



Energy Efficiency in Steam Systems

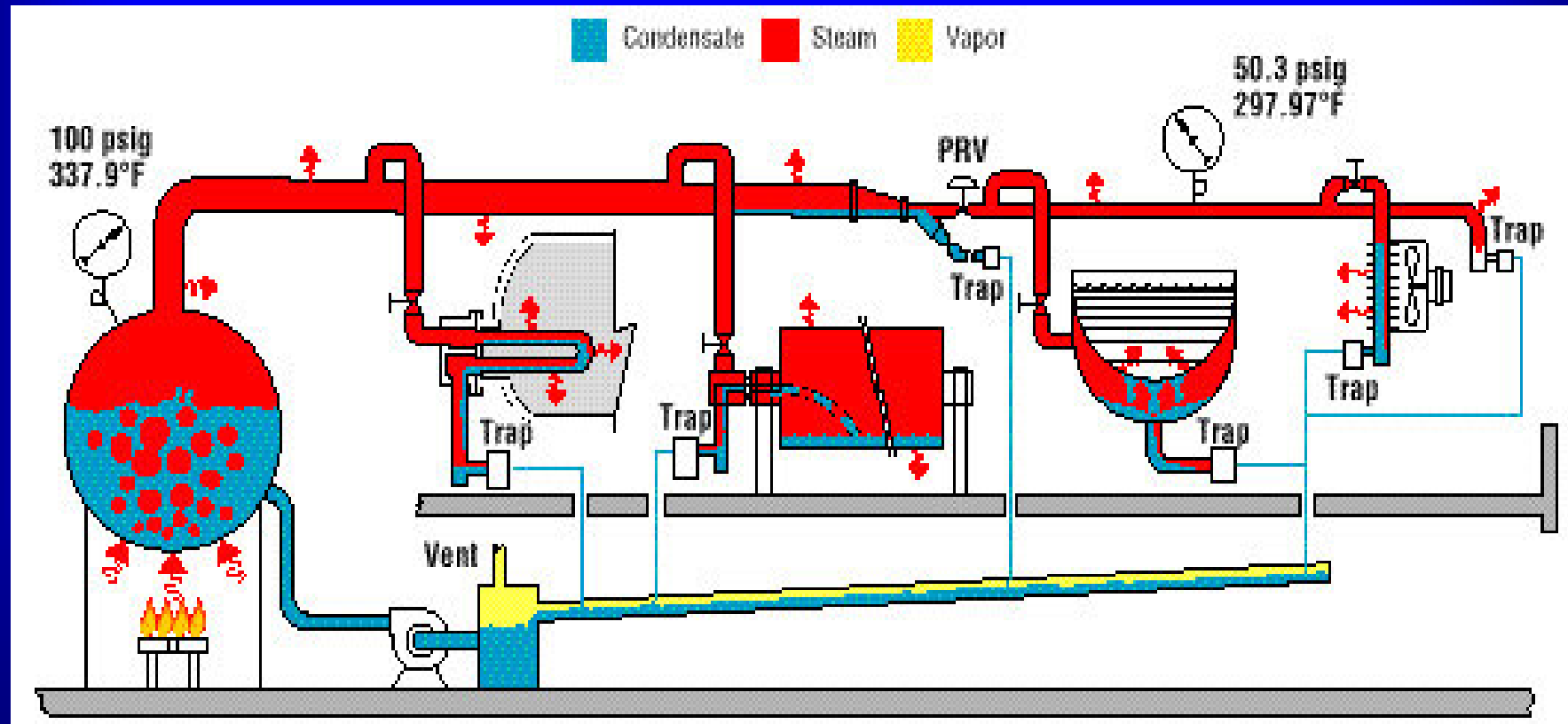
***Fundamentals of Energy Efficiency:
An Introductory Workshop
April 2008***

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Steam Systems have Four Basic Components

Generation, Distribution, End Use, Recovery



Source – DOE





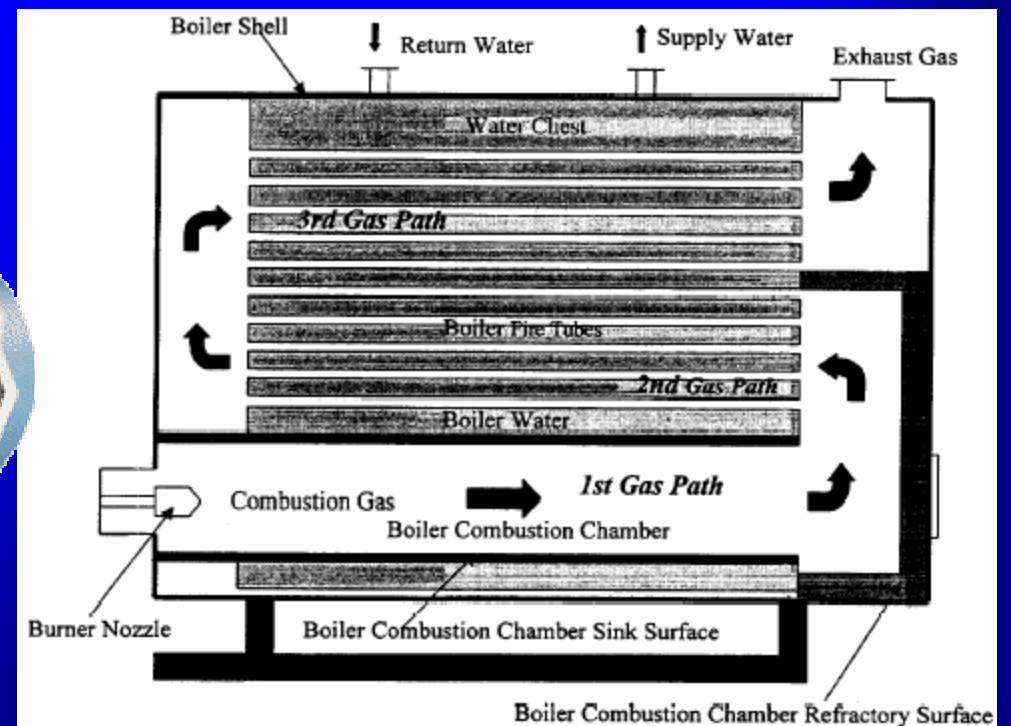
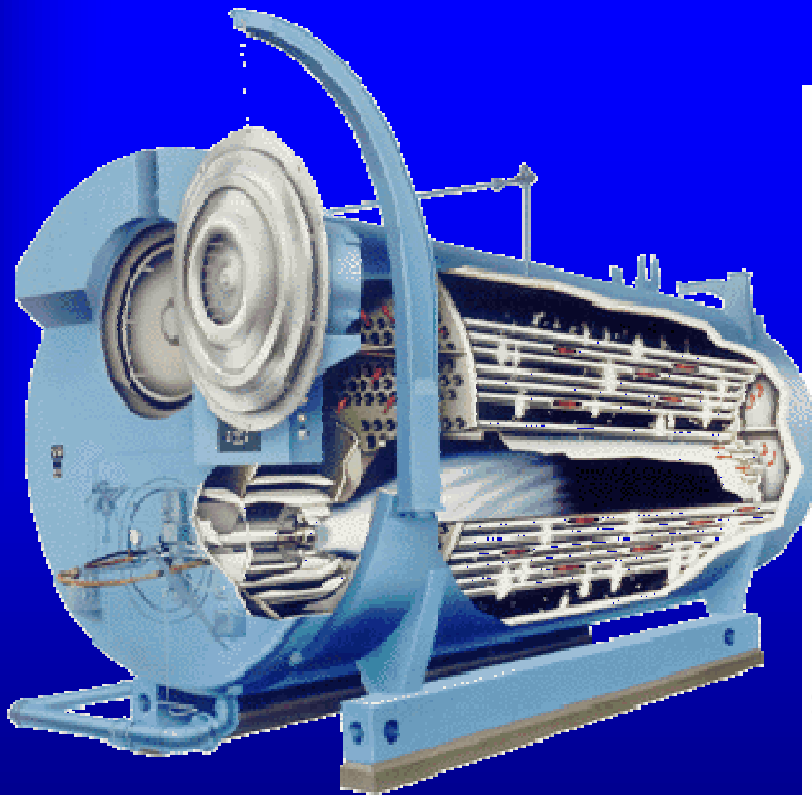
Steam System Components

