Boiler Basics

Jason R. Funk

HUGHES machinery

an FCX Performance Company

Topics

- Boiler Fundamentals
- Types of Boilers
- Boiler Efficiency Considerations

Boiler Fundamentals

What is a boiler?

ASME Section IV

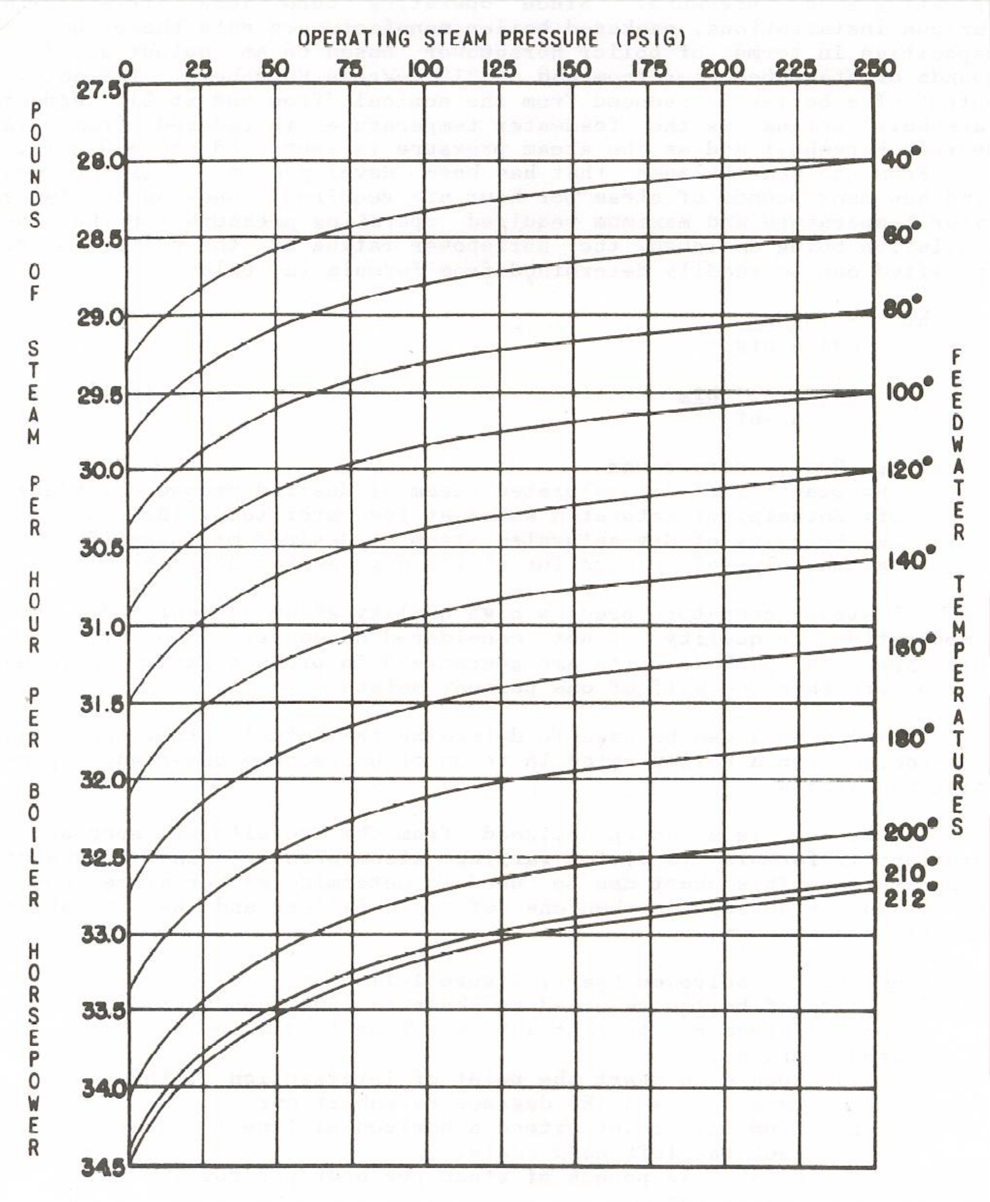
- Heating Boilers
- 15 PSIG Maximum steam pressure
- Hot Water Boilers below 250 F and 160 psig

ASME Section I

- Process Boiler
- Steam Boilers above 15 PSIG operating pressure
- Hot Water Boilers above 250 F or 160 psig

Boiler Horsepower

- 1 BHP = 34.5 lb/hr of steam generation at 212 F feedwater and 0 PSIG operating pressure
- 1 BHP = 34,500 BTU/hr for hot water boilers
- 1 BHP = 10 KW for electric boilers



Steam Output

Steam output at varying operating pressures and feedwater temperatures.

Heating Surface

- Surface area available for heat transfer is very important in boiler design.
- Most larger firetube boiler manufacturers build boilers at 5 sq ft of heating area/BHP
- Firebox Boilers are built at 4-5 sq ft/BHP
- Vertical Firetube Boilers can be as low as 3 sq ft/BHP

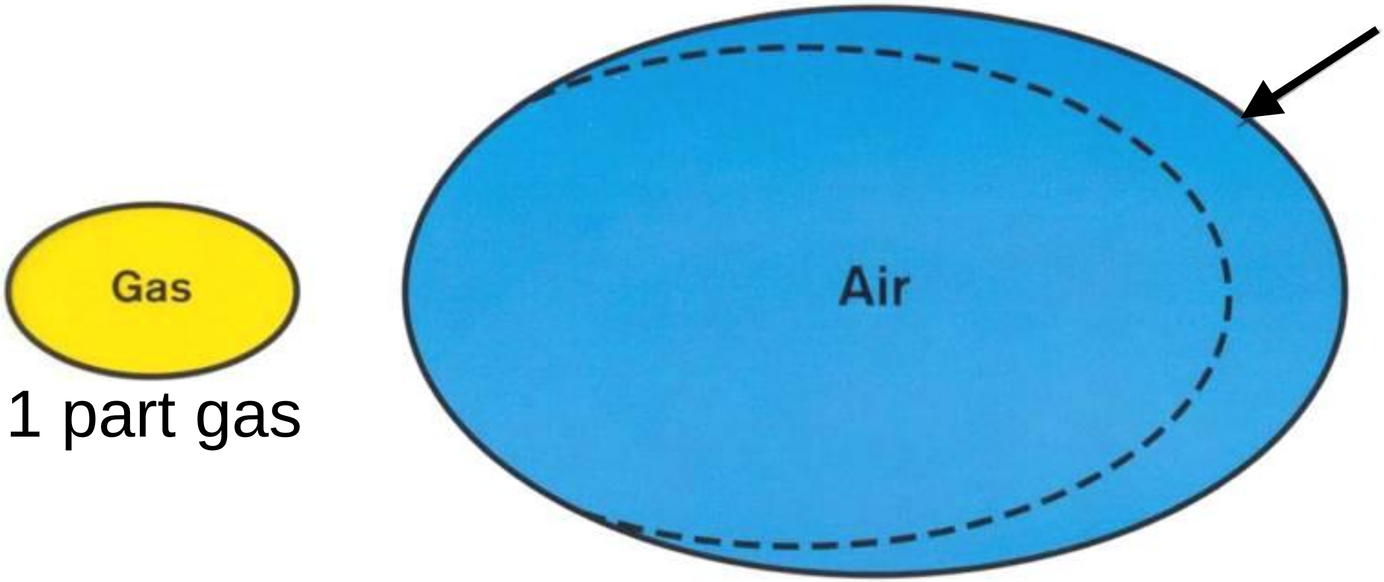
Combustion Air Requirements

- Code requires two sources of combustion air, one at a higher elevation and one lower

- Rule of thumb - 1/2 sq ft of free open area for every 1,000,000 BTU/HR

- Or burner BTU/HR capacity divided by 100 for CFH of air required for forced air delivery

NATURAL GAS COMBUSTION



10 parts air

Hot Water Boiler Comments

- BTU = Flow (gpm) X Delta T (F) X 500
- Must have water flow through the boiler when burner is firing
- Minimum of 140 F entering water temperature to avoid condensing, dependent on excess air settings
- Many boilers must operate with only a 20 to 30 F temperature rise through the boiler. Special designs can tolerate over 50F.

Boiler Short Cycling

- Evaluate burner turndown and the thermal mass of the system to prevent boiler short cycling.
- Boiler/burner short cycling can cause a 20% decrease in efficiency.
- Short cycling also imposes thermal stresses on the boiler and will cause premature component failure.

Types of Boilers

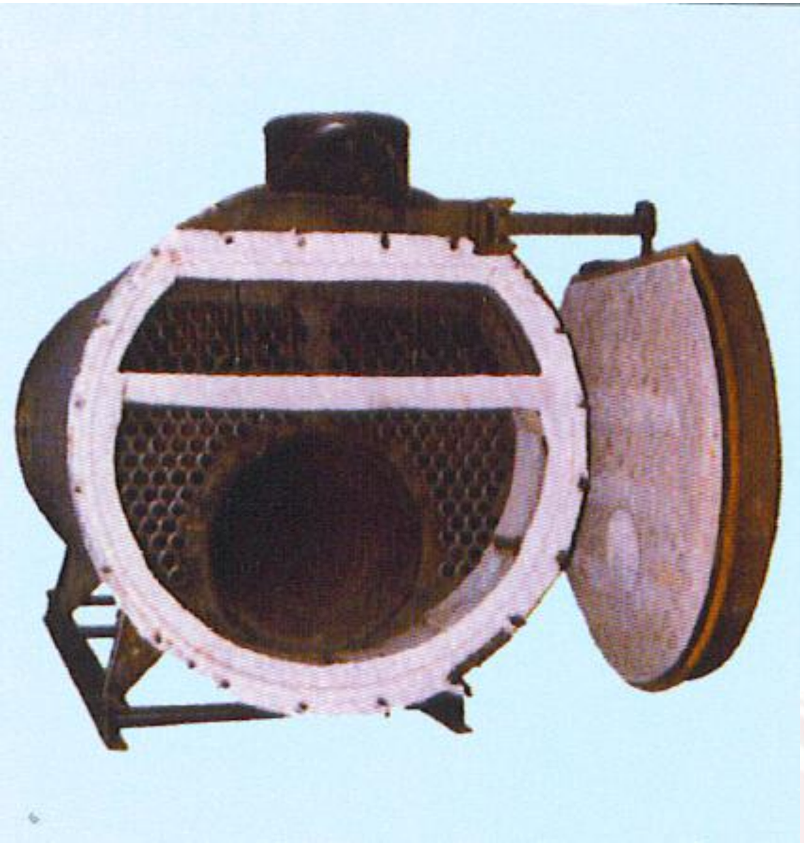
- Firetube
- Firebox
- Vertical
- Watertube
- Cast Iron
- Copper finned
- Condensing
- Electric

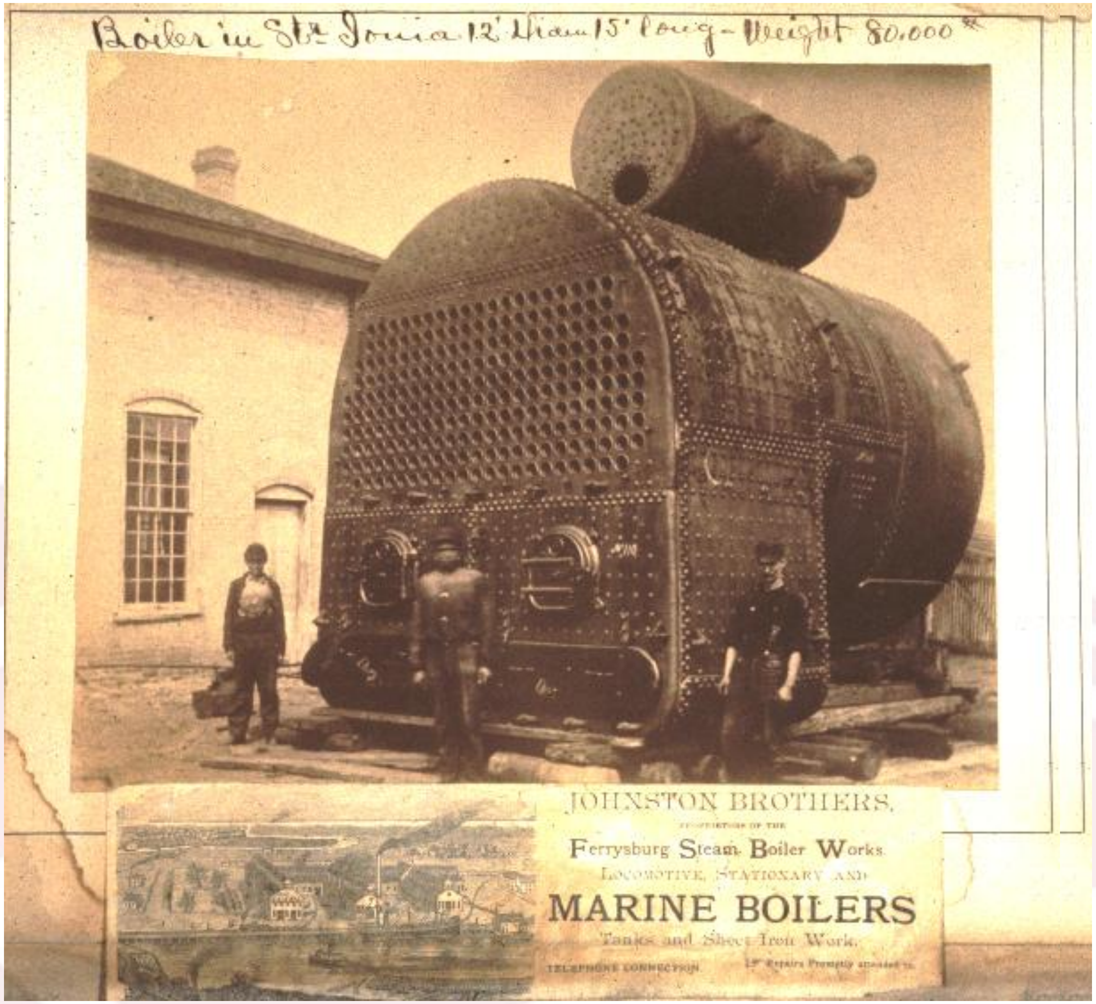
Firetube Boilers

- Great steam quality due to large steam volume within the boiler and large surface area for steam release
- Require long start up times
- Potential for thermal shock on hot water systems - 25 to 30 F maximum temperature rise through the boiler

