

Welcome to



**Boiler & Maintenance
Webinar**



Tim Carberry

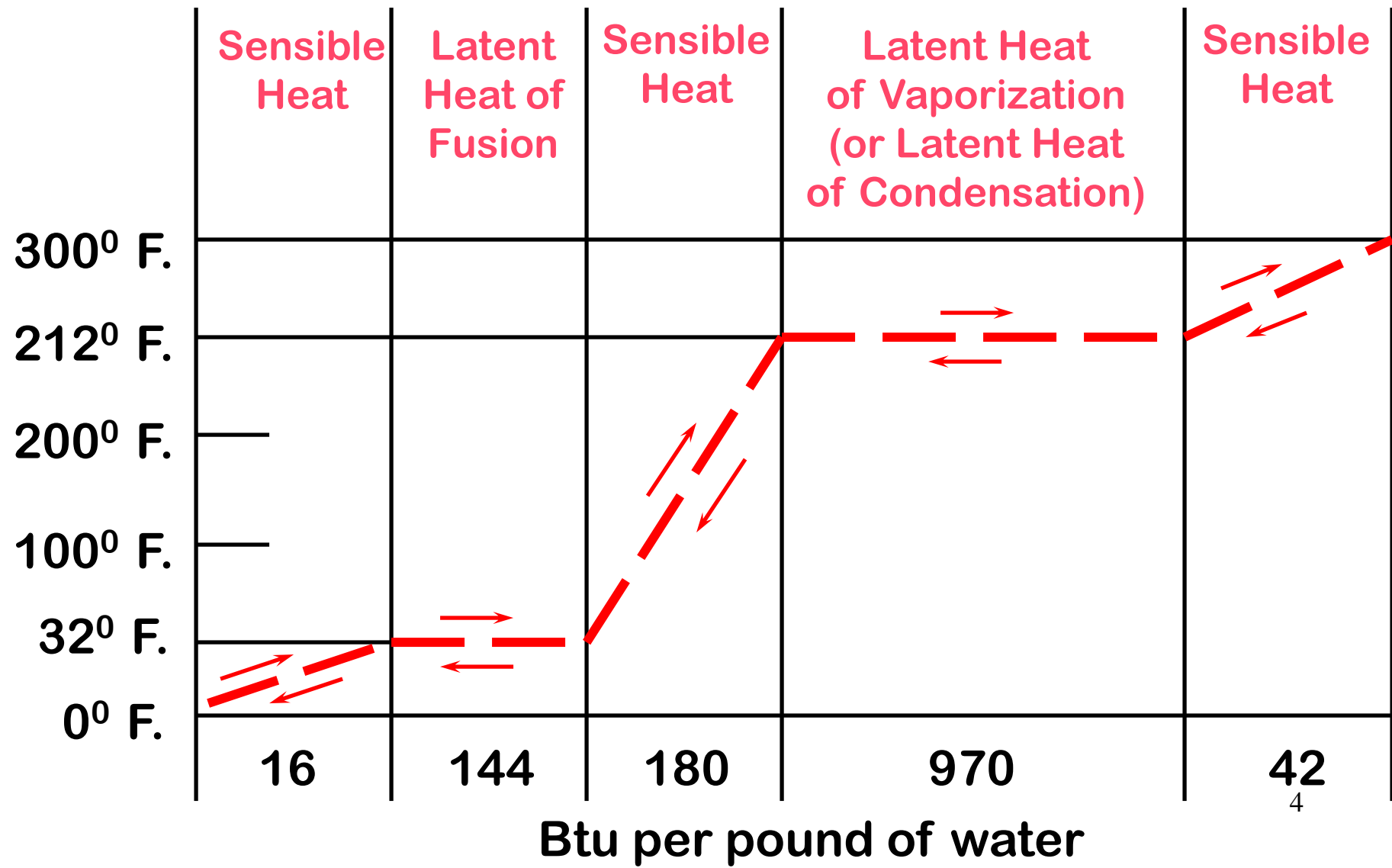


Tom Hantke

Thermodynamics

- Btu - British thermal unit
- Amount of energy required to raise one pound of water 1° F.

Temperature-Heat Diagram for 1 lb of Water at Atmospheric Pressure (14.7 psia)



Steam Tables

Psi	0	10	100
Boiling (° F.)	212.0	239.5	337.9
Volume (Cu-ft/lb)	26.40	16.46	3.89
Sens. heat (Btu/lb)	180.1	207.9	308.9
Latent heat (Btu/lb)	970.3	952.5	880.7
Total heat (Btu/lb)	1150.4	1160.4	1189.4

Thermodynamics

- One boiler horsepower equals
 - 34.5 Pounds of steam per hour (from and at 212⁰ F.)
 - 33,472 Btu per hour
 - 1000 Hp Boiler is = to 34,500 Pounds of steam per hour in high fire at 212⁰ F of feed water inlet temp



Theory of Combustion

- Starting combustion requires

- Heat
- Fuel
- Oxygen

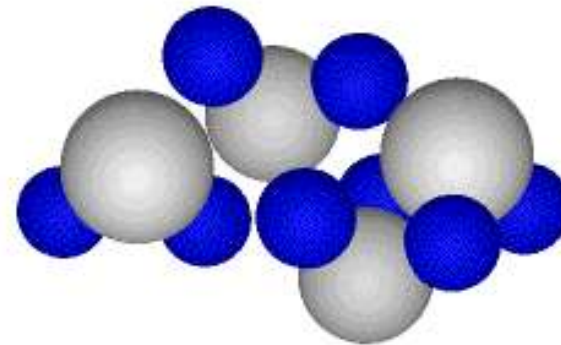


Theory of Combustion

- Supporting combustion requires
 - Time
 - Temperature
 - Turbulence

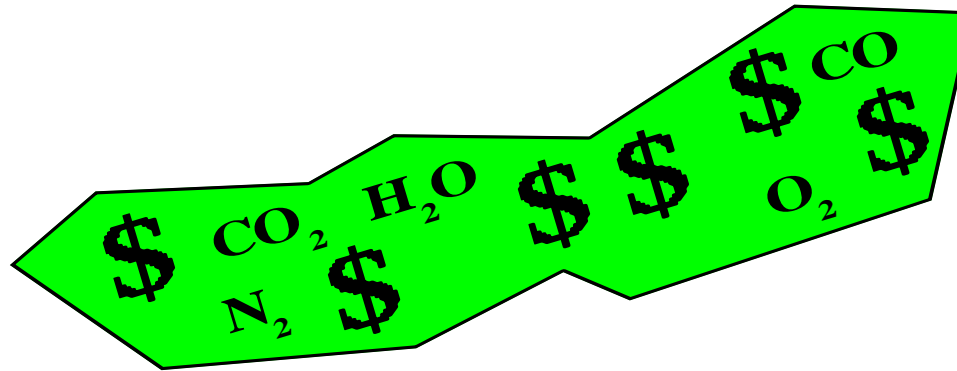
Theory of Combustion

- What is the reference point for setting combustion?
- Stoichiometric or perfect combustion

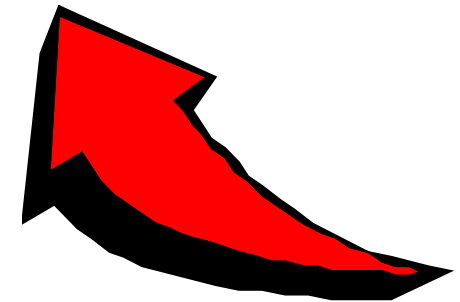
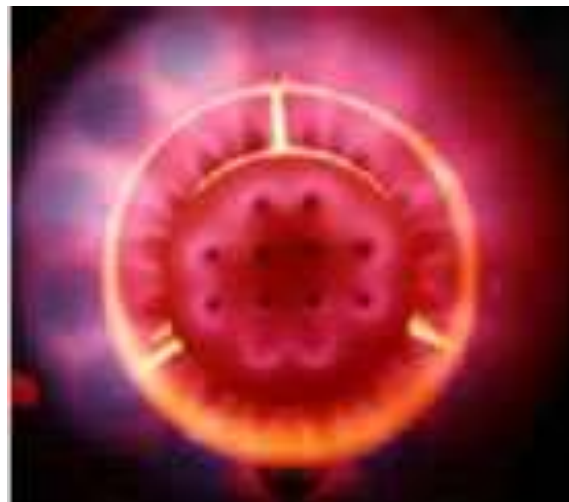


Theory of Combustion

- What happens with improper combustion?



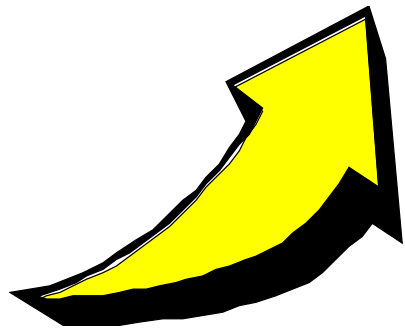
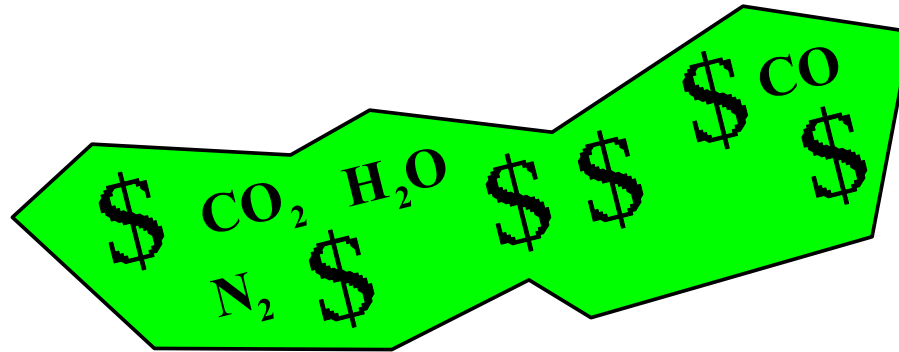
Oxygen rich



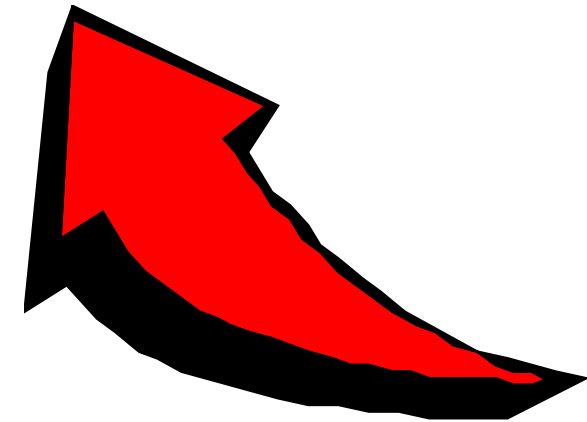
Fuel lean

Theory of Combustion

- What happens with improper combustion?



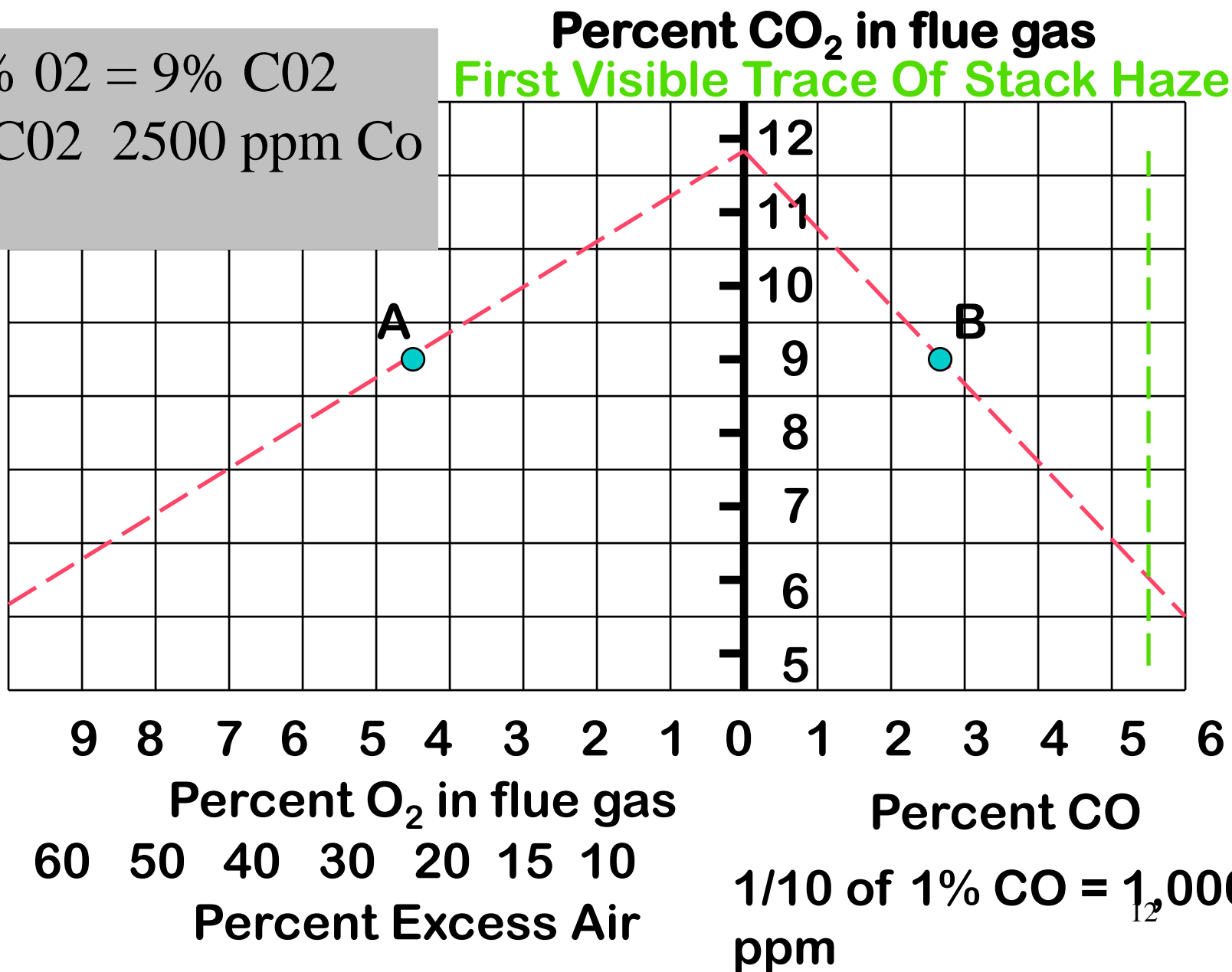
Oxygen lean



Fuel rich

Flue Gas Analysis for Natural Gas

A=4.5% O₂ = 9% CO₂
B=9% CO₂ 2500 ppm CO
No O₂



What is NOx

- In industrial boilers, NOx is primarily formed in two ways.
- Thermal NOx
- Fuel NOx

Thermal NOX

- Thermal NOx is formed when nitrogen and oxygen in the combustion air combine with one another at the high temperatures in a flame.
- Thermal NOx makes up the majority of NOx formed during the combustion of gases and light oils.
- The rate of NOx formation generally increases significantly above 2,800°F flame temperature.

Fuel NOX

- Fuel NO_x is formed by the reaction of nitrogen bound in the fuel with oxygen in the combustion air.
- It is rarely a problem with gaseous fuels. But in oils containing significant amounts of fuel-bound nitrogen, fuel NO_x can account for up to 50% of the total NO_x emissions.

Reducing NOX

- Flue gas recirculation, or FGR entails recirculating a portion of relatively cool exhaust gases back into the combustion process in order to lower the flame temperature and reduce NO_x formation.

