



Steam Boiler Basics

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Hughes Machinery

Topics

- ✦ Boiler Fundamentals
- ✦ Types of Firetube Boilers
- ✦ Steam Boiler Trim
- ✦ Steam Boiler Room Components



Boiler Fundamentals



Low Pressure Boiler

- ★ ASME Section IV, Heating Boiler
- ★ 15 PSIG Steam Boiler or lower
- ★ Hot Water Boilers below 250 F
- ★ Hot Water Boilers below 160 PSIG



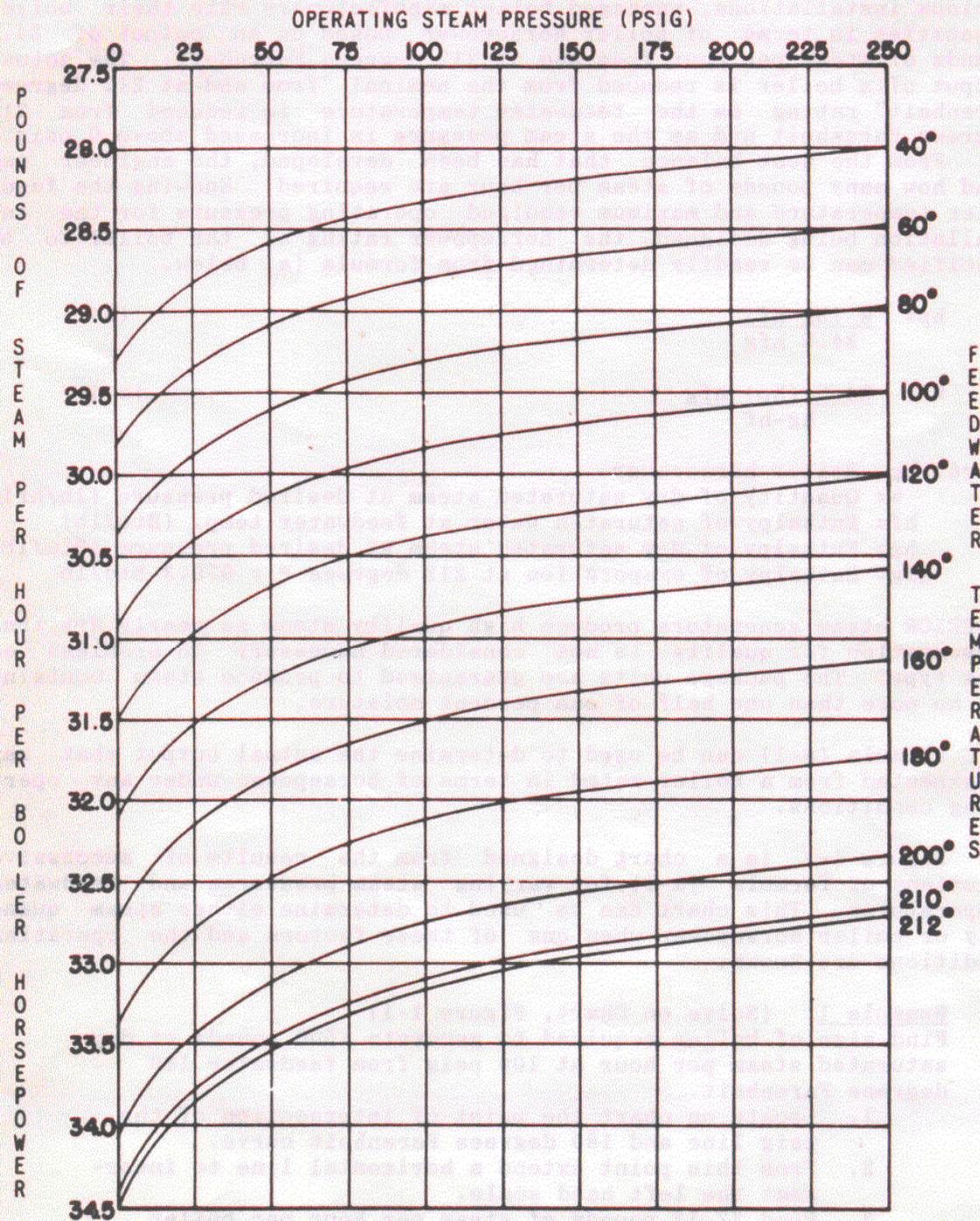
High Pressure Boilers

- ★ ASME Section I, Process Boiler
- ★ Steam Boilers above 15 PSIG
- ★ Hot Water Boilers above 250 F
- ★ Hot Water Boilers above 160 PSIG

Boiler Horsepower

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

Steam Output



Steam output at varying operating pressures and feedwater temperatures.

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

Combustion Air Requirements

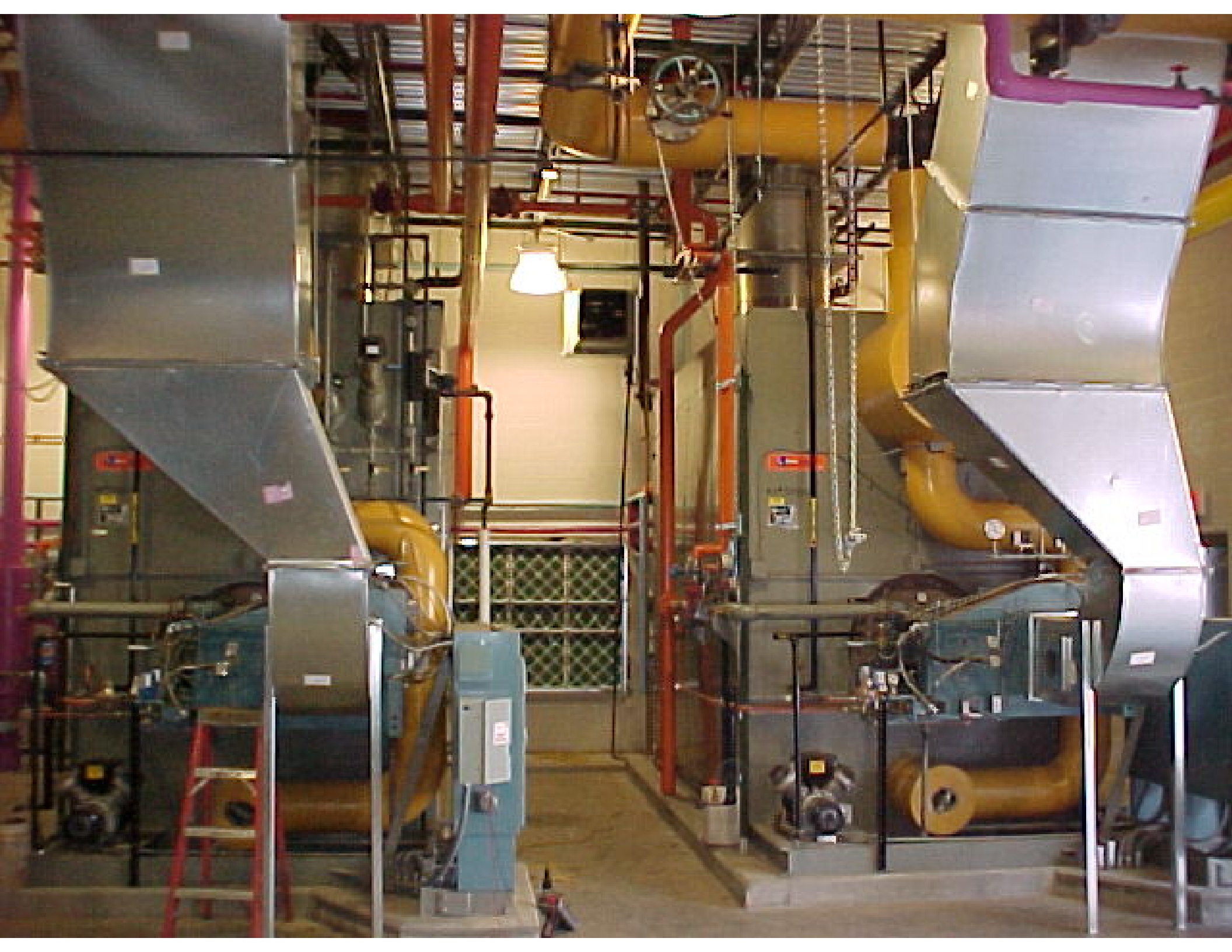
☀ Controlling Combustion Air Temp

- ☀ 1% per 50 Deg. of preheat
- ☀ Thermal shock
- ☀ Changes total mass through boiler

☀ VFD Burner Fans

- ☀ Electrical savings
- ☀ Reduce Noise

☀ Ducted Combustion Air with Heating Coil



Draft Control

- ✱ Most boilers prefer a neutral to a slightly negative draft at the flue gas discharge
- ✱ With taller stacks or excessive draft install barometric dampers or a modulating draft control system
- ✱ When draft is limited, induced draft fans may be required
- ✱ Boiler room pressure can influence draft



Boiler Short Cycling

- ✦ Evaluate burner turndown and the system volume to prevent boiler short cycling.
- ✦ Boiler/burner minimum output is greater than system demand.
- ✦ Short cycling turns your boiler into a reverse heat exchanger on purge cycles.
- ✦ Boiler short cycling can cost you 20% or more on fuel consumption.



Boiler Short Cycling

- ✦ Short cycling can cause decades of component cycle life in a few short months.
- ✦ Thermal Stress and Boiler Failure.
- ✦ Maximize your pressure control on/off settings.
- ✦ Standing pilot type flame safeguards may eliminate the need for purge cycles.

Boiler Short Cycling

- ✦ Increase Burner Turndown?
- ✦ Flames become unstable
- ✦ Condense products of Combustion
- ✦ Laminar vs Turbulent air/gas flow

Stack Loss vs O₂

Table B.1. Natural gas stack loss (%)

Flue gas O ₂ content (%)	Flue gas temperature—combustion air temperature (°F)														
	230	250	270	290	310	330	350	370	390	410	430	450	470	490	510
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Types of Boilers

- ✦ Firetube (Furnace Tube) Boilers
- ✦ Firebox Boilers
- ✦ Vertical Boilers
- ✦ Watertube Boilers
- ✦ Cast Iron Boilers
- ✦ Copper finned/Condensing Boilers
- ✦ Electric Boilers



Firetube Boilers

- ✦ Great steam quality due to large steam volume within the boiler and large surface area for steam release
- ✦ Requires long start up times
- ✦ Potential for thermal shock if Boiler Feedwater is not Pre-Heated

Firetube Boiler

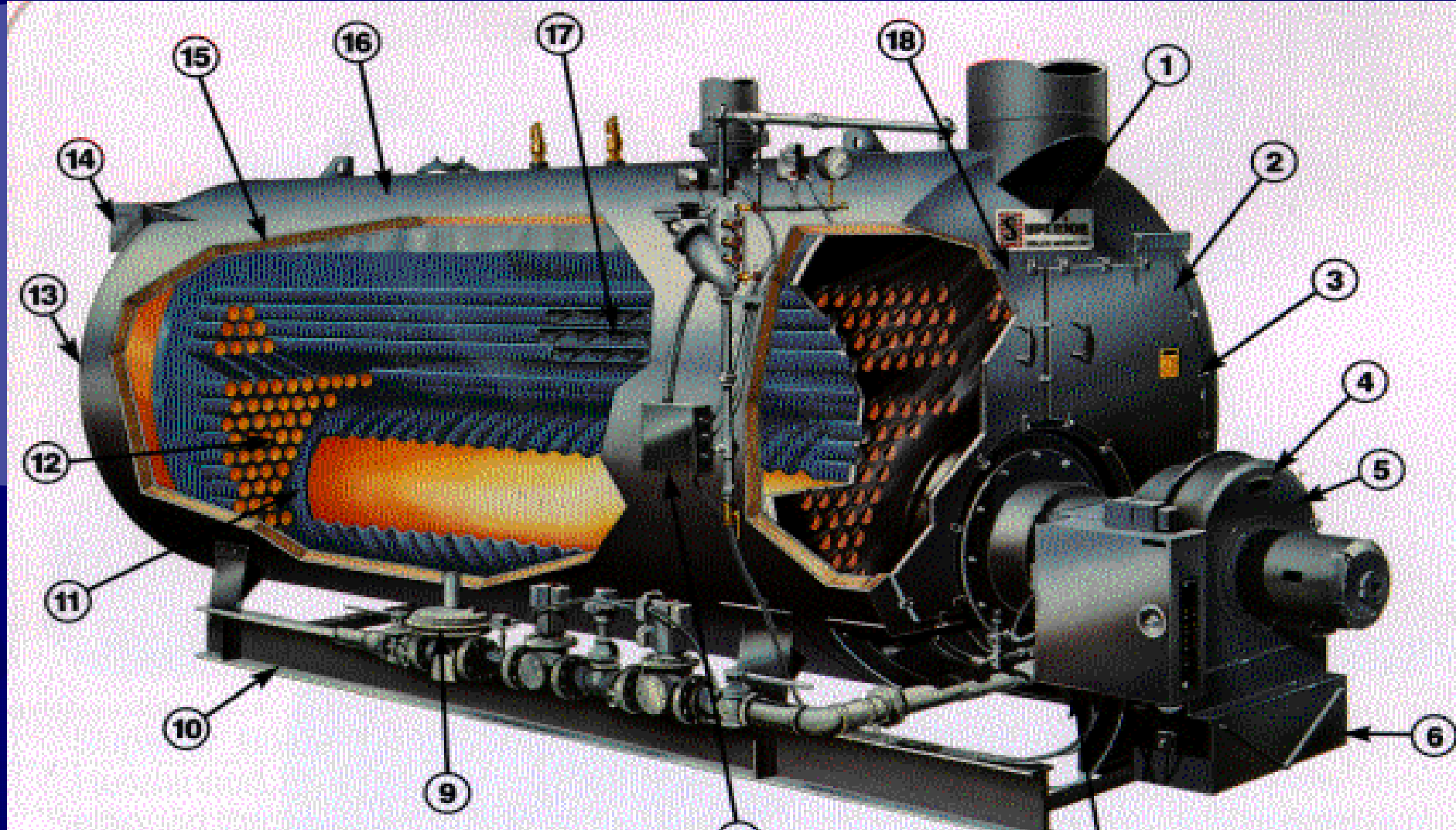
- ★ Dry Back Design - 2, 3 and 4 pass
- ★ Wet Back Design - 3 and 4 pass
- ★ Firebox - 3 pass design
- ★ Excellent Efficiencies