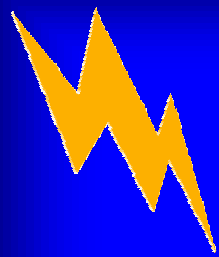
- Fuel Storage and handling equipment
- Boiler
- Boiler auxiliaries
- Steam piping
- Water treatment equipment
- Heat exchangers
- Pressure reducing stations
- Steam traps
- Condensate recovery
- Turbines



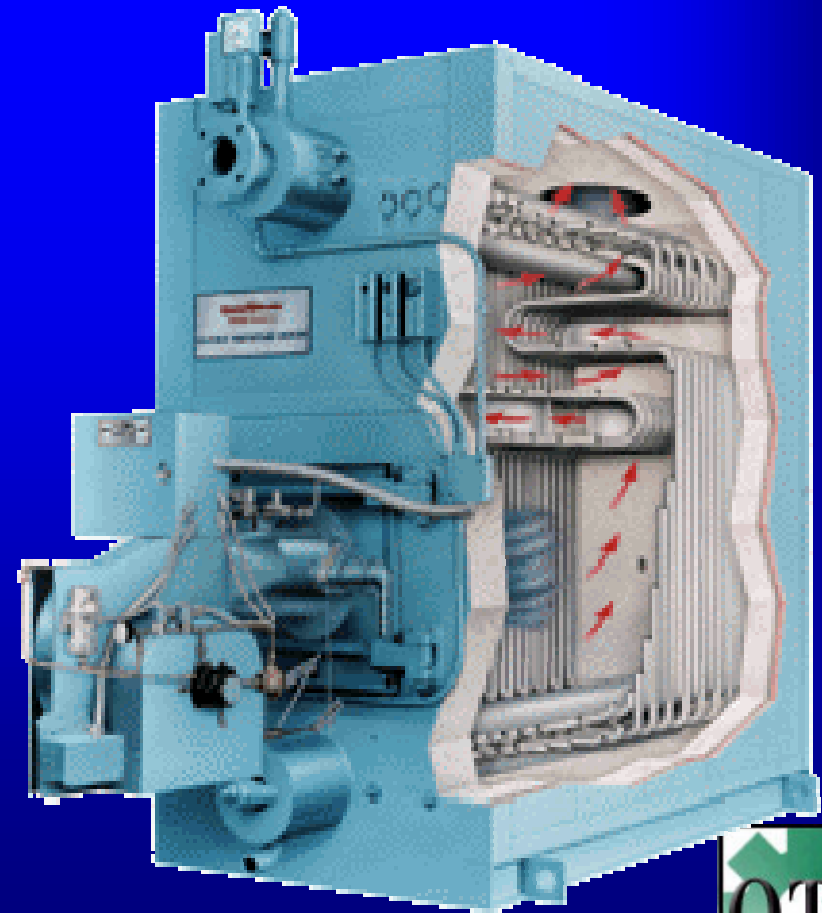
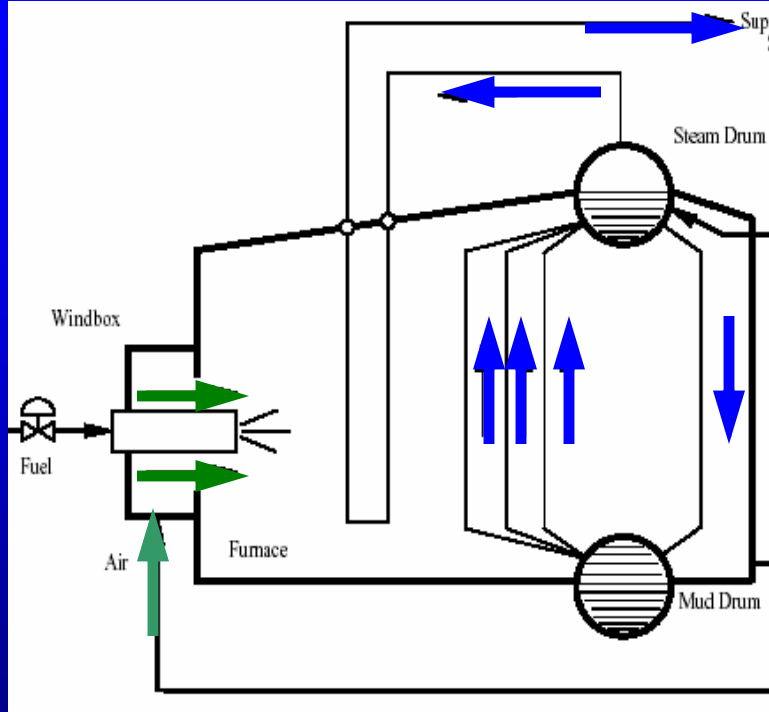


