Boiler Basics: Design & Application Differences

Presented by Steve Connor
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What We Are Covering Today

**Boiler Basics:**
- Design & Application
- Differences

- Understanding Boiler Load
- Boiler Manufacturing Requirements
- Design & Construction Details
- The Boiler Package
- Industry & Application Match-Up
- Types of Fueled Boilers

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CleaverBrooks
Boiler Manufacturing

Insurance Regulations

ASME Codes
Section I

- High pressure - Steam boilers above 15 psi. Hot water boilers above 160 psi (hydrostatic pressure) and/or 250°F outlet temperature
ASME Code
(American Society of Mechanical Engineering)

Section IV

- Low pressure - Steam boilers less than 15 psi. Hot water boilers less than 160 psi and/or 250° F. outlet temperature
Packaged Boiler Types

General Categories

Electric  Tubeless  Firetube  Watertube

Capacity
200 – 365,000 MBH
6 – 11,000 BHP
Steam & Hot Water
The Boiler Package

- Pressure vessel
- Burner
- Controls
Broad Industry Breakdown

**Commercial**
Primarily Low Pressure or Hot Water Comforting Heating

**Industrial**
Primarily Process Applications with some Comfort Heating
Commercial Steam & Hot Water

- Firetube
- Vertical Tubeless
- Electric
- Watertube
- Cast Iron
- Copper Fin
Industrial Steam & Hot Water

- Firetube
  - Horizontal
  - Vertical
- Vertical tubeless
- Electric
- Watertube
  - Natural
  - Forced Circulation
- IWT
Packaged Firetube Details

- **Size range:** 15 – 2200 HP
- **Design pressures:**
  - Steam: 15 - 250#
  - Water: 30 – 160#
Horizontal Firetube Boilers

The Dryback

Two (2) Tubesheets
Baffles
Refractory Filled Door
Tubesheet

1 2 3 4
Three (3) Tubesheets

The Wetback

• Three Tubesheets
• Difficult access, 2nd pass
Vertical Firetube Boiler

- **Size range:** 10 – 60 HP
- **Design Pressures:**
  - Steam: 150#
  - Water: 125#
- **Compact**
The Watertube Boiler

- Opposite of Firetube
- Water in the Tubes
- Natural and Forced Circulation
- Large Furnace
- Upper & Lower Drums or Headers
The Watertube Boiler

- Size Range: 15 – 300 HP
- Design Pressure:
  - Steam: 250#
  - Hot Water: 125#

Diagram:
- Bent
- Hx
- Down comers
- Sight port
- Riser tubes
- Straight Inclined
The Watertube Boiler

- Size Range: 35 – 500 HP
- Design Pressure
  - Steam: 150#
  - Hot Water: 160#

Flextube

Stack connection

Furnace
The Watertube Boiler

- Size Range: 100 – 300 HP
- Design Pressures:
  - Steam: 170#
- Requires Forced Circulation
- Low Water Volume
- Fast Steamer
- Water Quality is Critical
The Watertube boiler

- Size Range: 6 – 300 HP
- Design Pressures
  - Steam: 15#
  - Hot water: 60 - 80#
- Cast Iron
The Watertube boiler

- Size Range: 15 – 70 HP
- Design Pressure:
  - Hot Water: 160#
- No Steam
- Requires Circulation
- Atmospheric Burner or with Fan Assist
The Watertube boiler package

- Size Range: 10,000 – 300,000#/HR
- 300 – 9000 HP
- Design Pressure:
  - Steam: to 900#
  - HTHW: +400 Deg. F
- Natural Circulation
- Some Forced Circulation
Vertical Tubeless boiler

- **Size Range:** 6 – 100 HP
- **Design Pressure:**
  - Steam: 150 - 250#
  - Hot Water: 160#
- **Multiple Passes (2 – 4)**
Electric Boilers

- **Size range:**
  - Resistance: 12 – 3375 KW (1 – 350 BHP)
  - Electrode: 2 – 65 MW (200 – 7000 BHP)

- **Design Pressure**
  - Steam: To 250#
  - Hot water (Resistance) 160#

- No Emissions on Location
- High Point of Use Efficiency

**NOTE:**

MW = 1,000,000 watts
KW = 1000 watts or 3413 BTU/HR
Understanding the Load

Initial Questions:
• Total load?
• Pressure?
• Cyclicality?
• Load majority?
• Steam quality requirement?
Boiler Choice

Firetube?