Firetube Boilers - Dry Back

- ✱ Two tube sheets
- ✱ Large refractory rear door
- ✱ 2, 3 and 4 pass comparison
- ✱ Increased back pressure with more passes

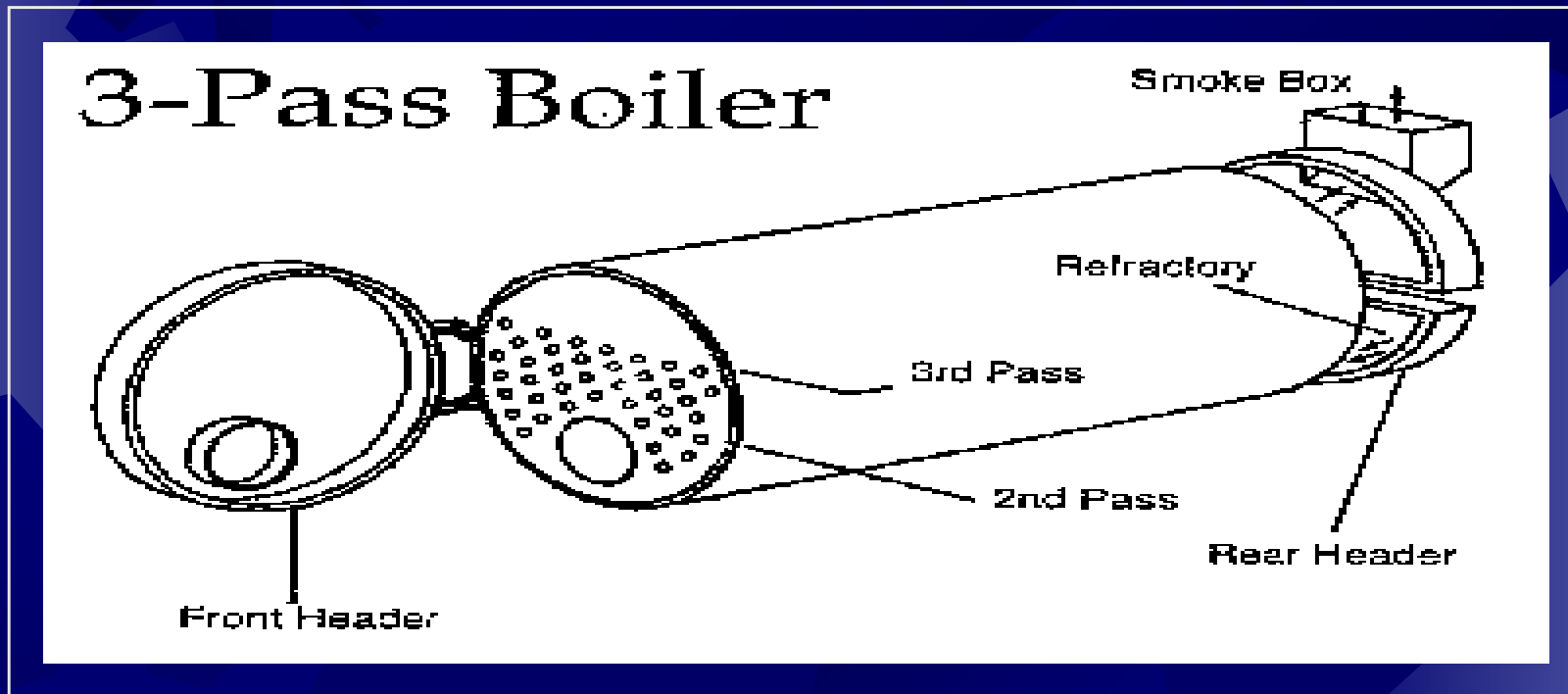
2-Pass Boiler



Heating Surface

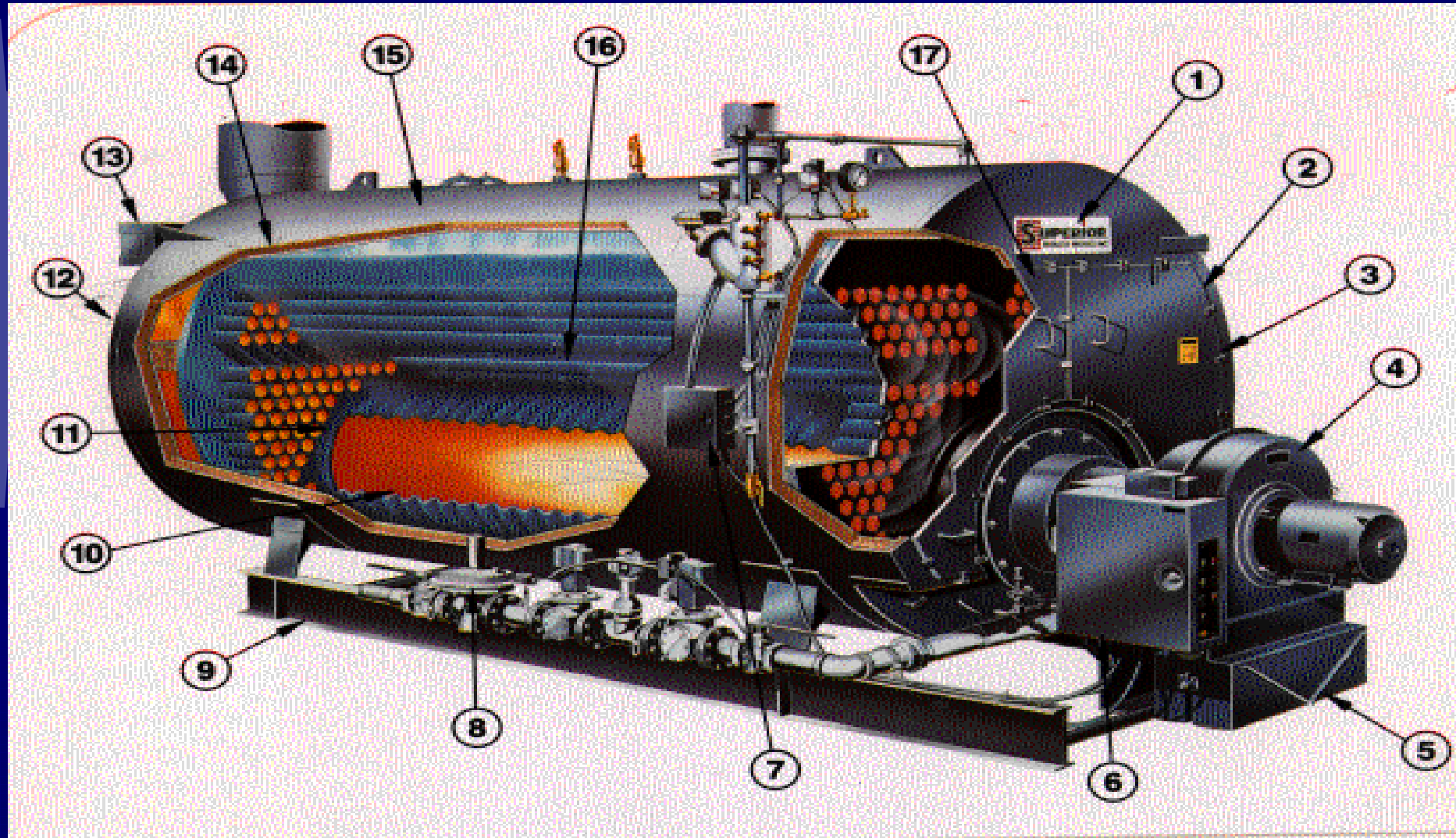
- ✱ Limited furnace area and volume on Firetube Boilers
- ✱ Most larger Firetube Boiler manufacturers build boilers at 5 sq ft of heating area/BHP
- ✱ Firebox Boilers are built at 4-5 sq ft/BHP
- ✱ Vertical Firetube Boilers can be as low as 3 sq ft/BHP

3-Pass Boiler



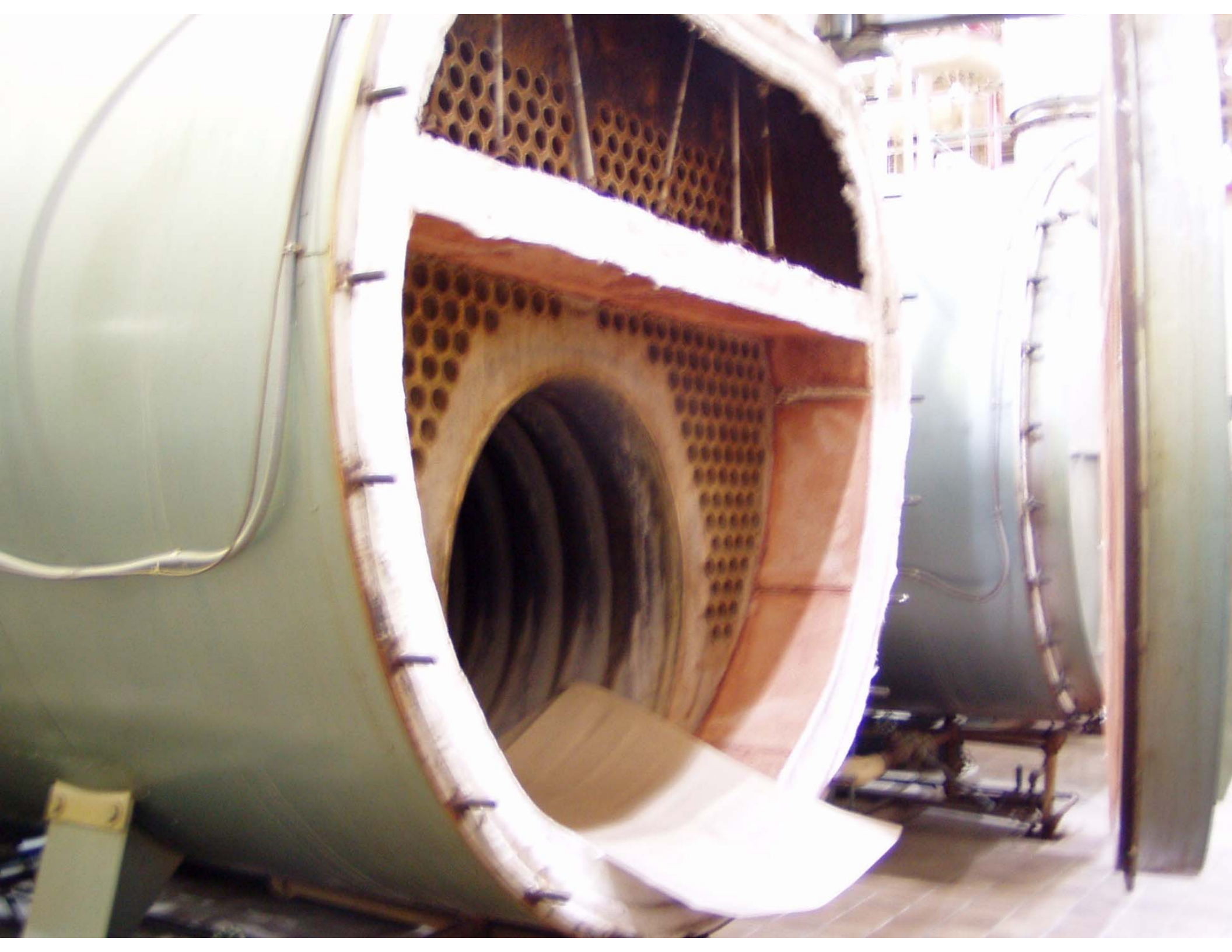
A popular firetube boiler design incorporates a single baffle in the rear turnaround area to provide three passes.