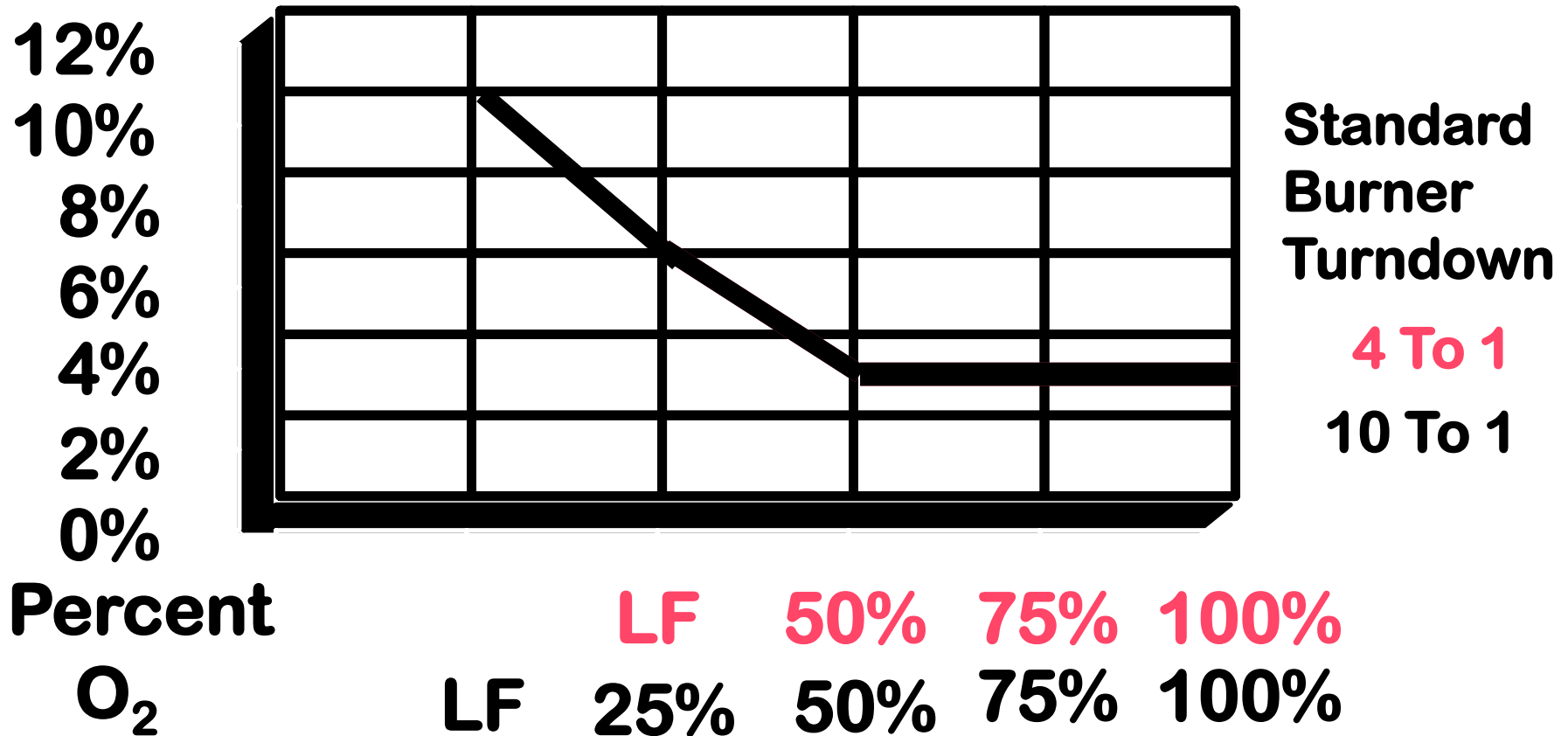


Theory of Combustion

- What are O_2 levels?
- Excess air levels above stoichiometric combustion

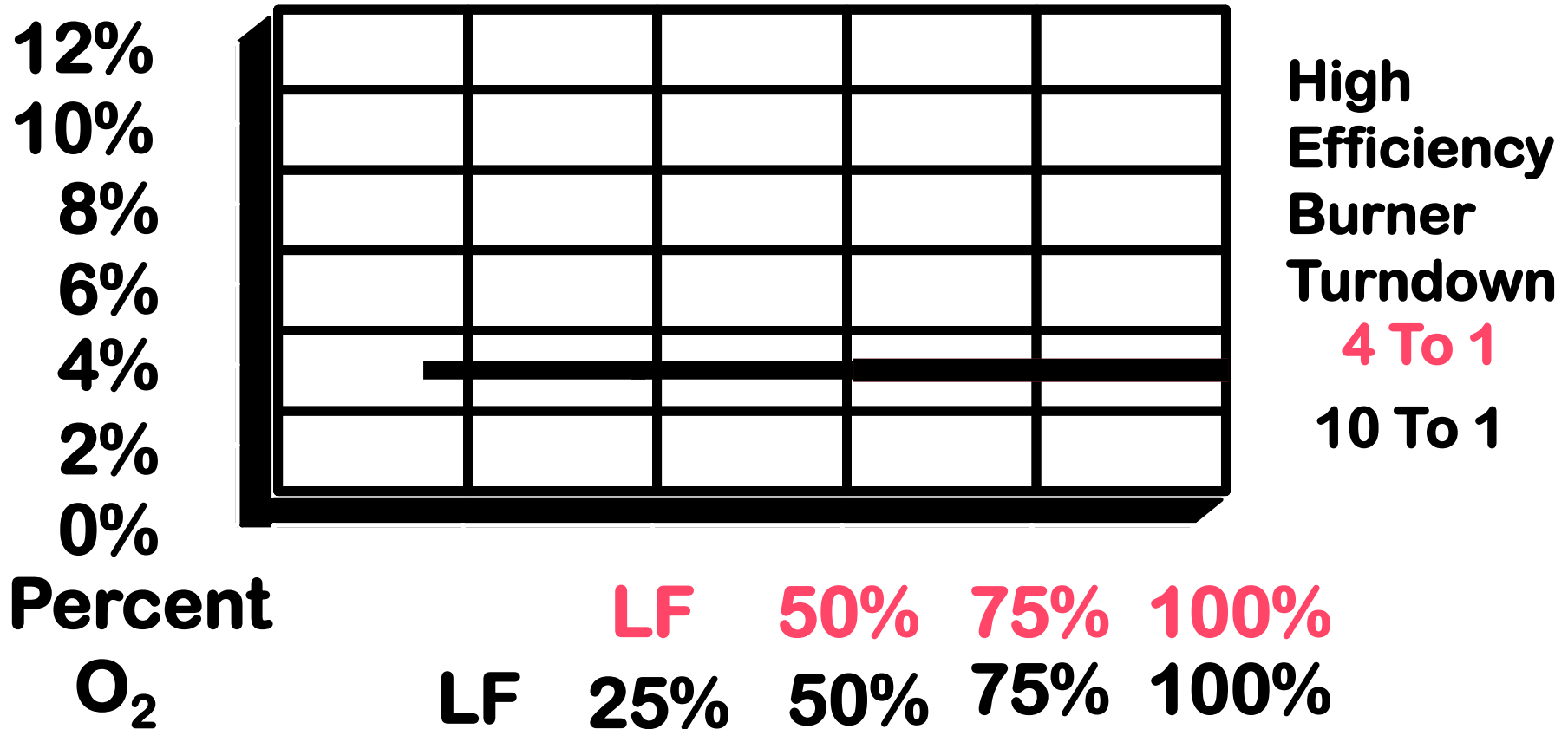
Theory of Combustion

Setting O₂ levels



Theory of Combustion

Setting O₂ levels



Theory of Combustion

- What affects combustion?



- Barometric pressure
 - Weather, storms, elevation.
 - Effected by temperature cooler air increase pressure.
 - Hotter air decreases temperature.

Effects on Air Properties

Temp.	Press.	Excess Air *	O2%
80	27	7.0 %	1.8%
80	28	11.0 %	2.4 %
80	29	15.0 %	3.0 %
80	30	19.0 %	3.8 %
80	31	23.0 %	4.4%

Making CO

Making CO

(Set Up)
Burner in
High Fire

* Expressed as a percent of the stoichiometric air required. Normal US average is 29 to 30

Theory of Combustion

- What affects combustion?
- Barometric pressure

Theory of Combustion

- What affects combustion?
- Barometric pressure
- Ambient air temperature

Effects on Air Properties

Temp.	Press.	Excess Air *	O ₂ %
40	29	25.5 %	5.0%
60	29	20.2 %	4.0 %
80	29	15.0 %	3.0 %
100	29	9.6 %	2.0 %
120	29	1.1 %	1.0 %

(Set Up)
Burner in
High Fire
Making CO
Making CO

* Expressed as a percent of the stoichiometric air required

Theory of Combustion

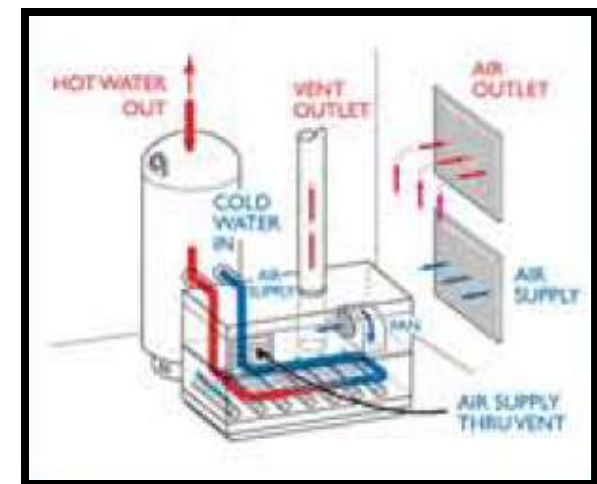
- What affects combustion?
- Barometric pressure
- Ambient air temperature

Theory of Combustion

- What affects combustion?
 - Barometric pressure
 - Ambient air temperature
 - Ventilation air

Combustion Air

- Power burner requirements
 - 10 cfm per boiler HP
 - 8 cfm for combustion
 - 2 cfm for ventilation
 - 1 square foot for every 250 cfm
- Atmospheric or fan assisted requirements
 - 2 in² per 1000 Btu/hr input
 - Ventilation & combustion air
 - Air direct from outside – reduce to ¼



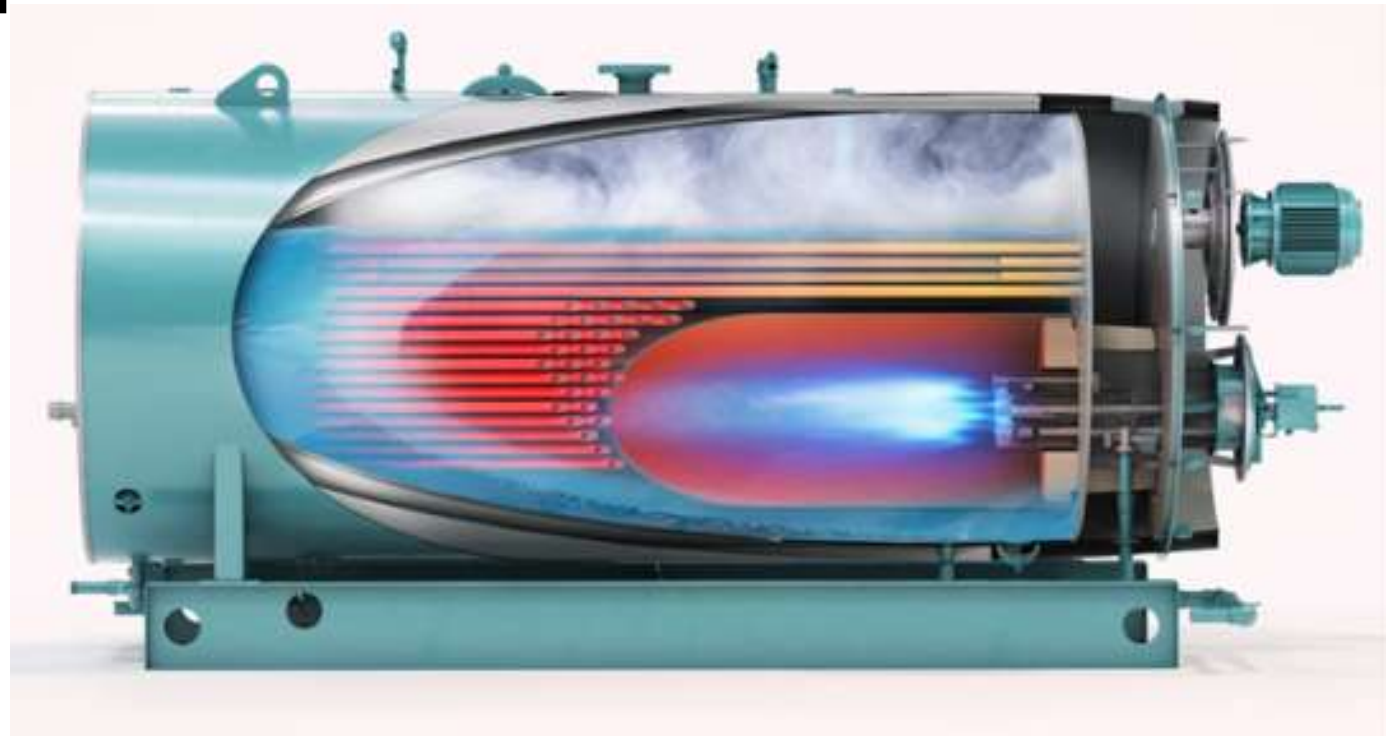
Boiler Design

- Boiler is nothing more than a heat exchanger with a burner attached
- The more heating surface we have the easier it is to transfer heat
- The greatest percentage of heat transfer occurs in the furnace
 - Highest temperature differentials
 - Radiant heat transfer

