

Types of Boilers

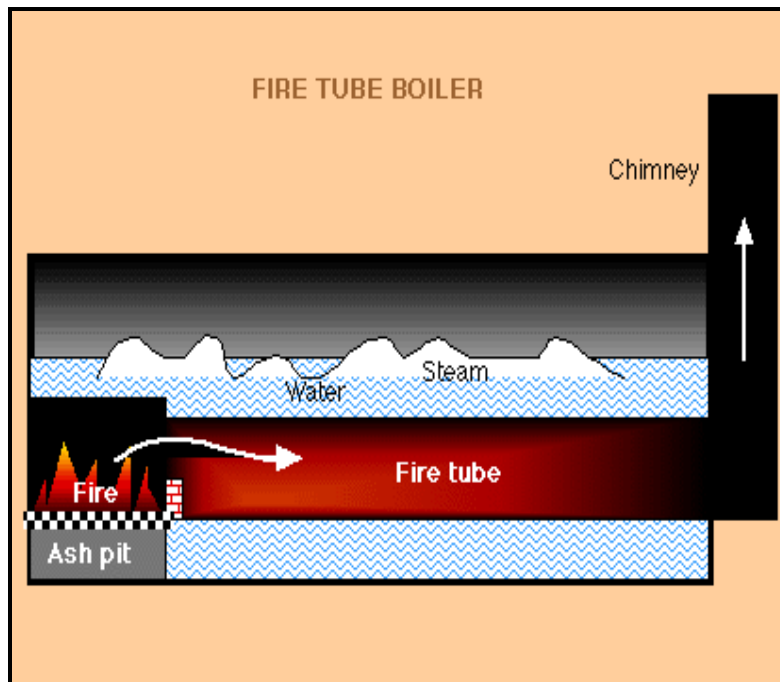
Boilers are divided in Two main Types

1. Fire Tube Boilers

2. Water Tube Boilers

Type of Boilers (Based on Tubes)

1. Fire Tube Boiler



A steam boiler in which the products of combustion pass through the tubes, which are surrounded by water.

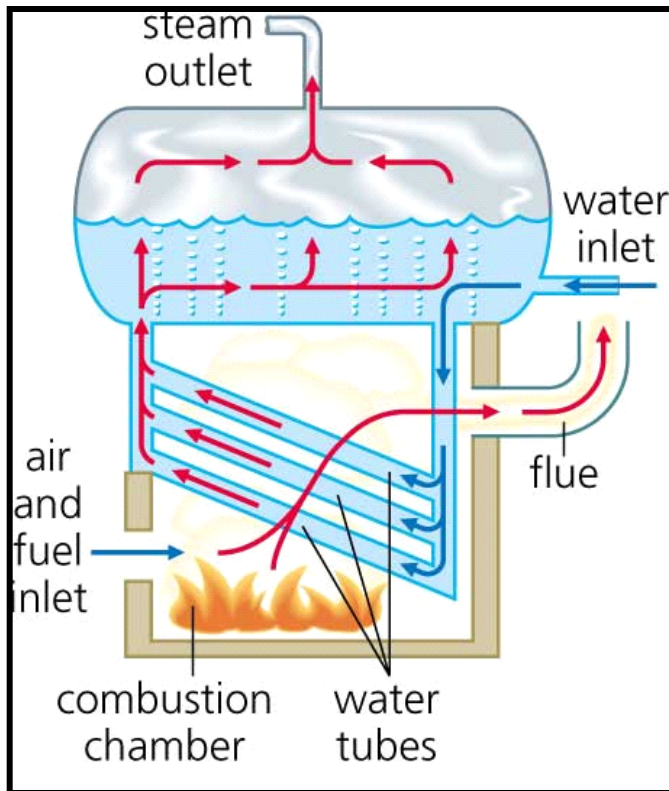
Type of Boilers (Based on Tubes)