3 Pass Boiler

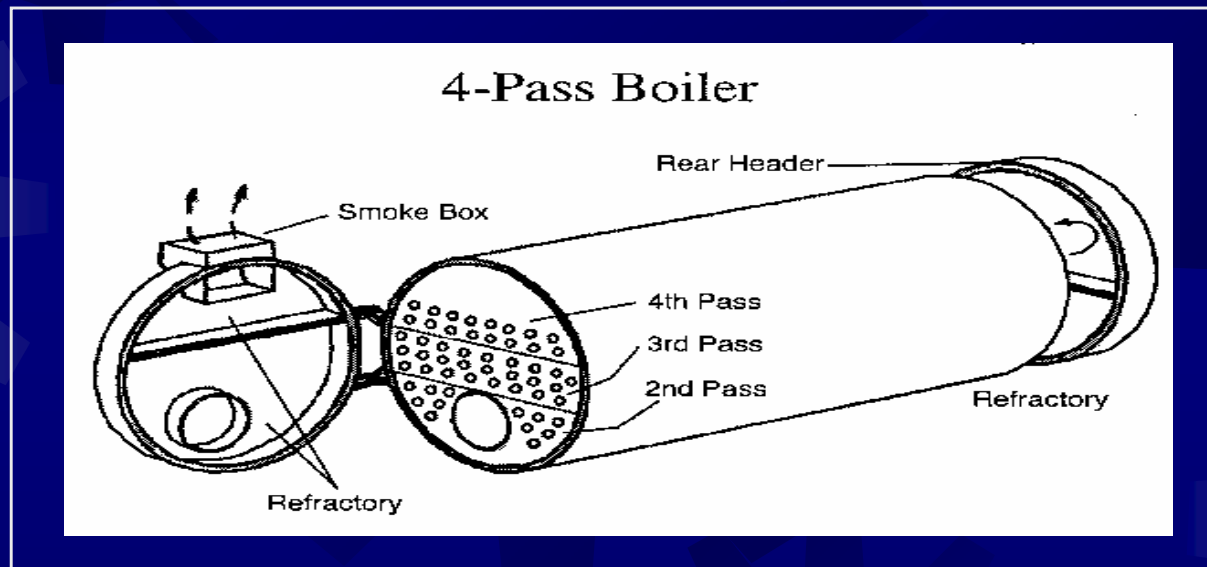


Firetube Boilers

- ★ Furnace design - corrugated or plain
- ★ Ligament spacing - tangent to tangent tube spacing
- ★ Tube sheet thickness
- ★ Tube thickness and diameter
- ★ All should be built at 5 sq ft per BHP
- ★ 30+ year life



4-Pass Boiler



The 4 pass boiler includes a baffle in the front turnaround area to achieve the additional pass.

There are fewer tubes in each pass, which affect gas velocities and heat transfer rates.



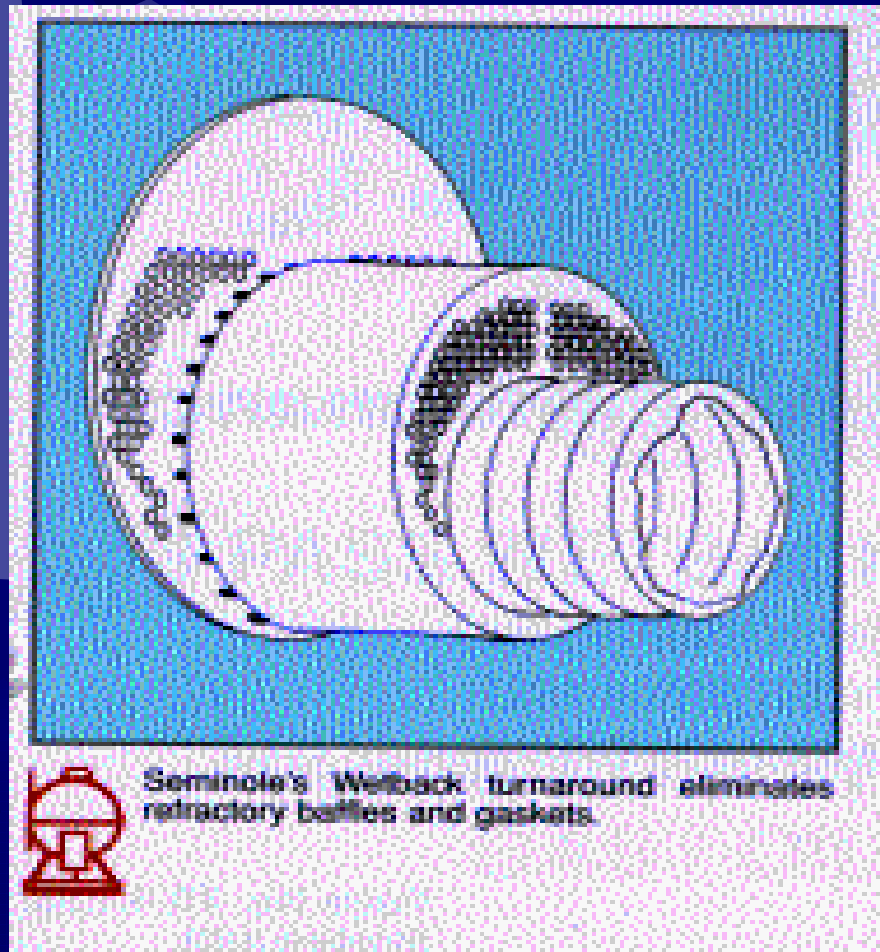
SUPERIOR
TANK WORKS INC.

49 '05

Firetube Boilers - Wetback

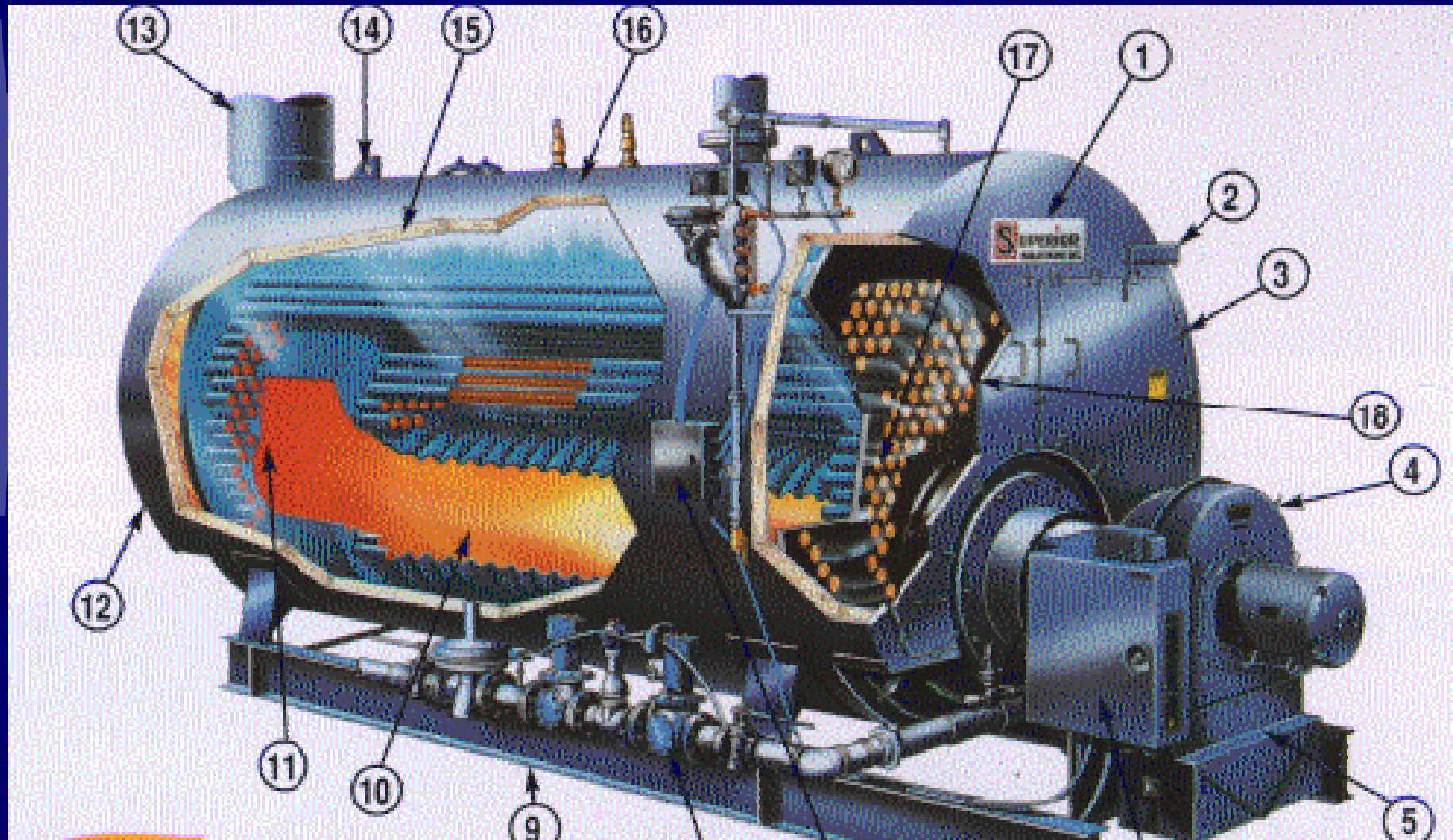
- ✱ Three tube sheets
- ✱ Intermediate tube sheet and turn around area with a water cooled rear wall
- ✱ 3 and 4 pass comparison

