Firetube Boiler Design, Construction & Engineering

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What We Are Covering Today

Advancing Firetube Boiler Design

- Brief on FT boiler evolution
- Major FT components
- Construction
- Dryback vs Wetback
- The Burner
- Engineering & Summary
NOTE:
These firetube boilers could weigh up to 200,000lbs and reach speeds of 100mph
Boiler Evolution

Steam Locomotive Cut-A-Way

NOTE:
These boilers were an integral part in leading the way in the industrial revolution starting in the 1860’s.
NOTE:
The Titanic was powered by 29 firetube boilers that contained 159 furnaces which were fired with 825 tons of coal per day.
Titanic’s Steam Engines

4 Cycle Steam Engines

- Discovered 13,000 feet deep
- 2.5 miles down...
Scotch Marine Boiler With Single or Multiple Furnaces
The Firebox boiler is only for low pressure steam and hot water.
Major Components

Pressure vessel

Stack

Burner

Controls
A Standard For Firetube Construction Was Created
Typical Industries Served

- Refinery & Petro-Chemical
- Universities/Colleges/Schools
- Government buildings
- Hospitals
- Hotels and Conference Centers
- Chemical/Pharmaceutical
- Automotive
- Food & Beverage
- Textiles
- Corrugated container
- Pulp & paper
- Building supplies
- Ethanol & Bio-Diesel
- Aerospace & Military
Construction

- Starts with flat plate
- Shell openings are cut in
Construction

Shell is rolled into form
Construction

- Seams are welded; longitudinal & circumferential
- X-Rayed and witnessed
- Tube sheets cut and drilled
Tube Sheets Installed

- First tacked
- Full penetration weld; Down hand position

Tack weld

Full penetration weld
Boiler Fittings Are Installed

- Outlet & return connections
- Safety valve connection(s)
- Vent connection
- Surface blow-off connection
- Feed water connection
- Bottom blowdown connections
- Water level control connections
- Stay braces for high pressure
After all pressure vessel welding is completed the entire assembly is stress relieved @ 1100 deg. F.
Burner & Trim Prepared

Trim assembled

Gas train

Burner components affixed

Feed water piping

Integral burner
Roll Stock

Rolling & Welding
Tubes Banded and Ready For Install
• Rolled and Welded
• Rolled and Beaded
• Rolled and Flared
Tube Attachment

Rolled and Beaded Tube

Rolled and Flared Tube

Rolled and Welded Tube

Tube End Cooling
Hydrostatic Testing

- 1 1/2 times the maximum allowable working pressure
Boiler Construction

- Insulation & lagging
- Throat & liner installation
- Front & rear door hanging
- Burner installation
- Final assembly & trim
- Test fire
Horizontal Firetube Boilers

The Dryback

Tubesheet

Baffles

Refractory Filled Door

Two (2) Tubesheets
The Wetback

Three (3) Tubesheets

- Three Tubesheets
- Difficult access, 2\textsuperscript{nd} pass

Rear access plug
Size & Pressure Ranges

- 100 – 2500 HP
- Design pressures to 350#
- Wetback design used above 800 - 900 HP
The Burner
Firetube Burner Types

Gun

Integral
Integral burner

Gun burner

Burner Types

Wind box
Blower/fan
Burner Ass’y
Diffuser
Blast tube
Air inlet
Types of Firing

- High-low-Off
- Modulating
- Turndown: 4:1 or 10:1
Fuels
Maximize Combustion Control

Single Point

Parallel Positioning

Fuel

Air

FGR

Note: Linkage is shown in approximate low fire position.
Emission Reduction

Flue Gas Recirculation

Integral burner

Gun burner

FGR
Range based on boiler capacity, Fuel, Firing rate and Operating Pressure/Temperature:

81 – 87%

NOTE: FGR may impact turndown, Reducing efficiency.
The Engineering Behind the Design
Established in 1880
Safety Becoming a Key Issue

The Sultana Boiler Explosion Kills 1238 in April 27, 1865

Commissioned Jan. 1863

Boiler repaired a few days before the explosion.

Events like this lead to safety regulations; stringent codes...
Steam Locomotive Explosions.....Devastating

Photo: Martin F. Wintermute

Incident in Northampton, N.Y., Lowenthal-Greenberg, 198
ASME Code
(American Society of Mechanical Engineering)

Section I
High pressure - Steam boilers above 15 psi.
Hot water boilers above 160 psi (hydrostatic pressure) and/or 250°F outlet temperature

Section IV
Low pressure - Steam boilers less than 15 psi. Hot water boilers less than 160 psi and/or 250°F outlet temperature
Steam Nozzle Sizing & Velocity

- Surface velocity: 10’/sec.
- Nozzle: 5000’/min.
Radiant & Convective Heat Transfer
Furnace Emissivity & Heat Release

Greater temperature difference by the power of 4!

Stefan’s Law \( M = T^4 \)
Burner and Furnace Matching
No difference in efficiency, durability or life expectancy
• **Reynolds number:**
  - Relation of viscous to inertia forces
  - Velocity = square root of temperature

• **Heat Transfer Coefficient:**
  - Proportionality between heat flow & Delta T
Convective Heat Transfer

Plain Tubes

Extended Surface Tubes
Convective Heat Transfer

Typical Boiler Tube

Boundary layer forms along tube walls, retarding heat transfer

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

No Boundary layer

Spiral tubes

+85% more heat transfer

INCREASED
INERTIA FORCES
\=
INCREASED HEAT TRANSFER
Reducing Weight and Footprint

NOTE:
These are attractive features to architects designing new boiler rooms when faced with budget restraints.

Typical:
- 30% less weight
- 15% less floor space
- Reduced fan motor horsepower
- Same or better efficiency, durability and life
Designing Boilers in the 21st Century

Is boiler R&D like it was in the past?
Computation Fluid Dynamics & Finite Element Analysis

CFD Modeling

FEA Proving
Tensile Strength

Metal Stresses

Metal Deformation

Tube Sheets

Tubes & Ligaments

Furnace
Summary

• The firetube boiler is a versatile package suitable for a plethora of applications including heating and process
• Typical size range is 100 – 2500 HP
• Pressures to 350#
• Construction follows ASME code Sections I & IV and includes close 3rd party inspections
• There are both dryback & wetback horizontal firetubes with each having advantages and disadvantages
• The fuel firing capability of these boilers is extensive including bio-fuels.
• The boiler is getting smaller in size and weight without compromising efficiency, durability and life span.
• The engineering is complex, but present day advancements in computer technology has accelerated and improved the process
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