1. Fire Tube Boiler

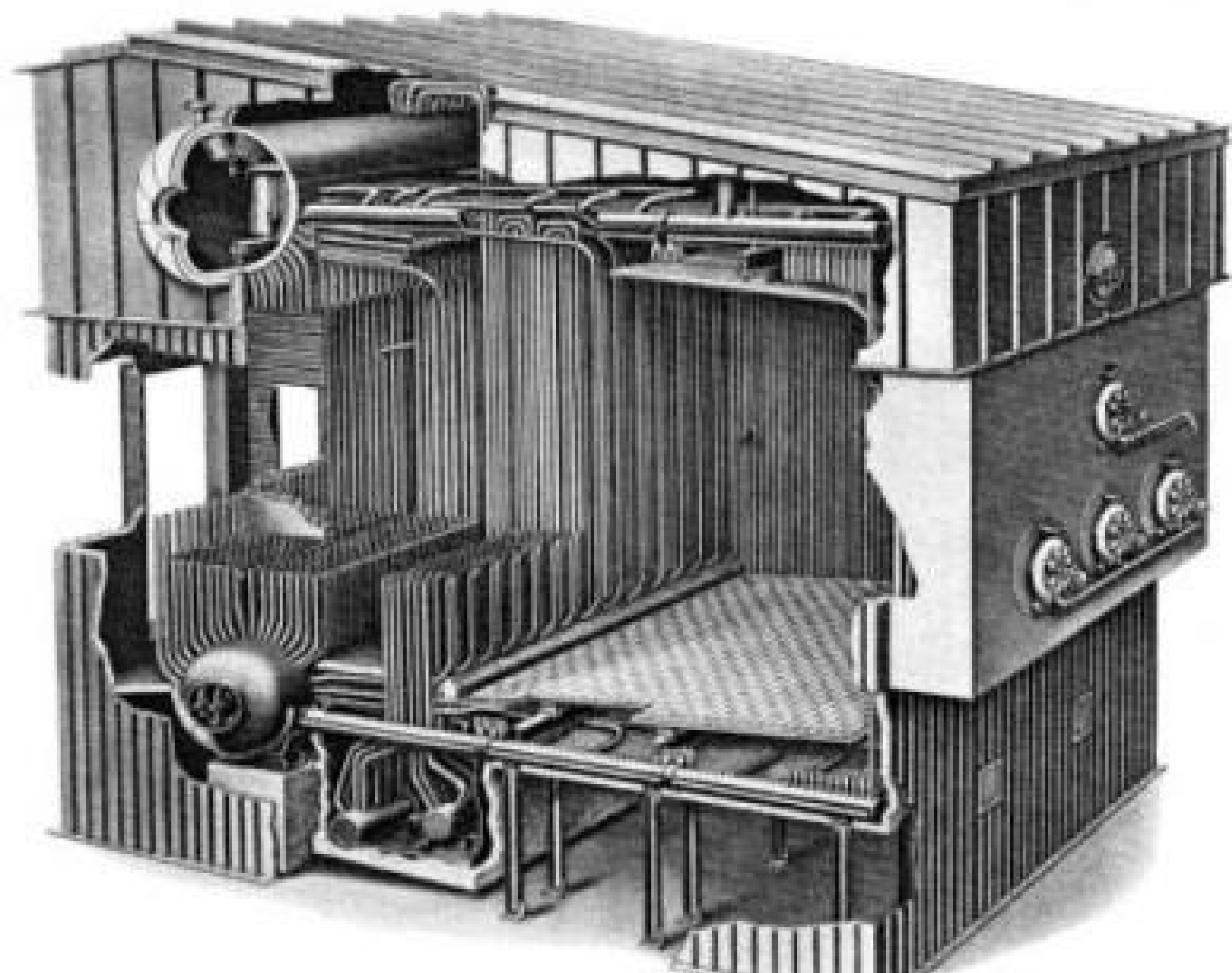
Advantages	Disadvantages
Easy to Clean	Not suitable for pressure higher than 30 bar
Relatively inexpensive	Limitation for high-capacity steam generation (upto 12,000 kg/hour)
Compact in size	
Well suited for industrial applications	
Operates with oil, gas or solid fuels	

Type of Boilers (Based on Tubes)

2. Water Tube Boiler



A steam boiler in which the water passes through the tubes and products of combustion surround the tubes.



Type of Boilers (Based on Tubes)

2. Water Tube Boiler

Advantages	Disadvantages
Available in larger capacities (4,500 – 120,000 kg/hour)	High initial capital cost
Able to handle higher pressures	Cleaning is difficult due to design structure
Faster response to changing loads	No commonality between tubes
Able to reach very high temperatures	Bigger in physical size
Provide an adequate furnace to ensure complete combustion	Lower tolerance for water quality and needs water treatment plant

Classification of Boilers

(Based on Fuels)

1. Gaseous Fuel

A steam boiler is fired by gas. The gas used for the boiler may be natural gas, propane gas, or any other liquid petroleum gas.

Advantages:

Good efficiency of combustion

Low cost fuel

Disadvantages:

High cost for the construction of pipelines

Classification of Boilers

(Based on Fuels)

2. Liquid Fuel

A steam boiler is fired by liquid fuel. The liquid used for the boiler may be heavy liquid oil, HSD or Light Diesel oil.