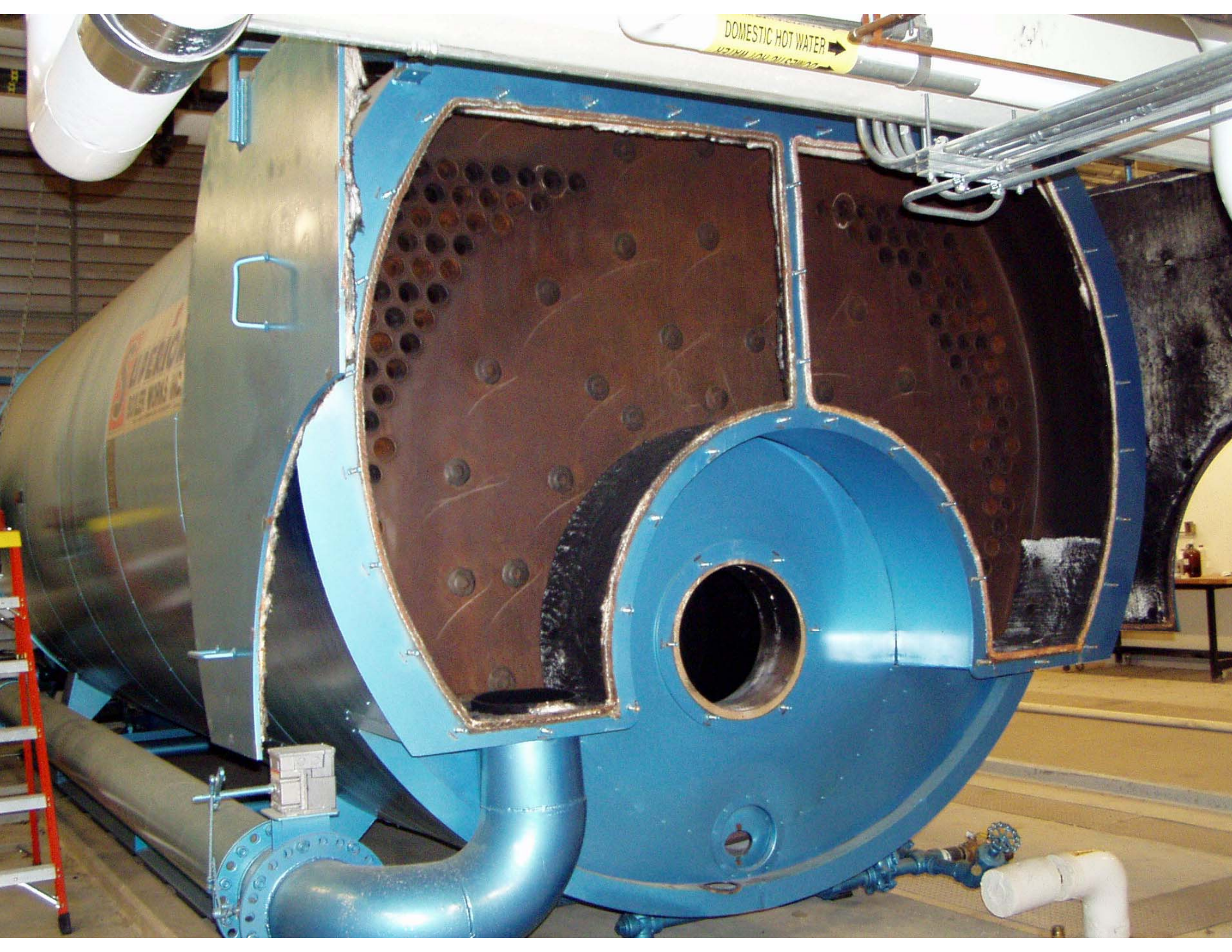
Turnaround



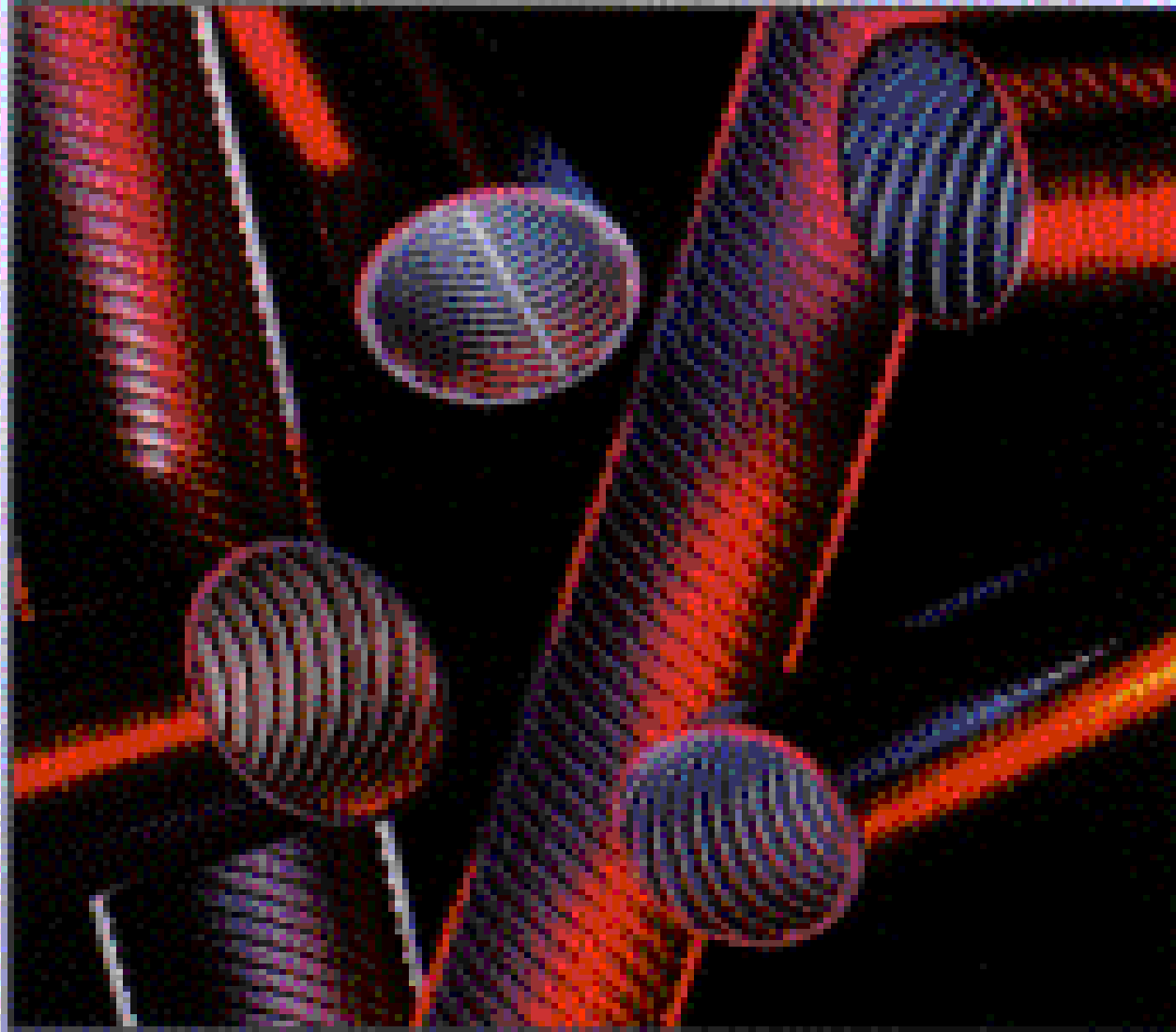
- ✦ Turnaround area allows for a water cooled rear wall
- ✦ Better for thermal shock
- ✦ No large door rear door swing

Firetube Boilers - Wetback





XID Tubing by Fintube Technologies



Firetube Summary

- ✦ Heat transfer and efficiency is a function of time, temperature and turbulence
- ✦ You may see a slight increase in efficiency with additional passes
- ✦ The more passes you have in a boiler the greater the back pressure (more fan HP) and the greater the thermal stresses

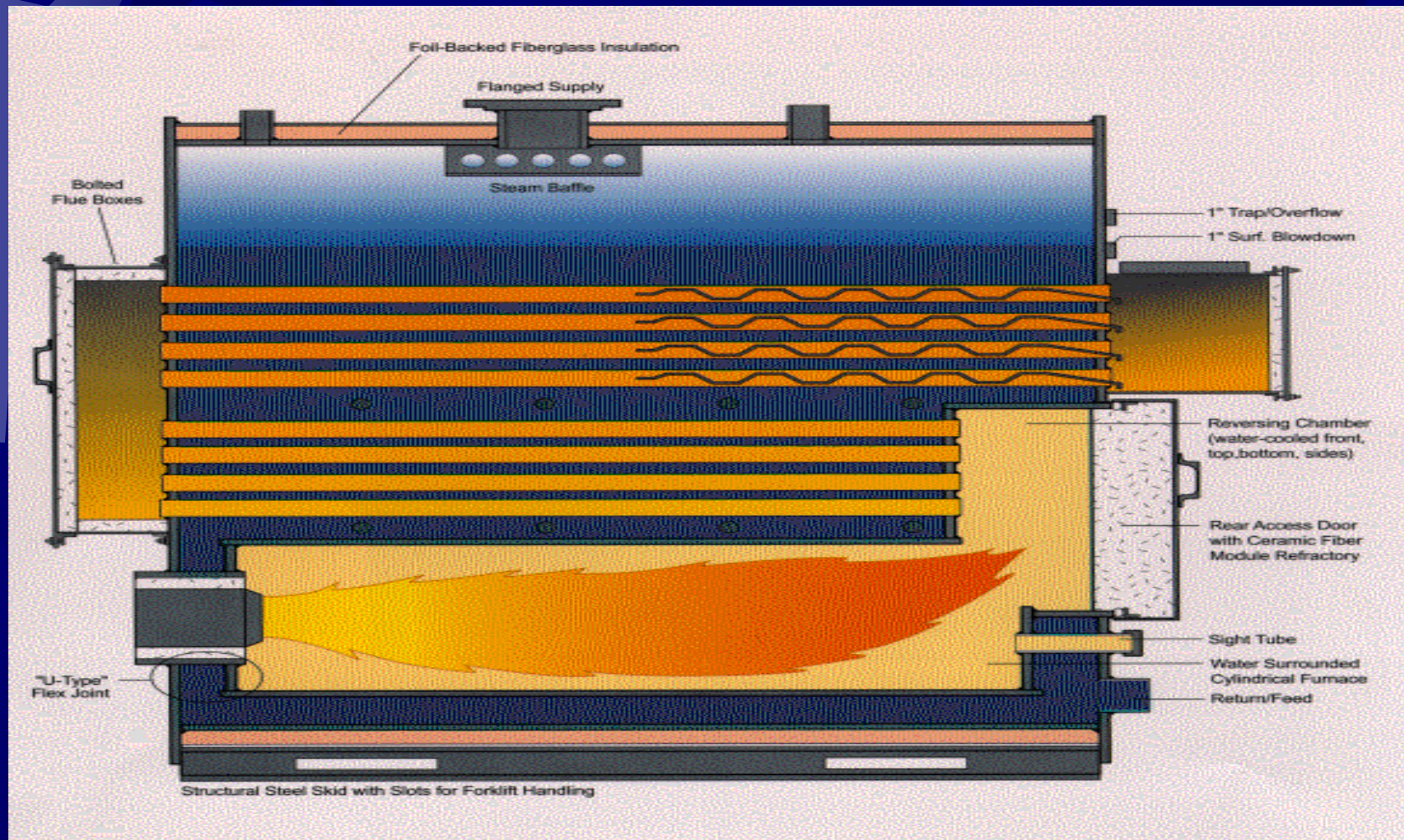




Firebox Boilers

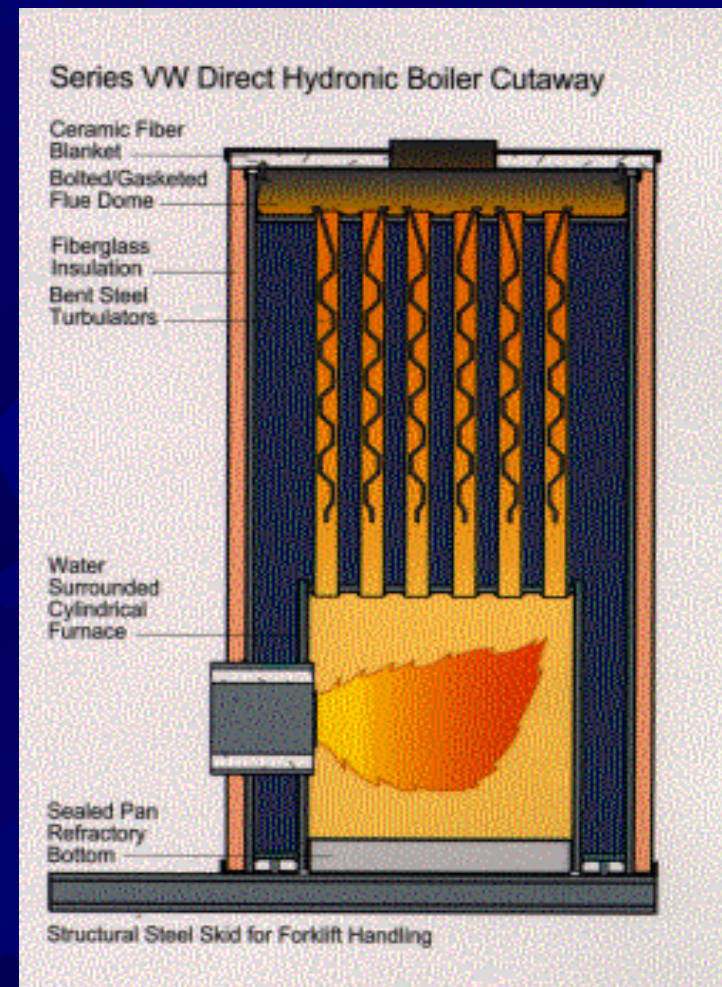
- ★ Section IV Heating Boilers
- ★ Large population
- ★ 30+ year life
- ★ Good steam quality
- ★ Hot water and steam

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”



Boiler Trim

- ✦ Comments on Burners and Controls
- ✦ We'll focus on required trim and valves for Section I Steam Boilers

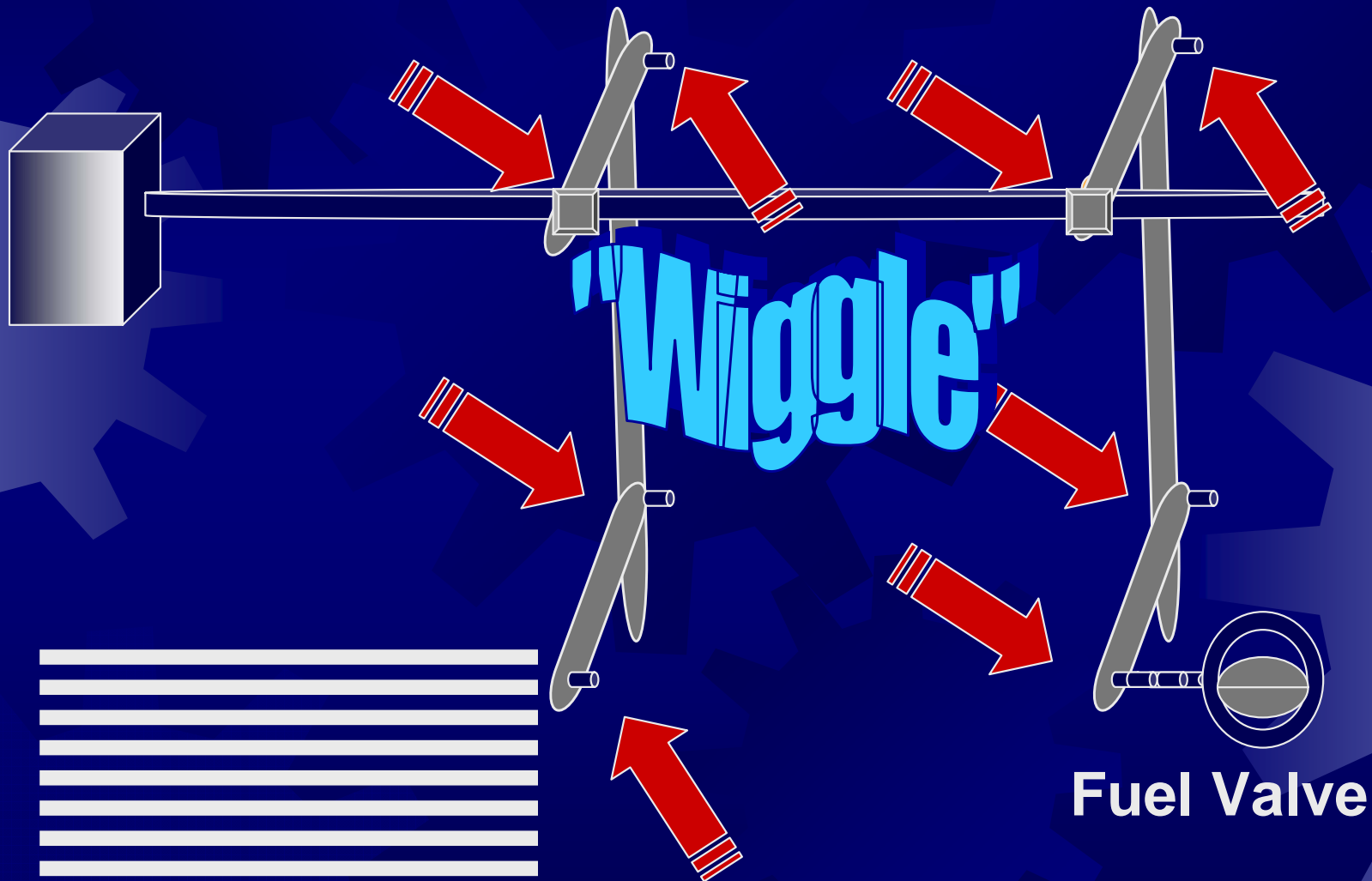
Boiler-Retrofits

★ New Burners

- ★ High turndown - at constant O₂
- ★ Parallel Positioning vs. Linkage System
- ★ O₂ Trim (1000HP and up) - Usually very costly and high annual maintenance.