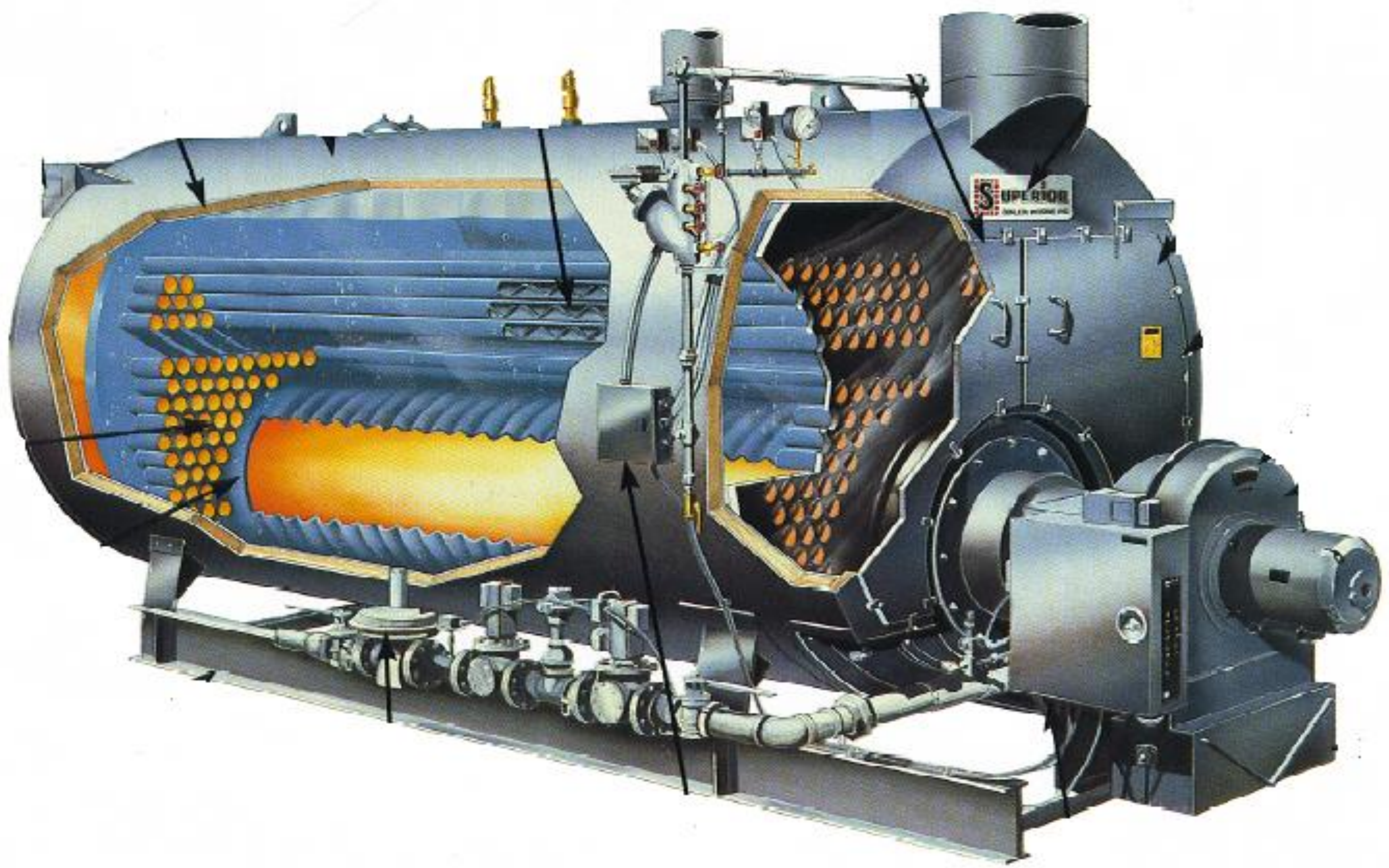
Firetube Boiler

- Dry Back Design - 2, 3 and 4 pass
- Wet Back Design - 3 and 4 pass
- Excellent Efficiencies
- Proven design

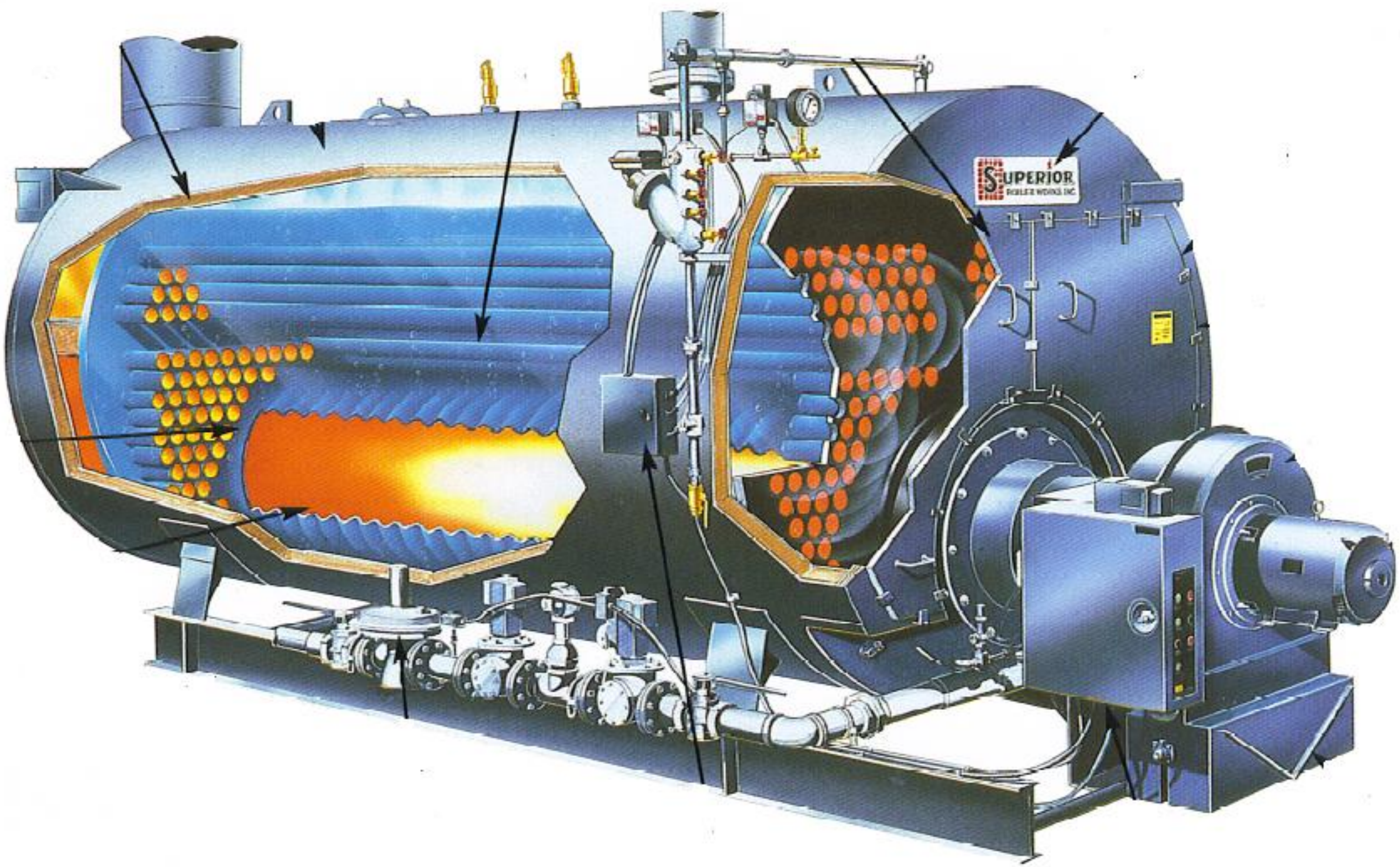



Boiler in Str Ionia 12' diam 15' long - Weight 80,000 #
JOHNSTON BROTHERS,
Ferrysburg Steam Boiler Works.
LOCOMOTIVE, STATIONARY AND
MARINE BOILERS
Tanks and Sheet Iron Work.
TELEPHONE CONNECTION