Advantages:

Residue of combustions are not numerous and easily cleaned

Disadvantages:

High cost fuel

High cost for the construction/ storage

Classification of Boilers

(Based on Fuels)

3. Solid Fuel

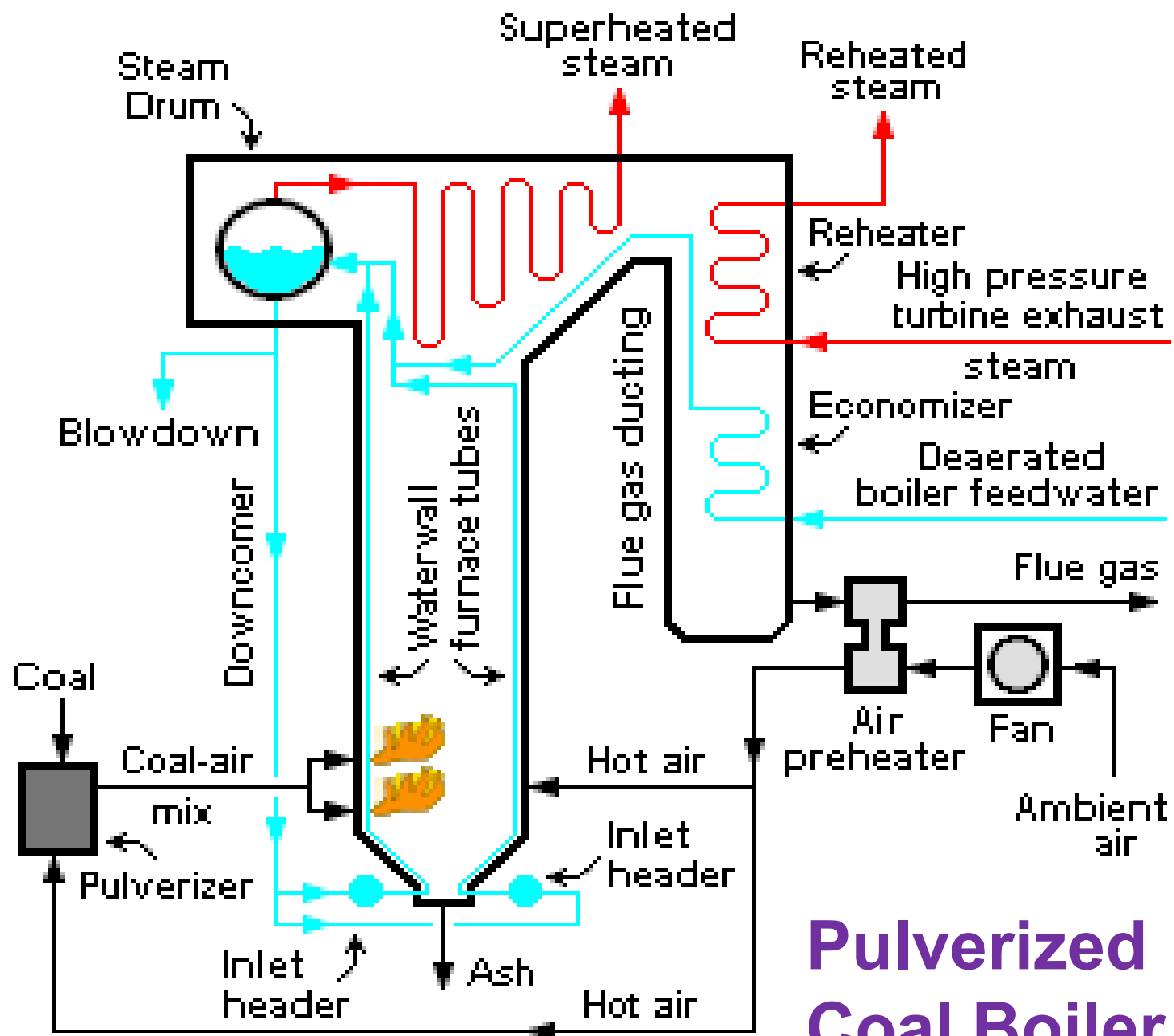
A steam boiler is fired by solid fuel. The solid used for the boiler may be coal, coke, peat, wood, baggase.