★ Smaller Summer Boiler

Linkage System

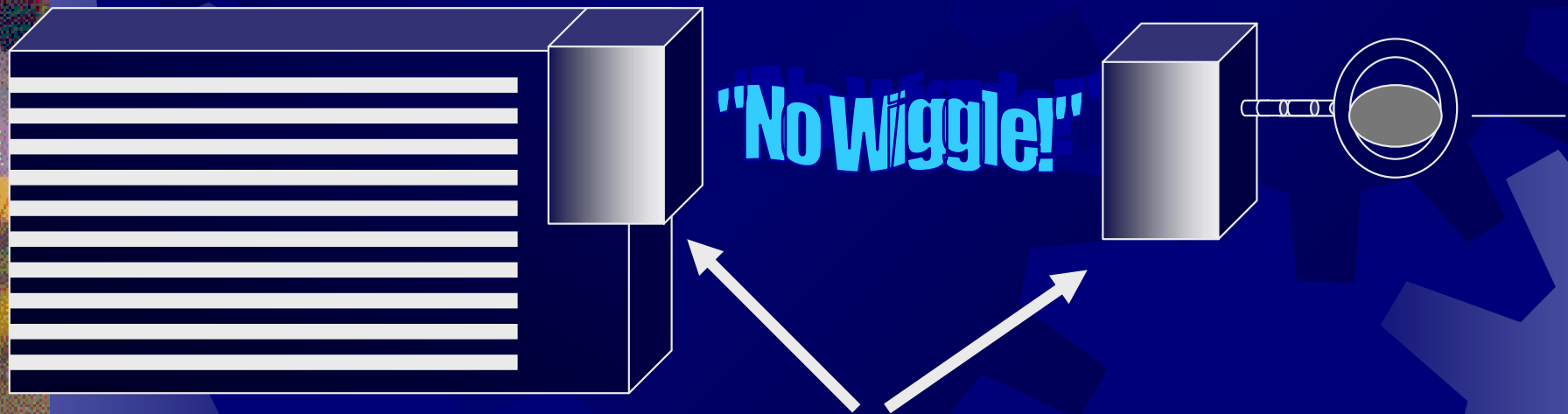




Linkage System

- ✱ Can slip - Dump gas up the stack or soot up boiler.
- ✱ Hard to set up - Especially with (2) fuels.
- ✱ Hysteresis - Different closing and opening position.
- ✱ Limited turndown

Parallel Positioning

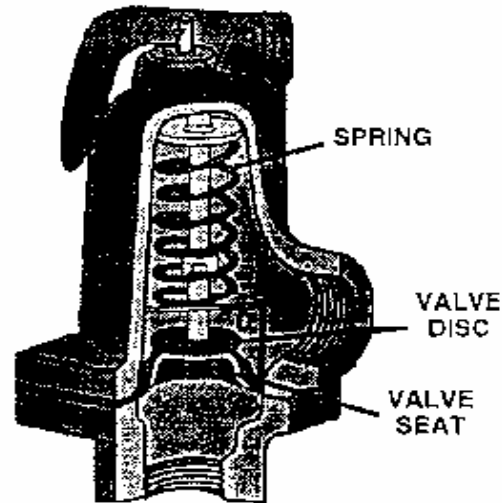


Air Damper

**Individual Positioning
Actuators**

**Direct Connection / Direct
Control**

Safety Relief Valve for Steam Service

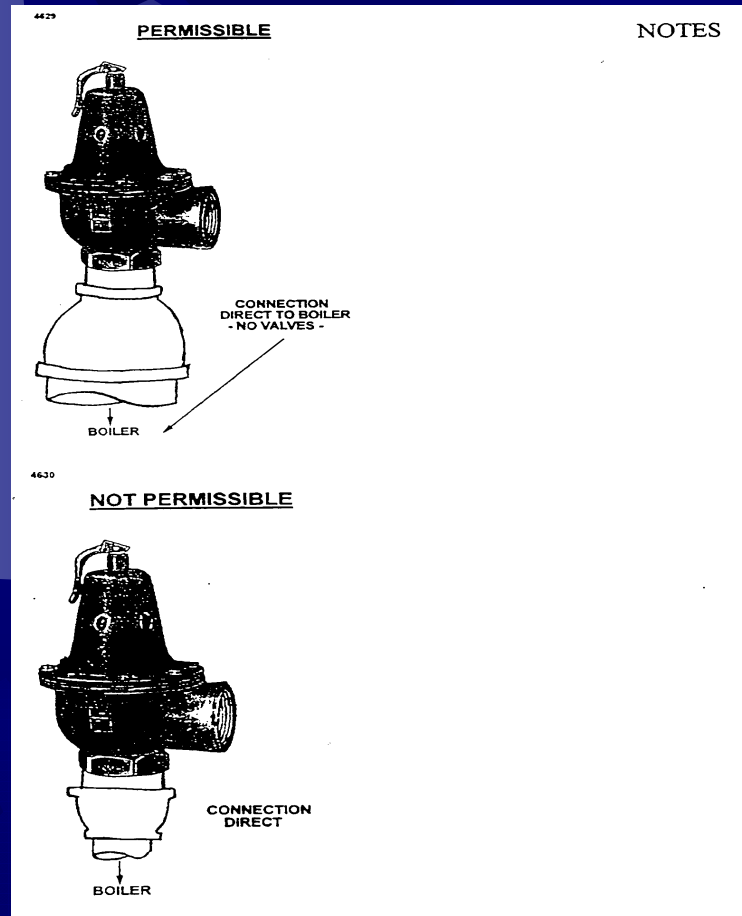


Safety Relief Valve for Steam Service

ASME requirements state that relief valve must be stamped with the pressure relief setting and the Btu/hr relieving capacity. The valves must also be equipped with a manual test lever.

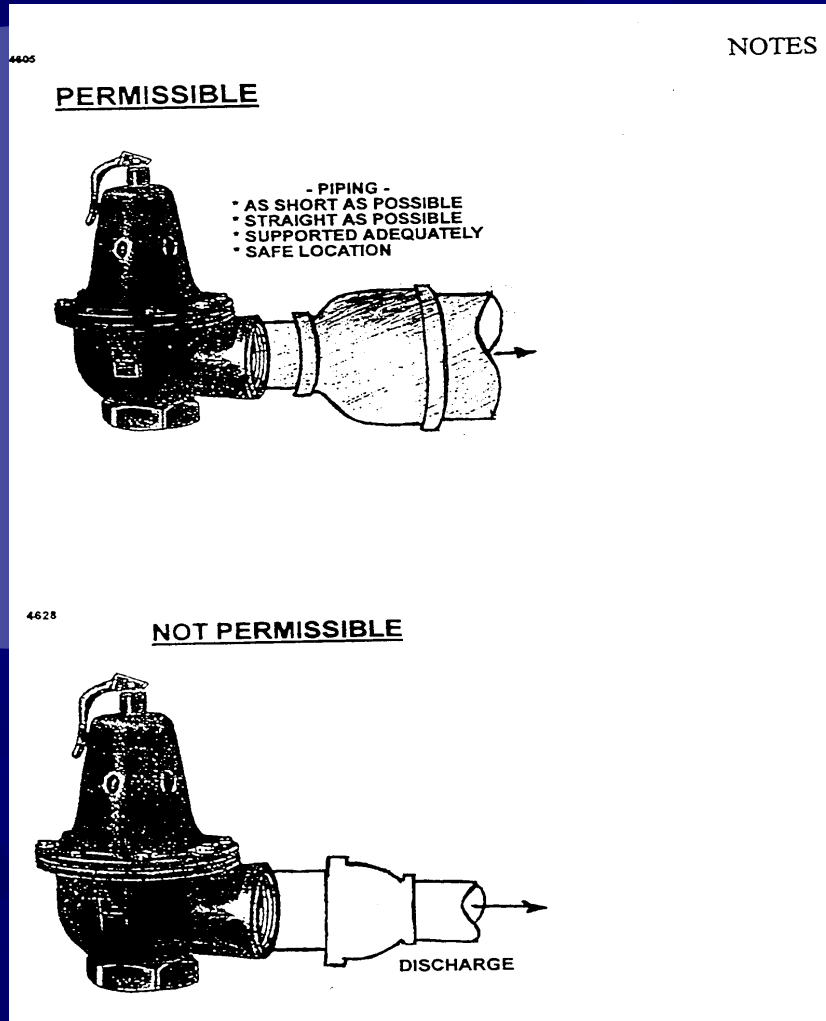
The ASME requires one or more safety relief valves capable of discharging all of the steam boiler can generate when firing at maximum rating. If the heating surface exceeds 500 ft², there must be two valves installed. The specifics for safety valve sizing and installation are such that if you have any questions, you should consult either the boiler manufacturer or your boiler inspector.

Relief Valve Piping



- ✦ It is permissible to reduce into the relief valve off the boiler but not increase
- ✦ Use drip pan elbows at the discharge side to minimize stresses and drain off moisture

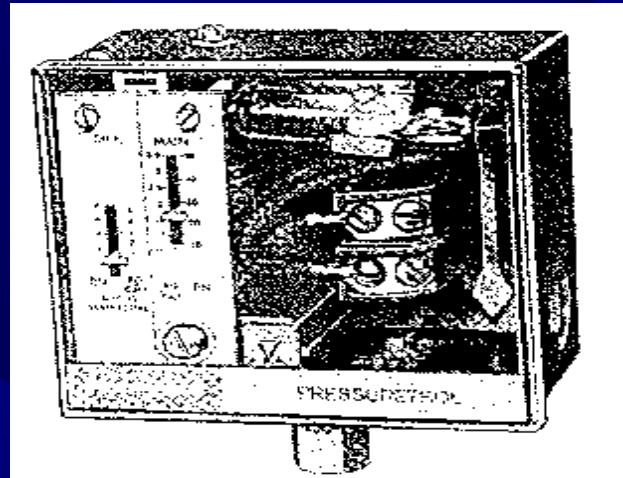
Relief Valve Piping



- ✦ It is permissible to increase at the discharge side of a relief valve but not to reduce in size
- ✦ It is also allowed to combine two or more relief valves but the area must be greater than the individual areas

Pressure/Temperature Controls

- ✦ Operating
- ✦ Limiting, MR
- ✦ Modulating
- ✦ Pressure controls for steam boilers and temperature controls for hot water



Boiler Operating Principals

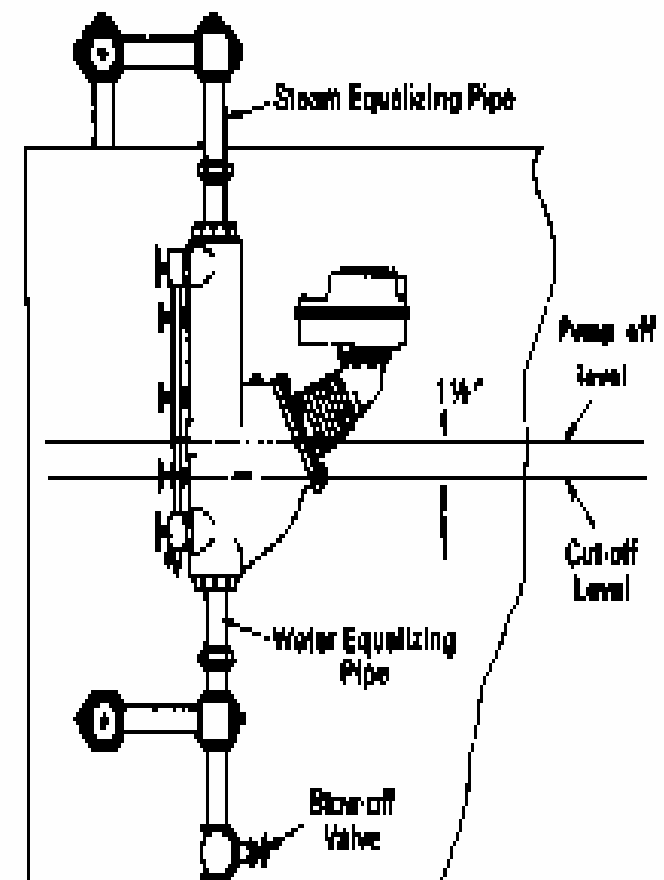
- ✱ Night/Weekend setback
- ✱ Turn Boiler off at night/weekend?
- ✱ Manually isolate boiler from steam system
- ✱ Increase the on/off pressure settings to minimize boiler short cycling

Water Level Controller

For steam boilers this device has three functions:

- ◆ Serve as the primary low water cut-off with automatic reset
- ◆ Gauge glass for visual indication of water level
- ◆ Introduce water into the boiler by way of on/off pump control or modulating feedwater control
- ◆ Steam boilers require two low water cut-offs, hot water only one