2-Pass Boiler

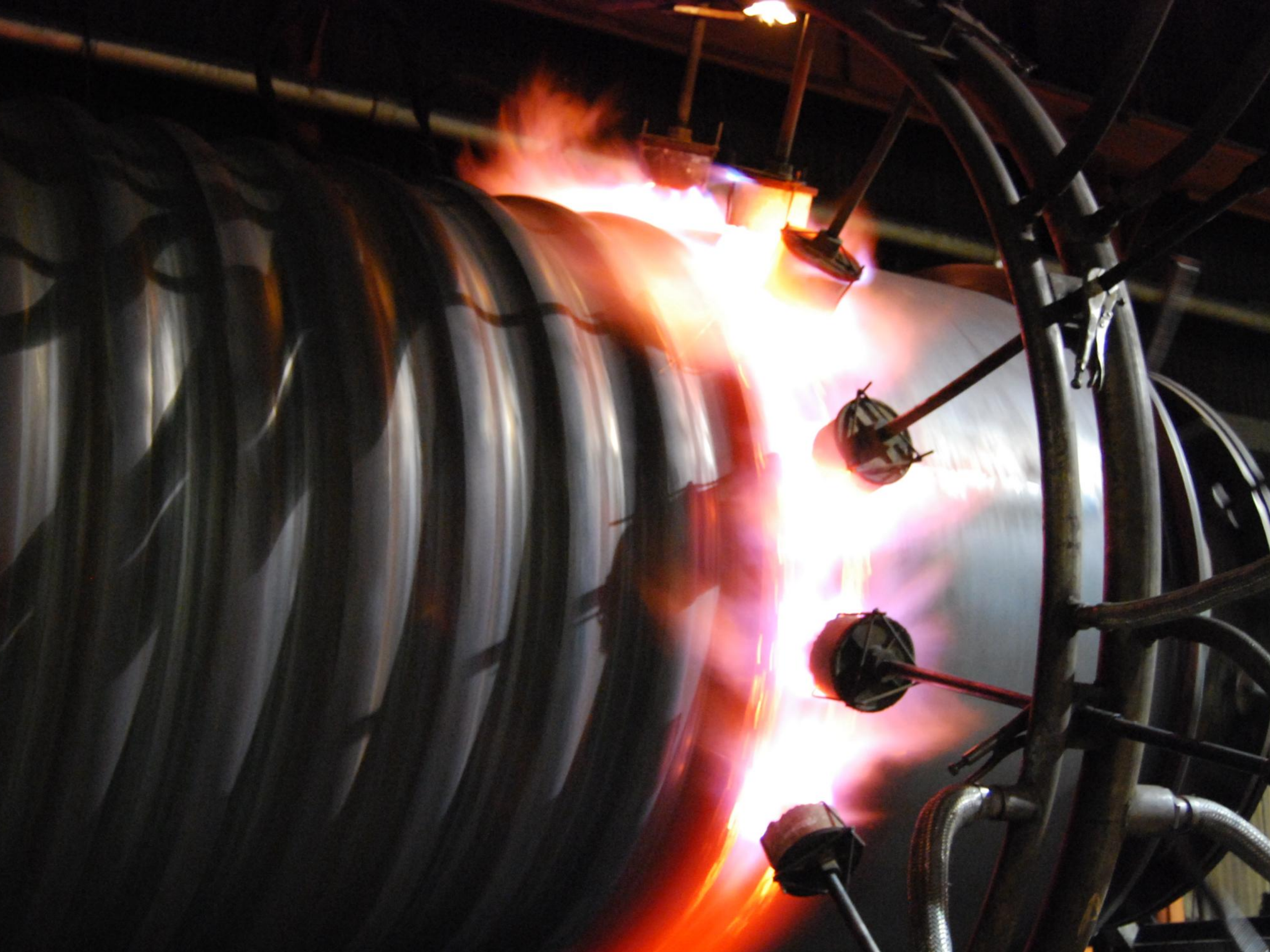


3 Pass Boiler

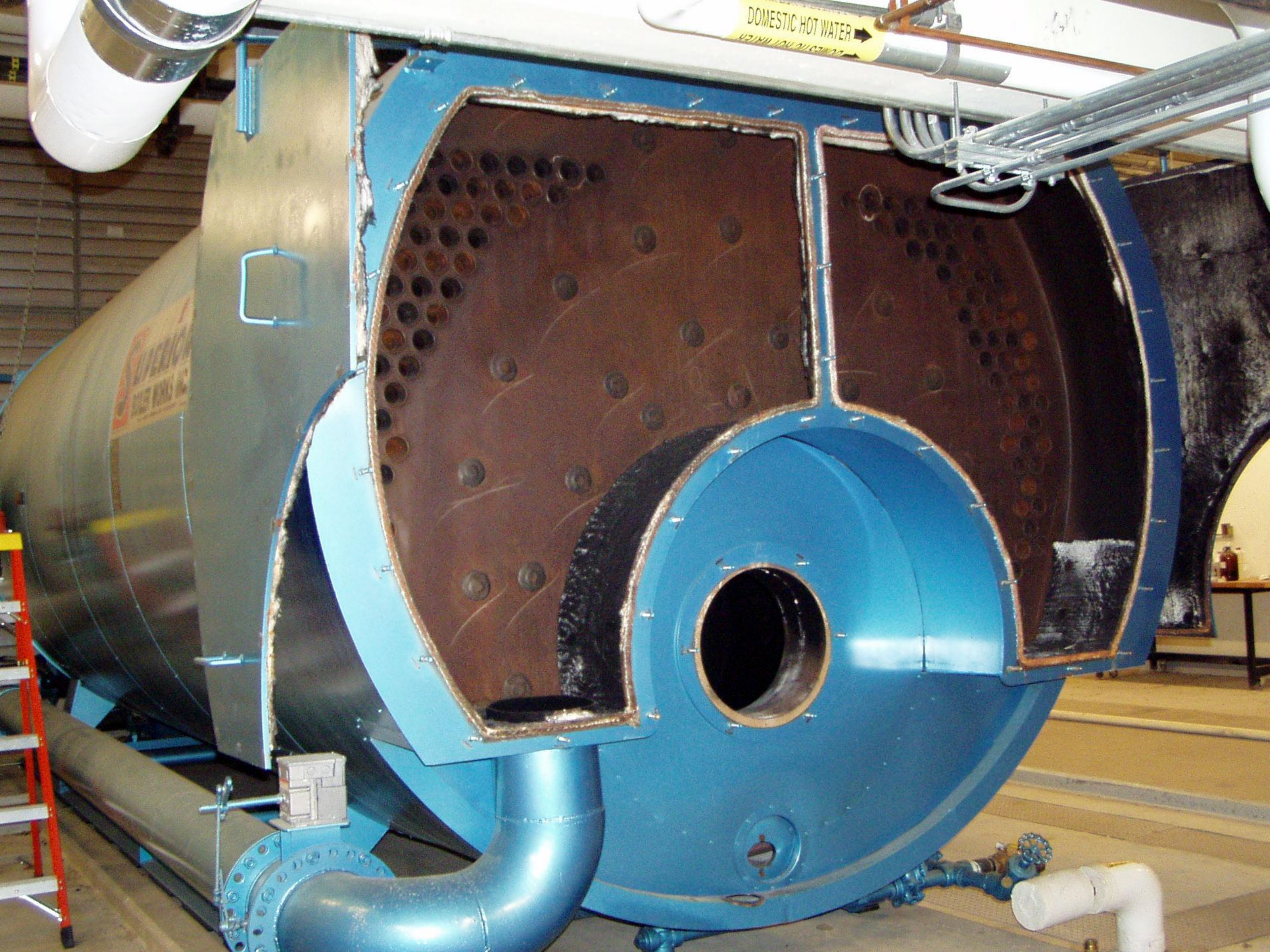


Firetube Boiler Design

- Furnace design - corrugated or plain
- Ligament spacing - tangent to tangent tube spacing
- Tube sheet thickness
- Tube thickness and diameter
- Should be built at a minimum 5 sq ft per BHP
- 30+ year life with proper maintenance

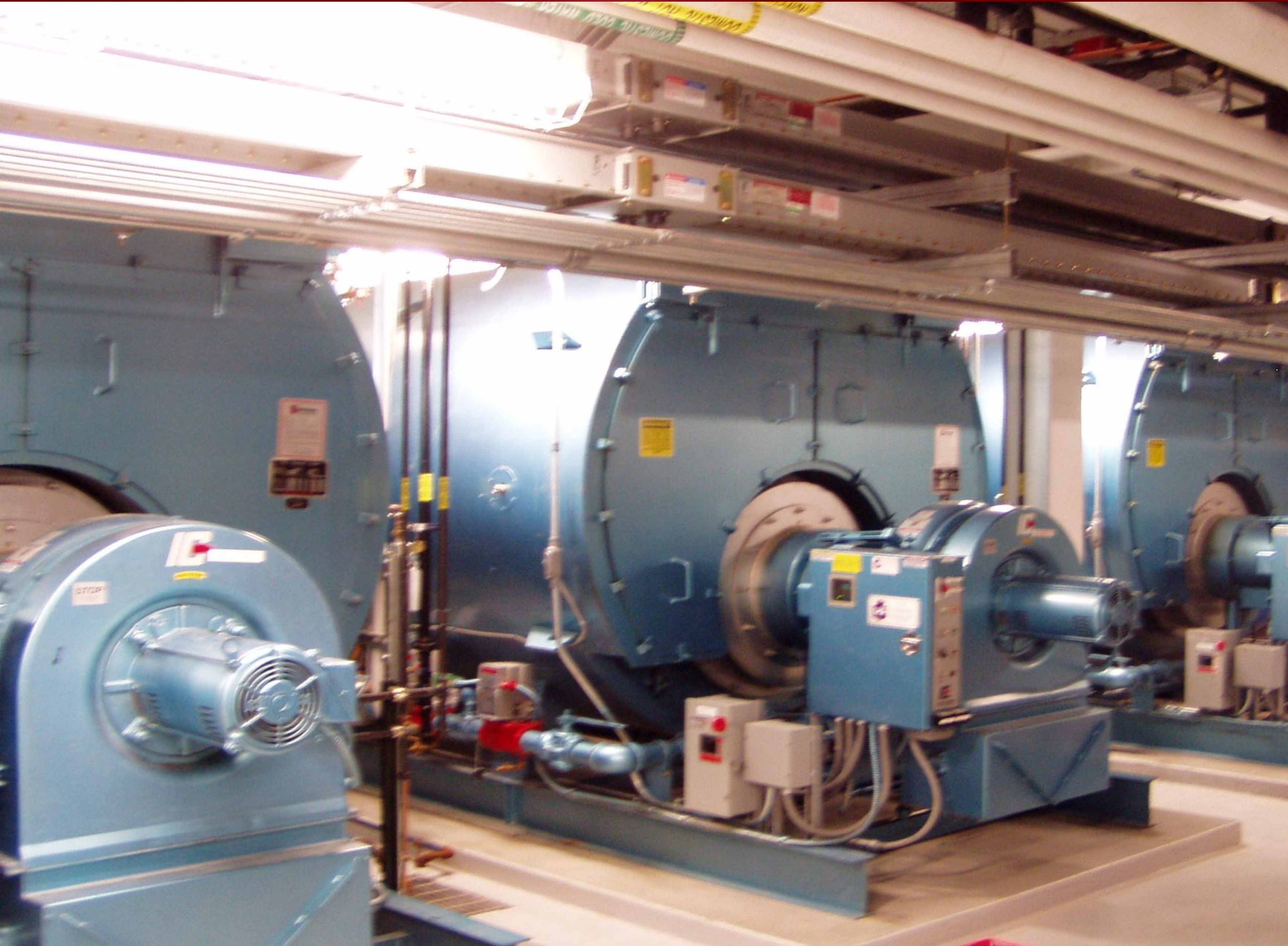



SUPERIOR


DOMESTIC HOT WATER

Firetube Summary

- Heat transfer and efficiency is a function of time, temperature and turbulence
- Additional passes creates slightly better efficiencies.
- The greater the # of passes, the greater the back pressure (more fan HP = more electricity)
- Additional passes also increase thermal stress

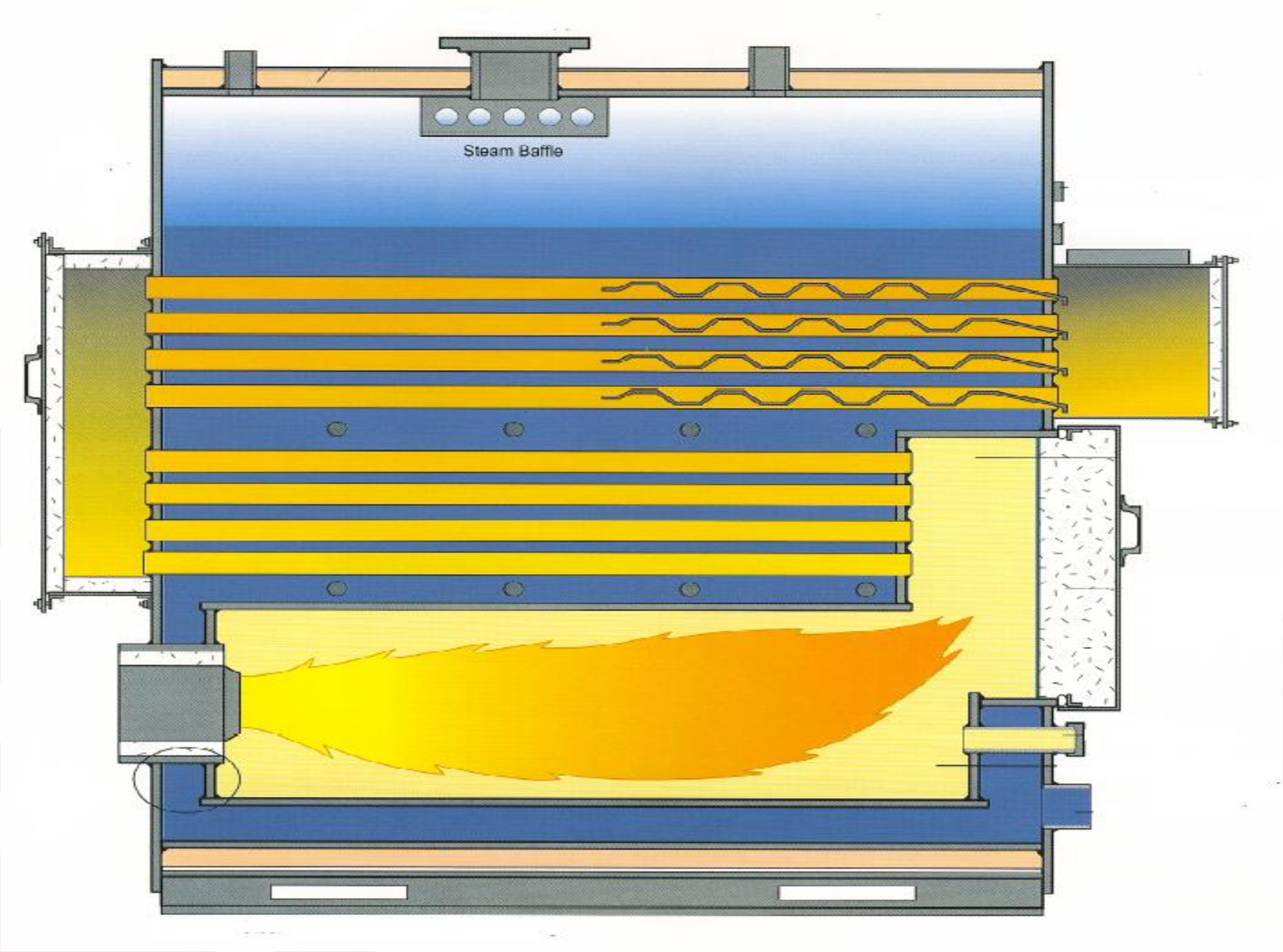


350 hp – 4-Pass Firetube

Firebox Boilers

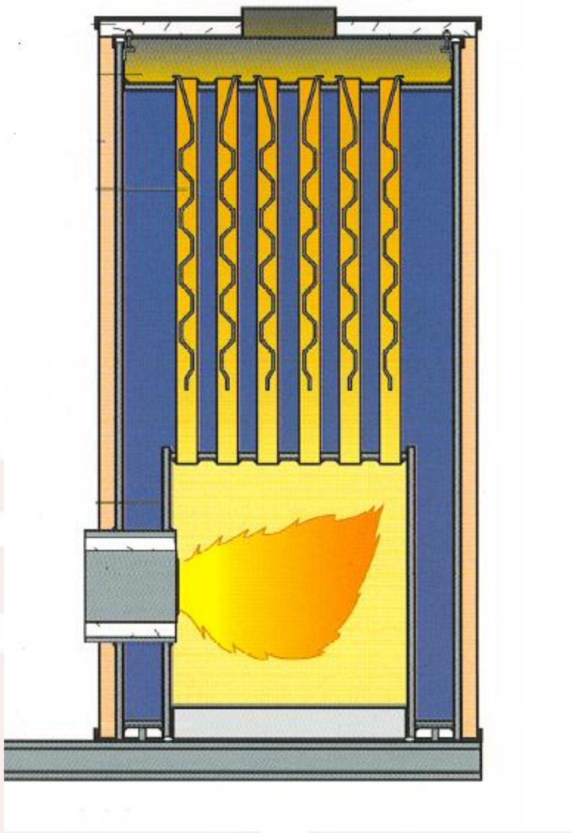
- Section IV Heating Boilers
- Large population, low cost
- 30+ year life
- Good steam quality
- Hot water and steam