Boiler Configurations – Fire-tube Boiler





Boiler Configurations – Water-tube Boiler





Establishing Boiler Cost and Operations Data

- Determine the total cost of fuel supplied to the boilers (\$/year, \$/month, and \$/season).
- Calculate the unit cost of fuel based on energy (\$/MMBtu).
- Compare the unit cost of fuel to other available fuel supplies.
- Determine the unit cost of electricity supplied to the facility (\$/MMBtu).

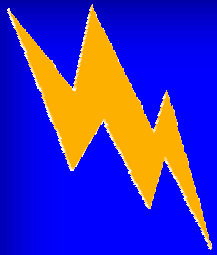




Establishing Boiler Cost and Operations Data

- Compare the unit cost of fuel to the cost of electricity supplied to the facility.
- Determine the typical steam production for the facility (lb/hr and lb/day).
- Determine the production cost of steam for the facility (\$/lb).
- Determine the amount of steam required to produce a product (lb steam/lb product).



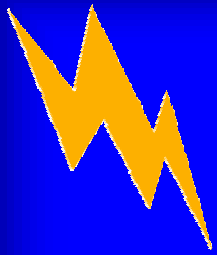


Boiler Performance

Objective → maximize efficiency

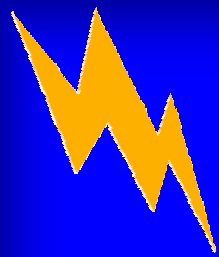
- Major sources of energy losses
 - Stack Gas Losses
 - Radiation and Convection Losses
 - Blow-down Losses
- Design Factors
 - Stack Gas Temperature
 - Boiler Excess Air
 - Radiation Losses
- Fuel Properties
- Operating Practices





Stack Losses

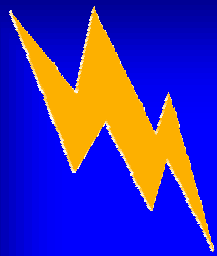
- Temperature and Combustion Losses
- ***Combustion Efficiency*** is the method used to determine stack losses
- ***Combustion Efficiency*** is determined by a chemical analysis of the flue gas and flue gas temperature measurement



Measuring Boiler Efficiency

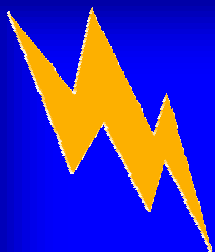


- The basic unit measures O_2 , CO_2 , and ambient and stack temperatures
- Optional sensors: NO , NO_2 , SO_2 and high CO concentrations

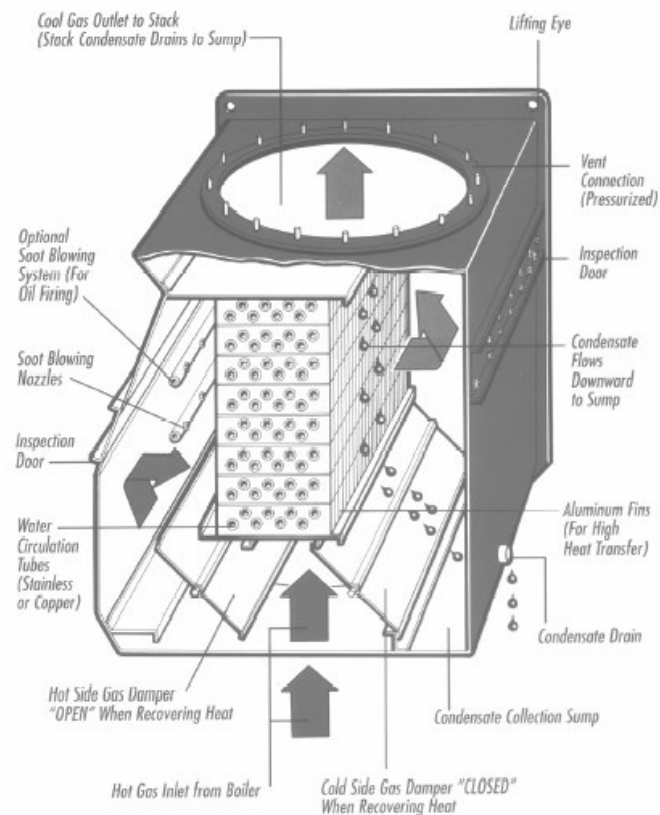
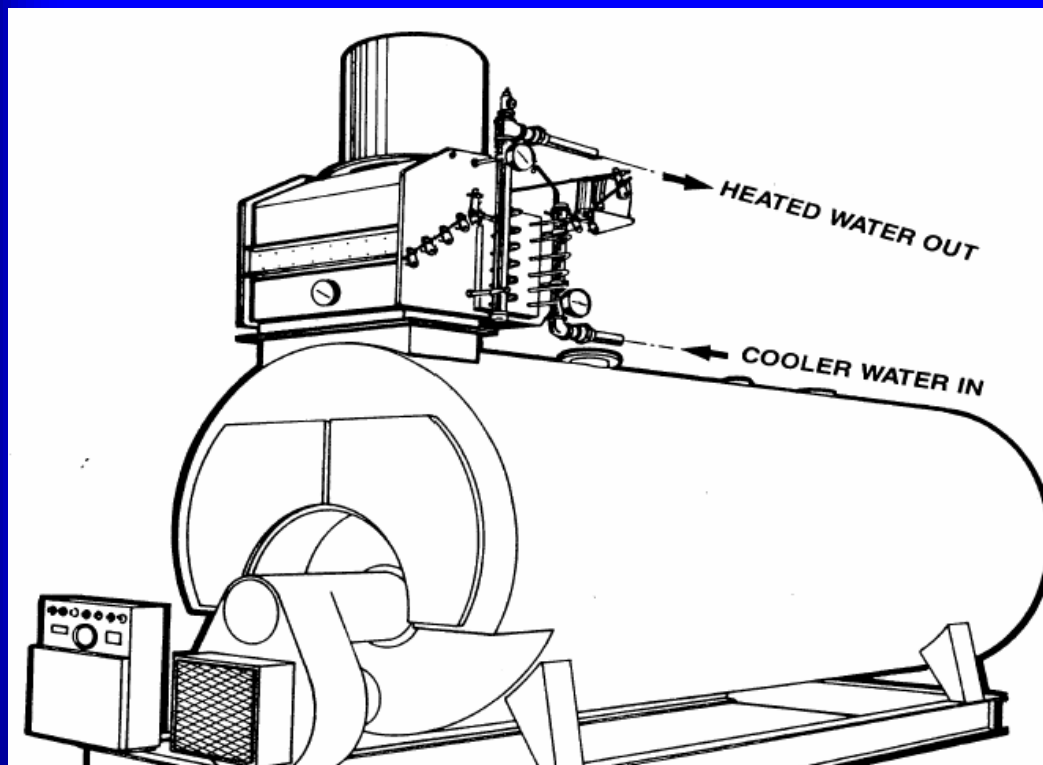


