/137</td>
<td>81.4</td>
</tr>
</tbody>
</table>
High Efficiency Gas Boilers

Equipment Economizers

- **Heat Sponge**
  Boilerroom Equipment Inc.
  Telephone: 866-866-8977
  Web site: [www.heatponge.com](http://www.heatponge.com)

- **Sidel USA Systems**
  PO Box 1866
  Atascadero, CA 93423
  Telephone: 805-462-1250 or 800-668-5003
  Web site: [www.sidelsystems.com](http://www.sidelsystems.com)

- **Kentube Engineered Products**
  555 West 41st Street
  Tulsa, Oklahoma 74107-7012
  Telephone: 918-446-4661
  Web site: [www.kentube.com](http://www.kentube.com)

- **Cain Industries**
  P.O. Box 189
  W194 N11826 McCormick
  Germantown, WI 53022
  Telephone: 262-251-0051
  Web site: [www.cainind.com](http://www.cainind.com)

- **Cannon Boiler Works, Inc.**
  510 Constitution Blvd.
  New Kensington, Pa 15068
  Telephone: 724-335-8541
  Web site: [www.cannonboilerworks.com](http://www.cannonboilerworks.com)

- **Combustion & Energy Systems, Ltd**
  25 Royal Crest Court, Suite 110
  Markham, Ontario
  Canada L3R 9X4
  Telephone: 905-415-9400
  Fax: 905-415-9482
  Web site: [www.combustionandenergy.com](http://www.combustionandenergy.com)

Enhancing Efficiency on Larger Boilers

- **Economizers**
  - Use exhaust heat to pre-heat feedwater to the boiler
  - Limited heat sink in lower pressure boilers

- **Flue Gas Condensers**
  - Use exhaust heat to meet some lower temperature load
  - Must have a lower temperature application
Questions?

Summary

> Issues in boiler systems
> Smaller condensing boilers
> High efficiency systems for large boilers
> Heat recovery heat exchanger
> Superboiler
References

Steam Tip Sheet #26B, Energy Efficiency and Renewable Energy
U.S. Department of Energy, iEPSADOO/GO-102006-2337 July 2007,
EERE Information Center 1-877-EERE-NF 1-877-337-3463,
www.eere.energy.gov

Questions?