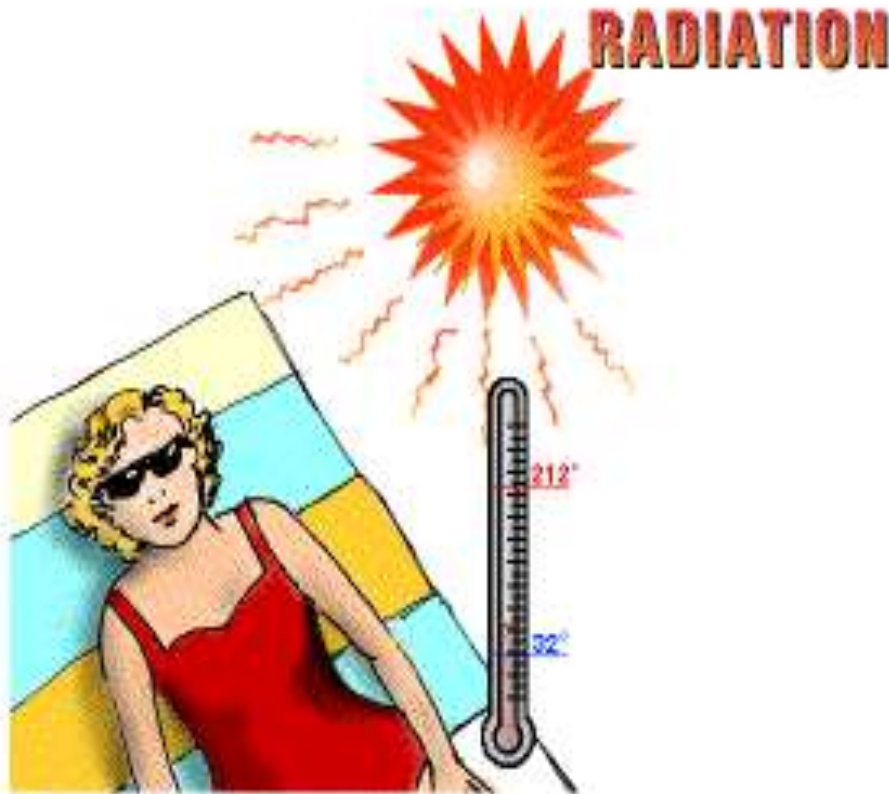


Heat Transfer

- Radiation
- Conduction
- Convection



Radiation

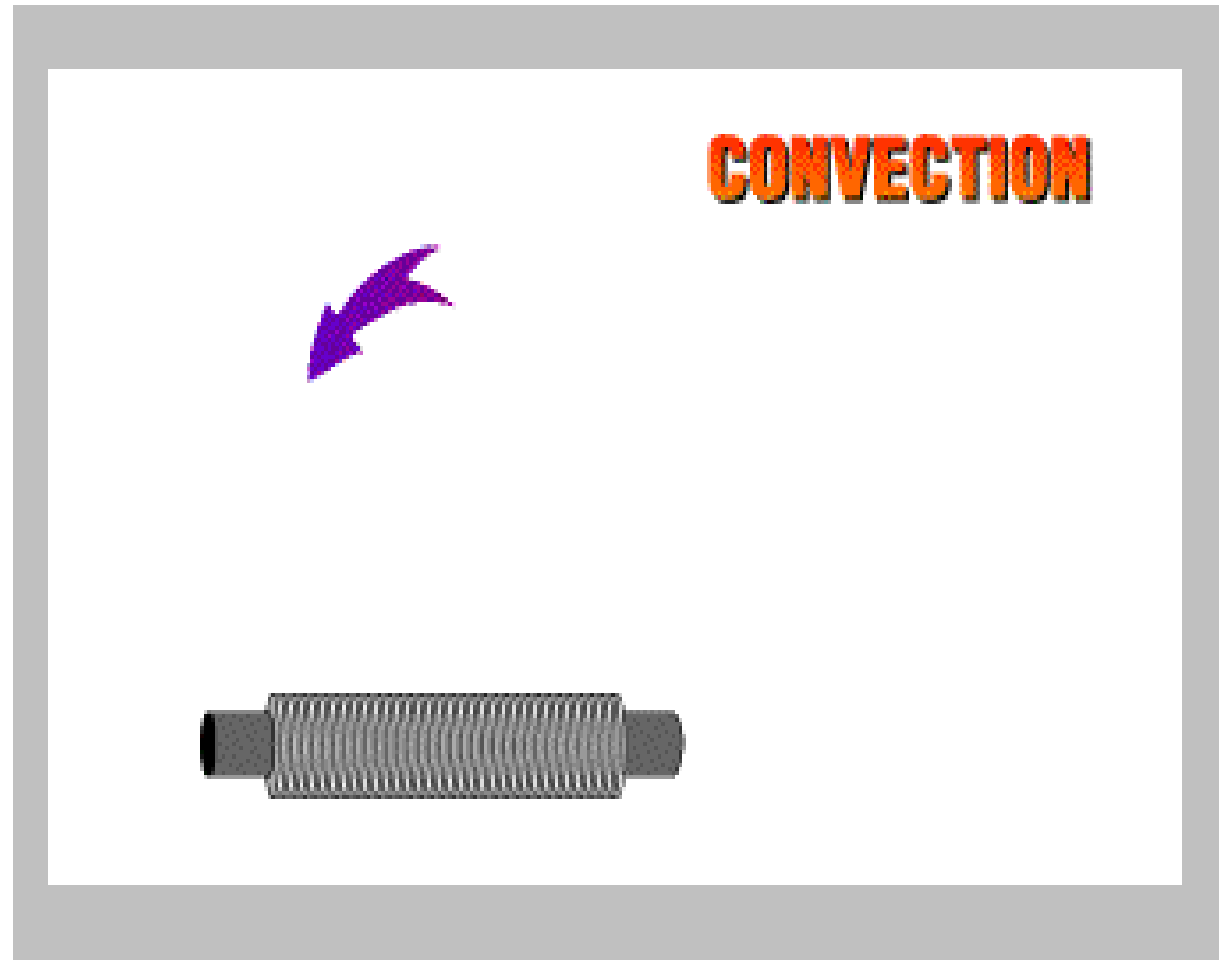


Conduction

CONDUCTION



Convection



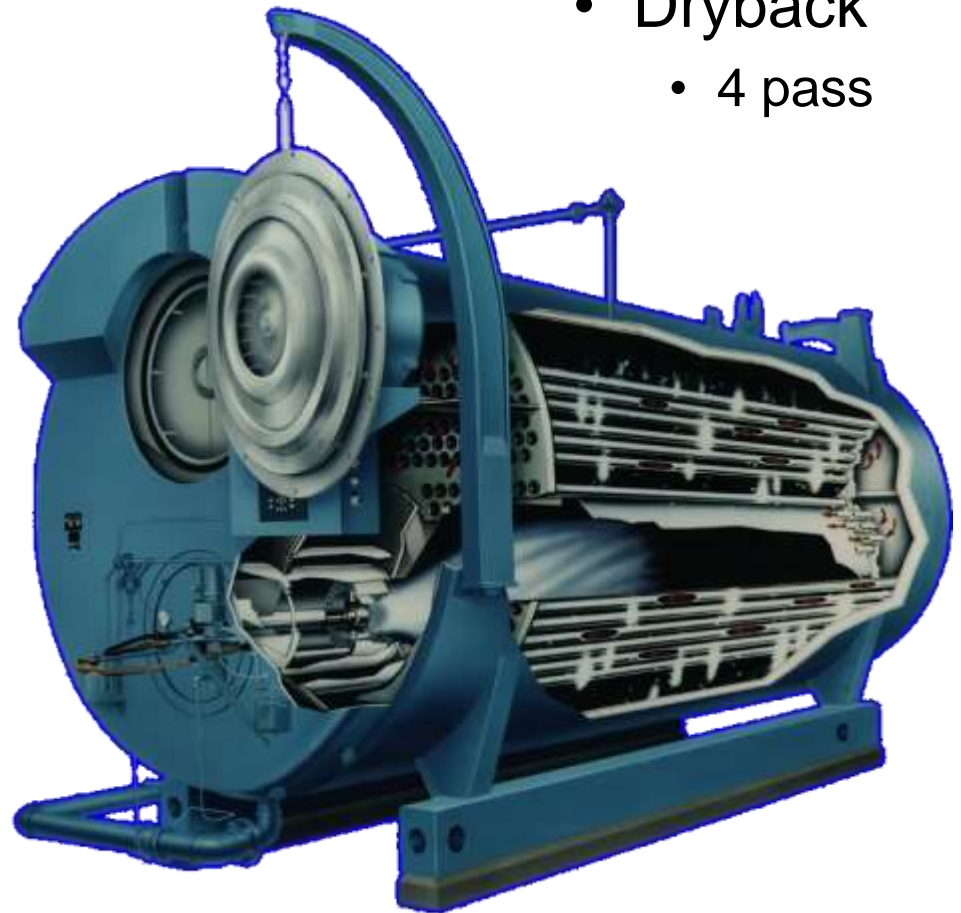
Boiler Types

- Steam & hot water boilers
- Generally broken down into a few main categories
- Firetube
 - Dryback
 - Wetback
 - Vertical
 - Firebox
- Watertube
- Cast iron sectional
- Copper finned tube
- Steam Generator

Firetube

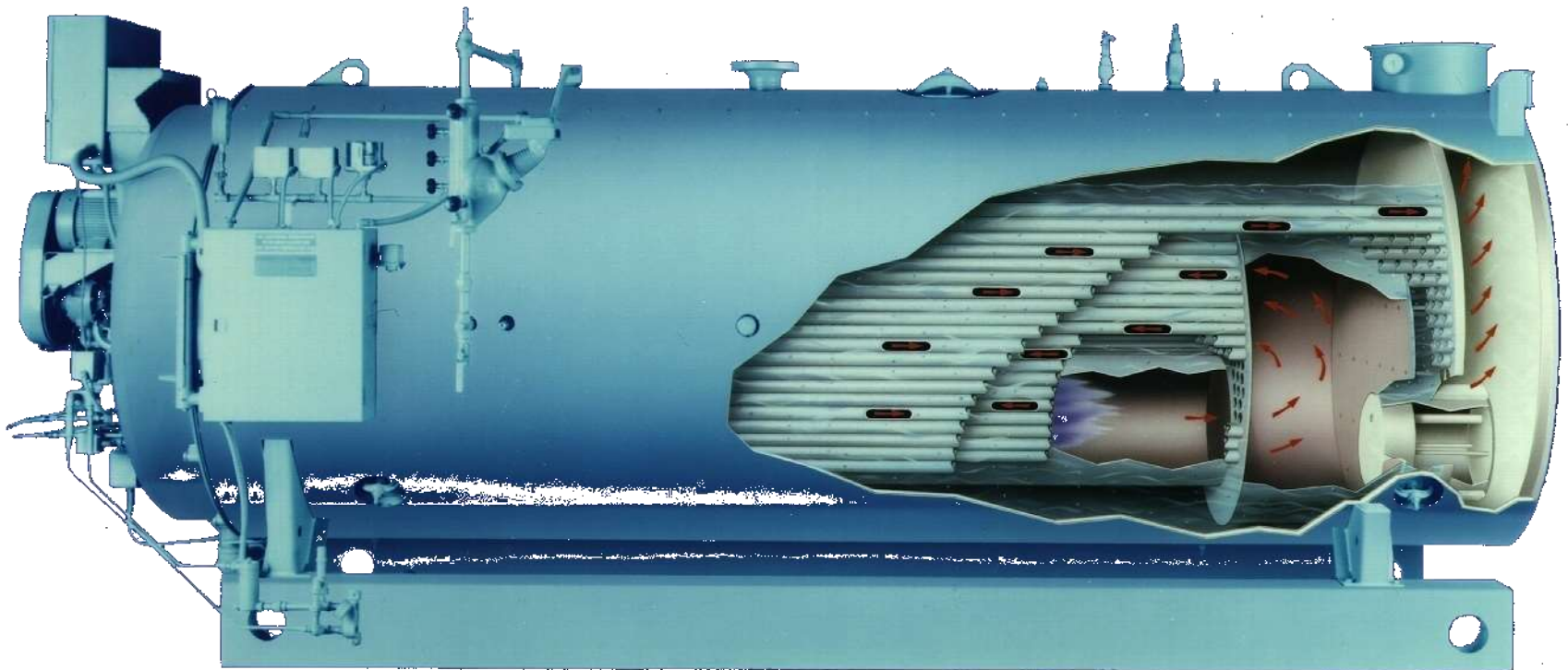
- Categorized by
 - Dryback
 - Wetback
 - Number of passes
 - Check all gaskets and baffle seals

- Dryback
 - 4 pass



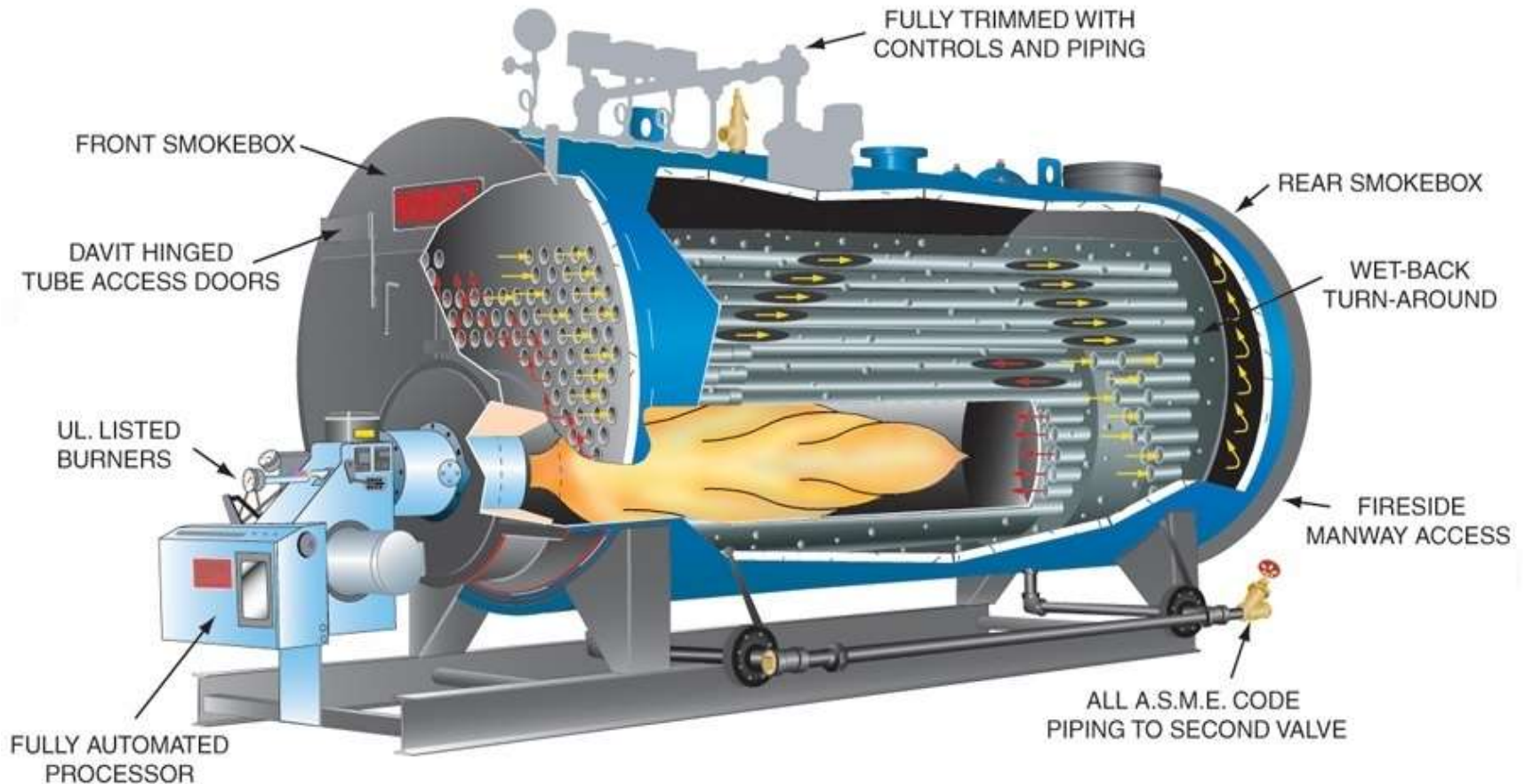
Firetube

- Wetback style
 - Water cooled turnaround from furnace
 - 3 Pass



Firetube

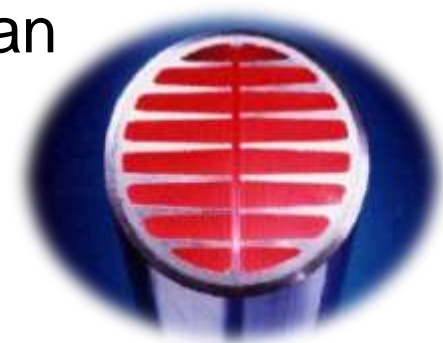
- Wetback style
 - Water cooled turnaround from furnace



Firetube

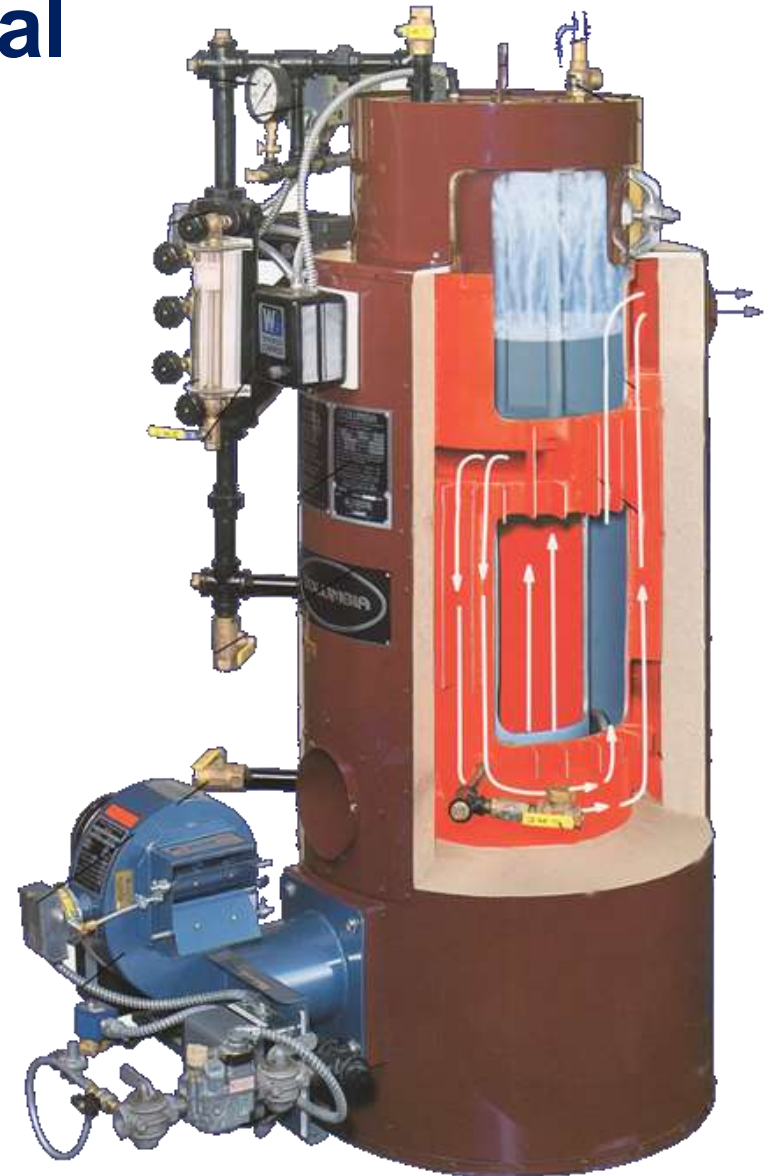


- Single pass Fire tube Boiler
- Fully Condensing Capable
- Hot Water Unit only
- 5 different sizes from 500,000 Btu/HR thru 2,500,000 Btu/HR
- Variable Speed Fan
 - 208 – 240/1/60
 - 120/1/60
- High Efficiency
 - 98 – 99 %
 - In Full Condensing Mode