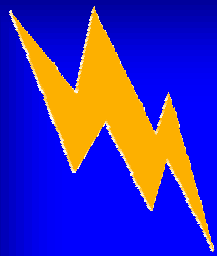
Methods to Improve Boiler Efficiency

- Some examples –
 - Install economizer
 - Reduce boiler pressure
 - Preheat combustion air
 - Automatic boiler combustion controls
 - Proper boiler water treatment



Install Economizer

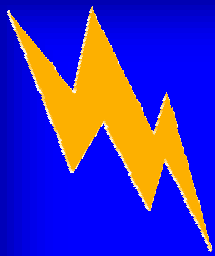




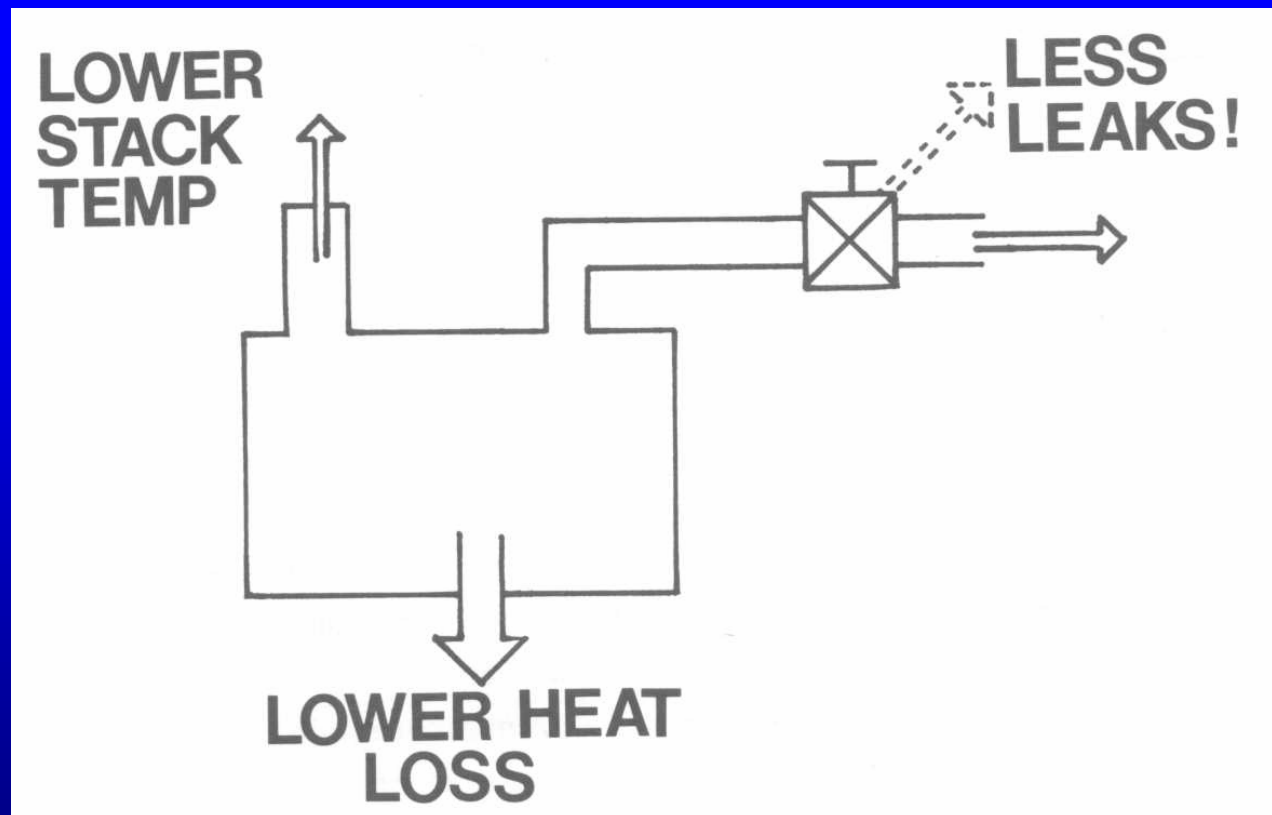
Install Economizer - Example

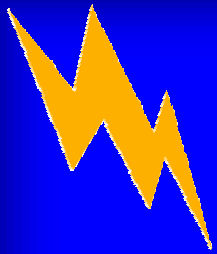
- 600 hp boiler (~ 26 MMBtu/hr)
- Fuel cost: \$4.50/MMBtu (#2 fuel oil)
- Annual fuel use: 126,000 MMBtu (900,000 gal)
- Efficiency increased from 78% to 82%
- Energy savings: 6,146 MMBtu/yr
- Cost savings: $\sim \$27,000$
- Implementation cost: $\sim \$47,000$
- Simple payback period: 1.8 years