Firebox Boiler



Vertical Boiler

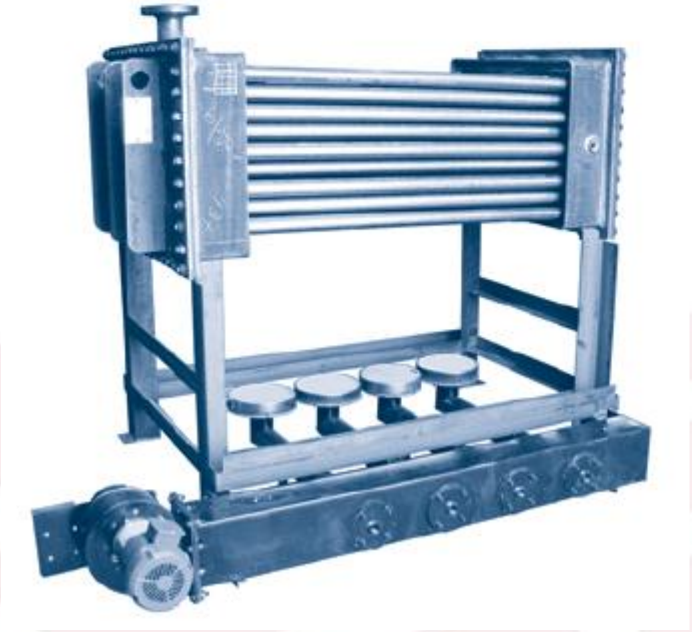
- Hot Water or Steam
- Small footprint
- Good high pressure, low capacity steam boiler
- Marginal steam quality
- Minimal heating surface, average efficiency



Watertube Boilers

- Inclined Watertube
- Flexible Bent Tube
- Membrane Wall - “D”, “S”, “O”, & “A”

Inclined Water Tube

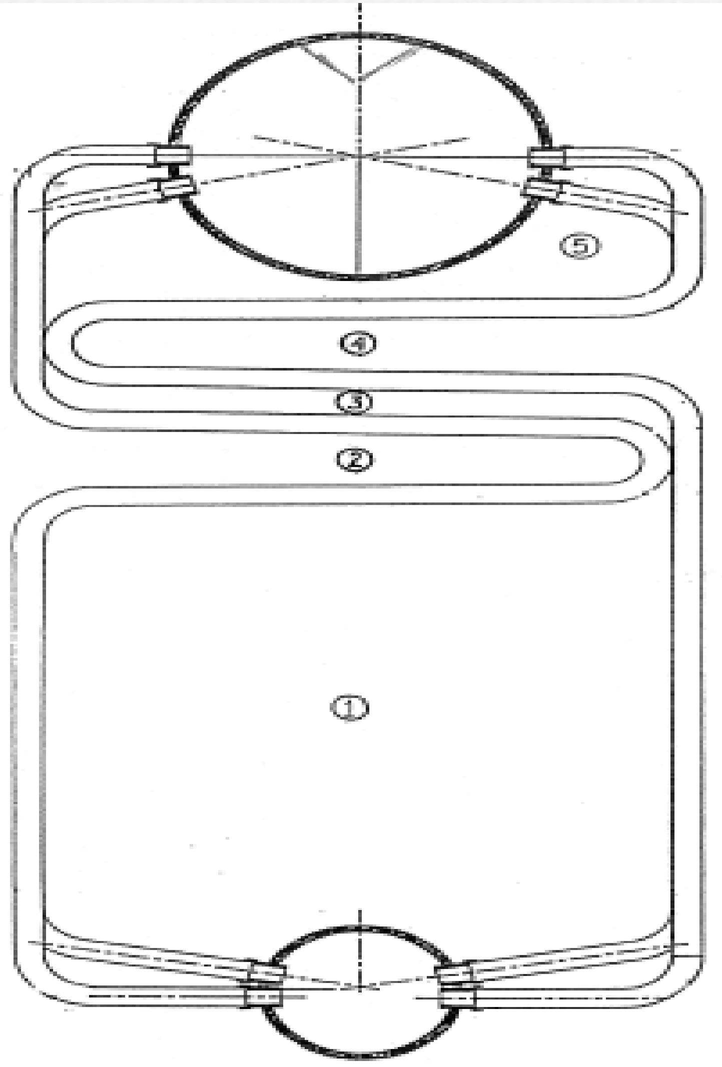


ASME Section IV low pressure steam and heating hot water boiler. Economical and are available with forced draft or atmospheric burners.

Watertube - Flexible Bent Tube

- Section I and IV
- Hot Water and Steam
- 20 year warranty on thermal shock -
  can handle temperature rises up to 100 F
- Tangent tube design
- Rapid start up

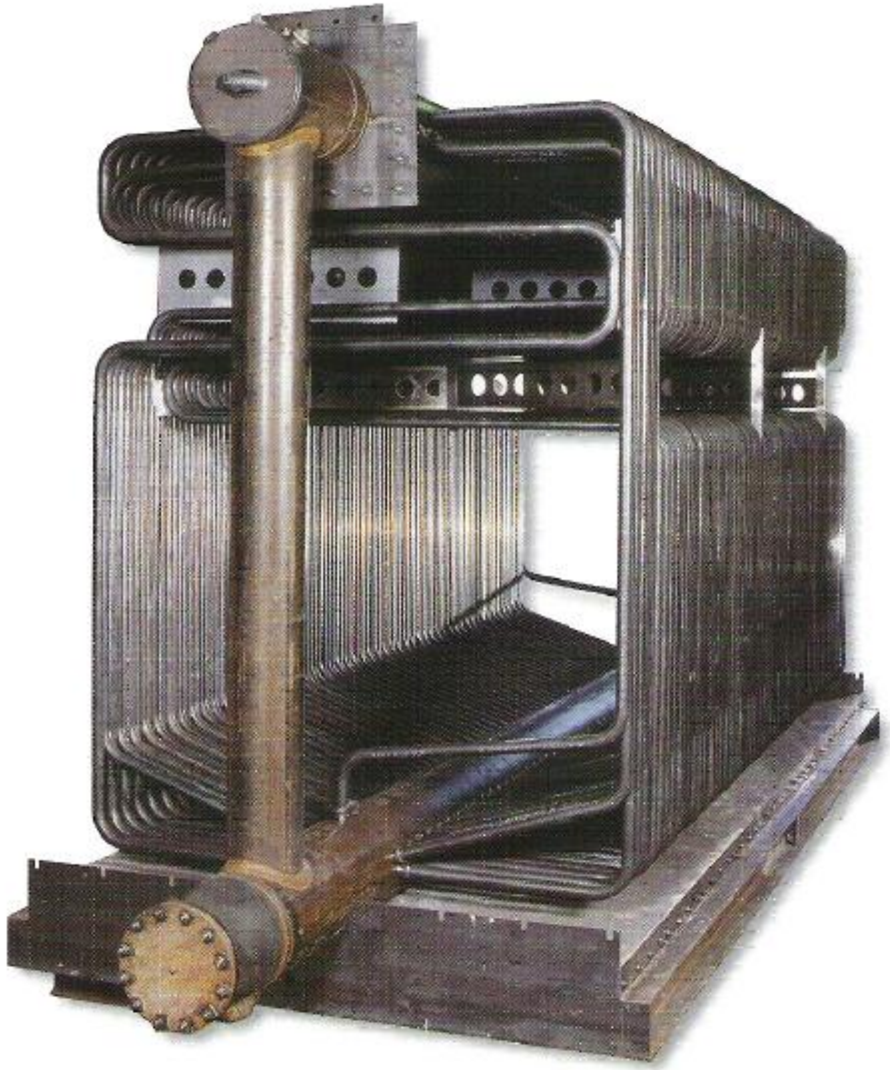
Flexible Bent Tube



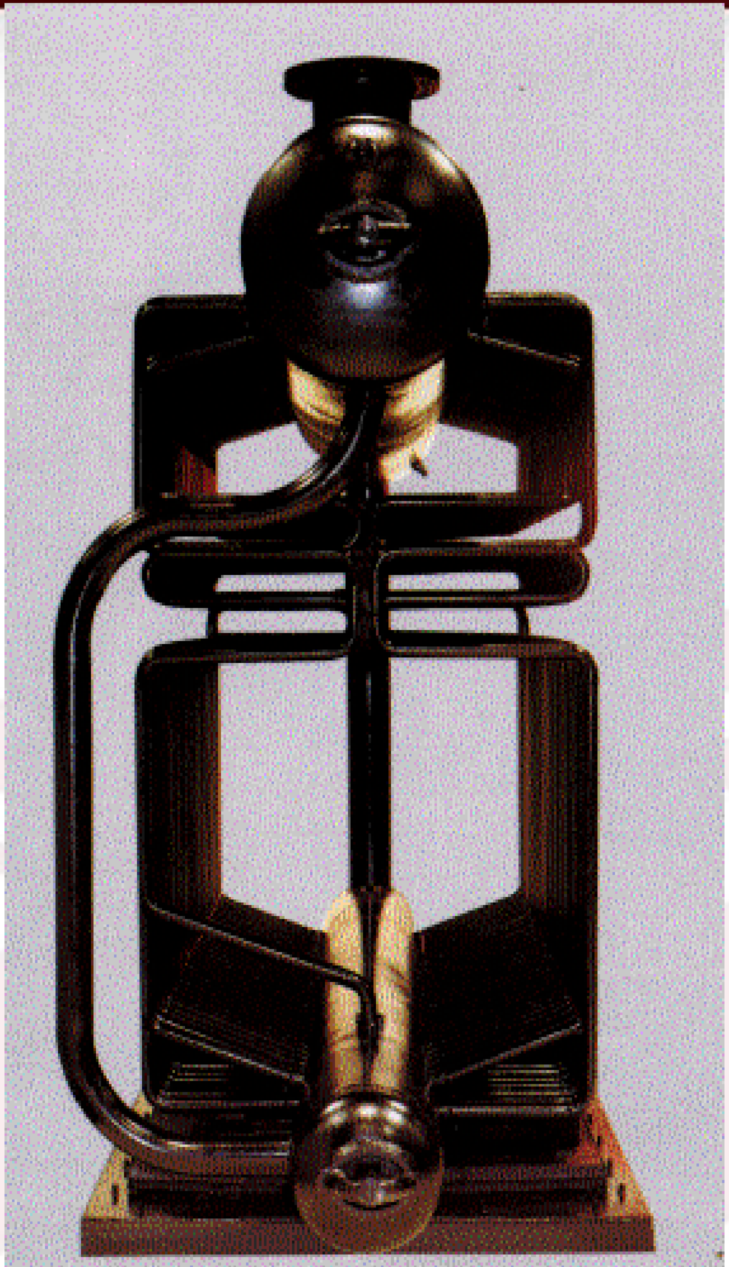
5-PASS UNILUX BOILER

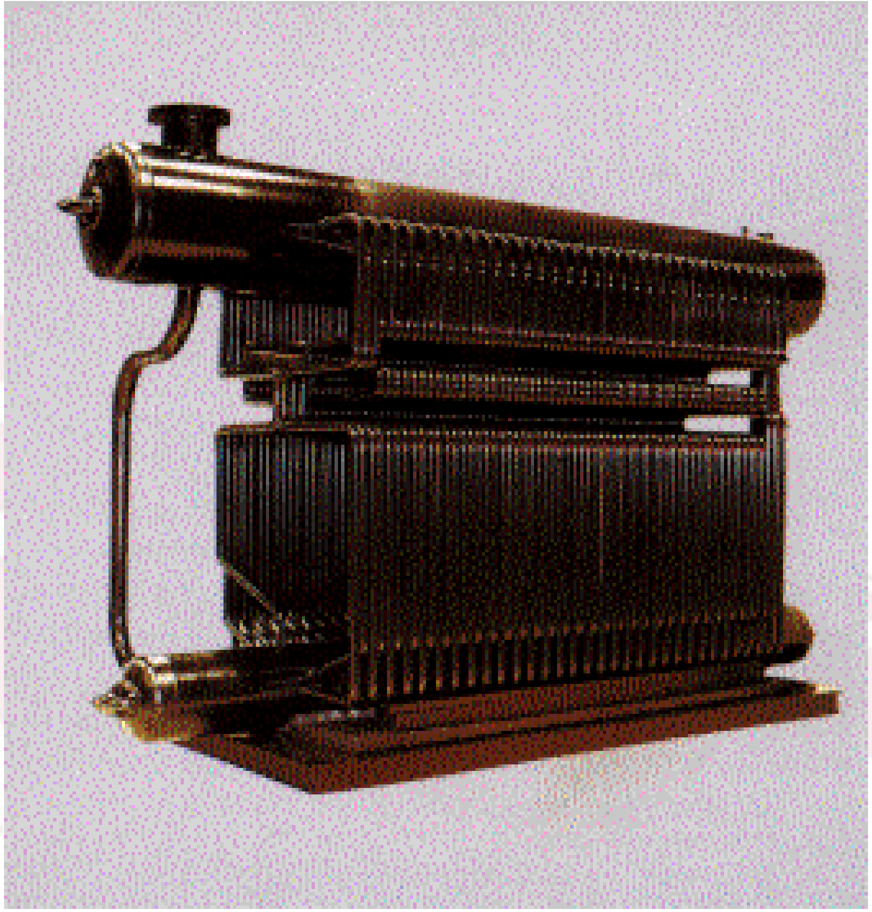
5-pass gas side flow pattern
Balanced design
4-sided waterwall furnace
High natural internal circulation rates