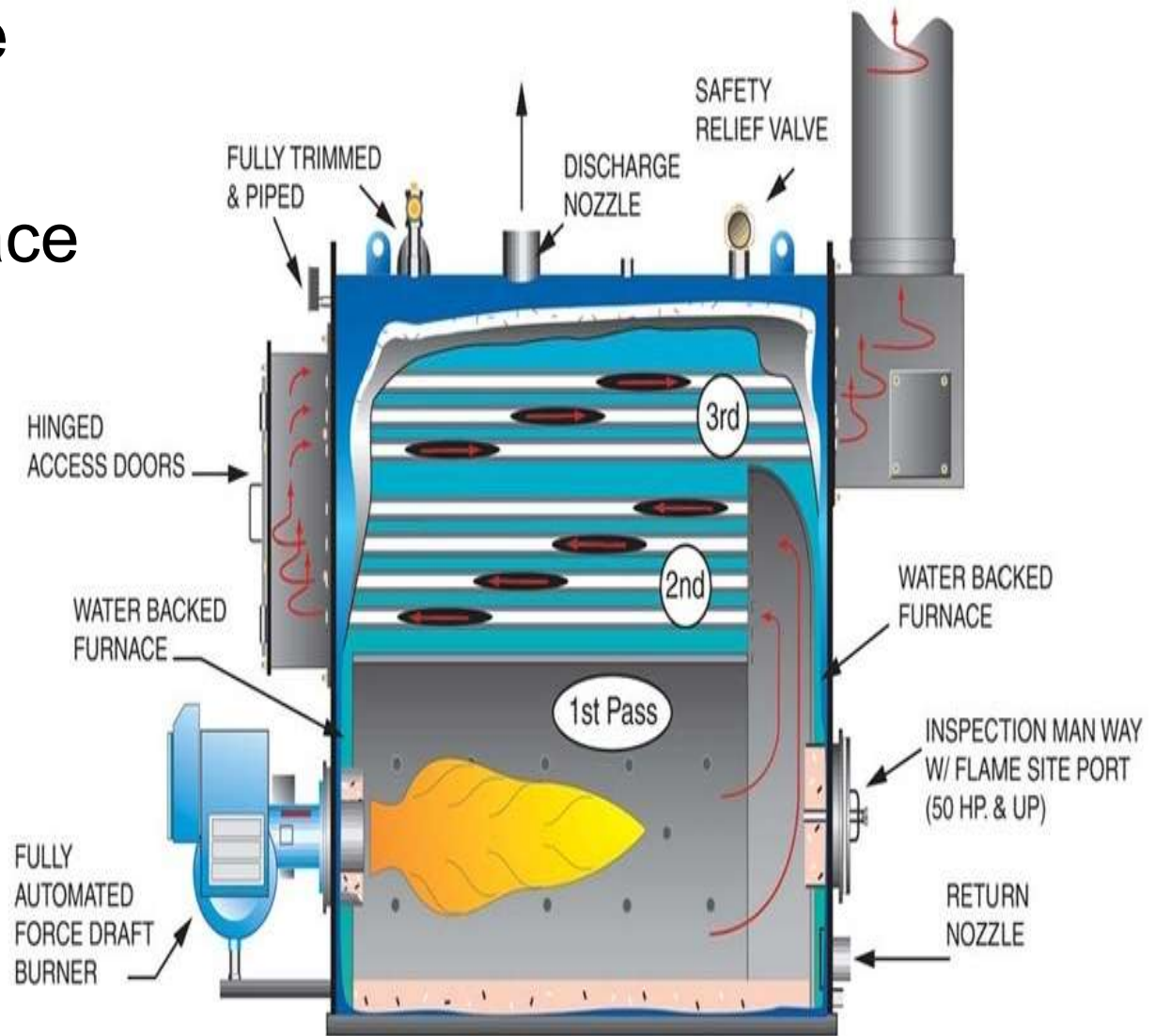
Vertical

- Tubeless
- Shell within a shell design
- Three pass



Firebox

- Scotchbox type
- Three pass
- “Floating” furnace design



Watertube

- Commercial
- Industrial
- Bent tube design



Watertube

- Industrial
10,000 to 300,000+
lbs./hr
- D, O & A types



300,000 lb/hr In Transit To Jobsite

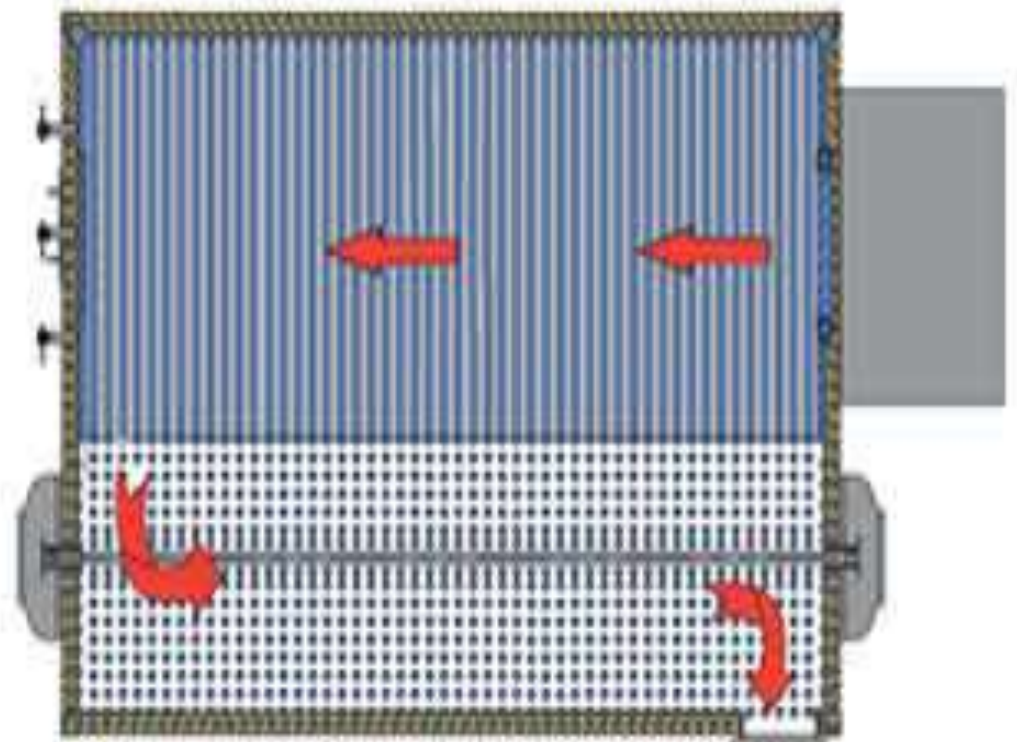
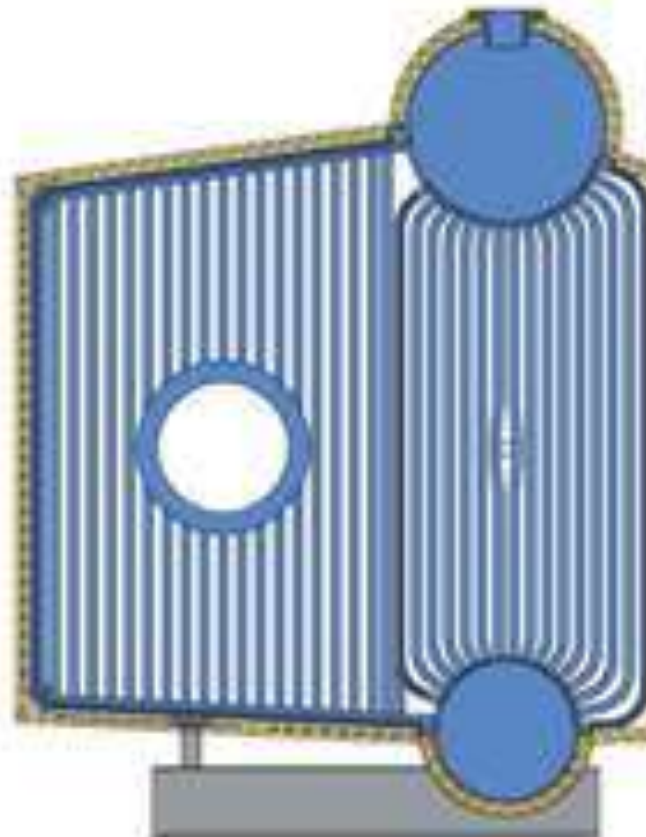
Watertube

- Pressure vessel
 - D type



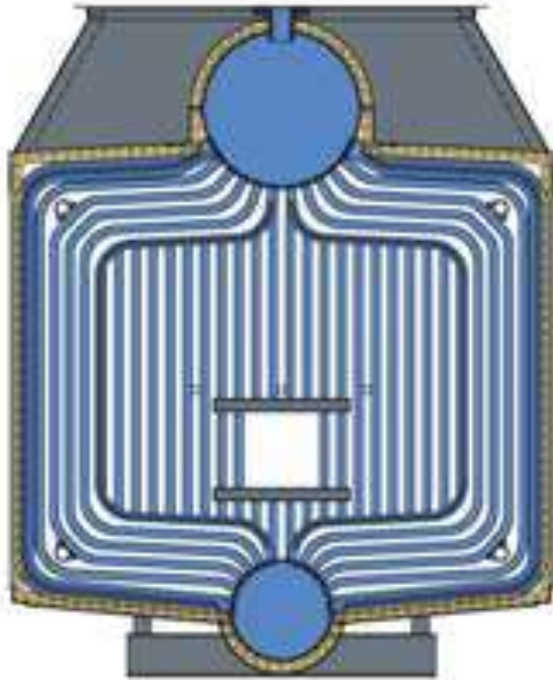
Watertube

- Pressure vessel
 - D type



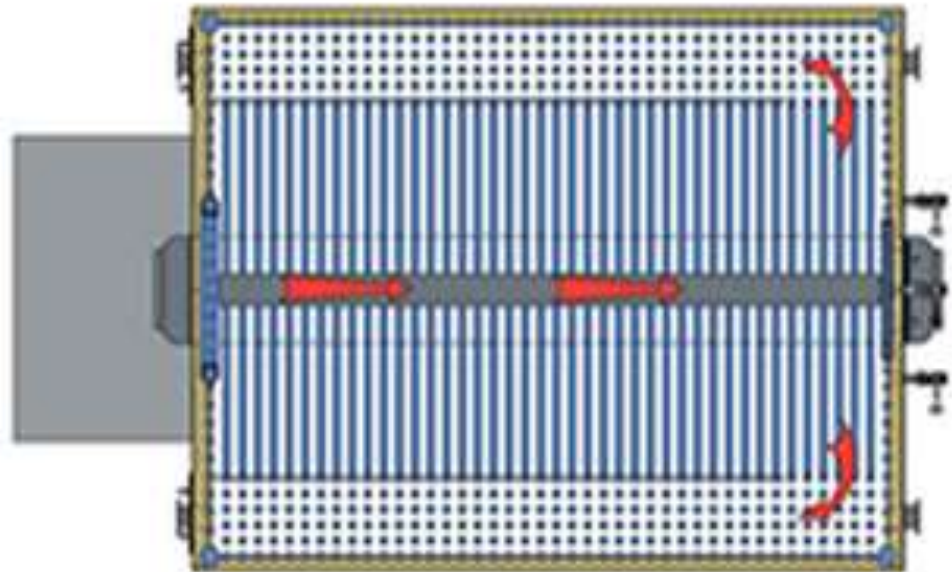
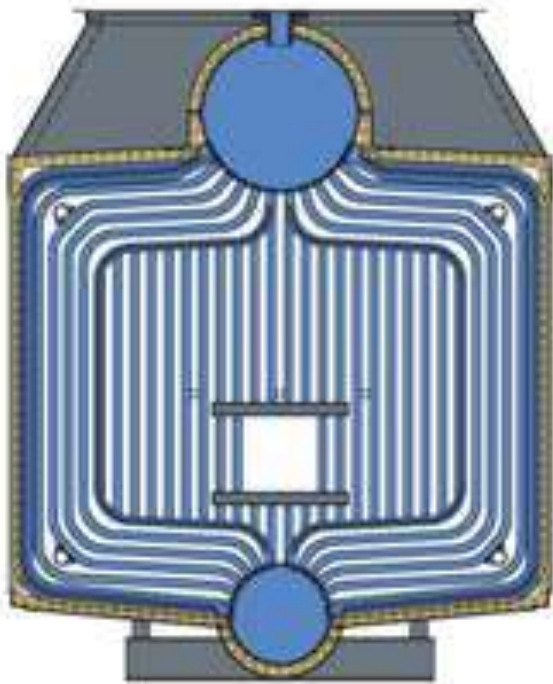
Watertube

- Pressure vessel
 - O Type



Watertube

- Pressure vessel
 - O Type



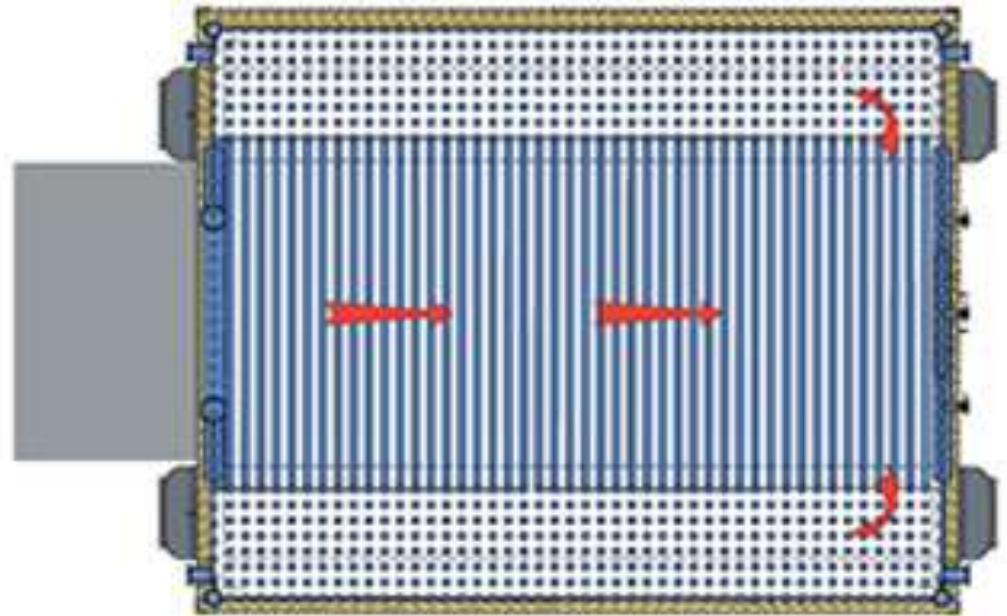
Watertube

- Pressure vessel
 - A Type



Watertube

- Pressure vessel
 - A Type



Thermal Exchange Gas Fired Water Heater

Primary Markets include:

Hot Water

Food Process Industries

- **Washdown**
- **Batch Production**
- **Vessel Filling**
- **Tank Cleaning**

Concrete Plants

- **Pre-Heated Water for batch production.**

Space Heating

- **Greenhouses**

Re-Circulated HW for general space heating

- **Light Manufacturing/Warehouses**

Re-Circulated HW for general space heating

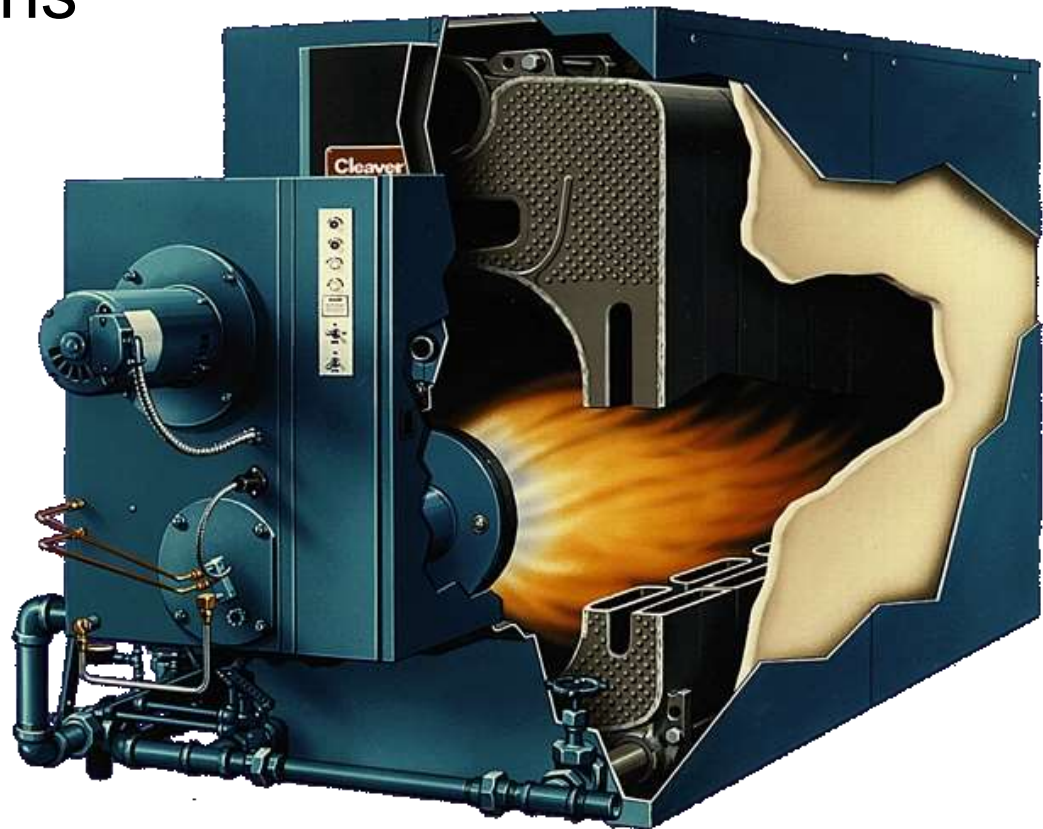
General Industry

- **Boiler Make-Up Water**



Cast Iron Sectional

- Only low pressure or hot water
- Heating applications



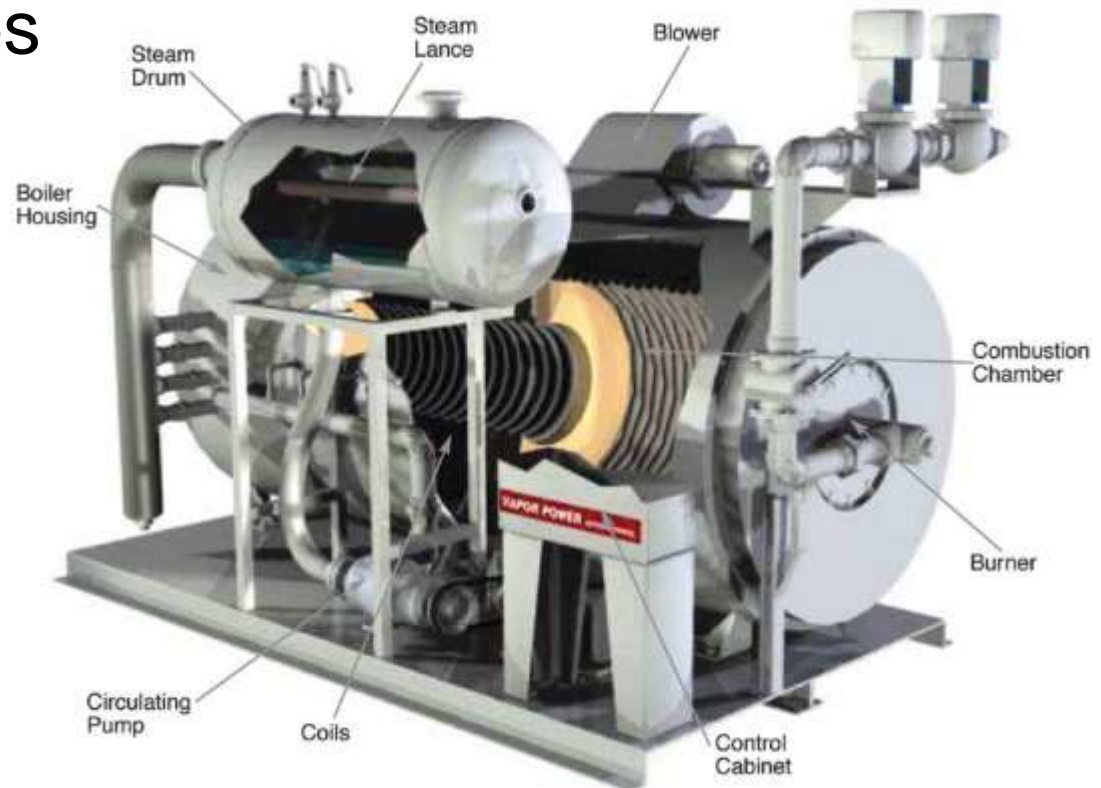
Copper Finned Tube

- Heating applications
- Hot water only
- Pool Heaters



Steam Generator

- Small amount of water
- Fast start-up
- Steam in 5 minutes



Boiler Efficiency

- Two parts comprise the overall efficiency of the boiler:
 - Pressure vessel (heat exchanger) design
 - Burner performance
 - Excess air levels
 - How much energy is lost heating excess air

Boiler Efficiency Terms

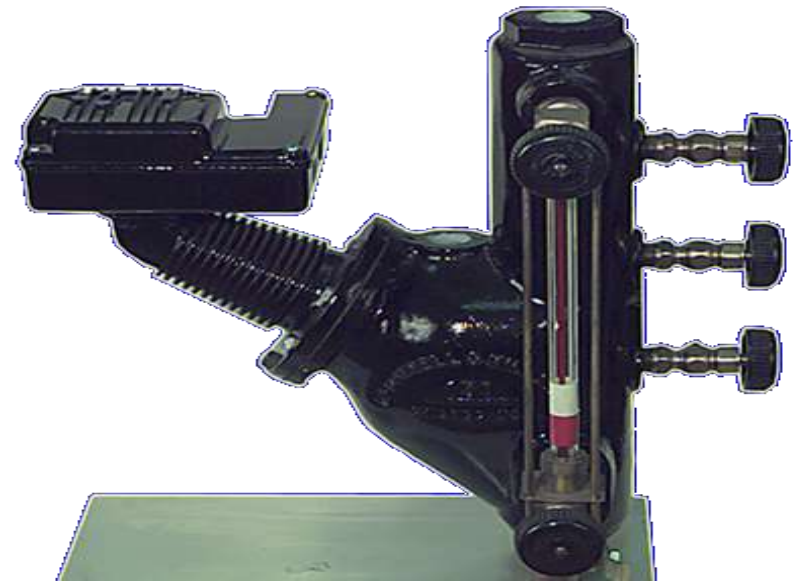
- Boiler efficiency
 - Fairly vague term, usually refers to the overall boiler efficiency
- Thermal efficiency
 - Also a bit vague, can refer to efficiency of heat exchanger or boiler/burner
 - Can also refer to overall boiler efficiency

Boiler Efficiency Terms

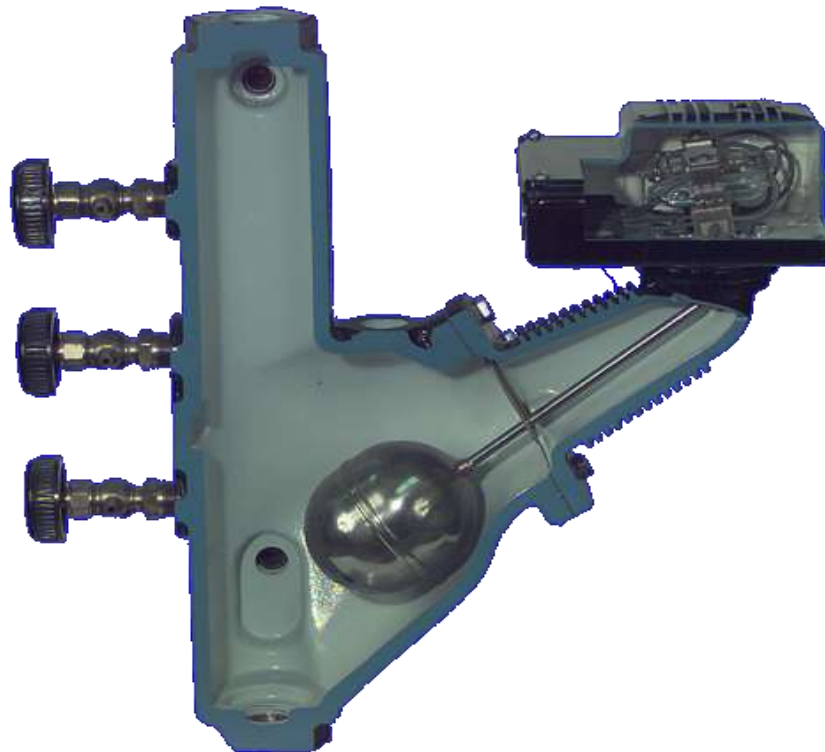
- Combustion efficiency
 - Usually refers to the efficiency related to the excess air level of the burner and the stack temperature
 - Usually does not consider the losses of the boiler in relation to radiation & convection
- Fuel to steam efficiency
 - How much fuel is put in versus steam (energy) out

Low Water Cut-off's & Boiler Maintenance

- The LWCO is the most important control on the boiler.
- Boiler should never be operated with out the LWCO functional.



Typical float type for a Firetube boiler.



Water Columns

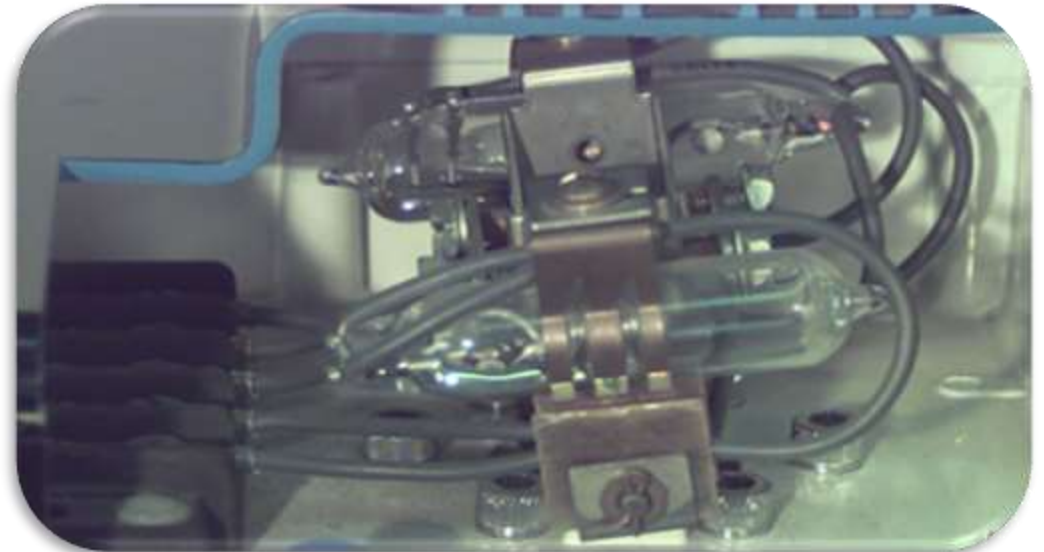
- Most common controls
 - LWCO - M & M 150/157 good to 150 PSI
- Pump control switch
 - Start and stop turbine feed pump
 - Open - close feed water valve
 - End switch
 - Modulating feed water valve
 - Centrifugal pumps
- LWCO switch
 - Shut off burner, illuminate an indicating light and sound an alarm

Water Columns

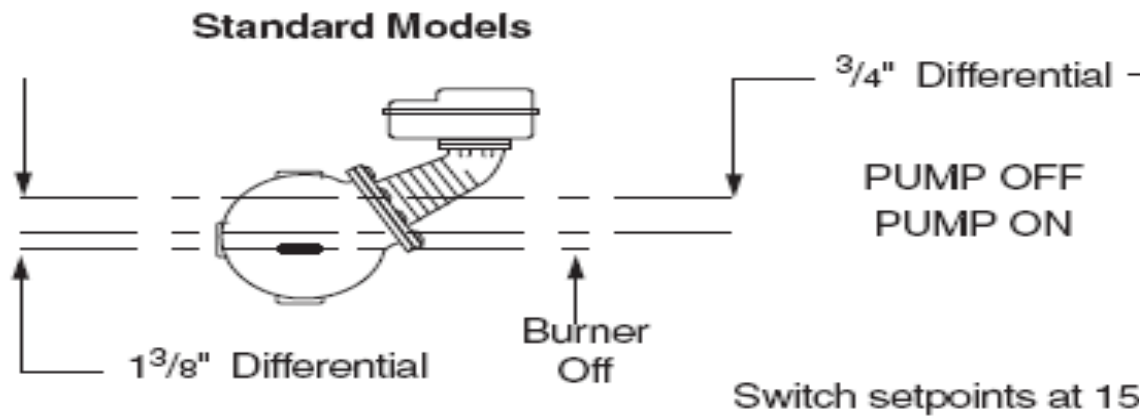


- Tricocks
 - No longer required by ASME code
 - High pressure boilers
 - Option - for local codes or customer request
 - Used to check water level if can't tell level using the sight glass

- The Mercury type style is no longer available
- All snap switch units are not adjustable in the field.
 - If tripping at wrong water levels unit needs to be re-piped.



- Water level gets down to casting mark that is low water



Water Columns

- Auxiliary low water cut-off
 - M & M 150
 - External probe
- LWCO or ALWCO may be manual reset
 - State or local code



Primary LWCO for Water tube Boilers

Sensitivities vs Maximum Probe Wire Distance*

SENSITIVITY CHARACTER	SENSITIVITY (KOHMS)	DISTANCE (FT)
A	4.7	900
B	10	600
C	26	250
D	50	100
E	100	50

* Based on type MTW or THHN wire, #14 or #16 Awg



What is recommended to use for boiler applications

Probe Install

The probe installation in Figure 4 is INCORRECT!!

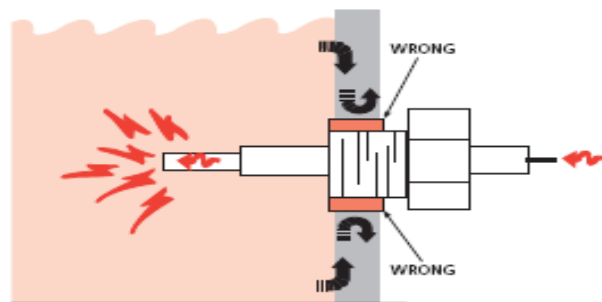


Figure 4

Insulating sealant or Teflon® tape blocks the continuity path, resulting in a weak electrical signal and a false low-water-level indication.

Installing the LWCO in the piping external to the boiler can have pitfalls:

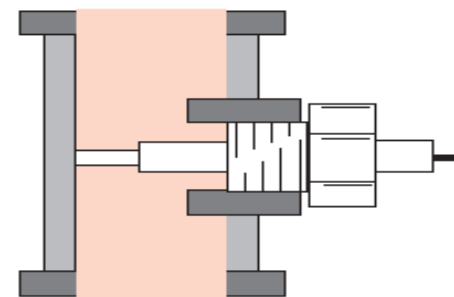


Figure 5

Probe too long - One potential problem may be the probe is too long for the installed location and the probe lacks proper clearance. Contact between the probe and pipe results in a shorted electrical path (Figure 5). If the probe touches the wall of the pipe, the circuit is completed and the LWCO "thinks" there is water in the system whether there is or not. If the water level drops below the level of the probe in this situation, the burner circuit will not be interrupted and a dry fire could occur.

