Advanced Boiler Design Technology

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The Evolution of Boiler Design
**Watertube Boilers** *(Low Mass)*

- 36 HP to >25,000 HP
- 1200 PPH to 1,000,000 PPH

**Firetube Boilers** *(High Mass)*

- 10 HP to 2,200 HP
- 345 PPH to >75,000 PPH
Fig. 3 Trevithick boiler, 1804.
Emissions Technology
**Water:**

- **H2O Liquid**
- **Dissolved Gases / Oxygen**
- **Dissolved Solids**
- **Other - Trace**

**Air:**

- **Nitrogen 78%**
- **Oxygen 21%**
- **Argon & Other 1%**
CFD: Computational Fluid Dynamics
Advanced Burner Design
Pressure Vessel Design
Pressure Vessel Design
Older High-Maintenance Refractory Brick Construction
100% Water Cooled
Engineered “Balanced” Design

- **Engineered Design**
  - Balanced temperatures and heat loads
  - Design from the ground up
  - Finite element
  - Components design using finite element analysis (FEA)
1. Heat Transfer Of The Tubes
The Fundamentals

**Typical Boiler Tube**

Hot flue gases enter boiler tube in turbulent pattern but quickly change to a laminar, or straight, flow.

Boundary layer forms along tube walls, retarding heat transfer.
• **Extended surfaces**
  - Optimized Heat transfer coefficient using CFD modeling
  - Cleaver Brooks designed and manufactures the extended heat transfer tubing
  - Turbulence in the tubes increased surface area and improved combustion performance

• **Compact footprint – 15% reduction**

• **Lower stress loads – longer life**

• **Reduced maintenance because combustion is more efficient**
1. Heat Transfer Of The Tubes
An Optimized Heat Transfer Tube

Cleaver-Brooks Advanced Heat Transfer Tube

Hot flue gases enter boiler tube in turbulent pattern and remain turbulent

Precisely designed ribs keep hot flue gases in turbulent flow throughout the tube profile
Combustion Technology
• On-line External Adjustability
• Design through CFD
• Low Excess Air
• High Turndown
Advanced Boiler Control

**Energy Saving Options:**
- Parallel-Positioning (FAR)
- Oxygen Trim System
- Variable Speed Drive
- PID Controls (PLC)
Parallel - Positioning

- FGR - Valve
- Air Damper
- Fuel – Oil Valve
- Fuel – Gas Valve
Parallel Positioning Control
Integrated Control System

Boiler Steam Pressure Sensing Transmitter

Fuel Control Valve
Fuel to Burner

Exhaust Gas
Boiler Stack

Flue Gas Recirculation Back to Combustion Air

Required for Low NO$_x$ - around 30 ppm and below

Variable Speed Drive

Combustion Air to Burner

Combustion Air Fan

CleaverBrooks®
Parallel-Positioning

Oxygen Trim System

Stoichiometric Combustion Curve

Low Fire

High Fire
O2, Extractive or In-Situ?

**Extractive**
- Sensor life span: 1-2 years (published)
- Response time: ?

**In-Situ**
- Sensor life span: > 5 years
- Response time: 0.5 sec max

Boiler Control System
Higher Efficiency Over The Entire Firing Range
Performance – Results

Boiler Horse Power: 800
Average Input: 51%
Average Input Efficiency: 82.5%
Projected Efficiency with O2 Trim: 83.5%
Run Hours Per Year: 8760
Fuel Cost: $0.87 per Therm
Electric Cost: $0.060 Per KW Hour

Boiler Firing Rate

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<th>Percent of Year</th>
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Variable Speed Drive Calculation

Motor Horse Power: 75
Cost of KW per Hour: $0.060
Total KW Hours with No VSD: 308,436.68
Total KW Hours with VSD: 58,269.74
Average Operating Cost No VSD: $18,506.20
Average Operating Cost with VSD: $3,496.18
Annual Projected Savings: $15,010.02

Parallel Positioning Calculation

Average Horse Power Output: 408
Average BTU/Horse Power Output: 13,657,800.00
Projected Gain: 1.2%
Average BTU/Horse Input with No PP: 16,554,909.09
Average BTU/Horse Input with PP: 16,317,562.72
Annual Fuel Cost with No PP: $1,261,682.73
Annual Fuel Cost with PP: $1,243,594.09
Annual Projected Savings: $18,088.64
(Removal of Linkage - 0.2%, Improved Combustion - 0.5%, Increased Turndown - 0.5%)

O2 Trim Calculation

Average Horse Power Output: 408
Average BTU/Horse Power Output: 13,657,800.00
Projected Efficiency Gain: 1.0%
Average BTU/Horse Input with No Trim: 16,554,909.09
Average BTU/Horse Input with Trim: 16,356,646.71
Annual Fuel Cost with No Trim: $1,261,682.73
Annual Fuel Cost with Trim: $1,246,572.76
Annual Projected Savings: $15,109.97
Heat Recovery
Focus on (2) wasted energy sources

- Flue Gas – Gas exiting the boiler to atmosphere via the stack

- Surface Blowdown – Contaminates (i.e. dissolved solids and particles) on the water surface within the Boiler that must be discarded to effectively operate the boiler
Condensing Feedwater Heaters - General Piping

- Make-up water
- To process
- Existing Feed Tank
- Boiler
- Economizer
- Economizer
• **Applications**  
  • Increase Make-Up Water Temperature  
  • Use Flash Steam for Low Pressure use

• **Keys**  
  • Adequate MakeUp Flow  
  • Consistent Surface Blowdowns

• **Equipment ROI – 10-12 months**