



CERTIFIED INDUSTRIAL ENERGY PROFESSIONAL
CIEP TRAINING PROGRAM
FOR INDUSTRIAL ENERGY SPECIALISTS
KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
ENERGY SPECIALIST CURRICULUM





BOILER AND STEAM SYSTEMS - 1
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WHAT SHOULD YOU LEARN



Water Tube, Fire Tube, and Condensing Boilers

Saturated & Superheated Steam

Estimate Combustion Efficiency

Calculate Heat Flows & Enthalpy Values using Steam Tables

Energy Savings: Blowdown Heat Recovery, Flash Steam Utilization, Economizers, & Air Preheating



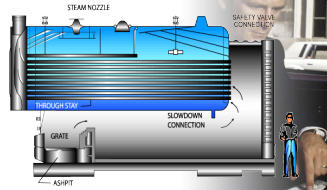
BOILERS AND THERMAL SYSTEMS; BOILER EFFICIENCY IMPROVEMENT



Boiler Types

☒ FIRE TUBE

As the name implies, the fire is in the tubes and the water outside. Most of the small “packaged” boilers in buildings and industry today are fire tube boilers and thus are likely the ones we will encounter.

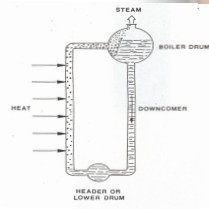


Source: Illustration recreated for web by Technologists Inc. using graphic supplied by The Boiler Efficiency Institute, Auburn, Alabama to PNL for use with EEP DMM B as a model.

WATER TUBE



Again, as the name implies, now the water is in the tube and the fire outside. Most of the larger boiler systems today are constructed water tube boilers. There are smaller packaged water tube boilers also. We will see water tube boilers but most of the larger ones are well designed and controlled. Thus, we will not spend much time on water tube boilers.



P: Boilers and Steam Systems & Boiler Efficiency Improvement - 4

PROPERTIES AND USE OF STEAM



- ☒ Steam is water in a vapor state
- ☒ Steam temperature is in °C or K
 $K = C + 273$
- ☒ Steam pressure is in kPa, MPa or bar
 $1 \text{ bar} = 100 \text{ KPa} = 0.1 \text{ Mpa}$
- ☒ Steam conditions are either:
 - ⇒ saturated - temperature or pressure specifies its properties
 - ⇒ superheated - must know temperature and pressure to find its properties

HEAT CONTENT OF STEAM



- ✓ The heat content of steam is called its enthalpy (h or H) measured in kJ/Kg
- ✓ By definition $h = H = 0$ at 0°C
- ✓ Enthalpy is the sum of the sensible plus latent heat.
 - ⇒ Sensible heat - heat absorbed or removed during a change in temperature without a change in state of phase
 - ⇒ Latent heat - heat absorbed or removed during a change of state or phase at constant temperature

STEAM DISTRIBUTION SYSTEM



- ✓ The steam distribution system on the next page shows a "typical" distribution system.
- ✓ The major components include
 - ⇒ The steam manifold and piping,
 - ⇒ heat exchangers,
 - ⇒ steam traps at each use point and at various locations throughout the system,
 - ⇒ pressure reducing valves,
 - ⇒ condensate return piping, condensate return tank(s), and
 - ⇒ various pumps.

STEAM TRAPS

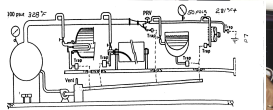


- ✓ Purposes
 - ⇒ Reject (Return) Condensate
 - ⇒ Reject Air
 - ⇒ Hold Back Steam 165 C and 7 bar (700 kPa) 140 C and 360 kPa

Not shown in the previous diagram are:

- ✓ make up water,
- ✓ water treatment for the make up water, and
- ✓ a feedwater tank which is typically between the condensate return tank and the boiler.

The feedwater tank will also normally have feedwater preheating and removal of oxygen (deaeration).



Typical steam system component

MONITORING

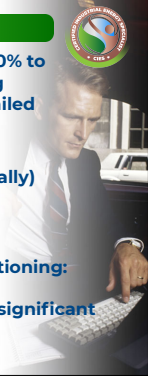
In a poorly maintained or non-maintained system, 20% to 30% of the steam traps are likely stuck open wasting significant amounts of expensive steam. To locate failed steam traps, use:

- 1.Sight (Watch the Discharge)
- 2.Sound (Listen to the Operation Possibly Ultrasonically)
- 3.Temperature (Watch the Delta T)

Note: Real Time MMS Available

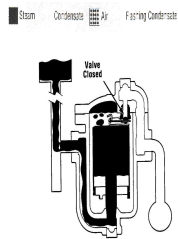
Other indications that a steam trap may be malfunctioning:

- ☑ the system has trouble holding pressure,
- ☑ the condensate return tank is unpressurized and significant flash steam is formed



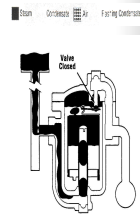
TYPES OF STEAM TRAPS- INVERTED BUCKET STEAM TRAP

1.Steam enters trap under bottom of bucket, where it rises and collects at top, imparting buoyancy. Bucket then rises and lifts valve towards its seat until valve is snapped tightly shut. Air and carbon dioxide continually pass through bucket vent and collect at top of trap. Any steam passing through vent is condensed by radiation from trap.



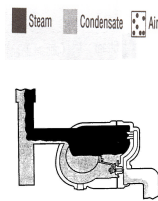
INVERTED BUCKET STEAM TRAP

2.As the entering condensate starts to fill the bucket, the bucket begins to exert a pull on the lever. As the condensate continues to rise, more force is exerted until there is enough to open the valve against the differential pressure.