Reduce Boiler Pressure





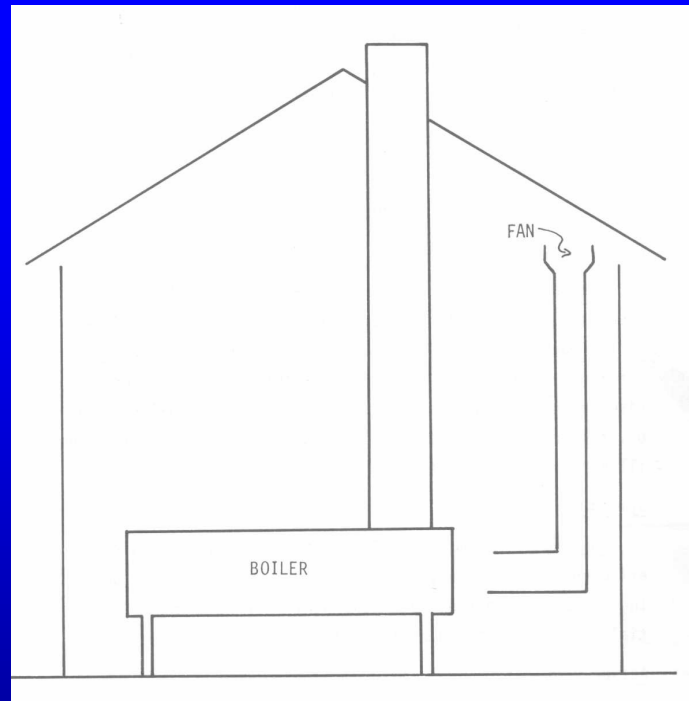
Reduce Boiler Pressure

- Saturated steam boiler pressure reduced from 54 psig (301 F) to 30 psig (274 F)
 - Flue gas temperature decreased by 38 F (which reduced the combustion loss approximately 1.5%)
 - Potential steam leak would be reduced by 30%
 - Heat transfer loss from properly insulated pipe should decrease by more than 10%



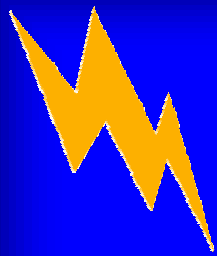


Preheat Combustion Air

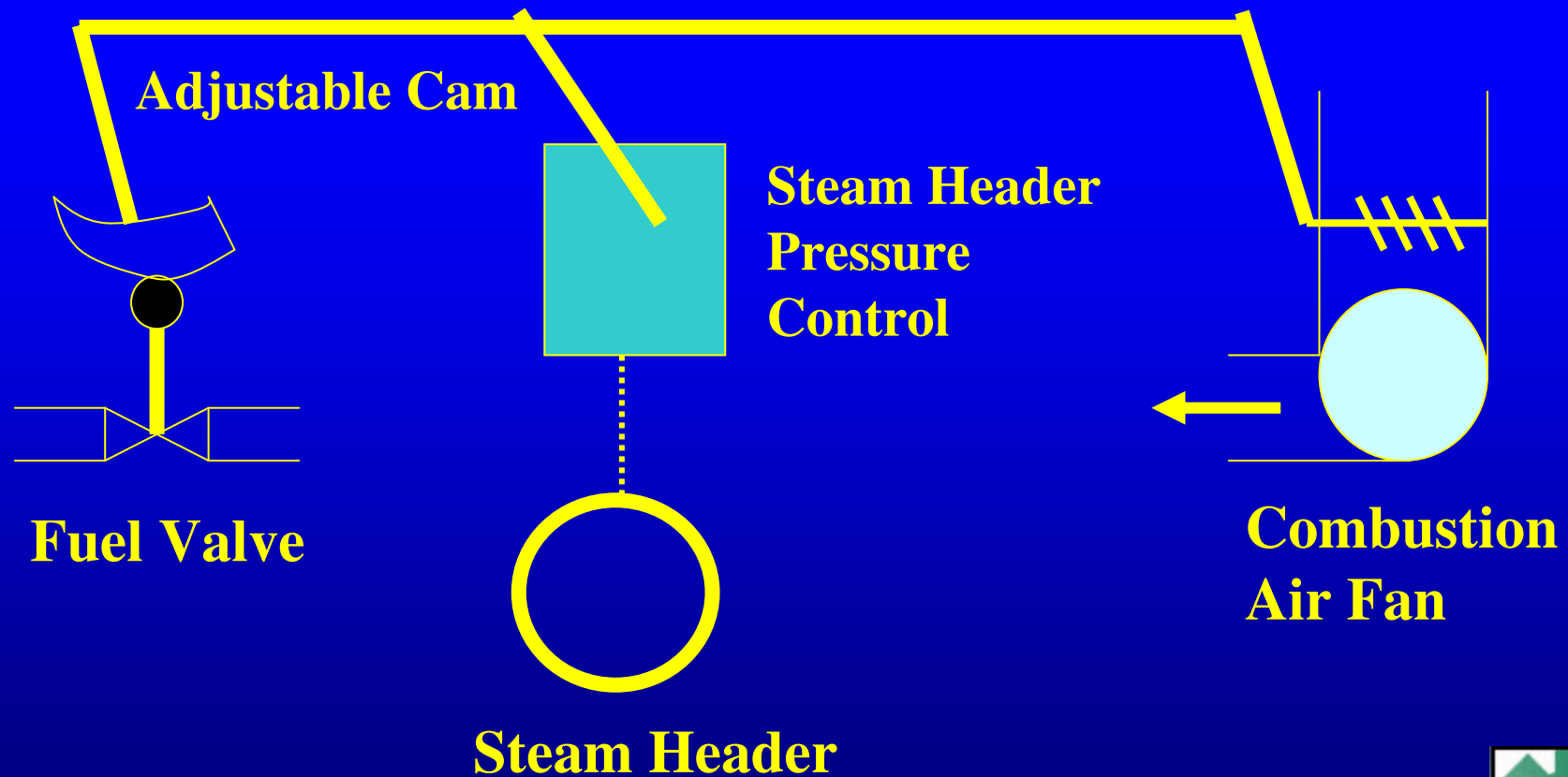



- A 40 F rise in combustion air temperature yields ~1% increase in boiler efficiency



