Outline

- Boiler Efficiency Classifications
- Condensing Boilers
  - Efficiency
  - Turndown
  - Materials
  - Designs/Types
  - Venting
  - Maintenance/Commissioning
- Other Ways to Increase System Efficiency
Boiler Efficiency Classifications

- **Standard Efficiency (80-85%)**
  - Kewanee, Hurst, Unilux, Cleaver Brooks, Slant Fin, Ray Pak, Superior

- **Mid Efficiency (87-88%)**
  - Thermal Solutions, Lochinvar

- **High Efficiency (90+%)**
  - Aerco, Viessmann, Lochinvar
## Boiler Comparison

<table>
<thead>
<tr>
<th></th>
<th>STD</th>
<th>MID</th>
<th>HIGH / CONDENSING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td>80-85%</td>
<td>87-88%</td>
<td>90+%</td>
</tr>
<tr>
<td><strong>Min RWT</strong></td>
<td>140°F</td>
<td>140°F</td>
<td>≤50°F</td>
</tr>
<tr>
<td><strong>Fuels</strong></td>
<td>Gas/Oil</td>
<td>Gas Only</td>
<td>Gas/Oil*</td>
</tr>
<tr>
<td><strong>Physical Size</strong></td>
<td>Large</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Venting Type</strong></td>
<td>Cat I or III</td>
<td>Cat I, II, III or IV</td>
<td>Cat IV</td>
</tr>
<tr>
<td><strong>Venting Size</strong></td>
<td>Med - Large</td>
<td>Med</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Longevity</strong></td>
<td>40+ Yrs</td>
<td>10+ Yrs</td>
<td>20+ Yrs</td>
</tr>
</tbody>
</table>

* Does not condense when firing on oil.
Condensing Boilers
Condensing Boilers Considerations

- Condensing?
- Actual Efficiency
- Material Type
- Technology/Type
  - Firetube
  - Watertube
  - Sectional
- Venting
  - Material
  - Size
  - Max Length
  - Boiler Exhaust Location
- Physical Size
- Clearances
- Noise
- Serviceability
  - Access
  - Parts
    - Qty
    - Proprietary
- Operating Parameters
  - Flow Rates (Min/Max)
  - Min Return Water Temp
  - Max ΔT
  - Max Operating Pressure
- Fuels
  - Nat
  - LP
  - LP Air Mix
  - Nat & LP
  - Digester
  - (Nat or LP) & Oil
- Turndown
- Included Features/Controls
- Years in Service
Efficiency

- **UP TO 99% THERMAL EFFICIENCY**

- **UP TO 99% EFFICIENCY**
  AHRI Certified up to 97% Efficiency

Once installed, boilers operate at up to 99% efficiency, while producing low NOx and CO2.

**FEATURES**
- High Mass and Water Volume
- Low Cost of Ownership
- Low Electrical Consumption
- Rugged, Robust, Reliable
  - Ultra High Efficiencies
- Simple Installation
- Minimal Maintenance Costs
How a Condensing Boiler Works

ASHRAE Handbook—HVAC Systems and Equipment

Fig. 6  Effect of Inlet Water Temperature on Efficiency of Condensing Boilers

- Natural Gas = 1050 Btu/ft³
- Stoichiometric Air = 17.24 lb/lb of fuel or 9.57 ft³/ft³ of fuel
- Noncondensing Mode
- Dew Point
- Condensing Mode
- 10% Excess Air
Boiler Combustion Efficiency

Fig. 6  Effect of Inlet Water Temperature on Efficiency of Condensing Boilers

2012 ASHRAE Handbook—HVAC Systems and Equipment

Natural gas = 1050 Btu/ft³
Stoichiometric air = 17.24 lb/lb of fuel
or 9.57 ft³/ft³ of fuel