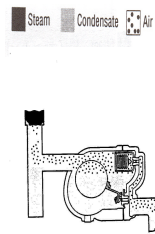
F&T STEAM TRAP

1. When steam reaches the trap, the thermostatic air vent closes in response to higher temperature. Condensate continues to flow through the main valve which is positioned by the float to discharge condensate at the same rate that it flows to the trap.



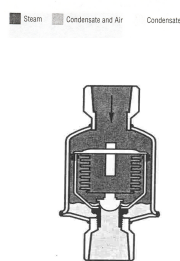
F&T STEAM TRAP

2. As air accumulates in the trap, the temperature drops below that of saturated steam. The balanced pressure thermostatic air vent opens and discharges air.



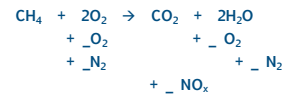
THERMOSTATIC STEAM TRAP

As the temperature inside the trap increases, it quickly heats the charged bellows element, increasing the vapor pressure inside. When pressure inside the element becomes balanced with system pressure in the trap body, the spring effect of the bellows causes the element to expand, closing the valve. When temperature in the trap drops a few degrees below saturated steam temperature, imbalanced pressure contracts the bellows, opening the valve.



COMBUSTION EFFICIENCY

- ✓ Combustion is an exothermic (heat producing) chemical reaction.
- ✓ The chemistry for the combustion of methane (natural gas is about 96% methane) is shown below.

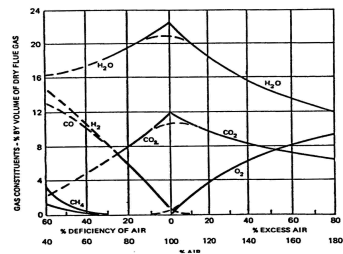


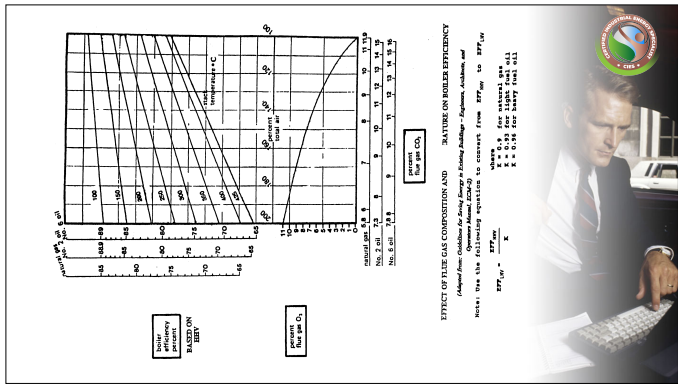
CONTROLLING COMBUSTION

- ✓ In any closed combustion system such as a boiler or a furnace without secondary air, we can measure precisely what occurred at the burner by carefully measuring the exhaust.
- ✓ The goal is to be able to carefully control the fuel and airflow to ensure complete and efficient combustion.
- ✓ We will see why excess air is important and why too much excess air is expensive.



NATURAL GAS FLUE GAS ANALYSIS VS. % COMBUSTION AIR





**ALL TEMPERATURES ARE STR IN °C
(STACK TEMPERATURE RISE)**

Percent savings = $\frac{\text{New efficiency} - \text{Old efficiency}}{\text{New efficiency}}$

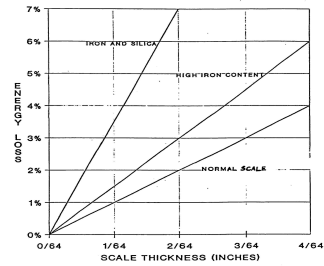
Savings = Percent savings × Fuel consumption

SCALE AND SOOT

Whether fire tube or water tube, it is important that the tubes remain clean. On the waterside, scaling can lead to a dramatic loss in efficiency. Scale is a good insulator, thus as scale forms the temperature of the fireside must increase to do the work on the waterside. Water treatment is essential to maintain this condensate return never have a scaling problem. Most of us will find it necessary to periodically shut the boiler down and remove scale. The Figure on the next page demonstrates the expected amount of loss due to scaling. Reverse osmosis water treatment will almost eliminate scaling problems.

Soot on the fireside has a similar effect. Running good combustion systems slightly on the excess airside ensures complete combustion and minimizes soot. However, soot blowers may be required, especially for certain fuels, and periodic brushing gas fired system, this brushing is likely required about once a year.

ENERGY LOSS FROM SCALE DEPOSITS



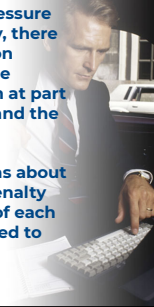
SOURCE: "How to Control Boiler Iron Deposits," Chemical Engineering, p. 174-175.



LOAD BALANCING

The boiler room is an interesting place. If the boiler room operator keeps the boiler working with adequate pressure everywhere in the plant, no one complains. Normally, there is an extra boiler or two for back up and load variation reasons. Therefore, there is a natural tendency for the operator to fire all the available boilers and run them at part load. If one goes down, the others quickly move up and the pressure is maintained.

Boilers don't run well at low loads and each boiler has about 3-5% "skin losses", so there is a significant energy penalty for this philosophy. Instead, profiling the efficiency of each boiler for varying loads will yield data that can be used to determine the optimum firing profile for any load.



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