Flexible Bent Tube



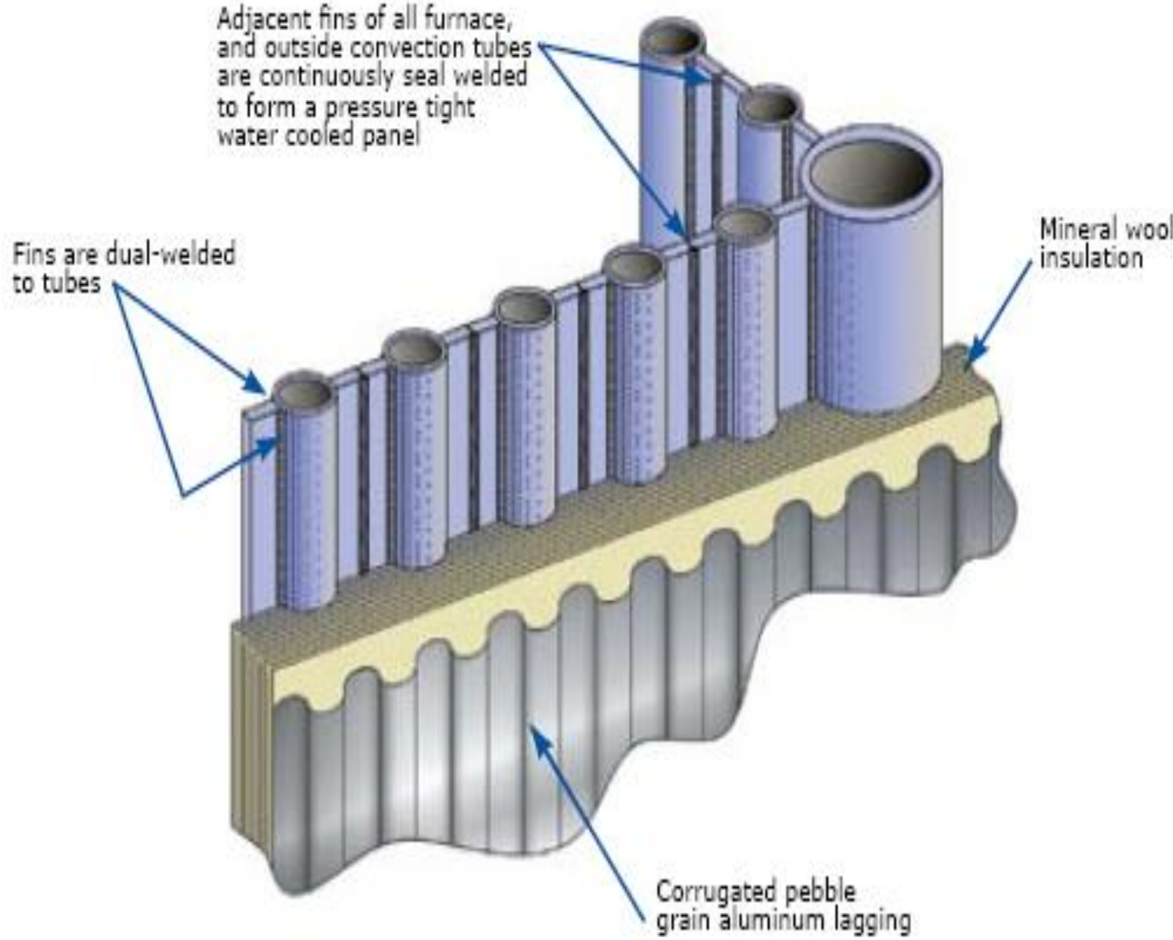
Boiler gas tight to +5” w.c.
Baffles installed in 2nd and 4th pass
Large external downcomer
Low water volume – rapid startups



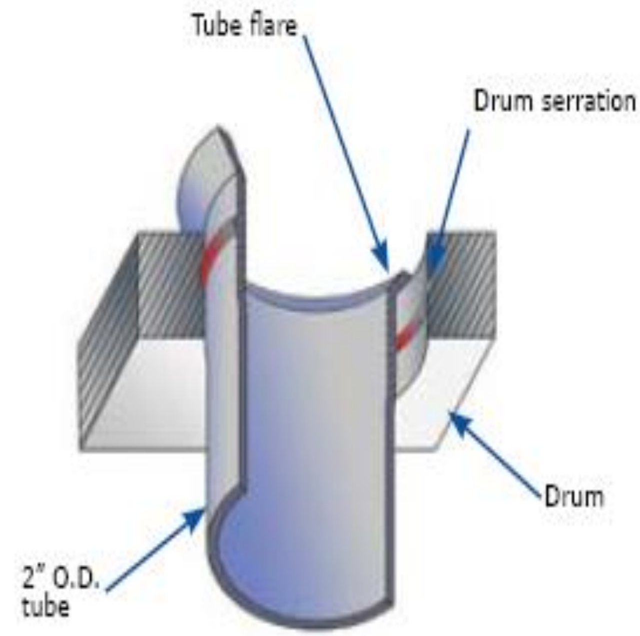


Watertube - Membrane Wall

- Larger Industrial Process Steam Boilers
- 20,000 to 500,000 lb/hr
- 40+ year life
- Highest cost
- Drum internals to improve steam quality
- Membrane wall construction
- “D”, “O”, “A”, and “S” comparison

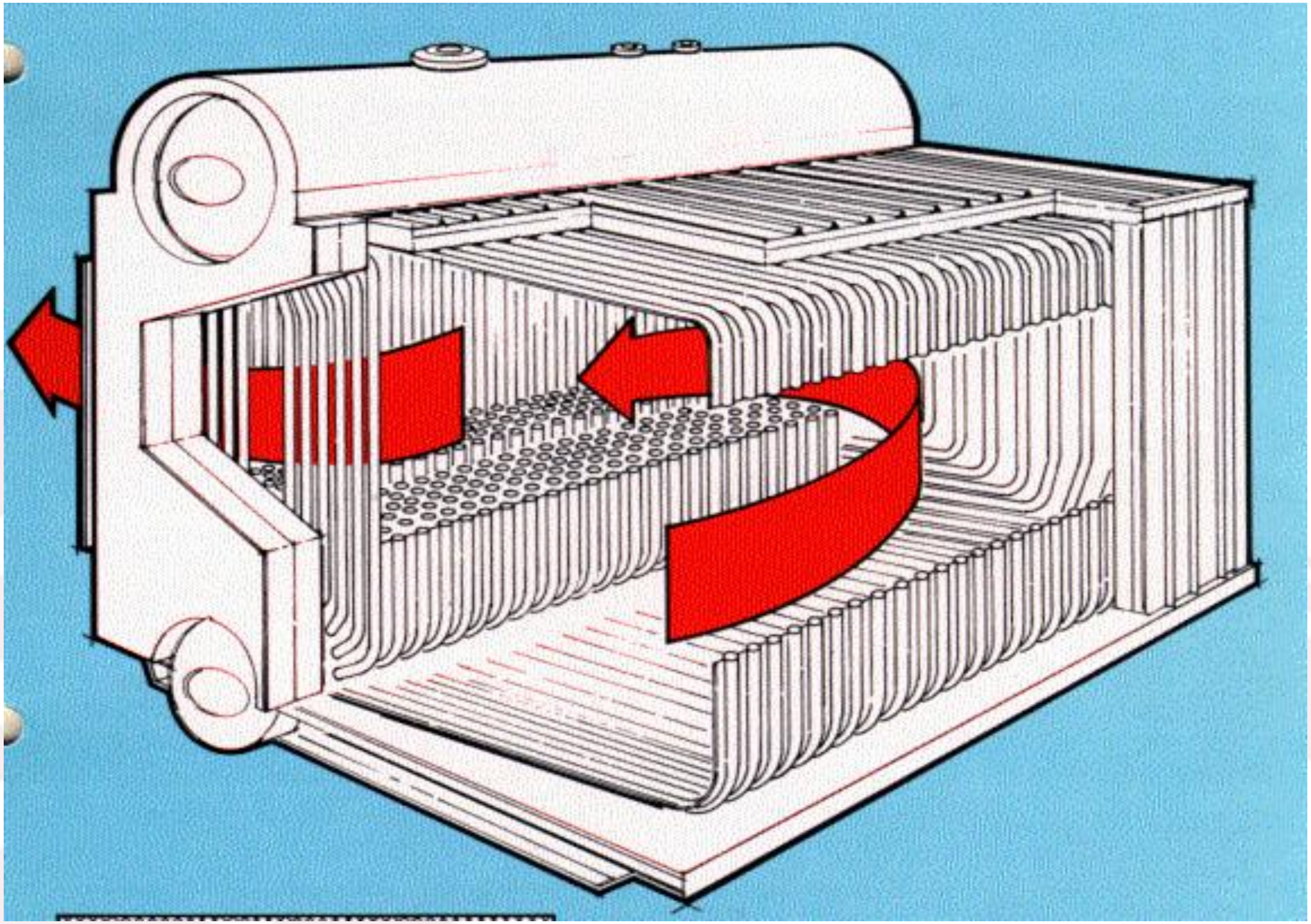


Side, front and rear wall construction featuring welded membrane design

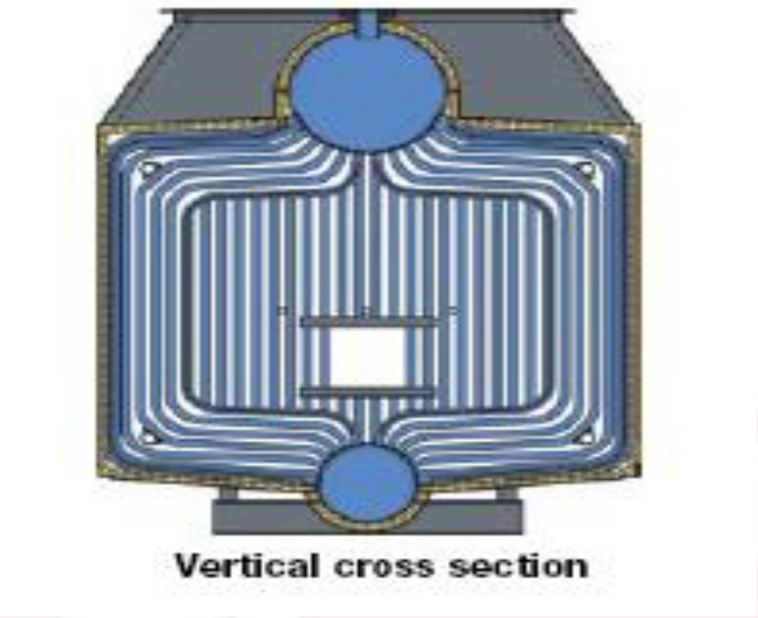


Torque-controlled, roller-expanded, tube-drum connections feature machined serrations for added strength. Welded connections are available for severe-duty service

Watertube - “D” Type



Watertube"O" Type



Another popular layout is the "O" type boiler that also includes a split path for the combustion gases.