**Pump Control - Low Water Cutoff Operation
Pressure Up To 150psi.**



Boiler Trim

- ☀ Low water cut-offs
- ☀ Reflex Gauge Glass
- ☀ Overflow trap



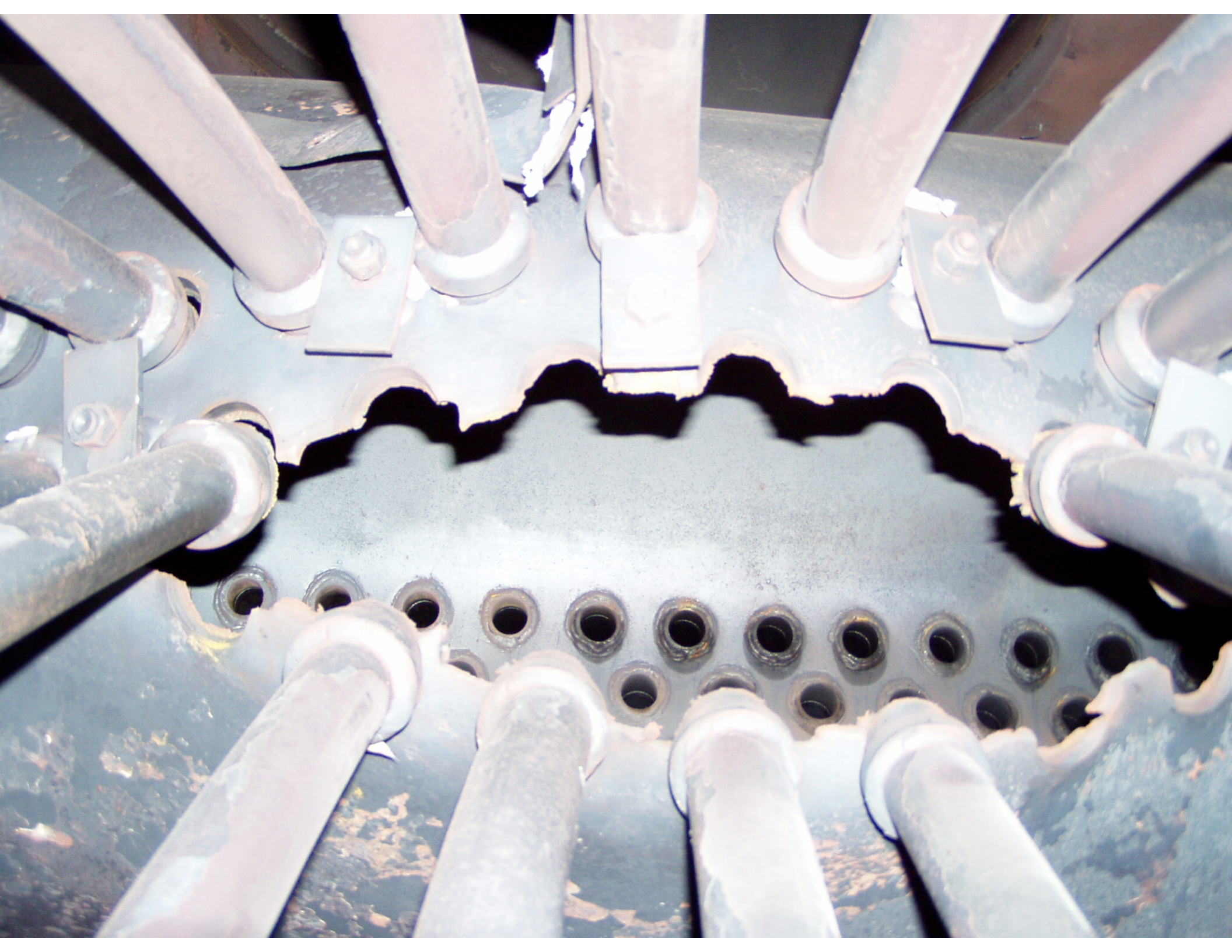


A AUX BOILER

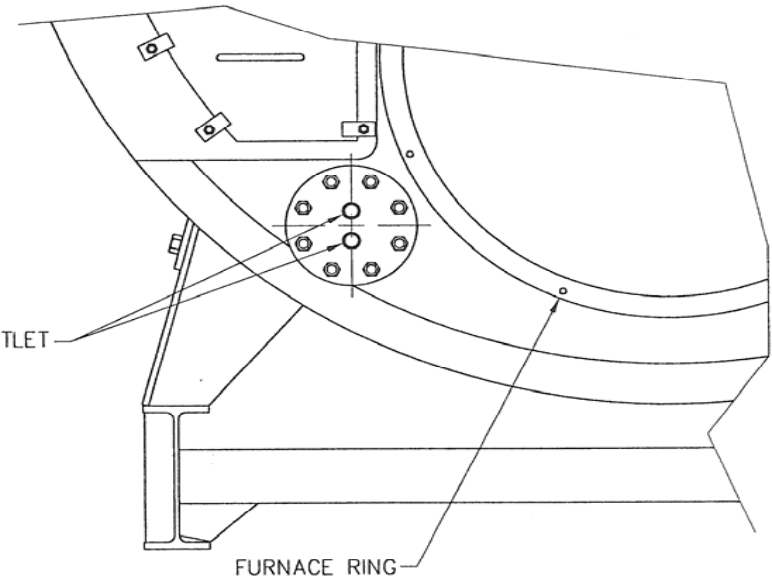
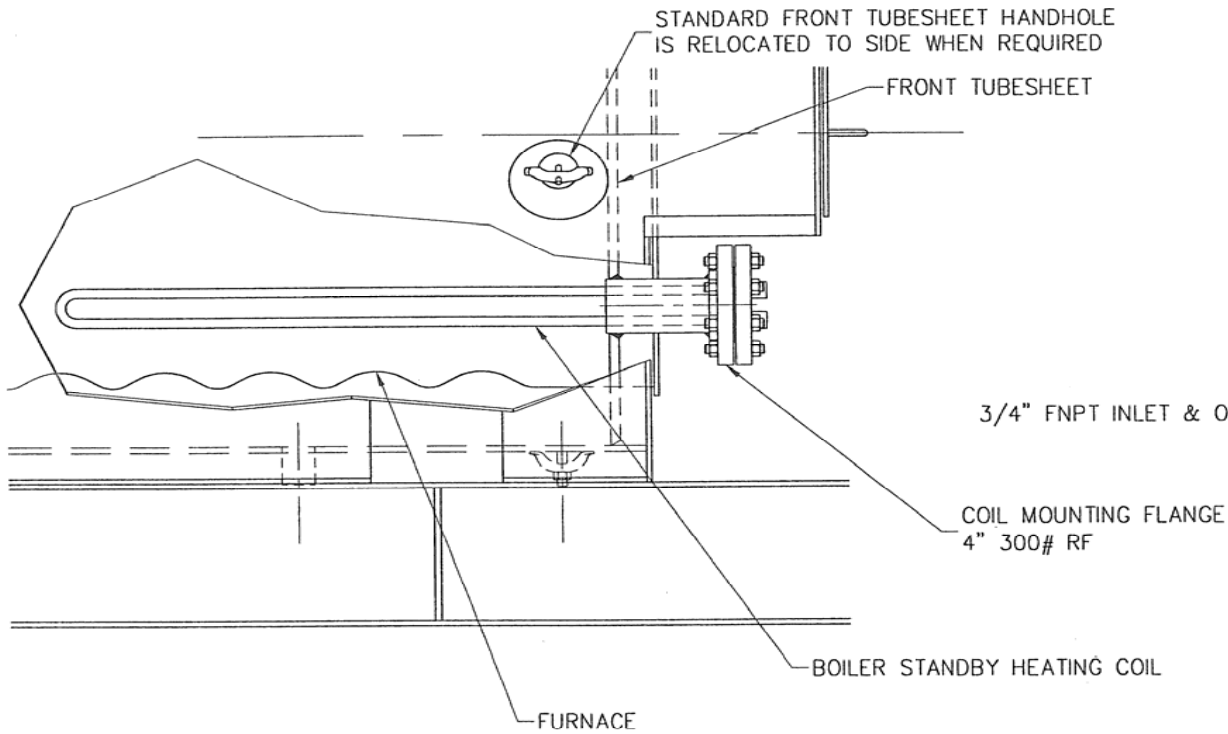
UNIVERSAL
Boiler Works
INC.
Manufacturers of the National
Steam Heating Boiler

A A

FLOW
←








STANDBY HEATING COIL IS AVAILABLE ON STANDARD 94" ID* & LARGER SHELL BOILERS.
 (FOR SMALLER ID SHELLS CONSULT FACTORY)

COIL DATA:

- CODE STAMP ASME B & PV CODE SECTION I
- DESIGN PRESSURE: 490 PSIG @ 700°F
- COIL TUBE OD: 3/4"
- COIL TUBE WALL THICKNESS: .065 MW
- COIL TUBE MATERIAL: SA-178A
- MINIMUM WALL AFTER FORMING .05" @ 23.33%
- *94" ID SHELL BOILERS INCLUDE 400 HP AZ, MO, SEMI, XSEM, & MOH & 500 HP APACHE

ORIGINAL™

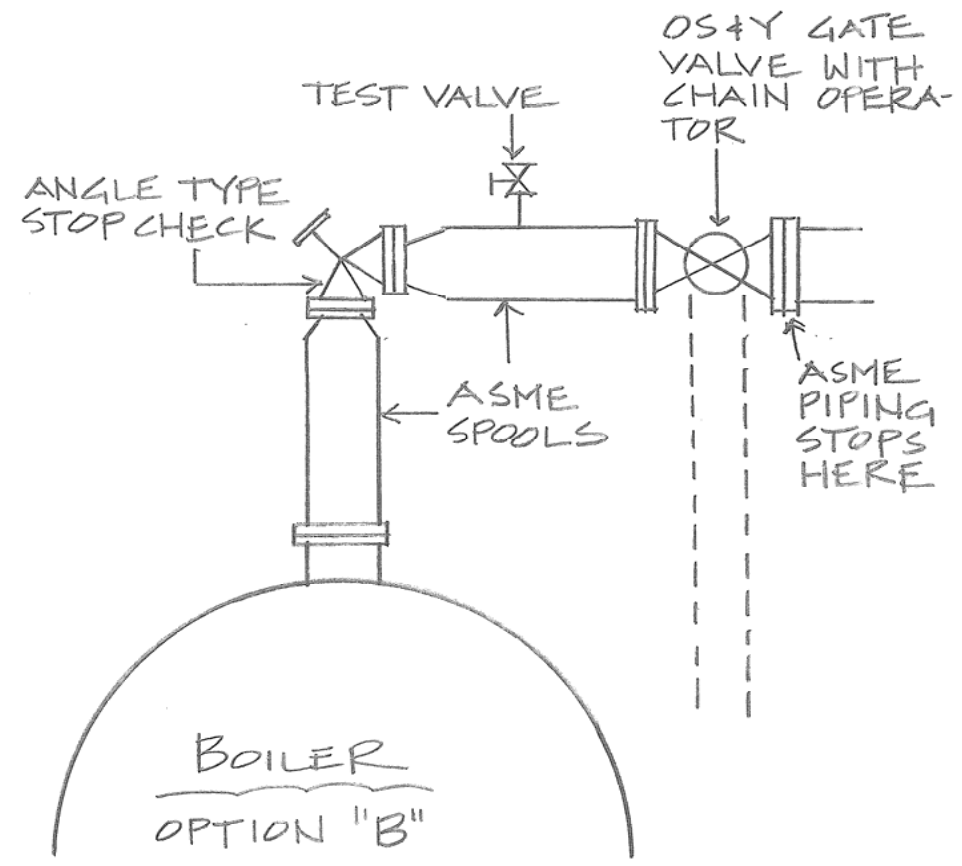
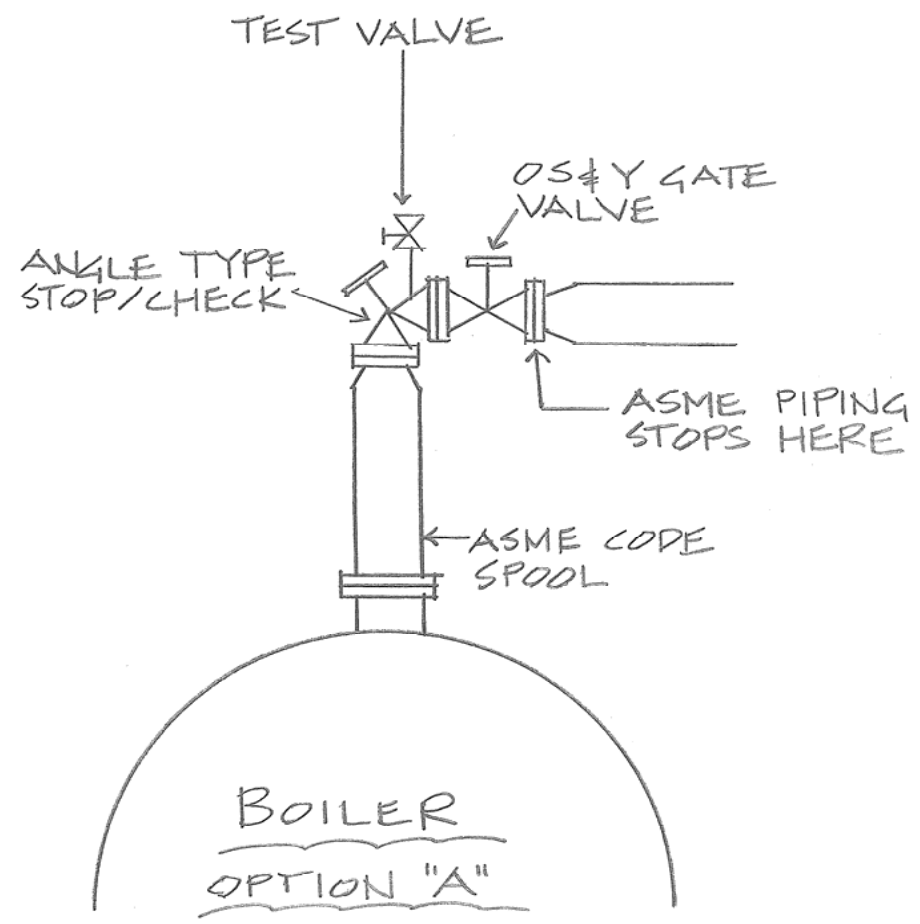
 SUPERIOR BOILER WORKS, INC. HUTCHINSON, KANSAS	CHECKED BY <i>M. MATALEAH</i>	SCALE 1/10	DRAWING NO.
	DRAWING NAME BOILER STANDBY STEAM HEATING COIL	DRAWN BY A. REUSSER	DATE 10-26-04