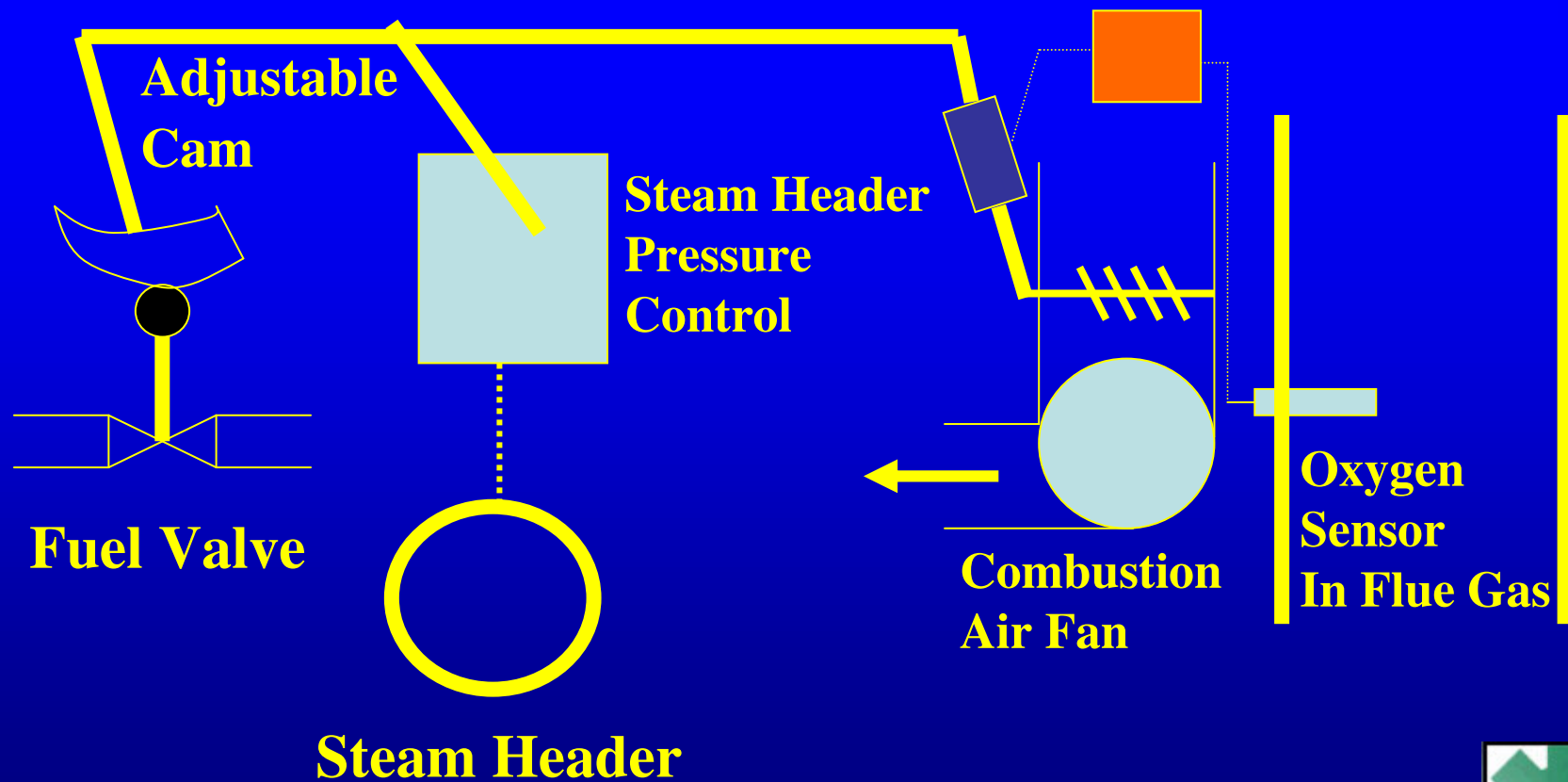


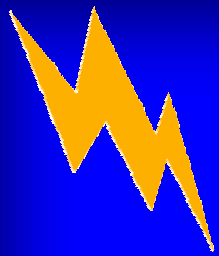
Boiler Combustion Control (Semi-automatic)





Boiler Combustion Control (Automatic)





Proper Boiler Water Treatment

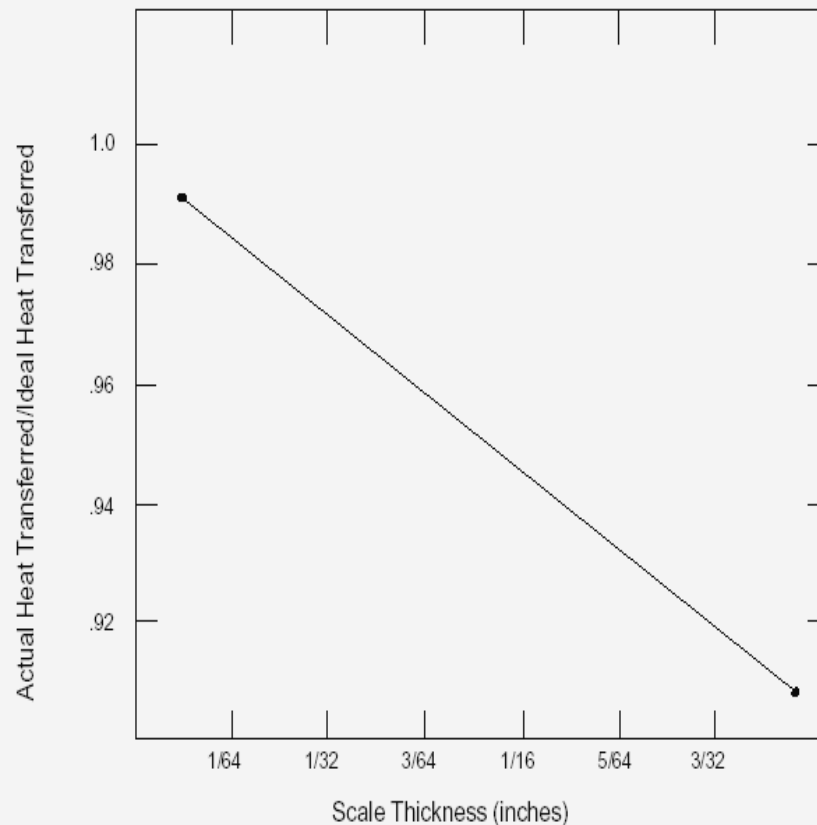
- Hardness precipitates as a solid **scale** or solid **sludge**.
- **Scale** - a continuous layer of material deposited on the water side of the boiler tubes that acts as an insulating material and a barrier to heat transfer.
 - Scale must be mechanically or chemically removed offline.
- **Sludge** - a general term applied to loose solid material found in boiler water.
 - Sludge contributes to tube plugging and is removed by blowdown.