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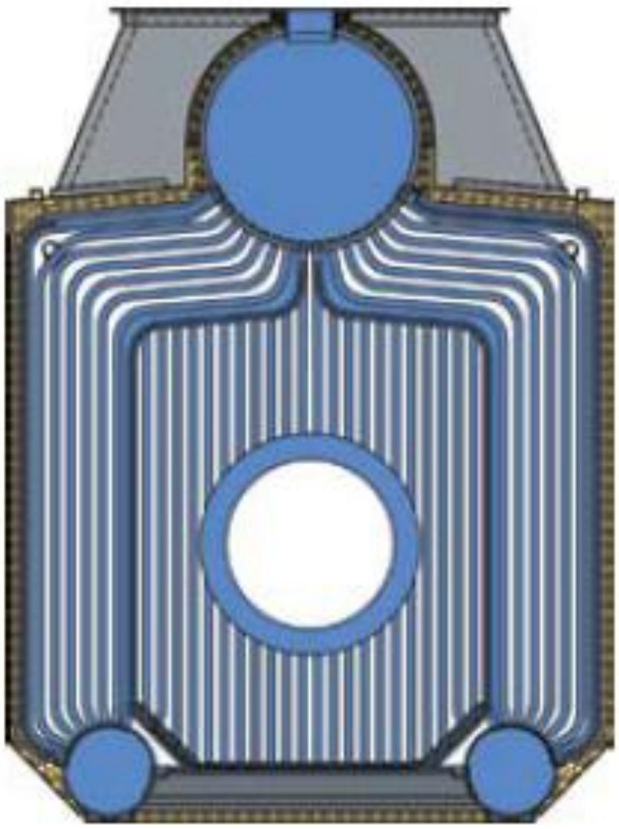
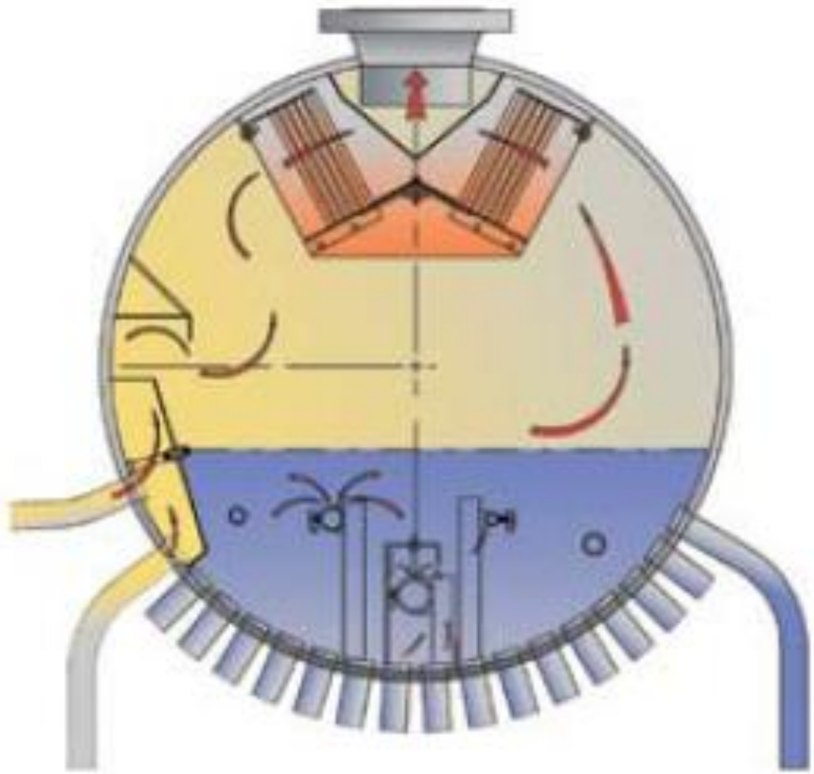
Watertube – “A” Type

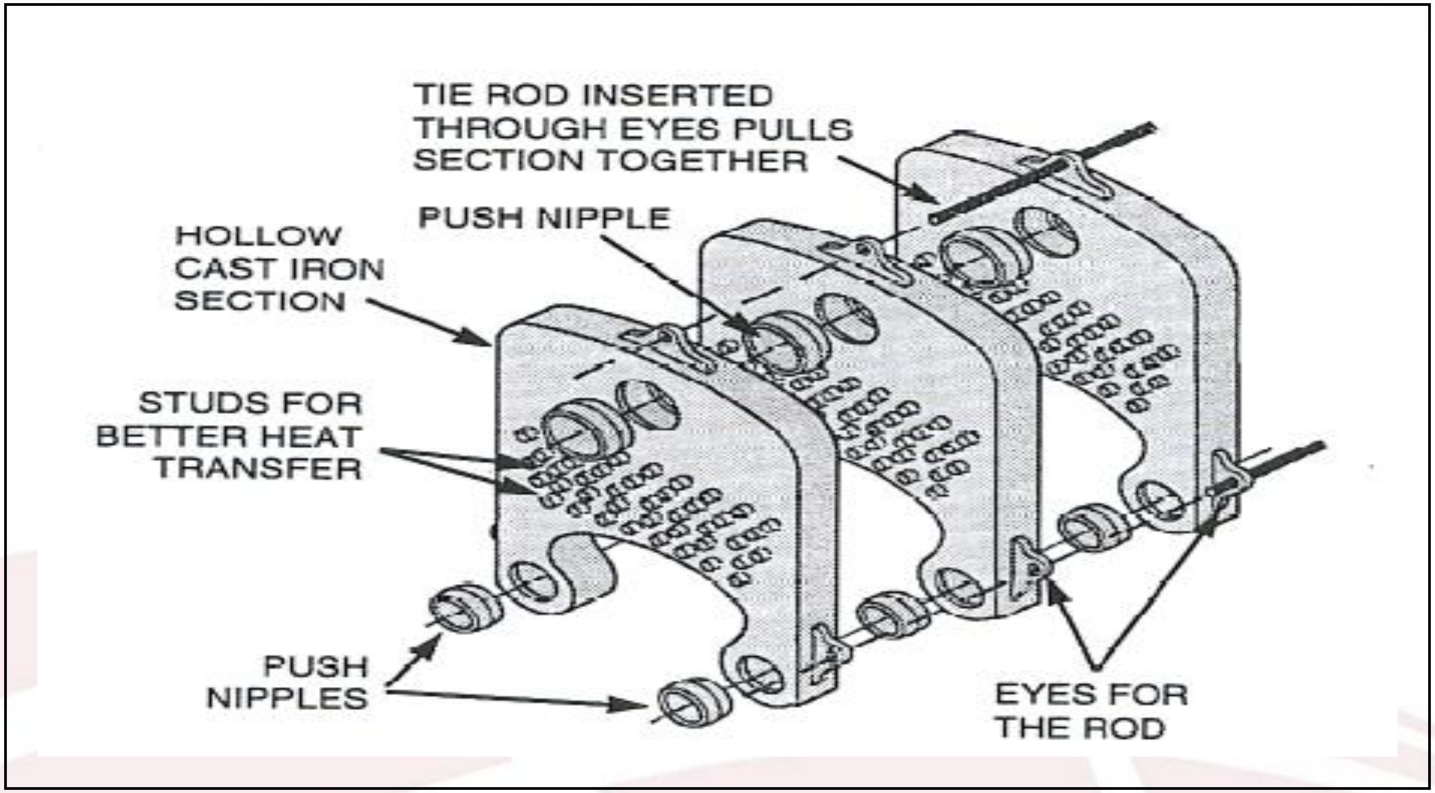




Cast Iron Boiler

- Heating hot water and steam
- Low cost
- Very prone to thermal shock
- Poor steam quality
- Build in place makes this a good choice for retrofits

Cast Iron Sectional Boiler



The hollow sections of a cast iron sectional boiler can be assembled in tight quarters.

Copper Finned

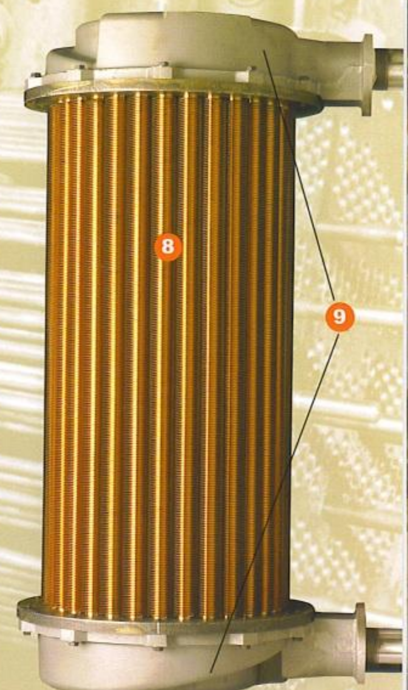
- High Efficiency – 85%+
- Small Footprint
- Section IV, hot water only
- Domestic water compatible
- Low capacity - may require many units to meet requirements

COPPER AND CAST IRON FOR BUILT-IN RELIABILITY...

8 Efficient heat transfer is assured by a design that is simple and reliable. The fins are extruded from the base metal of the tube itself (there are no mechanical tube-fin joints). The tubing is then drawn through dies that form this special fin pattern. Combustion gases cannot escape from the boiler without being forced across heat transfer surface. There are no baffles, tie-bands or insulation to loosen, corrode or interfere with periodic maintenance.

9 The heat exchanger uses bolted cast iron heads at both the top and bottom tubesheets. When these heads are removed, the tubes and tubesheets are fully visible and accessible. Engineered using state-of-the-art, computerized finite element techniques, the interior passageways are specially shaped to assure uniform water flow through every tube in the heat exchanger. A PK exclusive, this advanced design assures outstanding heat transfer performance and exceptional durability for years to come.

10 The tubesheets are finely machined. Tube holes are serrated and the tubes are then roller expanded into the holes for a joint of exceptional integrity. Notice the o-ring channels: that's how we seal the joint between tubesheet and cast iron heads. Reassembly after inspection is simple.



This heat exchanger can be furnished with non-ferrous water-side construction for domestic water heating applications.

...PROBABLY THE FINEST HEAT EXCHANGER OF ITS KIND, EVER.

Condensing

- ALL boilers can condense
- Condensing recaptures the latent heat in the waste flue gases
- Acid is a byproduct, SS or AL heat exchanger required.

We Call it a "Heat Engine"

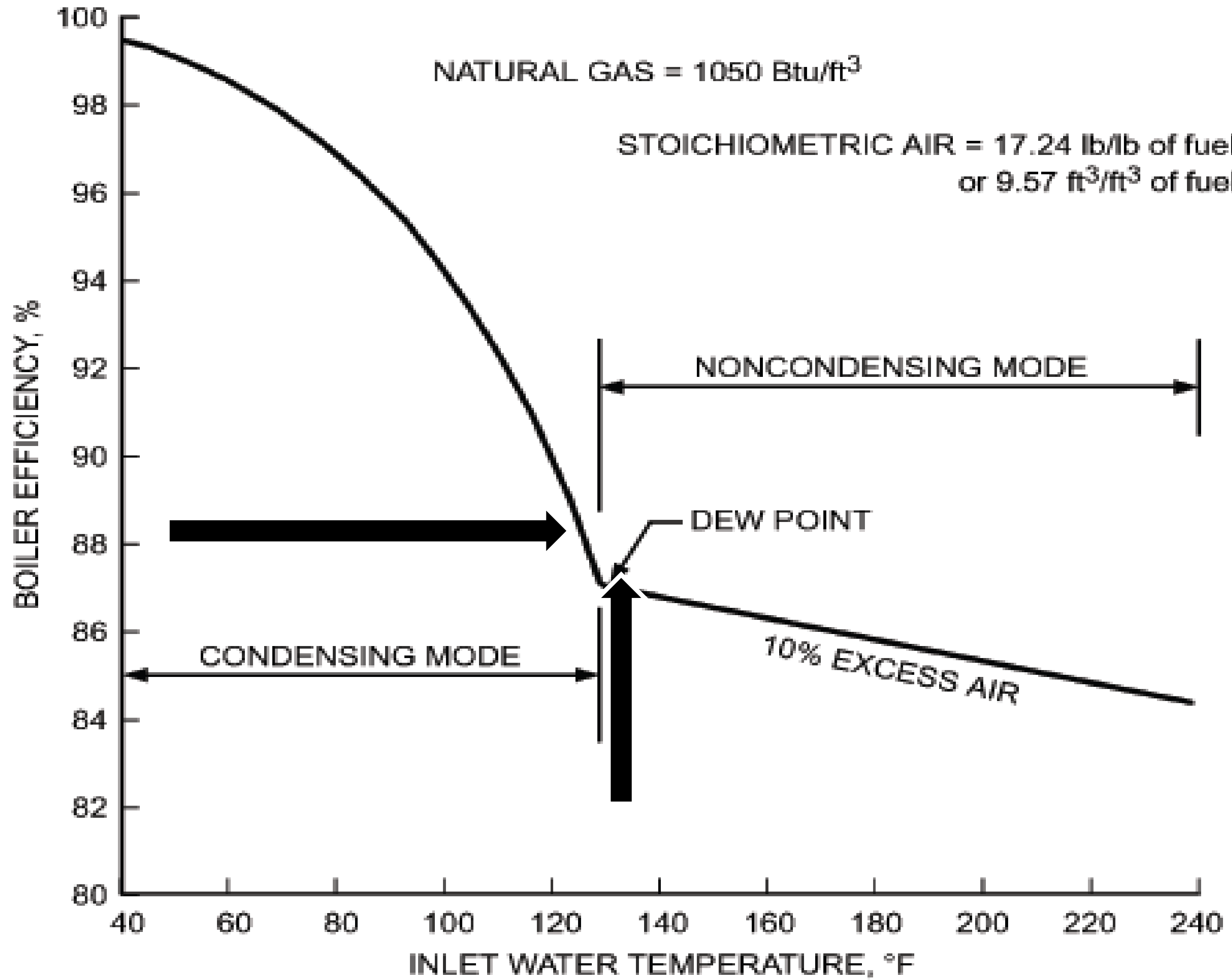
Variable temperatures…frequent cold starts…variable system flows…heat pump, radiant panel and snow melt systems…systems with running loads that are only a small fraction of the design load…common conditions that demand more from modern boilers than the traditional materials and methods of boiler design can achieve.