Advantages:

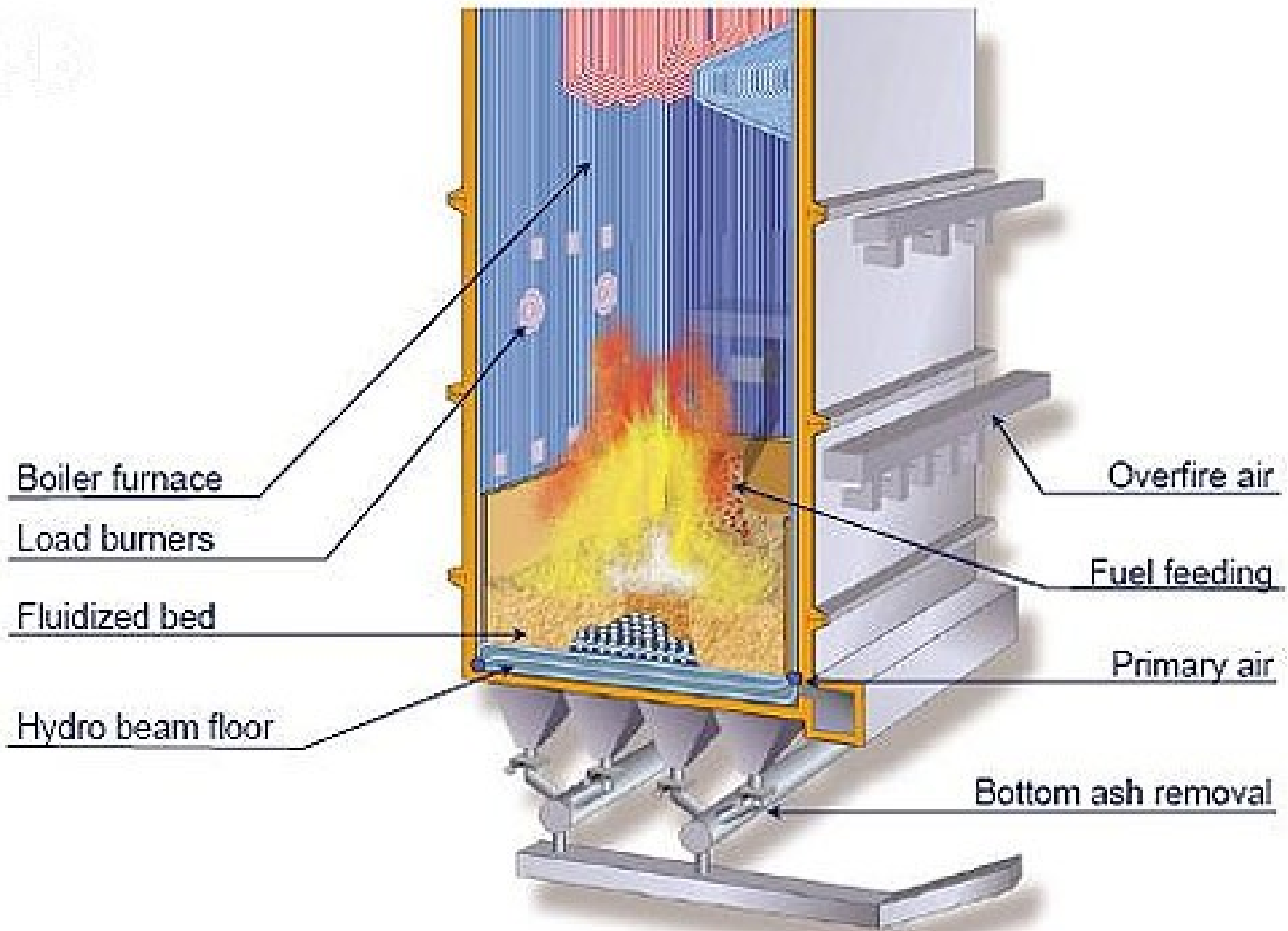
Low cost of fuel

Disadvantages:

Residue of combustions are hardly cleaned
Difficult to find good material



Pulverized Coal Boiler



Fluidized Bed Combustion Boiler

Classification of Boilers

(Based on Furnace Draft)

Draft

Draft is defined as difference between atmospheric pressure and static pressure of combustion gases in a furnace, gas passage, flue or stack.

Draft is classified into

Natural Draft

and

Mechanical Draft

Classification of Boilers

(Based on Furnace Draft)

Natural Draft:

A stack of sufficient height to cause the necessary pressure differential creates natural draft with the resulting air and flue gas flow.

Combustion gases are created when a fuel is burned in a boiler or a furnace. These combustion gases are often called “flue gases” as they are dispelled via the flues, which are the passes or ducts that connect the boiler with the stack.