Bottom line – scale and sludge reduce heat transfer (and \therefore efficiency)





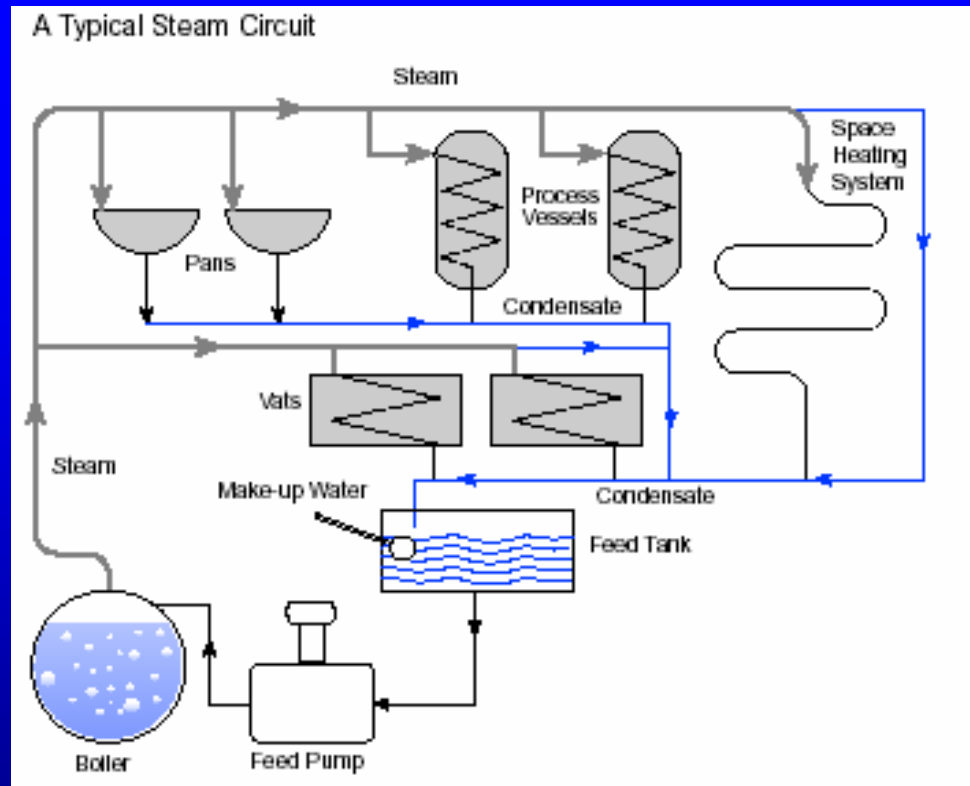
Scale Effect



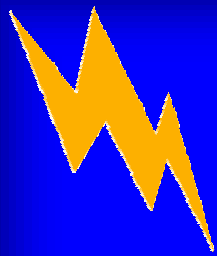
- 1/16" thick scale deposit reduces heat transfer coefficient by 6%
- As a result flue gas temperature will increase



Steam Distribution System

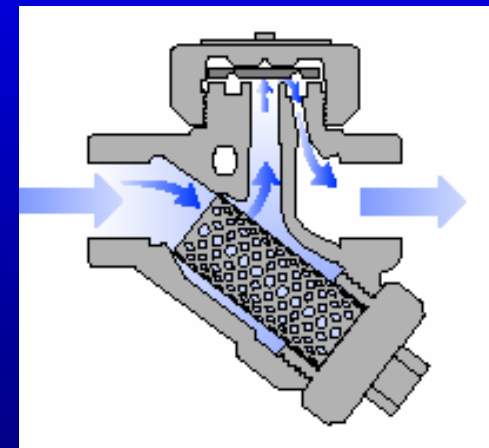
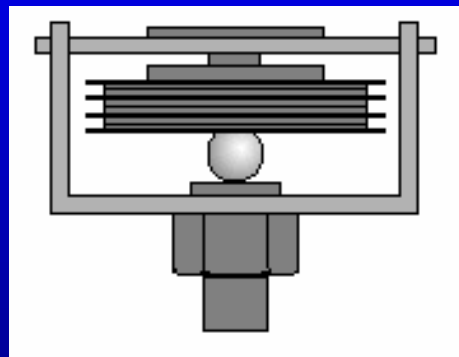
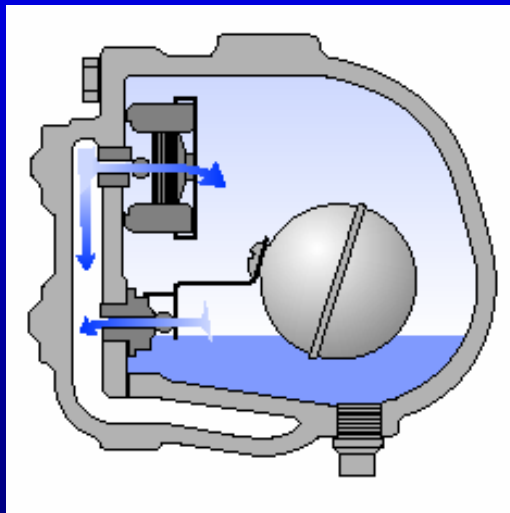


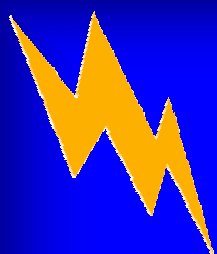
- Steam leaks
- Heat transfer loss through insulation
- Condensate loss



Steam Trap Operation

- Three types of steam traps
 - Mechanical or Density
 - Thermostatic or Temperature Controlled
 - Thermodynamic or Velocity Controlled





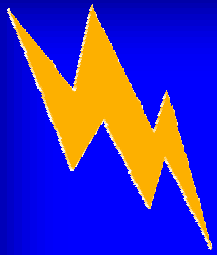
Steam Loss Can Be Expensive

Leaking Steam Trap Discharge Rate*

Trap Orifice Diameter, inches	Steam Loss, lb/hr			
	Steam Pressure, psig			
	15	100	150	300
1/32	0.85	3.3	4.8	—
1/16	3.4	13.2	18.9	36.2
1/8	13.7	52.8	75.8	145
3/16	30.7	119	170	326
1/4	54.7	211	303	579
3/8	123	475	682	1,303

* From the Boiler Efficiency Institute. Steam is discharging to atmospheric pressure through a re-entrant orifice with a coefficient of discharge equal to 0.72.