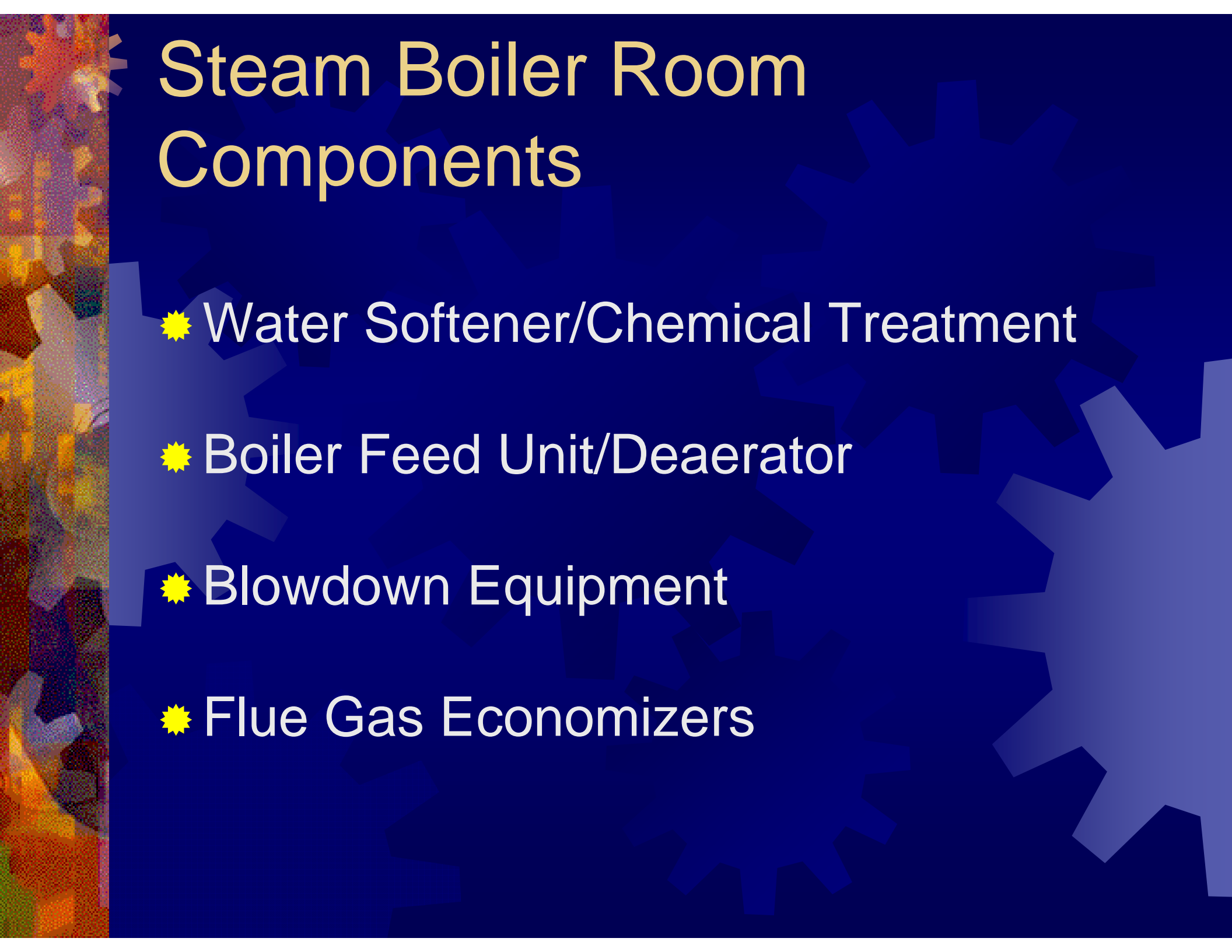
STANDBY CO

Steam Valves

- ★ Low pressure steam boiler require only one steam isolation valve
- ★ Multiple high pressure boilers with manways connected to a common header require two valves in series, the first being a stop/check. All piping up to the discharge of the second valve will be ASME code piping. A test valve between the two isolation valves is also required.

SECTION I BOILER STEAM PIPING





Steam Boiler Room Components

- ✦ Water Softener/Chemical Treatment
- ✦ Boiler Feed Unit/Deaerator
- ✦ Blowdown Equipment
- ✦ Flue Gas Economizers

Water Quality

- ☀ Dissolved Oxygen - less than 7 ppm
- ☀ PH - 7 to 10
- ☀ Total Hardness - 0 ppm
- ☀ Total Alkalinity - 400 ppm max
- ☀ Dissolved Solids - 3500 ppm max
- ☀ Silica - 150 ppm max
- ☀ Oily matter - 1 ppm max
- ☀ Total Iron - .05 ppm max

Boiler Operating Principals

- ★ Waterside scale build up can decrease boilers efficiencies
 - ★ 1/16" thick = 15% more fuel
 - ★ 1/8" thick = 20% more fuel
 - ★ 1/4" thick = 39% more fuel
- ★ Fireside sooting also will decrease efficiencies

Water Softener

- ✦ Ion exchanger designed to remove the hard calcium and magnesium and exchange the with a sodium ion.
- ✦ Twin alternating designs allow one tank to be on line and the other off line or regenerating

Water Softener

- ★ Twin alternating water softener with (2) resin tanks, a brine tank and automatic controls.





Chemical Treatment

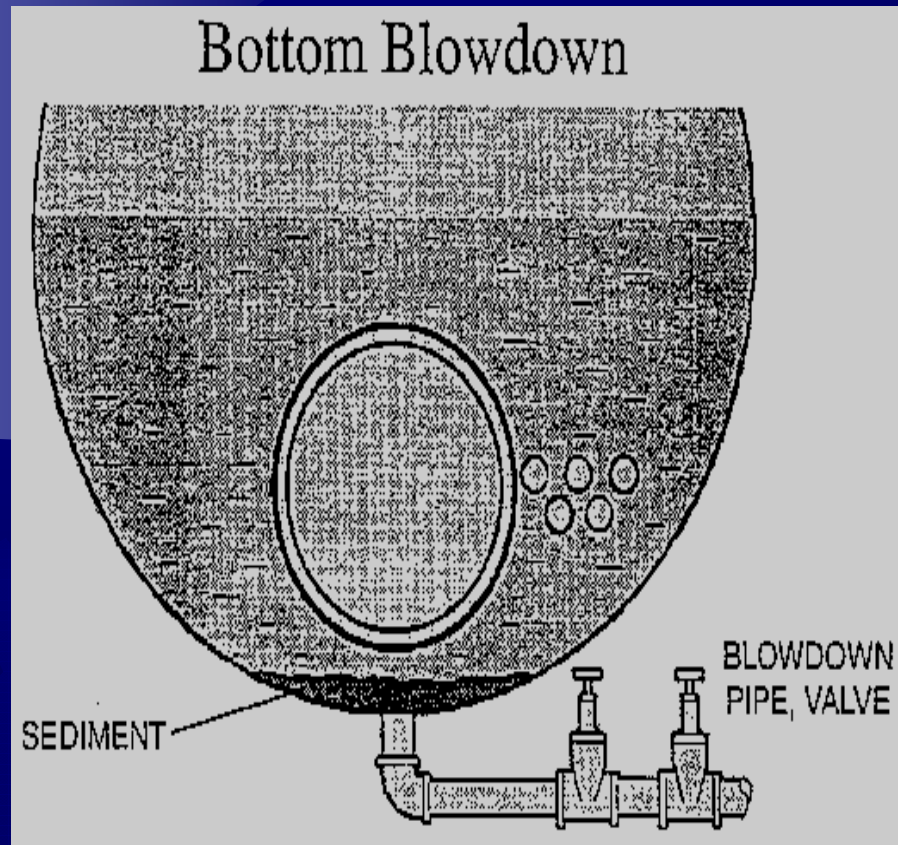
- ✦ Using Treated Boiler Steam in a process or air stream?
- ✦ Do not batch feed chemicals – meter the water make up.
- ✦ Must control steam quality with steam traps and separators
- ✦ Use a FDA recommended chemical



Boiler Blowdown

- ✦ Boiler Blowdown - Bottom and Surface
- ✦ Function of Quantity of make up and water quality.
- ✦ Raise levels of TDS with proper chemical treatment.
- ✦ Increase condensate return.

Bottom Blowdown



High pressure boilers require two bottom blowdown valves piped in series. Code requires the first valve to be quick opening and the second valve to be a slow opening type. Low pressure boilers require only one blowdown valve.

Blowdown Tank



This ASME tank accepts bottom and surface blowdown from high and low pressure steam boilers. Automatic aftercoolers should be installed to reduce drain discharge temperature down to 140 F

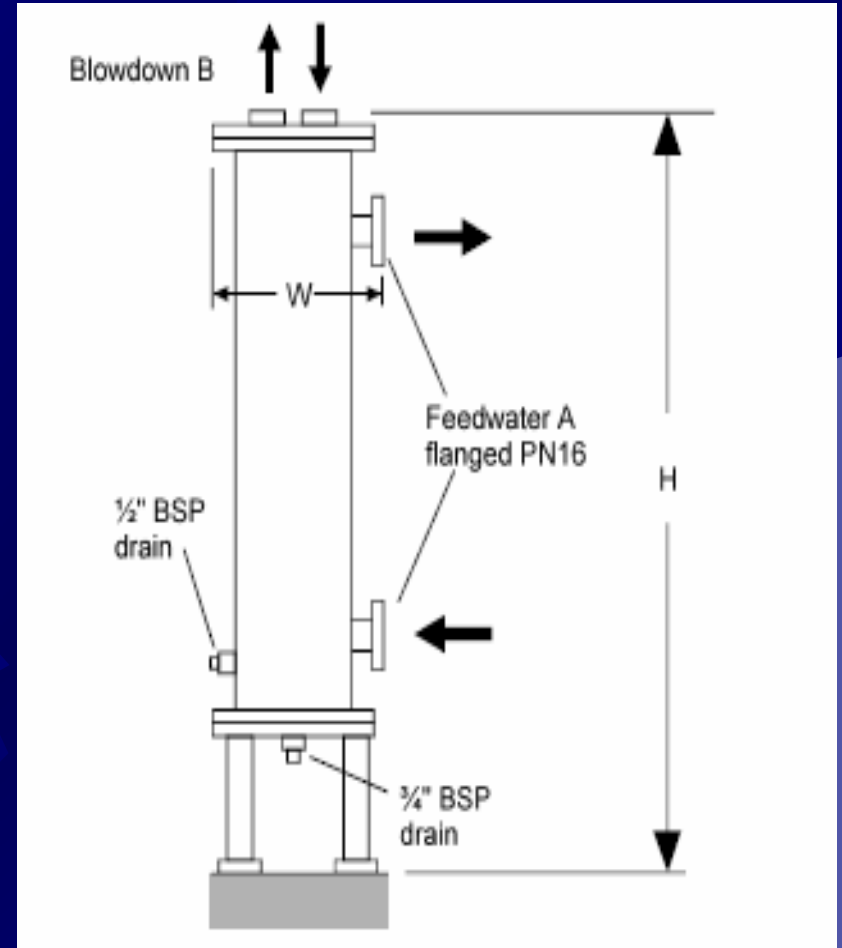


Surface Blowdown

- ✦ Surface blowdown is used to help keep water chemistry in balance
- ✦ Surface blowdown is continuous and usually very low flow rates.
- ✦ Automatic conductivity sensing devices available
- ✦ Good source for heat recovery