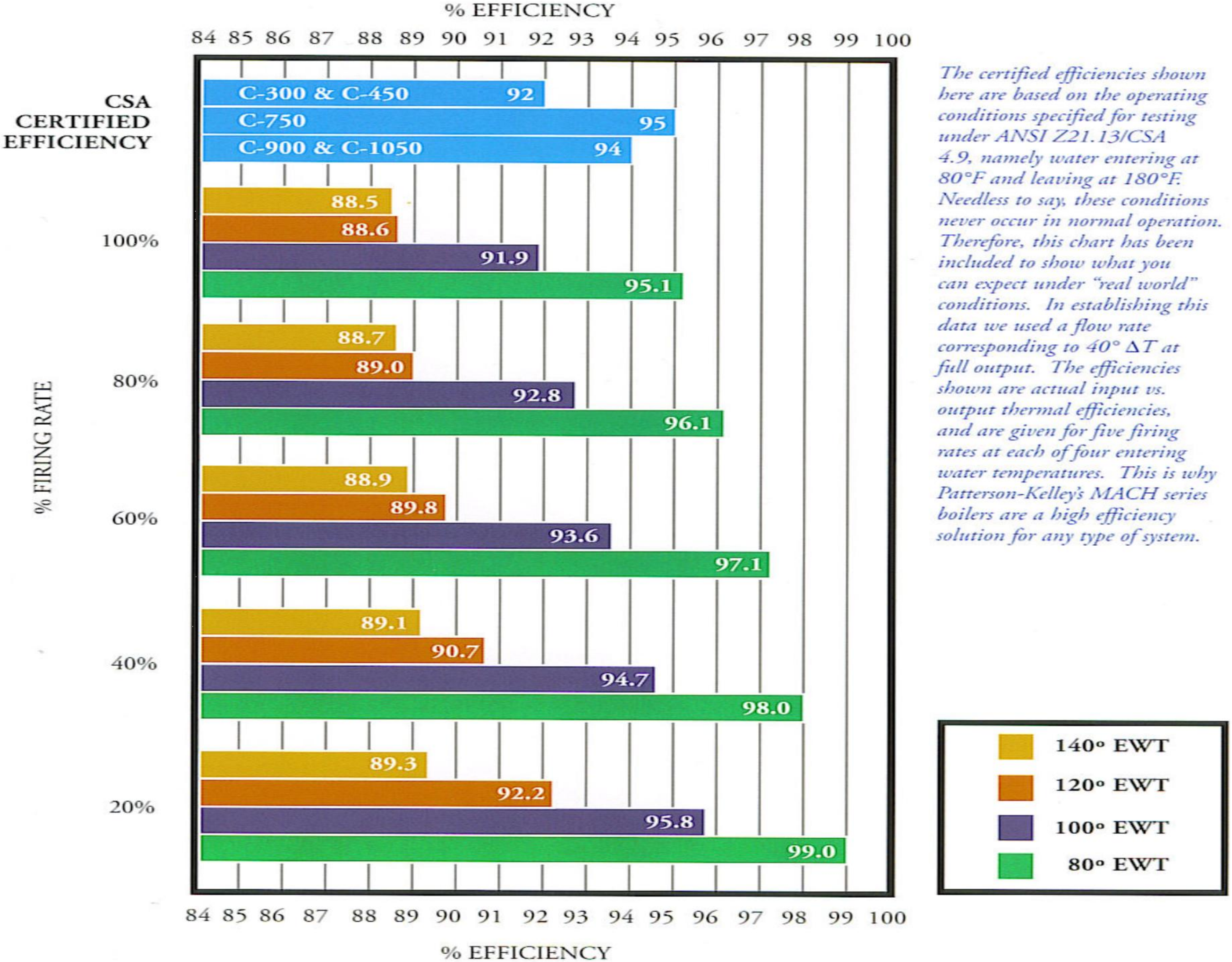
In response to all this, most manufacturers have modified old designs to add new functionality. But is this the best approach? There comes a time when the boiler designer has to build a new solution from the ground up, creating a machine precisely tailored to new conditions and requirements. Thus the MACH boiler.

MACH's basic building block is a cast sectional heat exchanger of revolutionary design. Unlike older cast iron sectional boilers, each section of the MACH boiler is a fully independent heat exchanger. The sections are mounted in parallel, and water enters and exits each section through external headers. Gone are the section-to-section push nipples or gaskets that were the weak link in older designs.

Our unique aluminum alloy has superior castability for more intricate, performance enhancing shapes and features. Water-side flow paths are engineered to create highest velocity at points of highest temperature. The configuration is both counter-flow and cross-flow, further enhancing heat transfer efficiency while minimizing pressure drop and pumping horsepower requirements.

Perhaps most important, this advanced alloy makes an oxide layer without pitting. This is the secret to building a boiler that can withstand the corrosive attack of condensed flue gases for years of reliable operation. The MACH heat exchanger features the best, most advanced metallurgy ever offered in a commercial heating boiler. When this heat exchanger is combined with its equally advanced burner assembly, we call it a "heat engine."


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 EFFICIENCY, %
100
98
96
94
92
90
88
86
84
82
80
40
60
80
100
120
140
160
180
200
220
240
INLET WATER TEMPERATURE, °F



The certified efficiencies shown here are based on the operating conditions specified for testing under ANSI Z21.13/CSA 4.9, namely water entering at 80°F and leaving at 180°F. Needless to say, these conditions never occur in normal operation. Therefore, this chart has been included to show what you can expect under "real world" conditions. In establishing this data we used a flow rate corresponding to 40° ΔT at full output. The efficiencies shown are actual input vs. output thermal efficiencies, and are given for five firing rates at each of four entering water temperatures. This is why Patterson-Kelley's MACH series boilers are a high efficiency solution for any type of system.

ASHRAE Handbook guidelines

For maximum reliability and durability over extended product life, condensing boilers should be constructed from corrosion resistant materials through out the fireside combustion chamber and heat exchanger. These materials include certain grades of stainless steel and aluminum.

The condensing portion of these boilers requires special material to resist the corrosive effects of the condensing flue gases. Cast iron, carbon steel, and copper are not suitable materials for the condensing section of a boiler. Certain stainless steels and aluminum alloys, however, are suitable.

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Copper-Fin HX -Condensing

- Secondary HX's are copper coated or Stainless Steel
- If the coating Fails this is what happens!
- Most Warranties do not cover condensate Corrosion

Condensing Design Considerations

- Dual fuel
- Turndown
- Minimum flow
- Primary/secondary pumping or variable primary
- Hybrid systems
- Water treatment


MACH
MACH
MACH
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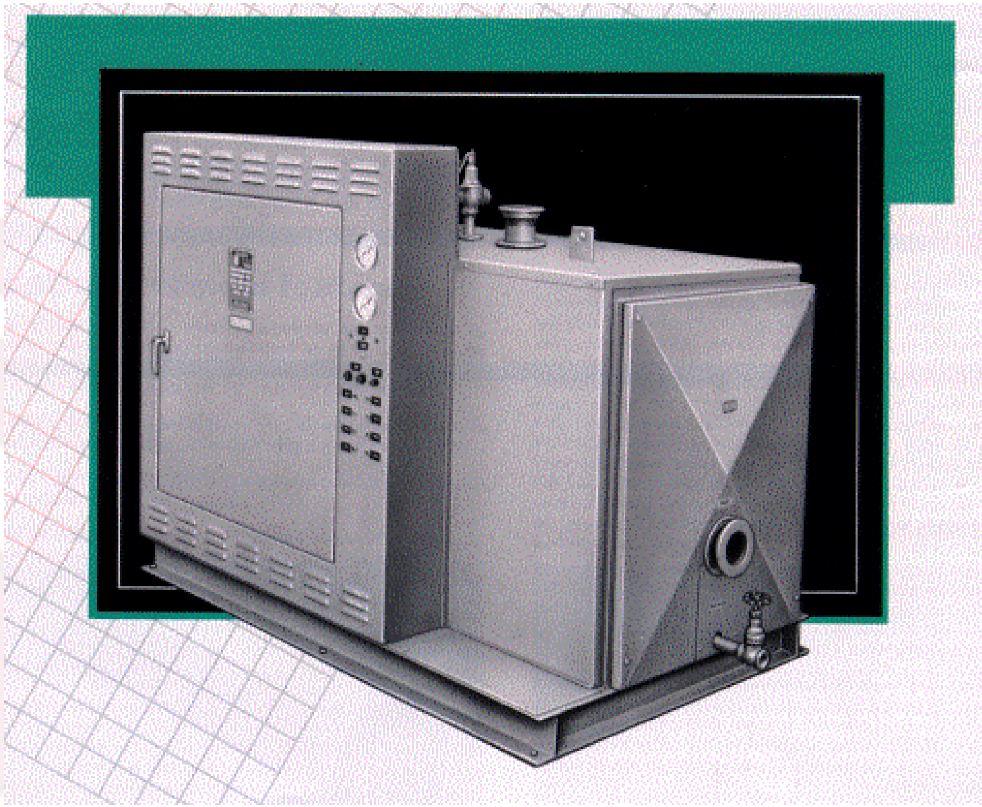
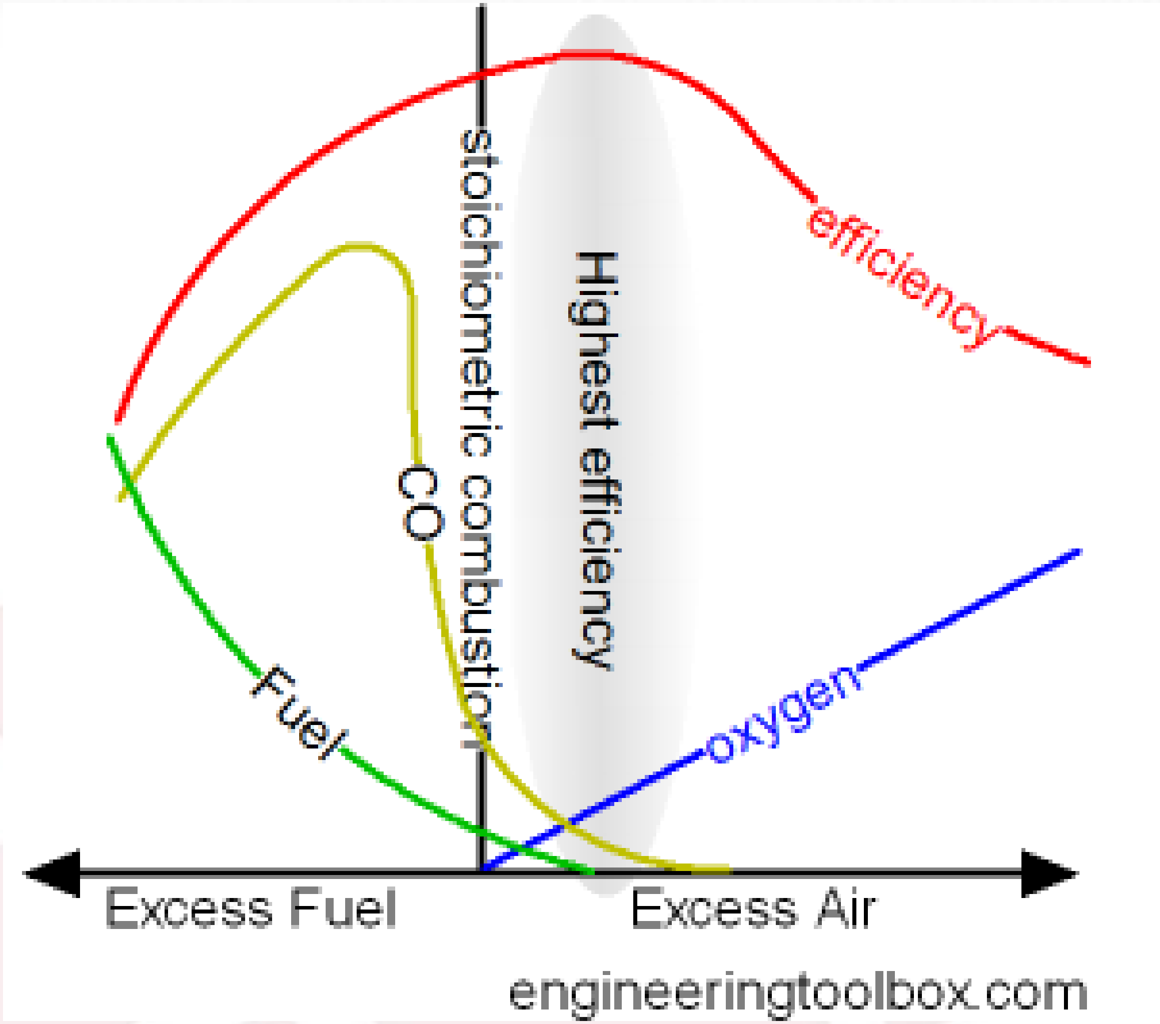
Electric Boilers