Classification of Boilers

(Based on Furnace Draft)

Mechanical Draft:

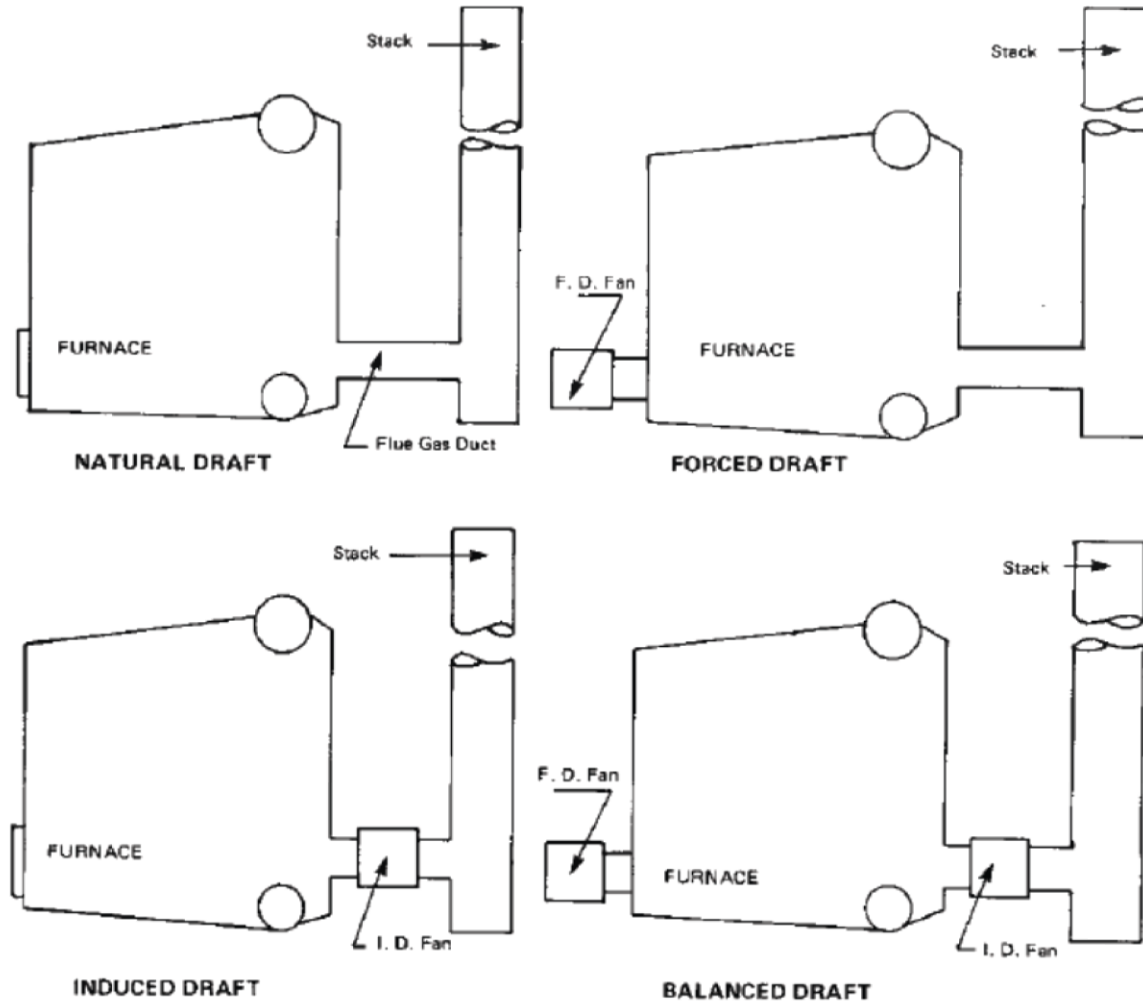
Draft is created by the mechanical fans.

- They may push the air and combustion gases through the boiler, in which case they are called forced draft fans (F.D. fans).
- They may also pull the air and gases through the boiler, in which case they are called induced draft fans (I.D. fans).
- When furnace draft is maintained at atmospheric pressure (or just below), by use of a combination of forced and induced draft fans, the draft is referred to as a balance draft system.

Classification of Boilers

(Based on Furnace Draft)

Types of Boilers



Classification of Boilers

(Based on Water Circulation)

Boilers must be designed in such a way that avoided the formation of steam out of the water wall tubes.