Probe Install

- The probes may need to be inspected and cleaned more frequently on systems where there is the potential of coating build-up on the probes. This includes systems:
 - High quantities of raw water make-up
 - No condensate return
 - Untreated boiler water
 - Inconsistent or infrequent boiler-water chemical treatment
 - Where significant changes have been made to the boiler-water chemical treatment process
 - Oil in the boiler water

- Magnetostrictive technology
- Non-contact, non-wearing
- No switches, no mercury
- Features
 - Level indication
 - Low water cutoff & alarm
 - High water alarm
 - Low & high water warning
 - On/off and modulating control in one unit
 - Continuous dynamic probe monitoring
 - Auto and manual reset
 - Real time clock

Level Master **CBLME**

Water Level Control



Water Columns

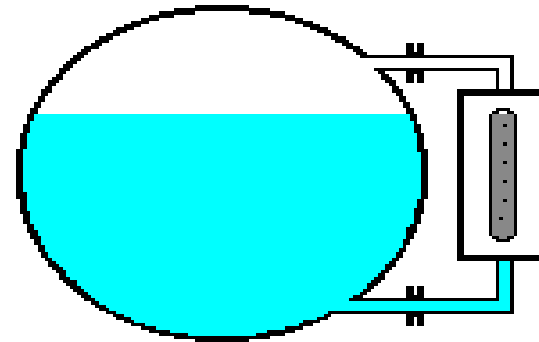
- Steam boilers up to 400 psi must have one direct reading gage glass
- Gauge glass
 - Tubular – standard
 - What to look at
 - Etching
 - Packing
 - Alignment



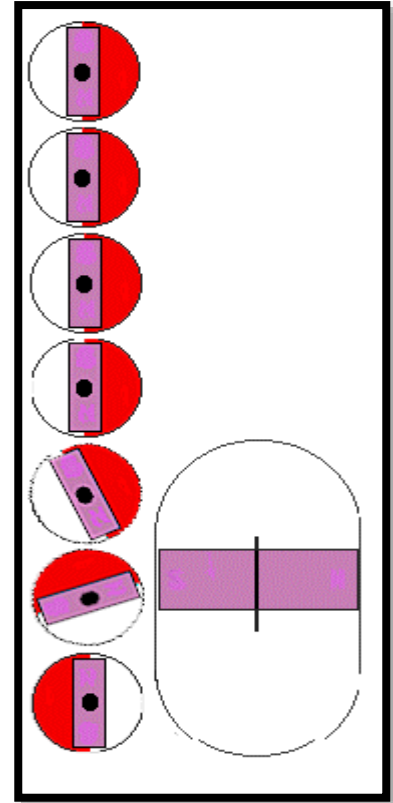
Water Columns

Prismatic

- Very high pressure
- Customer request
- Special water column
- Fluid level indication is the result of the different transparency property of the two media (i.e. liquid and air or vapor)



- Magnetic type level indicator cannot be used on boilers.
- Requirement is you need to see water in the gage glass.
- Tanks are ok



What to look out for

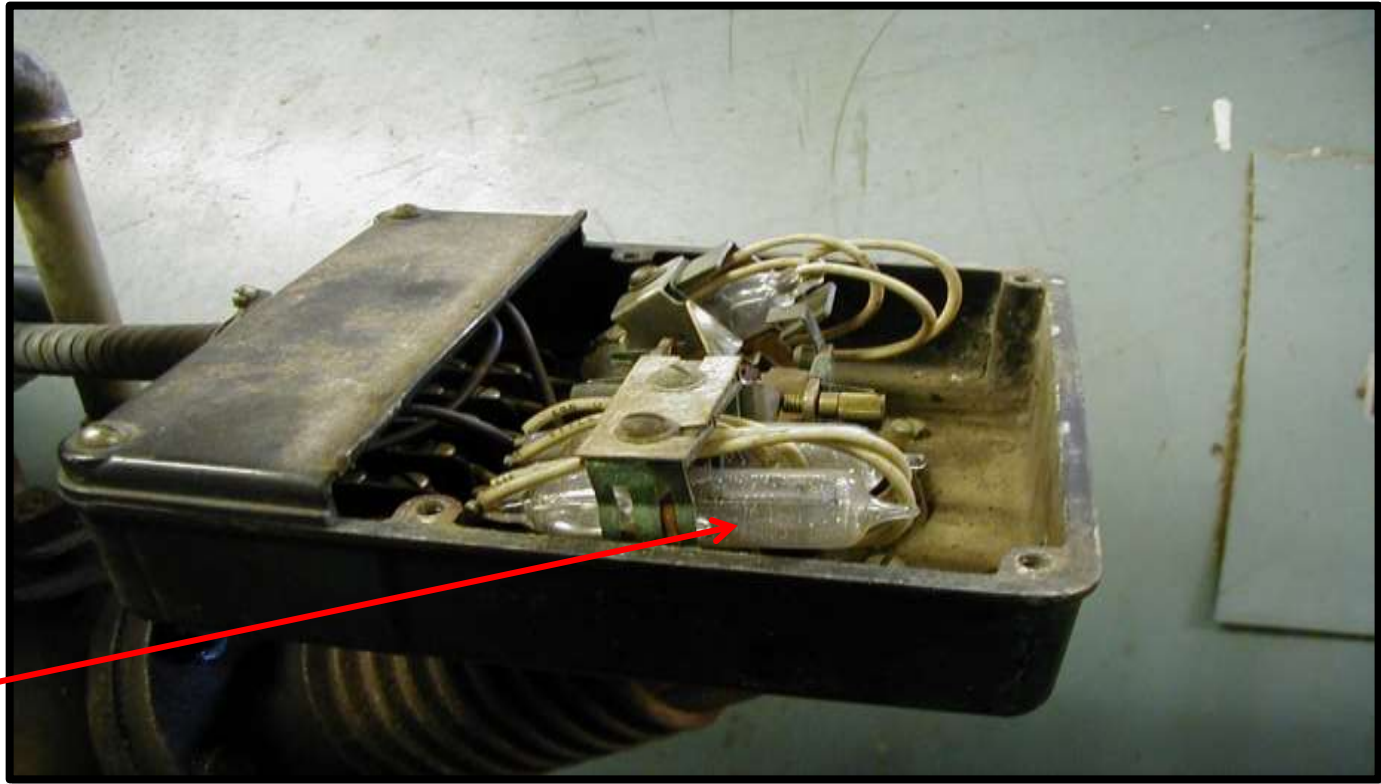


Proper Maintenance of LWCO

- Replace the Head mechanism every 5 years
- Replace Head when Switches don't work properly.
- Disassemble and inspect annually – including float chamber and equalizing piping



Inspect Mercury Switches

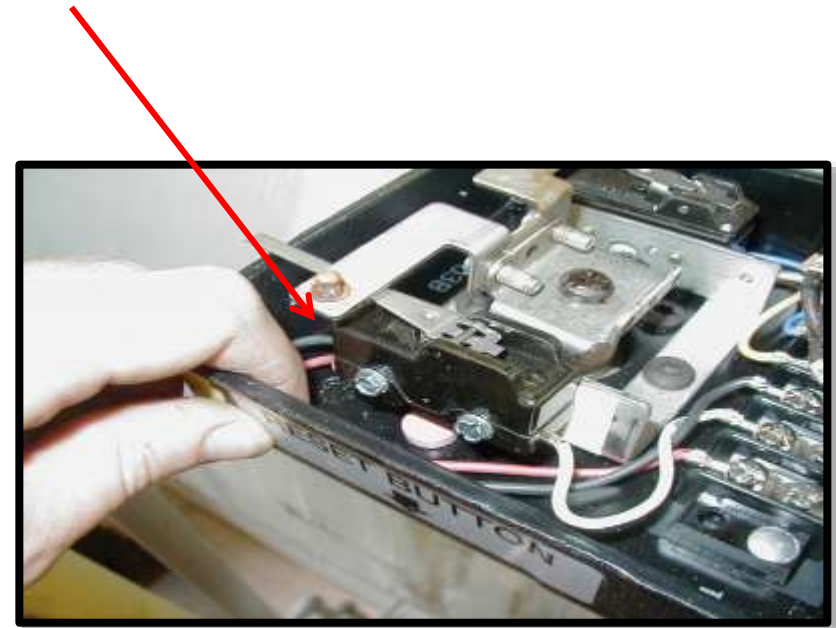
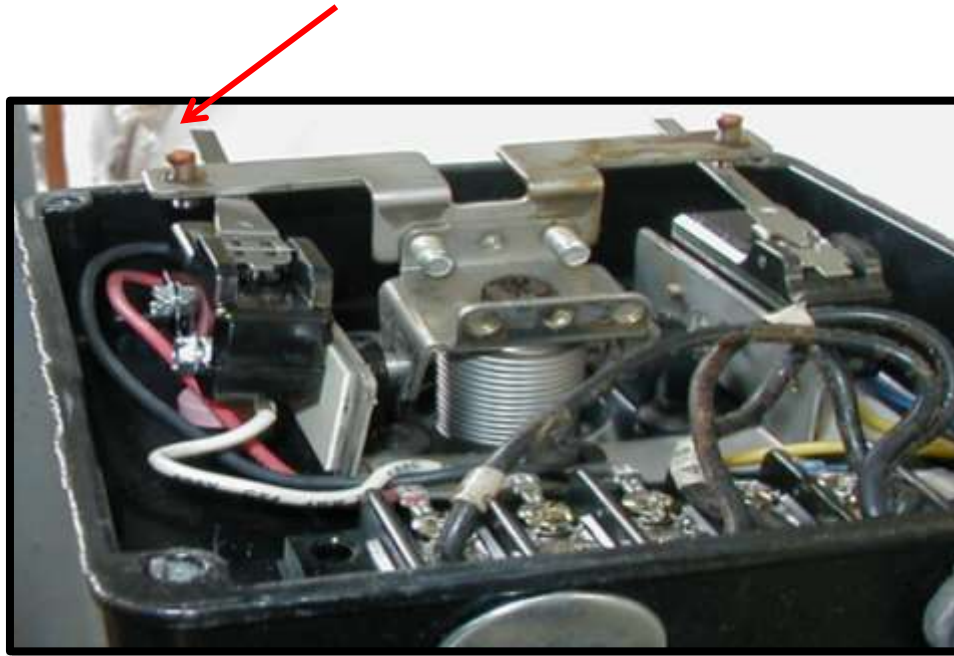


Inspect Mercury Switches

- Burned, cracked or brittle wire on the switches.
 - This should be high temperature wire
- Separated or discoloration of the mercury in the switches.
- Mercury should be shinny and clean and must move from one end of the switch to the other end when the switch trips.
- Make sure the switches are properly positioned.
- Do not jumper switch
- Make sure all connections are tight

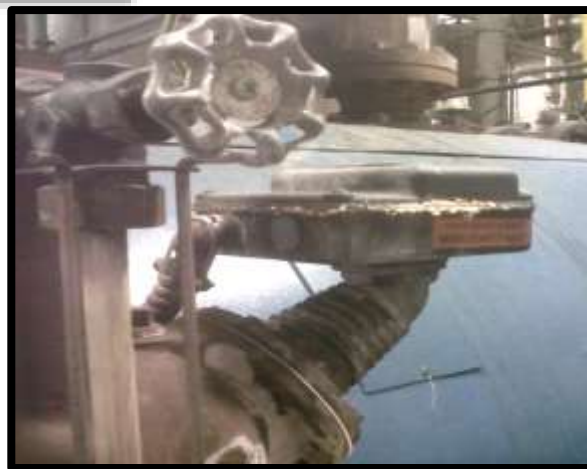


Inspect Snap Switches



Alignment

Remove Covers for Inspection



- Rod out pipe
 - Once a year
 - Steam & water side
 - Water columns
 - Pressure controls
- Match mark piping
 - Ensure their put back at the proper level



LWCO Piped

Steam



Top pipe can be common.

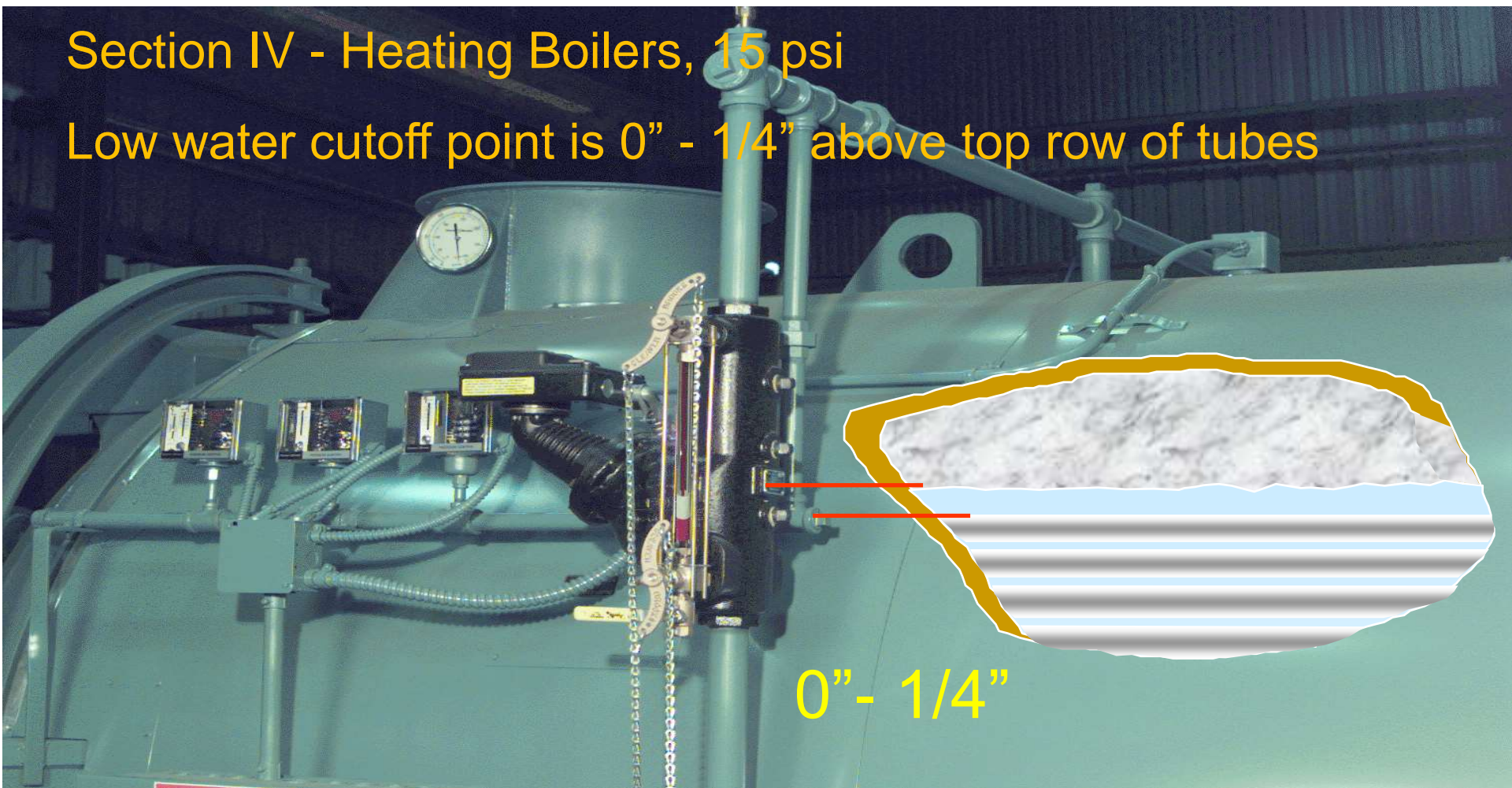
Bottom pipe needs
To be separate for steam