Boiler Efficiency, %

Inlet Water Temperature, °F

Noncondensing Mode

Condensing Mode

10% Excess Air

<table>
<thead>
<tr>
<th>O₂</th>
<th>Excess Air</th>
<th>CO₂</th>
<th>Dew Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>13%</td>
<td>10.5%</td>
<td>134.2°F</td>
</tr>
<tr>
<td>4%</td>
<td>19%</td>
<td>10.0%</td>
<td>132°F</td>
</tr>
<tr>
<td>5%</td>
<td>25%</td>
<td>9.6%</td>
<td>130°F</td>
</tr>
<tr>
<td>6%</td>
<td>33%</td>
<td>8.9%</td>
<td>127°F</td>
</tr>
<tr>
<td>7%</td>
<td>42%</td>
<td>8.3%</td>
<td>124.5°F</td>
</tr>
<tr>
<td>8%</td>
<td>55%</td>
<td>7.7%</td>
<td>120.7°F</td>
</tr>
<tr>
<td>9%</td>
<td>69%</td>
<td>7.1%</td>
<td>117.8°F</td>
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<tr>
<td>10%</td>
<td>84%</td>
<td>6.5%</td>
<td>114.5°F</td>
</tr>
<tr>
<td>11%</td>
<td>105%</td>
<td>5.8%</td>
<td>110.9°F</td>
</tr>
<tr>
<td>12%</td>
<td>124%</td>
<td>5.2%</td>
<td>106.5°F</td>
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<tr>
<td>13%</td>
<td>149%</td>
<td>4.7%</td>
<td>103.5°F</td>
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<tr>
<td>14%</td>
<td>173%</td>
<td>4.2%</td>
<td>100.3°F</td>
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<td>15%</td>
<td>210%</td>
<td>3.8%</td>
<td>97.9°F</td>
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<td>16%</td>
<td>235%</td>
<td>3.1%</td>
<td>92.1°F</td>
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<tr>
<td>17%</td>
<td>265%</td>
<td>2.7%</td>
<td>88.3°F</td>
</tr>
<tr>
<td>18%</td>
<td>255%</td>
<td>2.0%</td>
<td>82.5°F</td>
</tr>
<tr>
<td>19%</td>
<td>325%</td>
<td>1.5%</td>
<td>77°F</td>
</tr>
</tbody>
</table>

Chart B – O₂ & Dew Point
AHRI Boiler Eff

- Tests all Boilers at same conditions
  - 80-180
  - High fire
- Most boilers are listed
- www.ahridirectory.org
AHRI Boiler Eff

Directory of Certified Product Performance

The trusted source of performance certified heating, ventilation, air-conditioning, and commercial refrigeration equipment and components.

RESIDENTIAL

> Air Conditioners and Air Conditioner Coils
> Baseboard Radiation
> Boilers
> Direct Heating Equipment
> Furnaces
> High-Efficiency Central Space-heating Hot Water Boilers

COMMERCIAL

> Air-Cooled Chilling Packages
> Air to Air Energy Recovery Ventilators
> Automatic Commercial Ice-Cube Machines and Ice Storage Bins
> Boilers
> Central Station Air-Handling Units
> Commercial Refrigerated Display Merchandisers And Storage Cabinets
> Pinned Tube
> Forced Circulation Air-Cooling and Air-Heating Coils
> Furnaces

Resources

- Find ENERGY STAR Qualified Products
- Verify Certificates
- AHRI Announces New Certification Mark; Implementation Schedule
- Find CEE Qualified Air-Conditioning and Heat Pump Systems
- Find Standards | Learn more about Certification Programs
- List of Registered Products following AHRI Verification testing
- Listing of Products that have been Challenged through the AHRI Certification Program
- Find NATE-certified HVACR contractors
<table>
<thead>
<tr>
<th>Trade/Brand Name</th>
<th>Manufacturer</th>
<th>Model Number</th>
<th>Material</th>
<th>Location</th>
<th>Fuel Type</th>
<th>Heating Medium</th>
<th>Input (MBTUH)</th>
<th>Gross Output (MBTUH)</th>
<th>Combustion Efficiency (%)</th>
<th>Thermal Efficiency (%)</th>
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</thead>
<tbody>
<tr>
<td>AERCO</td>
<td>AERCO INTERNATIONAL, INC.</td>
<td>BMK 1000</td>
<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>1000.0</td>
<td>968</td>
<td>96.8</td>
<td>96.8</td>
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<td>AERCO</td>
<td>AERCO INTERNATIONAL, INC.</td>
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<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>1500.0</td>
<td>1419</td>
<td>95.1</td>
<td>94.6</td>
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<td>AERCO INTERNATIONAL, INC.</td>
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<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>2000.0</td>
<td>1892</td>
<td>95.1</td>
<td>94.6</td>
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<td>AERCO</td>
<td>AERCO INTERNATIONAL, INC.</td>
<td>BMK 2500</td>
<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>2500.0</td>
<td>2337</td>
<td>94.0</td>
<td>93.5</td>
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<td>AERCO</td>
<td>AERCO INTERNATIONAL, INC.</td>
<td>BMK 3.0 LN</td>
<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>3000.0</td>
<td>2856</td>
<td>95.2</td>
<td>93.9</td>
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<td>AERCO INTERNATIONAL, INC.</td>
<td>BMK 3000</td>
<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>3000.0</td>
<td>2805</td>
<td>94.0</td>
<td>93.5</td>
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<td>AERCO INTERNATIONAL, INC.</td>
<td>BMK 6000</td>
<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas, Propane Gas</td>
<td>Water</td>
<td>6000.0</td>
<td>5670</td>
<td>95.0</td>
<td>94.5</td>
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<td>BMK 750</td>
<td>Stainless Steel</td>
<td>Indoor</td>
<td>Natural Gas</td>
<td>Water</td>
<td>750.0</td>
<td>721</td>
<td>96.2</td>
<td>95.6</td>
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Excerpts:

“The turndown ratio has a significant effect on system performance; lack of consideration of the source system’s part-load capability has been responsible for many systems that either do not function properly or do so at the expense of excess energy consumption.” – 2012 ASHRAE Handbook

“A higher turndown ratio reduces burner starts, provides better load control, saves wear and tear on the burner, reduces refractory wear, reduces purge-air requirements, and provides fuel savings” – US Department of Energy, Upgrade Boilers with Energy-Efficient Burners
Turndown

- Ratio = Max Firing Rate / Min Firing Rate

Example 1:
- 2000MBH Boiler
- Minimum Firing Rate 100MBH
- TURNDOWN = 20:1 (2000/100)

Example 2:
- 2000MBH Boiler
- Minimum Firing Rate 400MBH
- TURNDOWN = 5:1 (2000/400)
Turndown

<table>
<thead>
<tr>
<th>Time</th>
<th>5:1 Minimum Firing Rate</th>
<th>20:1 Minimum Firing Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU</td>
<td></td>
<td></td>
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</tbody>
</table>
Material

- Stainless Steel (300/400 Series or Duplex)
- Aluminum
- Copper with External SS or Coated Heat Exchanger
- Carbon Steel & Duplex Stainless Steel
- Carbon Steel & Corten
- Cast Iron
Material

  - “Condensing boilers are typically made of stainless steel or aluminum because copper, cast iron and carbon steel will corrode because of acidic condensation”
  - “For maximum reliability and durability over the extended product life, condensing boilers should be constructed from corrosion resistant materials throughout the fireside combustion chamber and heat exchangers.”
Material

- Stainless Steel (300/400 Series or Duplex)
- Aluminum
- Copper with External SS or Coated Heat Exchanger
- Carbon Steel & Duplex Stainless Steel
- Carbon Steel & Corten
- Cast Iron
# Material

## Stainless Steel

<table>
<thead>
<tr>
<th></th>
<th>Austenitic 304/316</th>
<th>Ferritic 430, 439</th>
<th>Duplex 2205</th>
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<tbody>
<tr>
<td><strong>Moderately Strong</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Excellent Ductility, Toughness &amp; Weldability</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Corrosion Resistant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Susceptible to Stress Corrosion Cracking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Expensive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>High Thermal Expansion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low Thermal Conductivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Stainless Steel
- Austenitic Ferritic Duplex
- 304/316, 430, 439, 2205
- Moderately Strong
- Excellent Ductility, Toughness & Weldability
- Corrosion Resistant
- Susceptible to Stress Corrosion Cracking
- Expensive
- High Thermal Expansion
- Low Thermal Conductivity
Material

- Aluminum
  - Must Use Proper Glycol
  - Must maintain PH Level
Material

- Copper with External SS Heat Exchanger
Material

- Carbon Steel with Duplex
Material

- Carbon Steel with CorTen
Material

- Cast Iron
Condensing Boiler Types

- Firetube
- Watertube
- Sectionals
Condensing Boiler Types

- NOT SO GOOD
- MEDIUM
- GREAT
## Condensing Boiler Types

### Technology Comparison

<table>
<thead>
<tr>
<th>Water Volume</th>
<th>Firetube</th>
<th>Watertube</th>
<th>Flexible Watertube</th>
<th>Sectionals</th>
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<tbody>
<tr>
<td></td>
<td>Medium to High</td>
<td>Low</td>
<td>Medium</td>
<td>Low to Medium</td>
</tr>
<tr>
<td>Flow Requirements</td>
<td>Less Stringent</td>
<td>Very Stringent</td>
<td>Less Stringent</td>
<td>Varies</td>
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<tr>
<td></td>
<td>Any</td>
<td>Primary/Secondary Only</td>
<td>Any</td>
<td>Varies</td>
</tr>
<tr>
<td>Piping Requirements</td>
<td>Natural, Propane, Oil, Methane or Combination</td>
<td>Natural or Propane</td>
<td>Natural or Propane</td>
<td>Natural or Propane</td>
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<tr>
<td>Fireside Cleanability</td>
<td>Easy</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Hard</td>
</tr>
<tr>
<td>Waterside Scale Issues</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
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<tr>
<td>Easy Field Repariable HE</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>Moderate</td>
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</table>
Condensing Boiler Designs