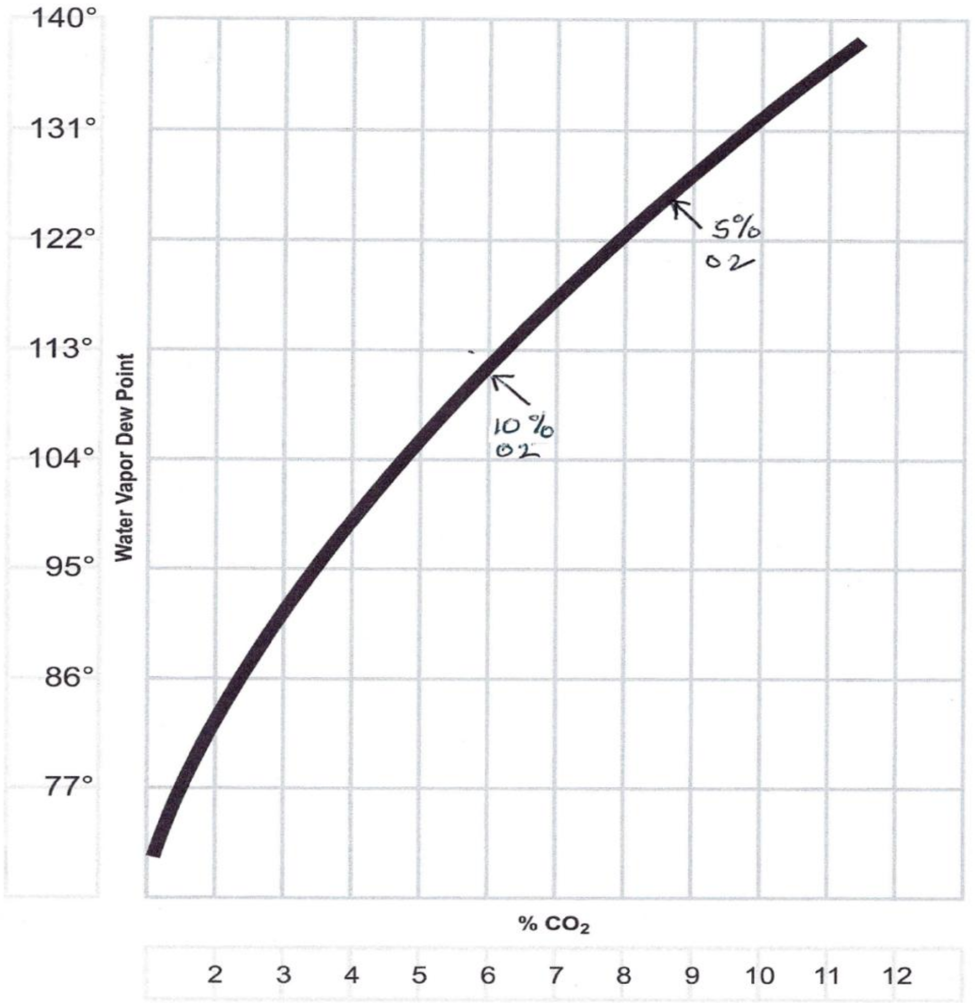
- Hot water and steam
- Section I and IV
- Good choice for all electric utility
- No combustion air or venting requirements



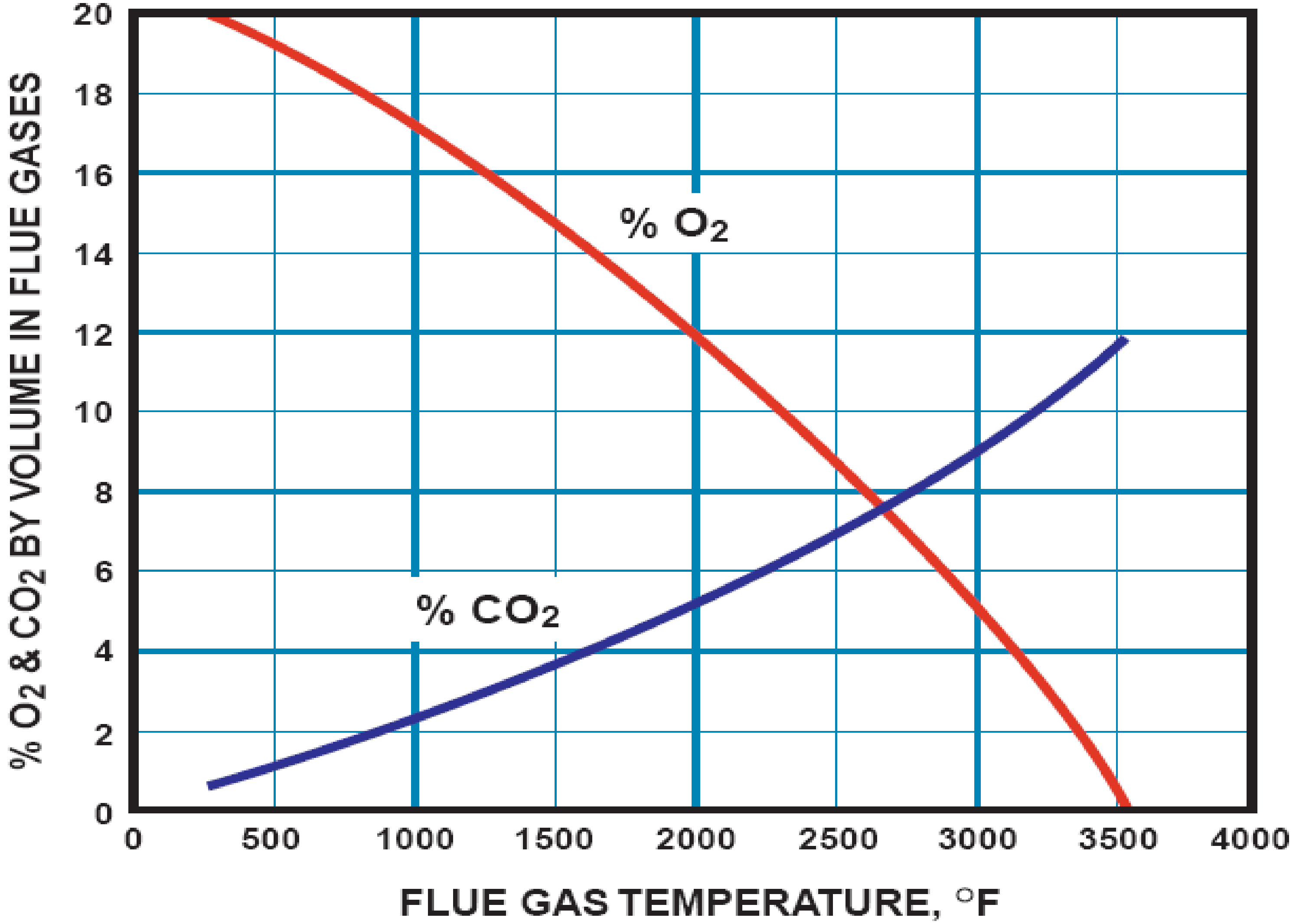
Boiler Efficiency Considerations


efficiency
stoichiometric combustion
Highest efficiency
CO
Fuel
oxygen
Excess Fuel
Excess Air
engineeringtoolbox.com

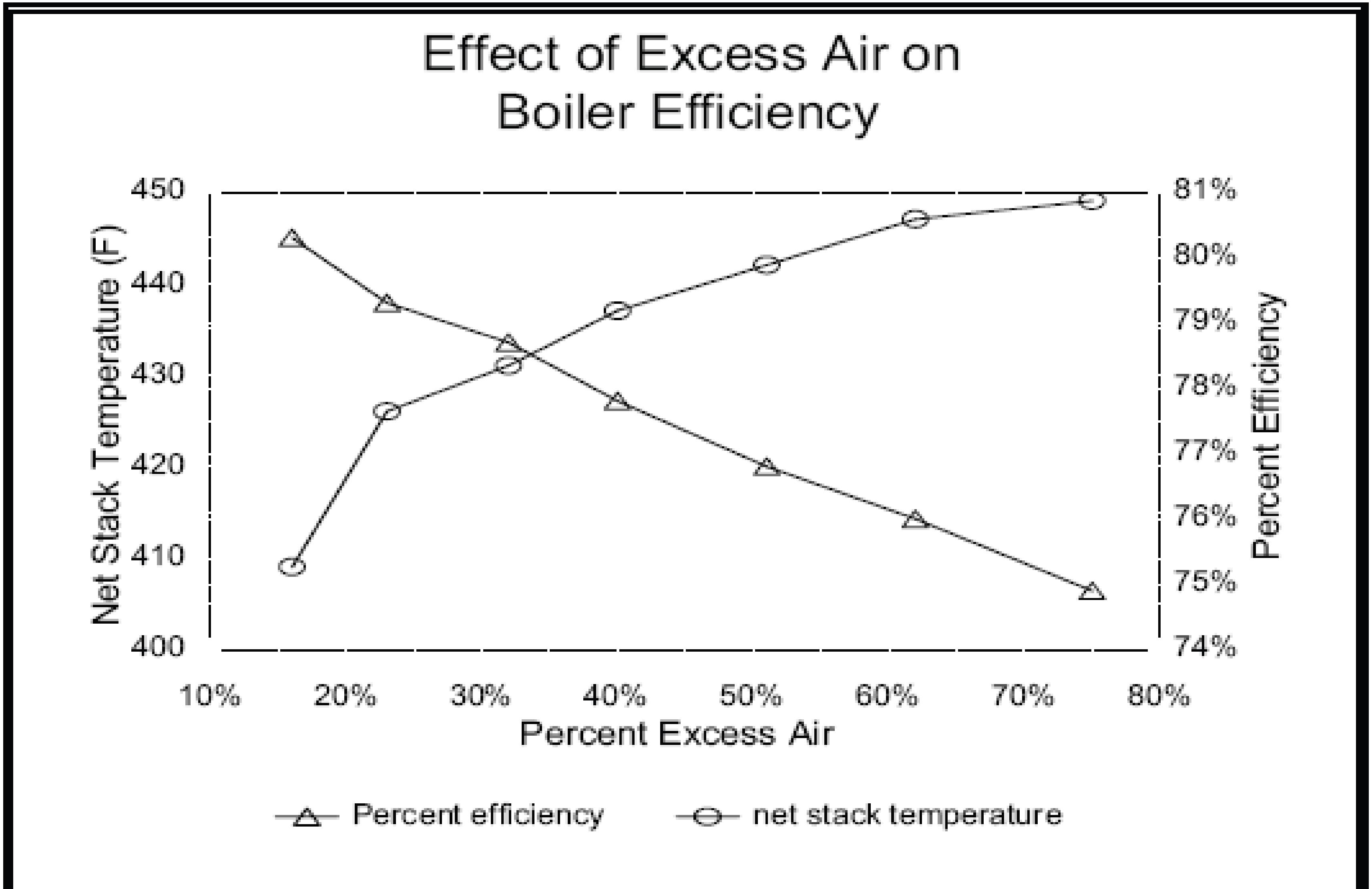

Buyer Beware



O²	CO²	Excess %
3.00%	10.00%	15.00%
4.00%	9.50%	20.00%
5.00%	9.00%	29.00%
6.00%	8.40%	36.00%
7.00%	7.90%	46.50%
8.00%	7.30%	56.50%
9.00%	6.70%	68.60%
10.00%	6.20%	83.50%
11.00%	5.60%	100.00%



20
18
16
14
12
10
8
6
4
2
0
0
500
1000
1500
2000
2500
3000
3500
4000
% O2
% CO2
% O2 & CO2 BY VOLUME IN FLUE GASES
FLUE GAS TEMPERATURE, °F



Effect of Excess Air on
Boiler Efficiency
Net Stack Temperature (F)
450
440
430
420
410
400
Percent Efficiency
81%
80%
79%
78%
77%
76%
75%
74%
10%
20%
30%
40%
50%
60%
70%
80%
Percent Excess Air
Percent efficiency
net stack temperature

Thank You!

- Questions?