Watertube?
• Spikes in demand?
• How much add to my normal load?
• How fast do they occur?
• Sudden or gradual?
• Maintaining pressure critical?
Cyclicality

Bent Tube

Sudden swings in load??

IWT

Flextube
Burner Choice

Sized for optimum firing rate majority of operating time.

Normally 4:1 or 10:1

Burner Turndown
Purge Losses

ENERGY WASTE
Load Majority

Boiler’s “Sweet spot”
Boiler Efficiency & Firing Rate

TYPICAL FIRING RATE THROUGH TURNDOWN

% Efficiency

% Firing Rate

Typical boiler firing range

Typical Firetube
Burner Choice

Percent $O_2$

12%
10%
8%
6%
4%
2%
0%

Burner Turndown
4 To 1
or
10 to 1

Typical firing range for many oversized boilers

Firing Rate

Typical firing range for many oversized boilers

Firing Rate

Typical firing range for many oversized boilers
Burner Choice

RULE OF THUMB

For every 2% increase in O₂, you lose 1% in efficiency

EXCESS AIR EFFECTS ON EFFICIENCY FOR NATURAL GAS

% of Excess Air | % Oxygen (O₂) | % Efficiency Decrease
--- | --- | ---
15 | 3 | 0
25 | 4.5 | -0.5
35 | 5.8 | -1.0
45 | 7 | -1.5
55 | 7.9 | -2.0
Combustion Control Choice

Single Point

Parallel Positioning

*Incr. — Increase
*Decr. — Decrease
Note: Linkage is shown in approximate low fire position.
Multiple Boilers
Central Control Unit
Summer boiler

Smaller Summer Boiler

Complete Skidded Package
# Steam Quality

## American Boiler Manufacturer's Association (ABMA)

### Watertube Boilers

**Recommended Boiler Water Limits and Associated Steam Purity**

**(At Steady State, Full-Load Operation)**

<table>
<thead>
<tr>
<th>Drum Pressure Range Total (PSIG)</th>
<th>Range Total</th>
<th>Susp'd Solids</th>
<th>Range Total</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Dissolved Solids (1)</td>
<td>Alkalinity Boiler Water ppm</td>
<td>(2,5) ppm (MAX)</td>
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<tr>
<td>0-300</td>
<td>700-3500</td>
<td>140-700</td>
<td>15</td>
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<tr>
<td>301-450</td>
<td>600-3000</td>
<td>120-600</td>
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<td>451-600</td>
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<td>601-750</td>
<td>200-1000</td>
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<td>150-750</td>
<td>30-150</td>
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<td>125-625</td>
<td>25-125</td>
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<td>1001-1800</td>
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<tr>
<td>2601-2900</td>
<td>15</td>
<td>NOTE (3)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**TDS Control**

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*NOTE (3):* Values may vary depending on specific boiler type and operating conditions.
Steam Quality

Three Element Control System
Monitoring water level, steam flow and feedwater flow
Steam Quality

- Secondary separation with labyrinth or chevron internal separators
- Steam endures a tortuous path
- End result is 99.5% dry steam, or < 0.5% moisture to process
Steam Quality
Steam Quality

Note:

1 Safety Relief Valve to be set at 10 psi higher or 10 times higher than the downstream pressure, whichever is greater.
Summary

- Boilers constructed per ASME Sections I (HP) & IV (LP & HW)
- The boiler package consists of pressure vessel, burner & controls (BMS & CCS)
- Various types of firetubes & watertubes
- Firetube package limit @ 2200 HP and 250#
- Watertube packages limit at 9000 HP & 900#
- The watertube boiler is normally superior in handling “swing” loads
- Cast Iron boilers are LP & HW only
- Copper boilers are HW only
- When considering the total load, look for cyclicality spikes
- Know where the load is the majority of the time assuring the spikes can be handled within the boilers turndown
- Know where the boiler’s “sweet spot” is
- Remember 2% increase in O2 = 1% loss in efficiency
- Steam quality can be a process issue