- Firetube - Vertical
Condensing Boiler Designs

- Firetube - Horizontal
Condensing Boiler Designs

- Watertube – Stainless Steel
Condensing Boiler Designs

- Watertube – Stainless Steel
Condensing Boiler Designs

- Watertube (Flexible) – Stainless Steel
Condensing Boiler Designs

- Watertube – Copperfin Tube
Condensing Boiler Designs

- Cast Aluminum Sectional
Condensing Boiler Designs

- Cast Iron Sectional
Venting for Condensing Boilers

- Multiple Configurations

Vent Configurations:
- Single sidewall vent room air
- Single makeup air
- Single sidewall
- Single vertical vent
- Single Vertical-Concentric Vent
- Sidewall Concentric Vent
- Multi sidewall vent room air
- Multi makeup air
- Multi sidewall
- Multi vertical vent
Venting

- AL29-4C
- Polypropylene
- CPVC
- PVC
## Maintenance / Commissioning

- **Tune Ups / Maintenance**

<table>
<thead>
<tr>
<th>Section</th>
<th>Item</th>
<th>6 Mos.</th>
<th>12 Mos.</th>
<th>24 Mos.</th>
<th>Labor Time</th>
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<tbody>
<tr>
<td>7.2</td>
<td>Igniter-Injector Kit (58023)</td>
<td>*Inspect</td>
<td>Inspect</td>
<td>Replace</td>
<td>15 mins.</td>
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<tr>
<td>7.3</td>
<td>Flame Detector Kit (24356-1)</td>
<td>*Inspect</td>
<td>Inspect</td>
<td>Replace</td>
<td>15 mins.</td>
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<td>7.4</td>
<td>Lean O₂ Sensor (61026)</td>
<td>*Inspect</td>
<td>Inspect</td>
<td></td>
<td>15 mins.</td>
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<tr>
<td>7.5</td>
<td>Combustion Calibration</td>
<td>*Check</td>
<td>Check</td>
<td></td>
<td>1 hr.</td>
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<tr>
<td>7.6</td>
<td>Testing of Safety Devices</td>
<td></td>
<td>See ASME CSD-1 Chart</td>
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<td>45 mins.</td>
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<tr>
<td>7.7</td>
<td>Burner</td>
<td></td>
<td></td>
<td>Inspect</td>
<td>2 hrs.</td>
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<tr>
<td>7.8</td>
<td>Condensate Drain Trap</td>
<td>*Inspect</td>
<td>Inspect, Clean &amp; Replace Gaskets</td>
<td>Inspect, Clean &amp; Replace Gaskets</td>
<td>30 mins.</td>
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<td>7.9</td>
<td>Air Filter (59139)</td>
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<td>Clean</td>
<td>Replace</td>
<td>15 mins.</td>
</tr>
</tbody>
</table>

* Only performed after initial 6 month period after initial startup.
Maintenance / Commissioning

- Commissioning
  - Verify Proper Operation/Sequencing
  - Verify Flow
  - Use Warm Weather Setback
Controls

- Sequencing Boilers
  - Building Management System / Controls Contractor
  - Separate Boiler Sequencing Panel
  - Onboard Integrated Sequencing Controller
Other Ways to Increase System Efficiency

- Upgrade Burner
  - New Modulating
  - Add Linkageless Controls
  - Higher Burner/Boiler Turndown
- Install Coalescing Air Separator
- Install Stack Economizer
- Use Variable Flow Pumps
- New Boilers
  - Base Load
  - Modular
  - New Plant (Std, Mid or High Eff)
New Burner

- Higher Efficiency
- Modulation in lieu of On/Off or Low/High
- Higher Turndown
- Add Backup Fuel
- Reduce Capacity
Linkageless Controls

- Greater Accuracy
- Greater Efficiency
- 3-15% Fuel Savings
- Higher Turndown
- Less Service Time
- Less Down Time
- Independent Fuel Curves
- O2 Trim Capable
Coalescing Air Separator

- Superior Air Removal
- Increases Efficiency
  - Increases Heat Transfer
  - Reduces Corrosion
  - Maintains Available Pump Head
- Reduces Maintenance Costs
  - Low Heat Calls
  - Air Bleeding
  - Equipment Corrosion Damage
  - Pump Cavitation Damage
Stack Economizers

- Recovers Wasted Stack Heat
- Steam Boilers – Preheat Boiler Feed Water
- Hot Water Boilers – Preheat Return Water
- Preheat Domestic Water
Variable Speed Pumps

- Reduces Energy Consumption
Base Loading

- Multiple Boiler System
- One smaller boiler handles majority of load
- Winter / High Demand - Use std fire tube / water tube boilers
- Summer / Low Demand - Use high efficiency condensing boilers
- Extend life of large boiler
Modular Systems

- Multiple Burner Turndown
  - 1 = 20:1
  - 2 = 40:1
  - 3 = 60:1
  - 4 = 80:1
  - 5 = 100:1
THANK YOU

tmccotton.com