Hot Water



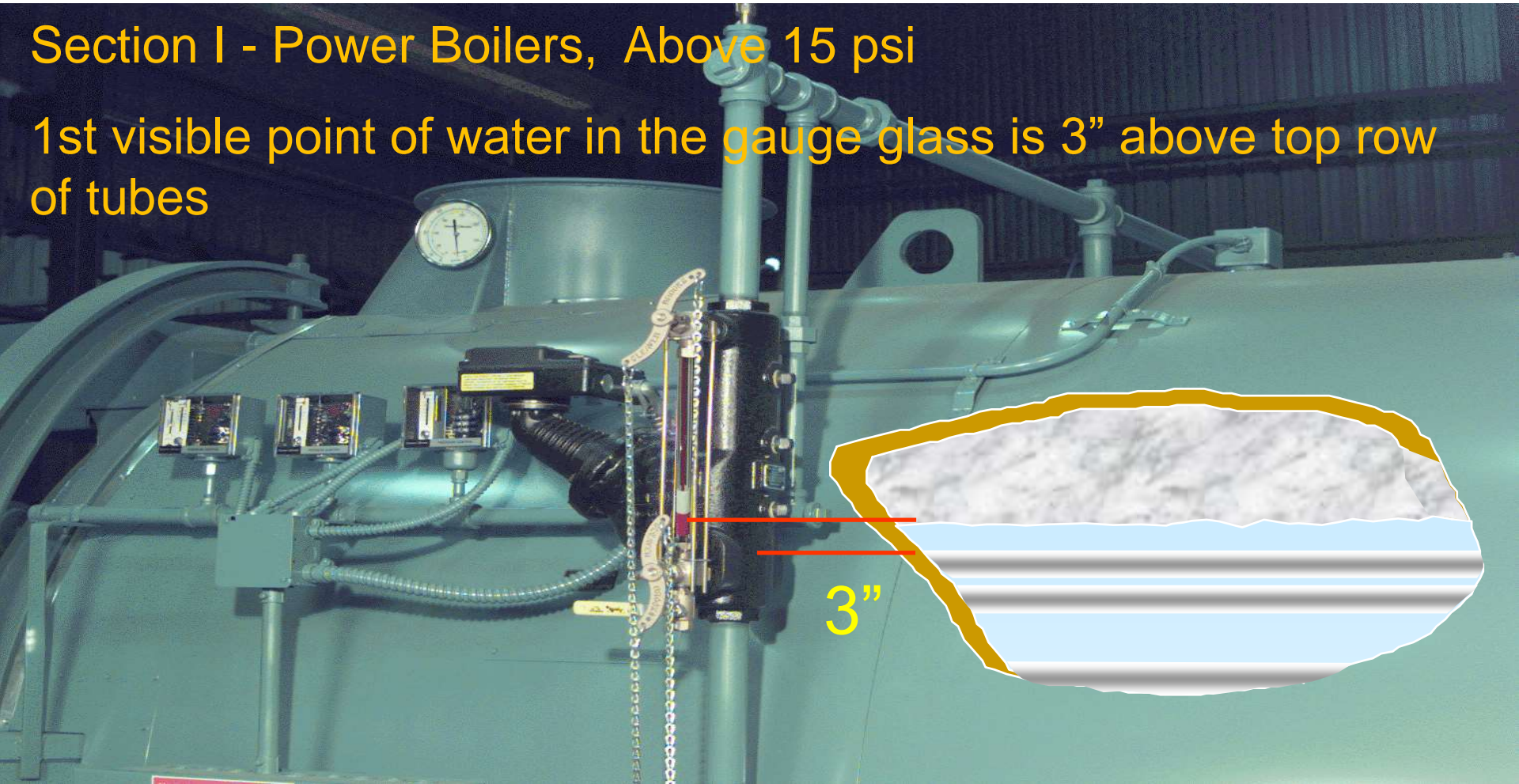
Section IV - Heating Boilers, 15 psi

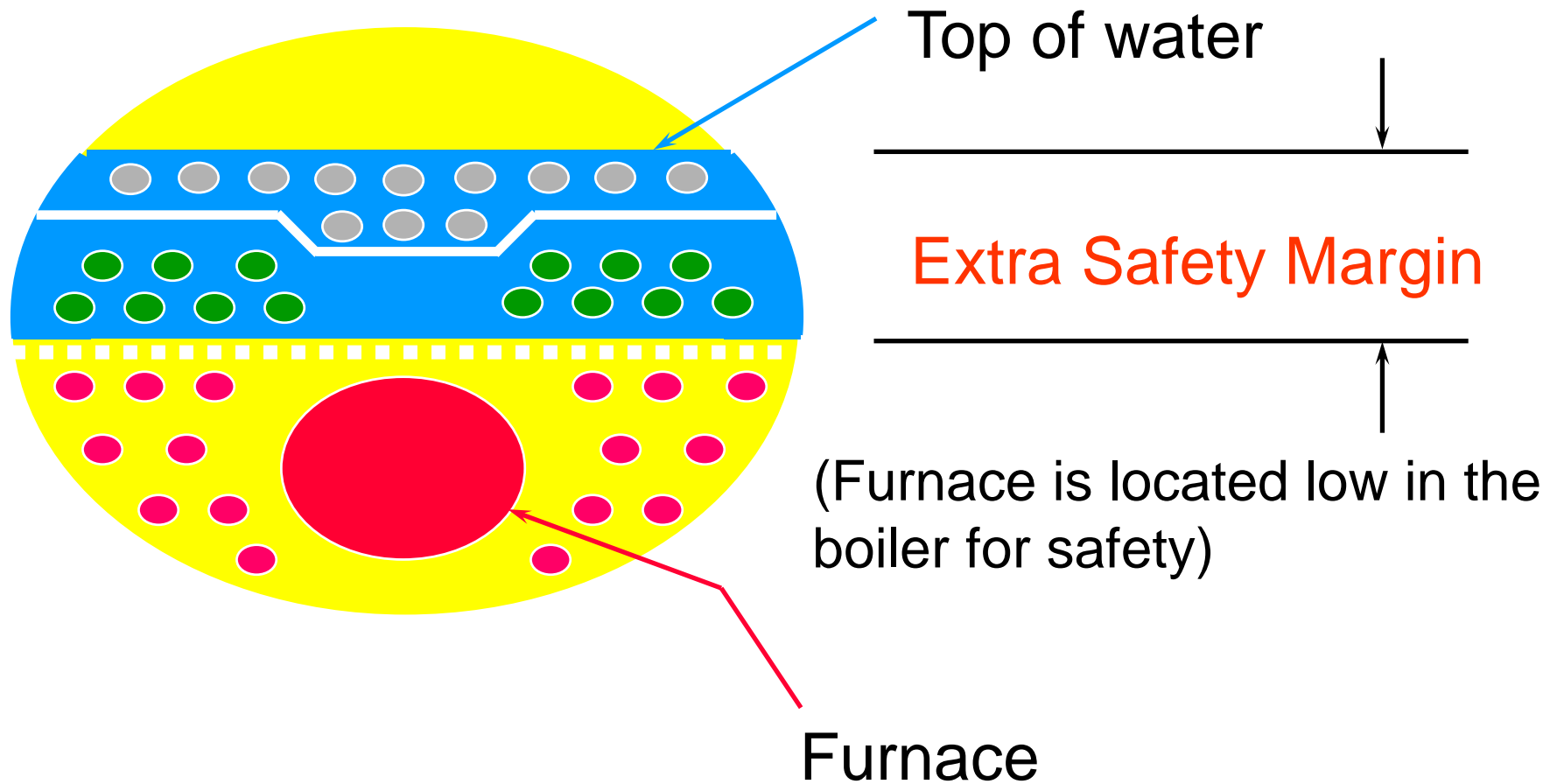
Low water cutoff point is 0" - 1/4" above top row of tubes



Section I - Power Boilers, Above 15 psi

1st visible point of water in the gauge glass is 3" above top row of tubes





Test the Low Water Cutoff

- Monitor water level in the gauge glass
- Burner must shut off when water level reaches the marking on the casting of the Low Water Cutoff
- If burner does not shut off at the low water cutoff point:
 - Turn the burner switch off
 - Cool down the boiler and inspect the Low Water Cutoff

Methods of Testing the Low Water Cutoff

- Evaporation test. **Best way**
 - Boiler steams off naturally
- Under Constant Attendance and burner at low fire:
 - Stop feedwater flow to the boiler
 - Shut off pump
 - Close a valve - Use caution
- Alternative
 - Slow drain test with bottom blow.

Blowing down Water Columns

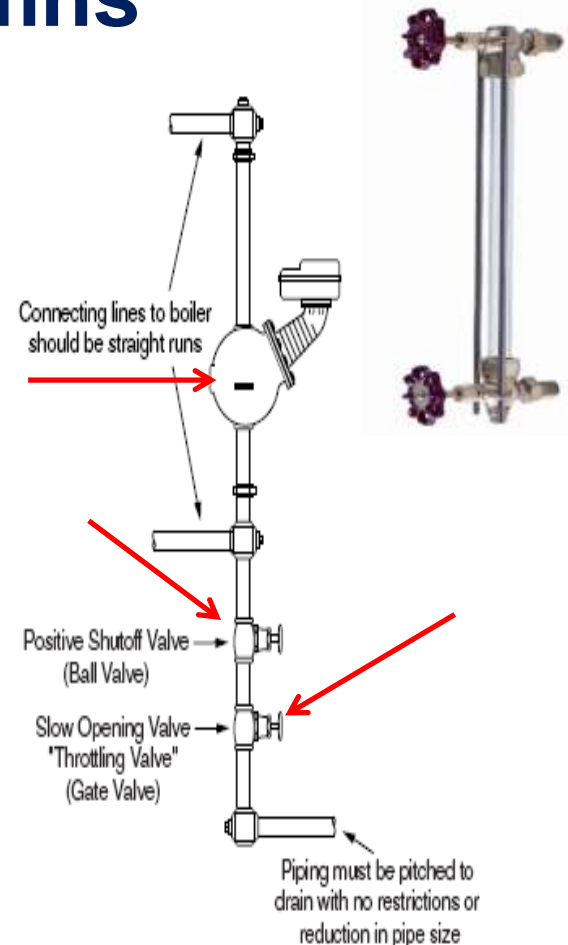
- When blowing down a control at pressure, the blow down valve should be opened slowly.
- The piping needs to be warmed up and stagnant water in the drain piping needs to be pushed out. Suddenly opening a blow down valve causes steam to condense, which creates water hammer.
- Crushed floats and damaged linkages can occur when water hammer occurs due to improper blow down piping.



Blowing down Water Columns

1. Boiler water level is at normal, open "Positive Shut-off Ball Valve".
2. Open "Throttling Gate Valve" slowly until drain piping heats up and then open fully. Observe that the water level starts falling in the gauge glass.
3. Water level reaches casting mark boiler/ burner should shut off.

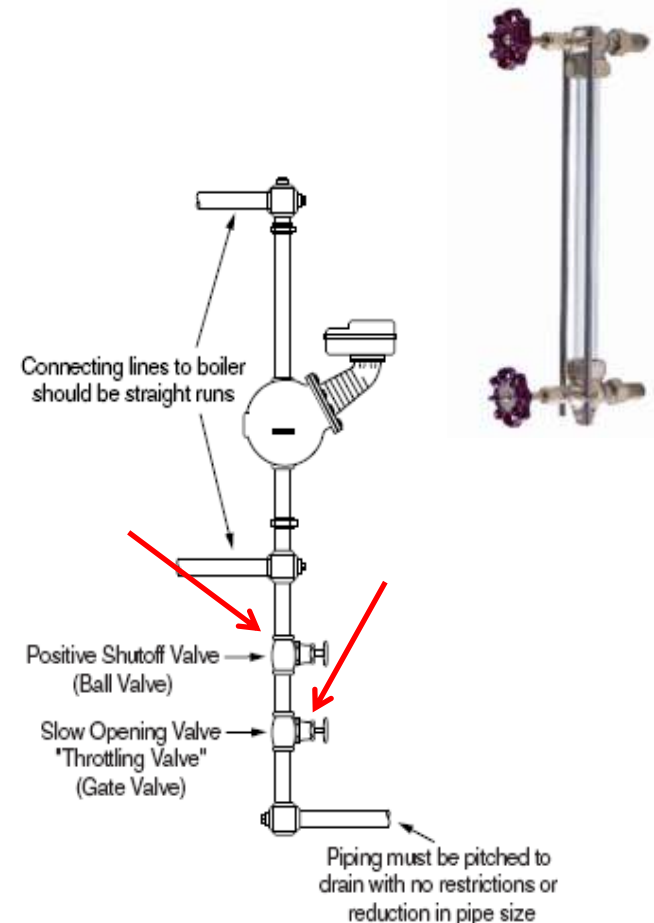
Note: If this does not happen, immediately close all valves, turn off burner and correct the problem



Blowing down Water Columns

4. Close throttling valve.
5. Close "Positive Shut-off Ball Valve".
6. Observe that the water level returns to its normal level.

This tests the low water cutoff, but
Does not prove it works under
normal boiler operation. Better to
The evaporation or slow drain test



Boiler Accidents

No matter the pressure vessel manufacturer, when you install the wrong parts or do not keep up with the proper maintenance and testing safety devices you can have accidents.

This was a preventable accident

- Boiler operator was not properly trained to operate boiler safely.
- Maintenance personnel installed an Improper relay for the Auxiliary LWCO

Correct



Photo #16a - 1c1d0a Relay with Manual Reset

Wrong
By installing this
one they bypassed
the ALWCO



Photo #16b - 1d1d0 Relay without Manual Reset

Modulating Feed Water Valve

- They disconnected the linkage to the feed water valve because it did not move.



Manual Feed Water Bypass

- Boiler would not maintain proper water with the modulating feed valve.
- They opened up the manual bypass which would be ok if they would have kept a eye on the water level and controlled the bypass to maintain proper level



(M&M) Series 193-7B

- Found after inspection that the (M&M) series 193-7B control had broken and bent springs that would prevent the control to work properly for:
 - Low water cut-out
 - Modulating feed water valve control



(M&M) Series 193-7B

- Shows low water cut-out float stuck in the up position
 - Low water would never trip.
 - Modulating feed water valve would stay closed and never modulate open.



View of East Wall from Outside Plant (Note Rear Boiler Door in Ditch)



View of Pedestrian Walkway Bridge



Knocked Down Exterior Wall Viewed from Inside Boiler Room (East Wall)



Interior Wall of Boiler Room (South Wall)



Hole Created by Boiler through Roll Up Door Wall (West Wall)









Final Location of Boiler after Explosion (Roll Up Door on Boiler)



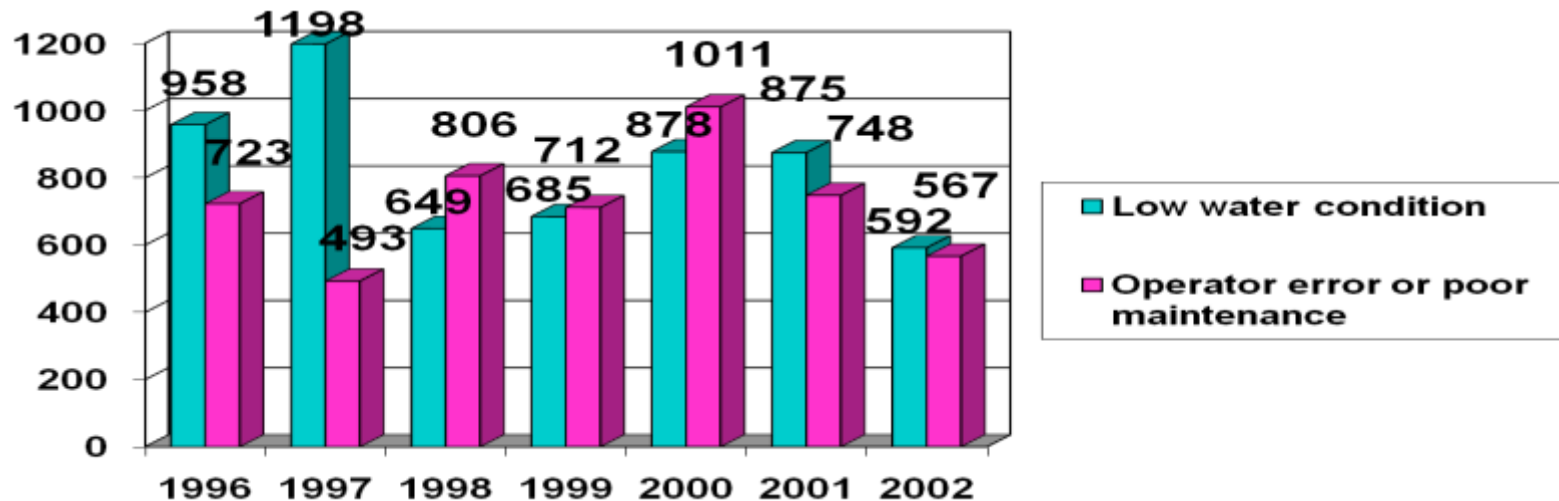
Probable Cause

- The sudden introduction of feed water in the boiler. At the time of the explosion, the boiler was operating in a dry-fire state. Before the explosion, inoperative controls and safety devices allowed the boiler to continue to fire even though water levels in the boiler were dangerously low.
- Boiler operator was in the front of the boiler and heard a hissing sound right before it blew.
- Operator walked out of hole in wall made by the explosion and passed out. He did survive.

What Went Wrong

- Installed wrong ALWCO relay same as installing a jumper.
- LWCO was stuck in the up position.
 - LWCO did not work.
 - Feed water valve did not open.
- Operator opened manual bypass halfway.
 - Ok if operator would have watched water level and operated bypass to maintain normal water level in the boiler.
- If they would have blown down and tested the LWCO and ALWCO they could have avoided this.

Top Two Causes Of Incidents 1996 - 2002



Low water condition includes:
High pressure and low pressure
steam & hot water boilers.

Operator error or poor maintenance includes:
High pressure and low pressure steam
& hot water boilers and unfired pressure vessels.

Boiler Maintenance & Boiler Inspection

General Maintenance

- Boiler room equipment biography
- Keep written operating procedures
- Good housekeeping a must
- Keep electrical equipment clean
- Keep fresh air supply adequate
- Keep accurate fuel records
- Establish a regular schedule
- Use a log sheet
- SAFETY - SAFETY - SAFETY

Annual Maintenance

- Coordinate with inspector
- What do inspectors care about



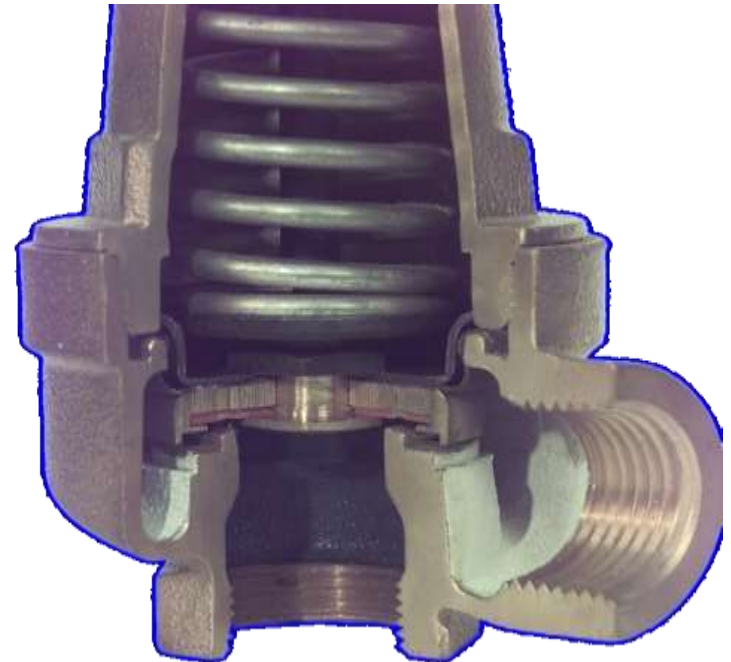
Safety Valves

- Test per your Inspector
- Make sure label is readable.
- Safety seal is in place.
- No plugs in tell tale drain.
- Capacity is sized correctly for boiler
 - Over or under sized.