Testing Steam Traps

- Visual testing
- Ultrasonic trap testing
- Temperature testing
- Conductivity testing

Recommended Testing Intervals

- High-Pressure (150 psig and above): *Weekly to Monthly*
- Medium-Pressure (30 to 150 psig): *Monthly to Quarterly*
- Low-Pressure (below 30 psig): *Annually*



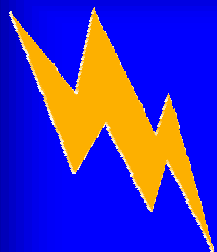


Condensate Recovery

Why it Matters -

- The energy contained in the condensate
- Water commodity cost
- Water treatment cost
- Wastewater charges





Condensate Recovery – Flash Steam

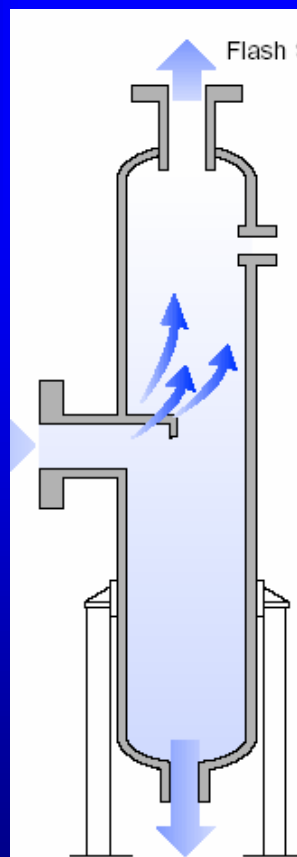
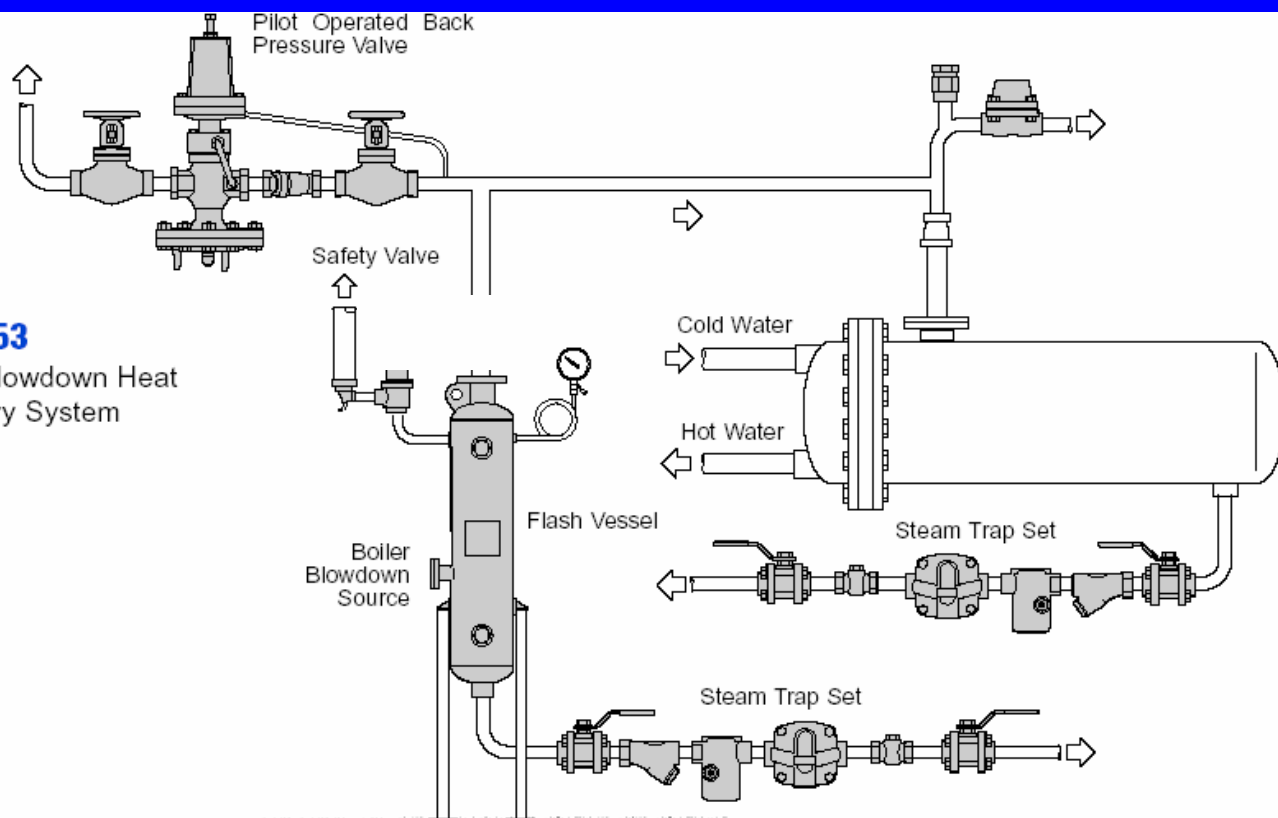


Figure 53
Boiler Blowdown Heat
Recovery System

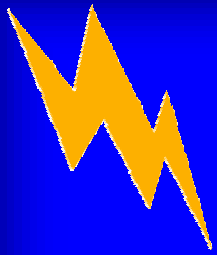




Additional Steam System Energy Efficiency Measures

- Consider steam turbine drives for rotating equipment
- Replace pressure-reducing valves with backpressure turbogenerators (i.e., install Combined Heat and Power [CHP])
- Upgrade Boilers with Energy-Efficient Burners
- Cover Heated, Open Vessels
- Install an Automatic Blowdown Control System
- Use Low Grade Waste Steam to Power Absorption Chillers





DOE Steam Tools

LOT of resources available -

- Software – Steam System Scoping Tool, Steam System Assessment Tool (SSAT), 3E Plus (insulation)
- Publications – guides, Tip Sheets, case studies
- <http://www1.eere.energy.gov/industry/bestpractices/steam.html>





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