The circulation of water and steam in the boiler occurs because:

1. Difference of density between water and steam.
2. The existence of mixture of water and steam.

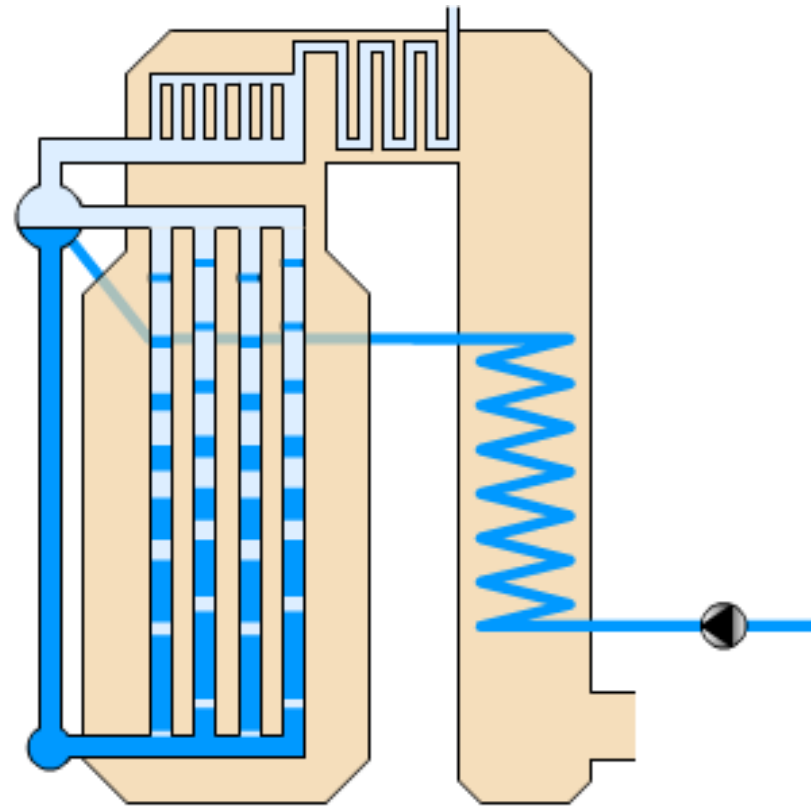
Classification of Boilers

(Based on Water Circulation)

The water circulation in the steam boiler can be classified into two types, namely:

1. Natural Circulation

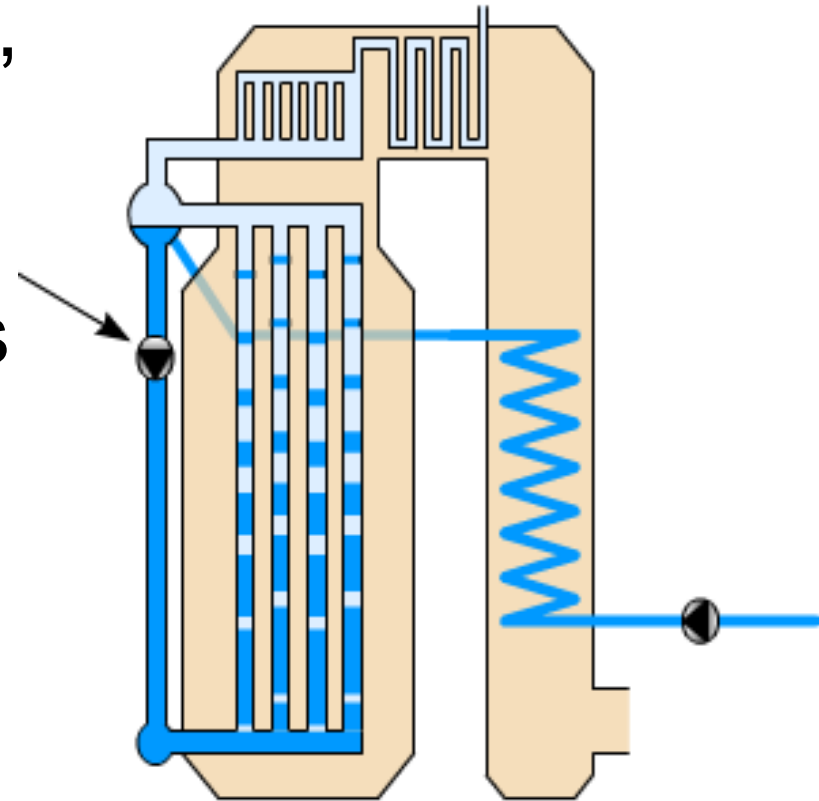
The water flowing from upper drum through downcomers to mud drum. From mud drum, water flow back into the steam drum after passing through the evaporator tubes.