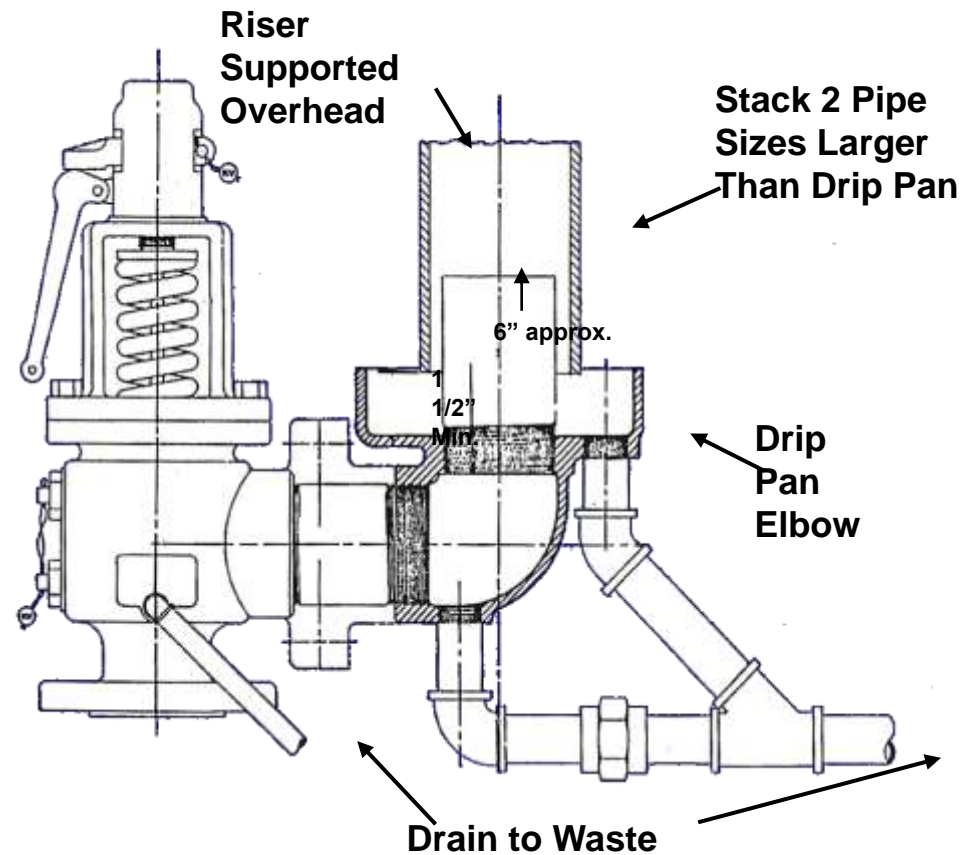


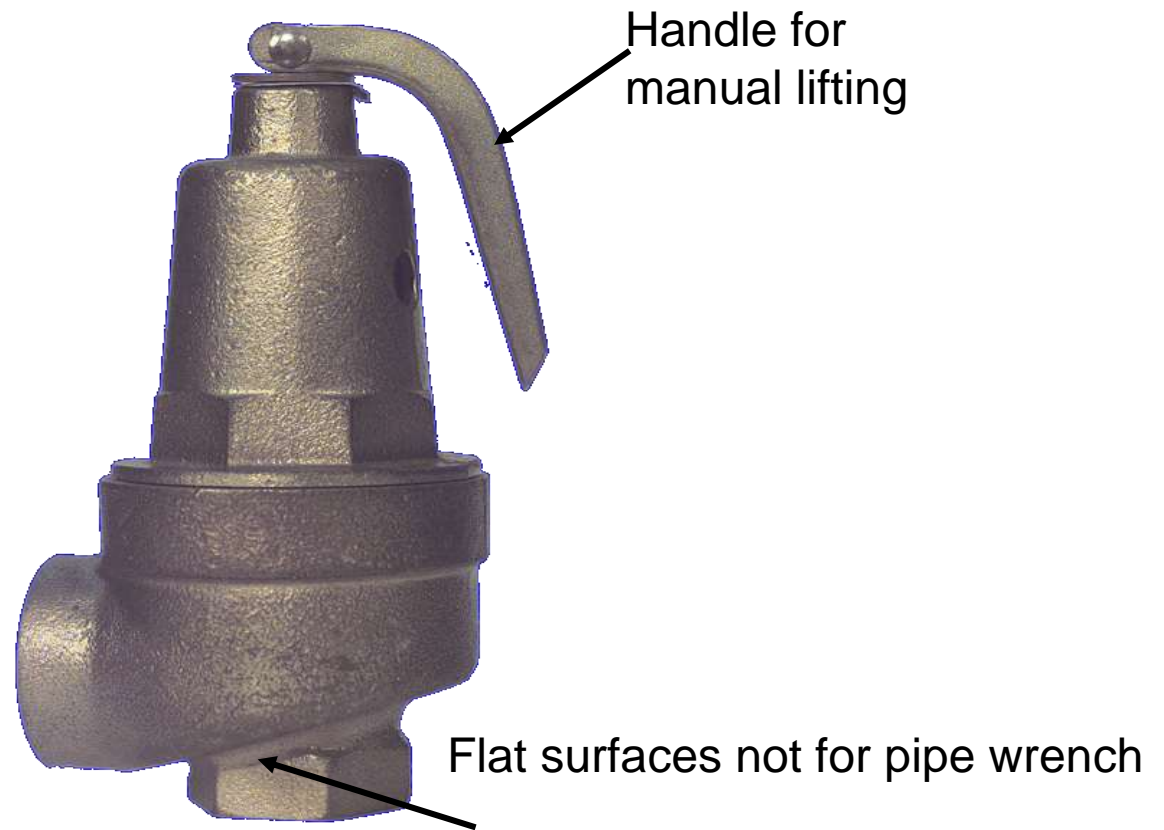
Safety Valves

- Remove and Recondition safety valves
 - Inspect piping for loose hangers putting weight on valves



Safety Valve Piping - 150 psi





Annual Maintenance

- Waterside and fireside surfaces
- The inspector will look for evidence of waterside deposits, plugging, pitting, corrosion, leaks, cracks, bulges, blisters, overheating, surging, carryover, staining, and any sign of damage



Stress cracking in the tube plate of a
firetube boiler.



Waterside

- Tube surfaces
- Water level and colorations
- Security of internals
- Continuous blowdown line
- Bottom blowdown line
- Evidence of corrosion
- Manhole and handhole seals
- Boiler shell and tubesheet



Field Repair

- Any welding on the pressure vessel
 - Bottom blow and steam piping up to first valve
 - Tube sheets
 - Company that has:
 - Repair forms
 - Repair procedures
 - R Stamp



ASME Code

- Section VIII
 - Unfired pressure vessels
 - Deaerators or pressurized tanks
 - Requires non destructive testing every 5 years



Annual Maintenance

- Control line and Controls
- LWCO
- ALWCO

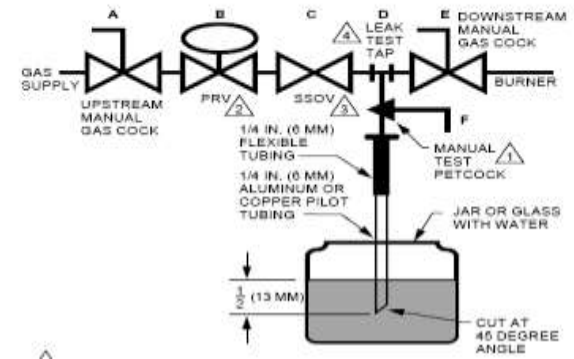


Annual Maintenance

- CSD-1 up to 300 HP
- Greater then 300 NFPA 85
- Check hydraulic valves
 - Bubble test for valve seat tightness check.
 - Follow valve manufacture procedure
 - Actuators open & close properly

Valve Leak Test (Fig. 7)

This is a test for checking the closure tightness of a gas safety shutoff valve. It should be performed by qualified personnel during the initial startup of a burner system, or whenever the valve or valve bonnet is replaced (see Service Information section). It is recommended that this test also be included in the scheduled inspection and maintenance procedures. For a periodic inspection test, follow steps 1, 3, 4, 5, 8, 9, 10, 12, 13, 16, and 17.



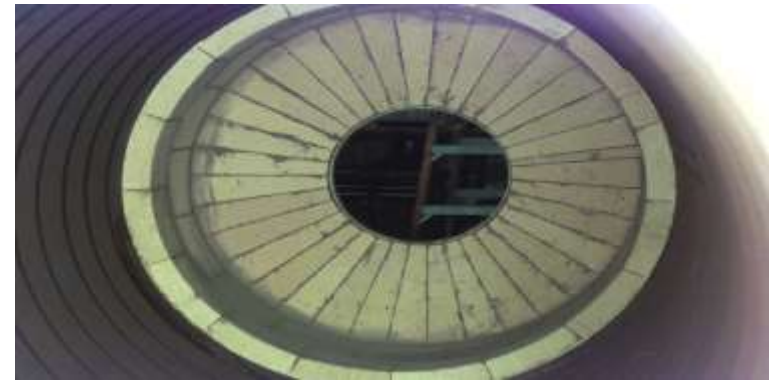
Annual Maintenance

- Clean fireside surfaces
 - Brush & vacuum tubes
 - Amount of soot indicates how well burner is performing
- Inspect Brickwork.



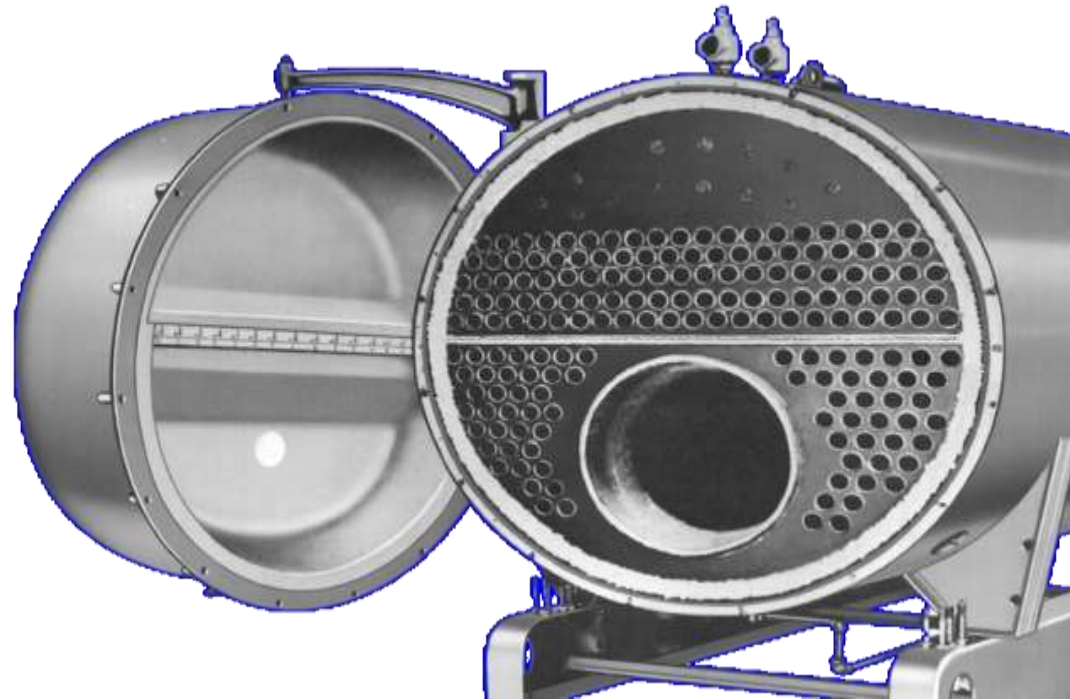
Annual Maintenance

- Repair refractory
 - Throat & Liner
 - No loose bricks
 - Seal between housing and throat
 - Rear door
 - No loose sections
 - Baffle to lower half joint
- Wash-coat lightly, if any



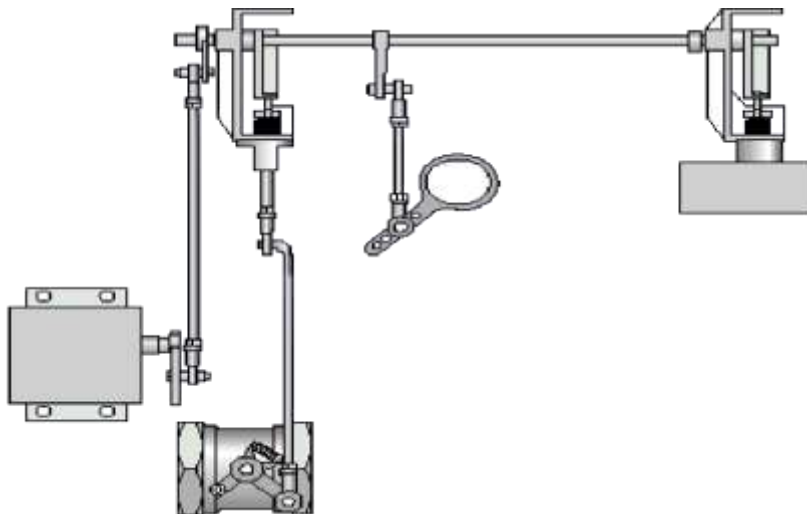
Annual Maintenance

- Repair refractory
 - Cracks 1/8" and under will close up when heated
 - Look for loose sections



Annual Maintenance

- Check linkages
 - Lubricate
 - Tighten
 - Replace worn parts




RECOMMENDED INSPECTION / MAINTENANCE BOILER ROOM LOG

ANNUAL INSPECTION

BOILER NUMBER:	DATE							
	TIME							
INSPECT FIRESIDE SURFACES								
INSPECT WATERSIDE SURFACES								
INSPECT BREECHING								
CLEAN FIRESIDE SURFACES								
CLEAN WATERSIDE SURFACES								
CLEAN BREECHING								
TEST SAFETY VALVES								
CHECK OPERATING PRESSURE CONTROLLER								
CHECK HIGH PRESSURE CONTROLLER								
CHECK OTHER BOILER SAFETY CONTROLS								
CHECK BOILER FEED PUMPS								
CHECK CONDENSATE RECEIVERS								
CHECK CHEMICAL FEED SYSTEMS								
CHECK DRIP LEG / STRAINER								
CHECK AUTOMATIC CHANGE OVER CONTROL								
CHECK FLUID LEVELS ON HYDRAULIC VALVES								
TIGHTEN ALL ELECTRICAL TERMINALS								
GAS PILOTS - CONDUCT PILOT TURNDOWN TEST								
REPLACE IGNITION AND FLAME RODS								
PERFORM GAS LEAKAGE TEST								
CHECK COMBUSTION AND ADJUST IF NECESSARY								

THIS LIST CONSISTS OF RECOMMENDED INSPECTION / MAINTENANCE - IT MAY NOT INCLUDE ALL POINTS OF INSPECTION / MAINTENANCE FOR THE SPECIFIC BOILER ROOM.
IT MAY BE BENEFICIAL TO EXPAND UPON THIS LIST FOR RECORD KEEPING AND MAINTENANCE PURPOSES. THIS LIST DOES NOT GUARANTEE UNFORESEEABLE BOILER FAILURES,
BUT WILL CONTRIBUTE TO IMPROVED BOILER MAINTENANCE.



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PBBS Information

Request for Literature

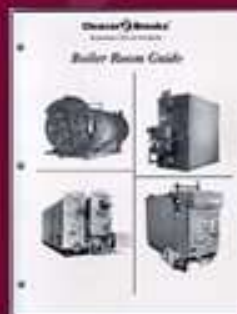
If you reside within our service area, we can offer two helpful guides FREE of charge. Complete the form below by selecting the Efficiency Facts Booklet and/or The Boiler Room Guide by Cleaver Brooks to receive your copy today.



The Efficiency Facts Booklet is designed to clearly define boiler efficiency. It will also give you the background in efficiency needed to ask the key questions when evaluating efficiency data, and provide you with the tools necessary to accurately compare fuel usage of boiler products, specifically firetube type boilers.

A typical boiler will consume many times the initial capital expense in fuel usage annually. Consequently, a difference of just a few percentage points in boiler efficiency between units can translate into substantial savings.

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This guide is provided to assist supervisory, operating, and maintenance personnel in understanding the operation of boiler room to achieve safe and efficient operation of the equipment.

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