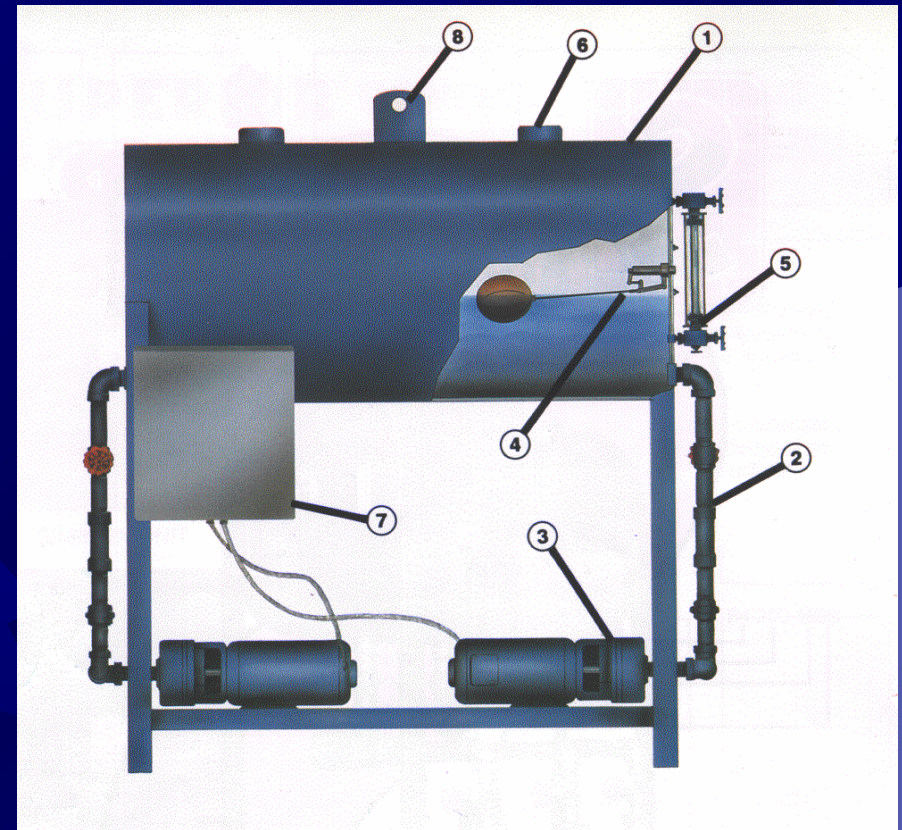
Boiler Blowdown

- ☀ Surface Blowdown Heat Recovery
 - Heats make-up water
 - Cools blowdown



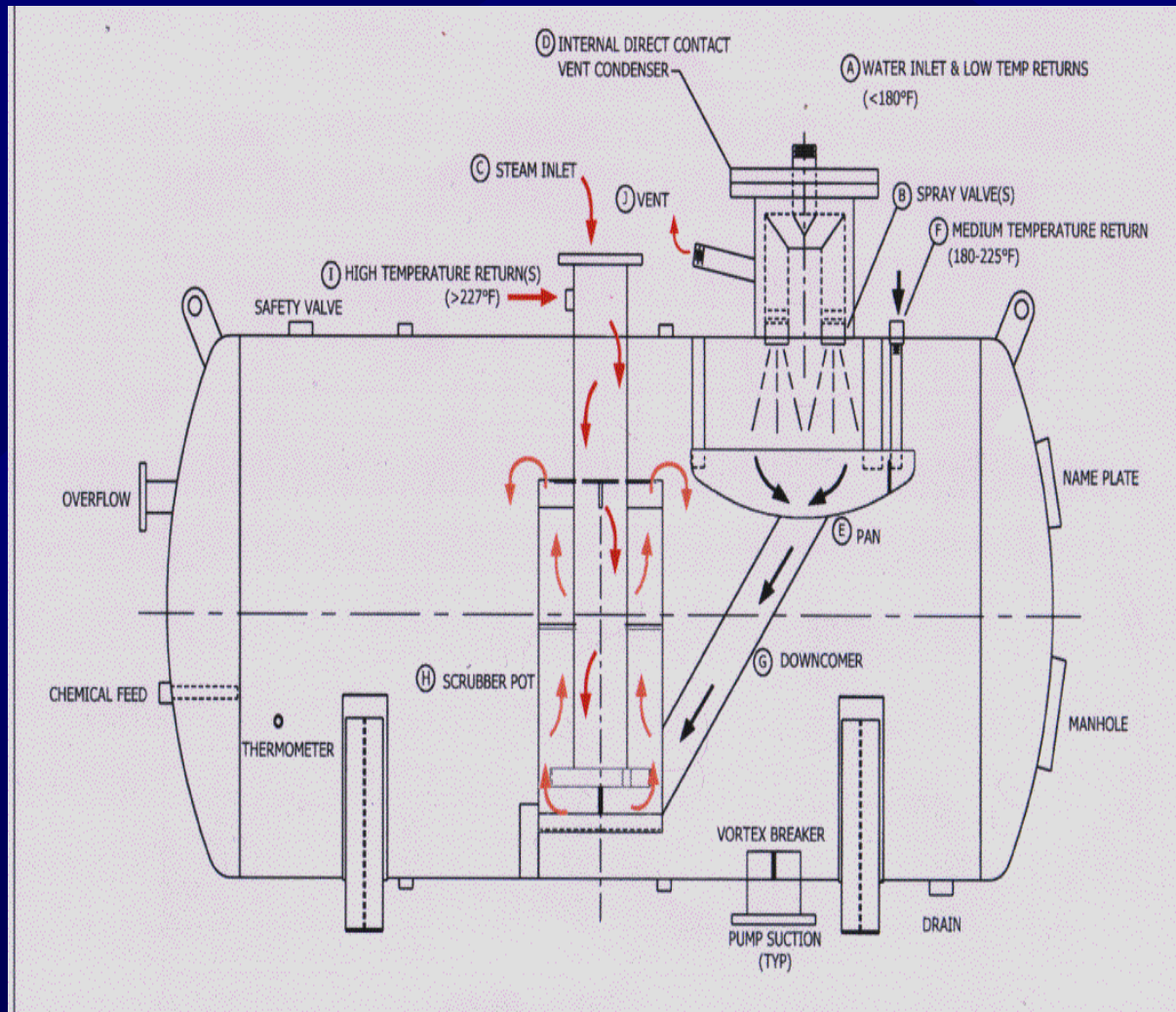
Boiler Feed Unit

- ✦ Stores water for the boiler and accepts condense return
- ✦ Boiler feed pumps deliver water to boiler
- ✦ Automatic water make-up valve
- ✦ Add steam heater to raise water temp

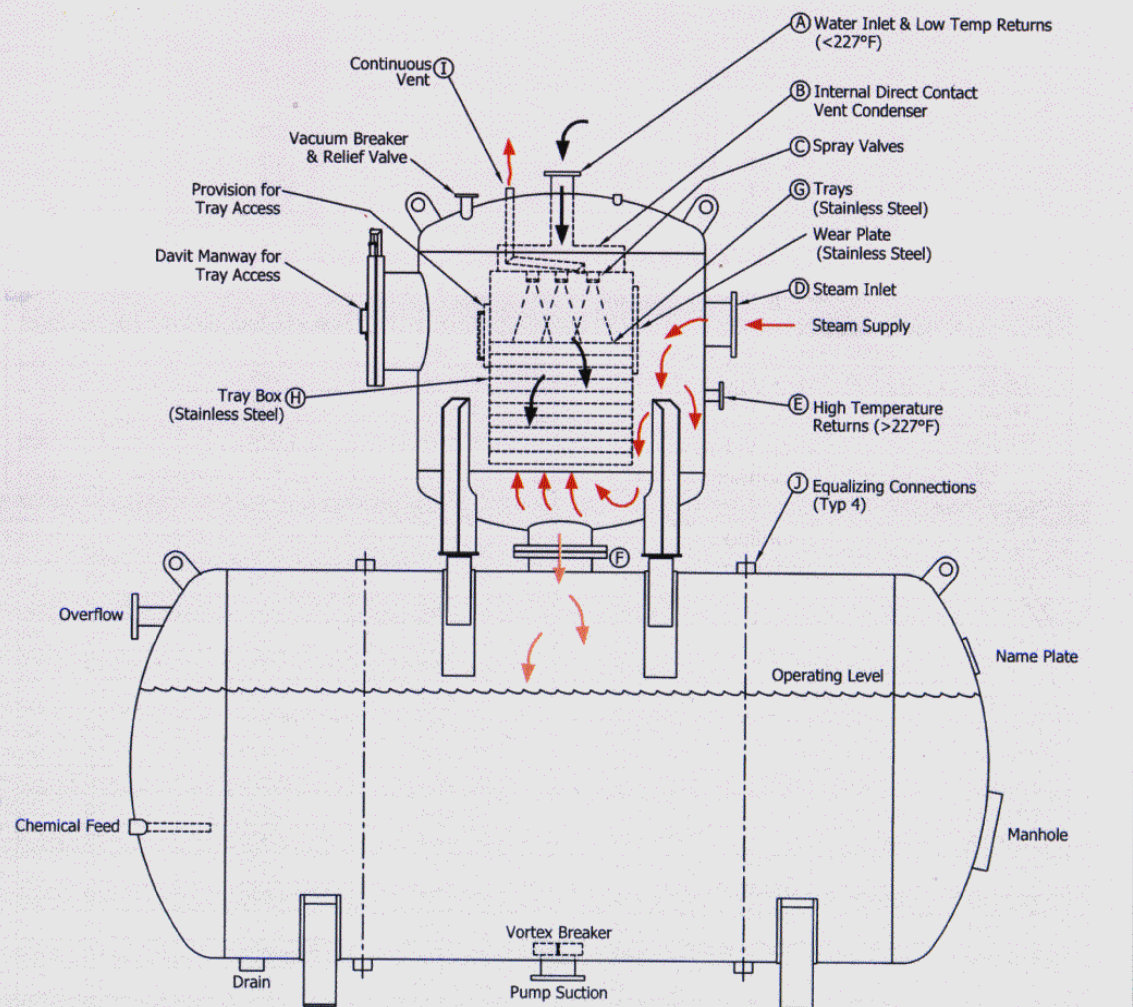


Deaerators - Spray Scrubber

A spray deaerator mechanically removes the dissolved oxygen by spraying the water into a steam chest and then scrubs the water in the scrubber section

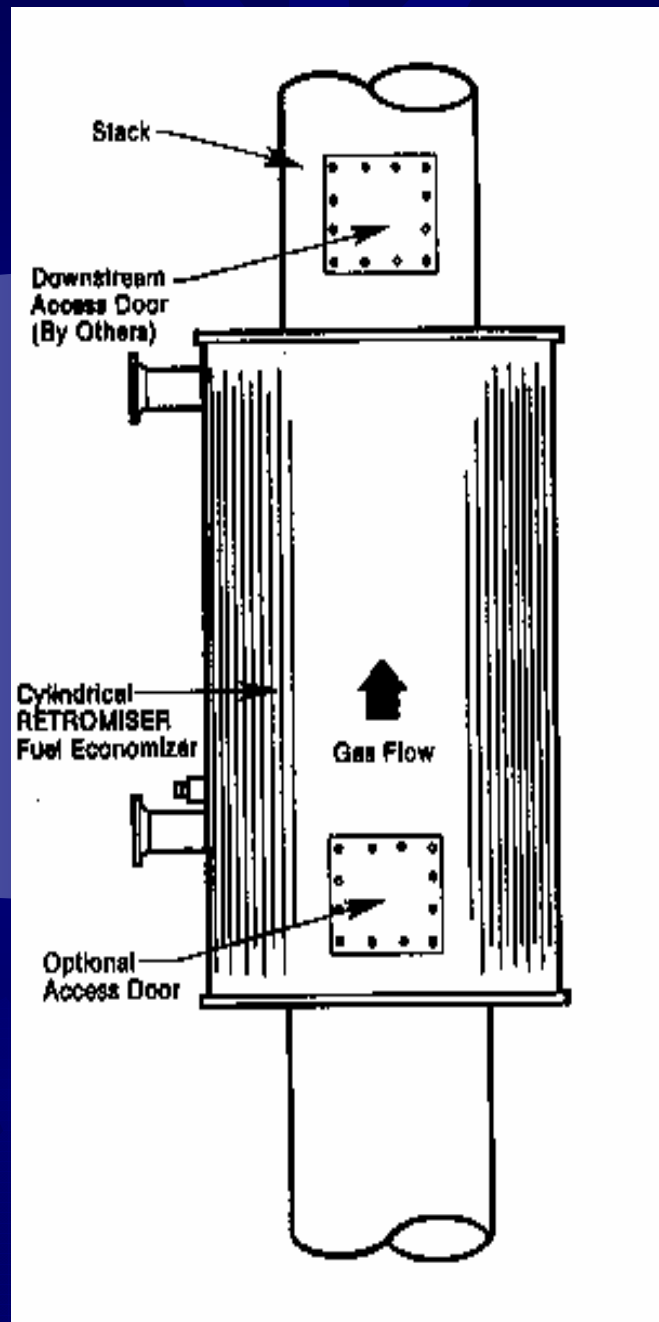


Deaerator - Tray Type



A tray deaerator mechanically removes the dissolved oxygen by spraying the water into a steam chest and then allowing it to flow over a series of trays giving more contact time with the steam

Economizers



- ★ Designed to recover heat off the flue gas on high pressure steam boilers with stack temperatures above 350 F
- ★ DO NOT CONDENSE! If stack temperatures drop below 300 F, condensing may occur
- ★ No real application on low pressure steam or hot water
- ★ 1% increase in efficiency for every 40 F taken out of the stack

Stack Loss vs O₂

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11.00	18.89	19.73	20.57	21.42	22.26	23.11	23.96	24.81	25.67	26.52	27.38	28.24	29.10	29.97	30.83
12.00	19.87	20.80	21.73	22.66	23.60	24.54	25.48	26.43	27.37	28.32	29.27	30.22	31.18	32.13	33.09

Steam/Condensate Systems

★ COST OF GAS AND STEAM!

- ★ \$9.00/MMBtu
- ★ \$12-14 per/1000lbs steam

★ Cost of Blow thru traps

- ★ Financial impact
- ★ Boiler output not captured
- ★ System impacts

Steam System Leaks

Table 6. Steam leak rates

Hole diameter (in.)	Leak rate (lb _m /h) at steam temperature of 500°F						
	Steam pressure (psig)						
	50	100	150	200	250	300	350
1/8	23	41	59	77	96	119	134
1/4	91	163	235	308	382	478	536
3/8	206	366	529	693	860	1,075	1,207
1/2	366	651	940	1,232	1,528	1,912	2,145
3/4	822	1,465	2,115	2,773	3,438	4,302	4,826
1.00	1,462	2,605	3,761	4,929	6,112	7,648	8,580
1.25	2,285	4,071	5,876	7,702	9,551	11,949	13,406
1.50	3,290	5,862	8,462	11,091	13,753	17,207	19,305

Steam System Leaks

- ★ Trap leaking with 1/4" orifice and 100 psig operating pressure
- ★ $163 \text{ lb/hr} \times 8760 \text{ hrs/year} = 1,427,880$ lbs of steam per year from (1) trap
- ★ $1427 \text{ MIb} \times \$12 \text{ per thousand} = \$17,134$



Steam/Condensate System

★ Steam Trap Audits

- ★ Locate, test and tag all steam traps
- ★ Replace/Repair bad traps and leaks
- ★ Follow-up with annual inspections

★ Checking Steam Traps

- ★ Temperature, Sound and Visual



Thank You

☀ Questions?