Classification of Boilers (Based on Water Circulation)

2. Forced Circulation

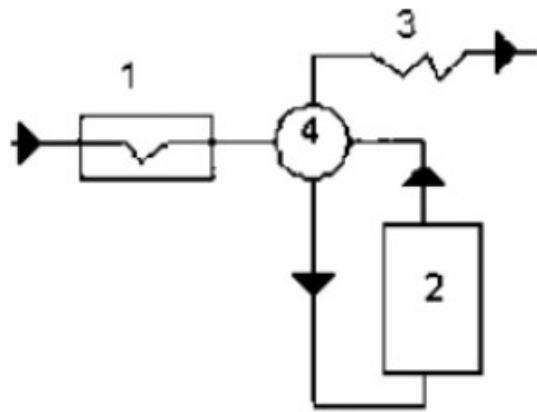
In forced circulation, water is pumped from drum, through the water wall tubes. This causes the boiler water/steam to circulate.



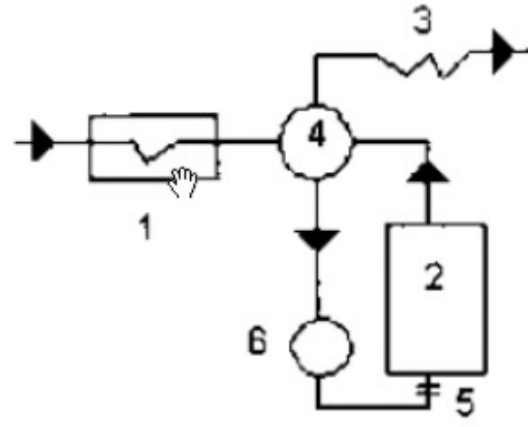
Classification of Boilers

(Based on Water Circulation)

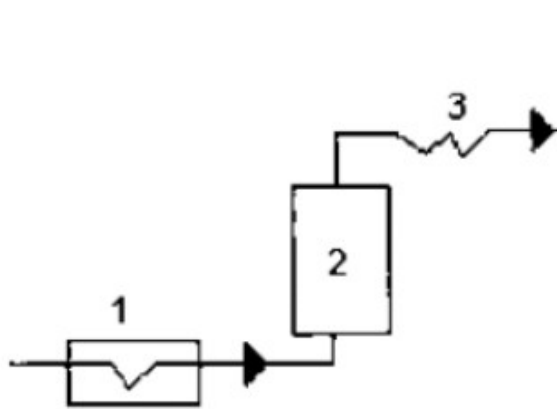
Types of Boilers



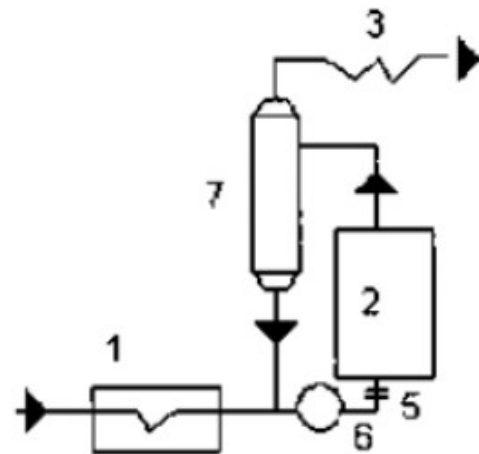
(a) Natural



(b) Forced Circulation



(c) Once Through



(d) Once Through with superimposed

Parts List

1. Economizer
2. Furnace
3. Super Heater
4. Drum
5. Orifice
6. Circulating Pump
7. Separator

Classification of Boilers

(Based on Burner Arrangement)

The burners in furnace may be arranged in different ways that gives different characteristic. There are three distinct methods:

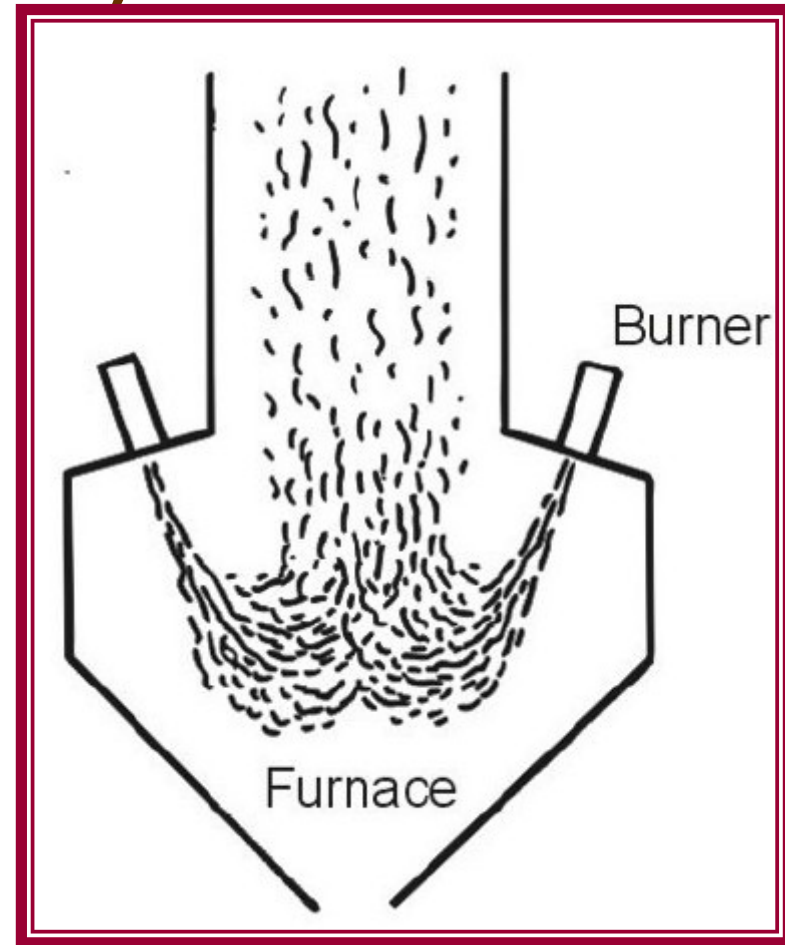
- | | |
|-----------------|------------|
| 1. Roof-fired | Down shot |
| 2. Wall-fired | Horizontal |
| 3. Corner-fired | Tangential |

Classification of Boilers

(Based on Burner Arrangement)

1. Roof-fired (Down shot)

The fuel is injected downstream. This arrangement provides a long flame path for fuels that do not ignite easily are burnt rapidly.

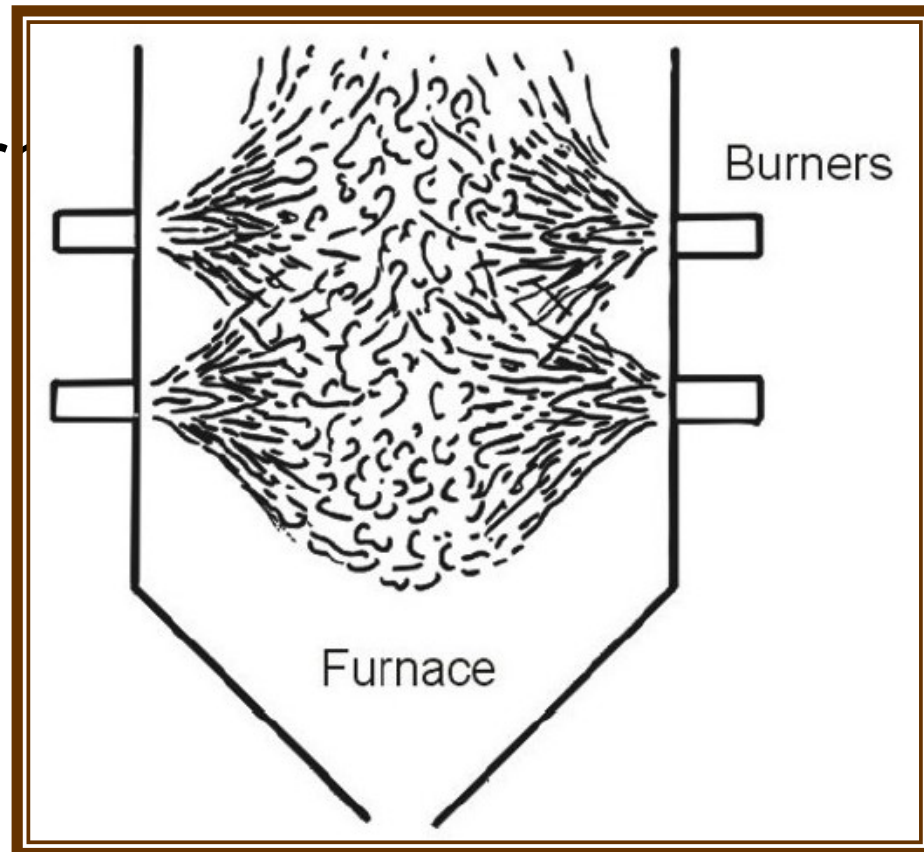


Classification of Boilers

(Based on Burner Arrangement)

1. Wall-fired (Horizontal)

Burners are arranged in a pattern on front or back or both front and back wall of the furnace. The fuel is injected horizontally with turbulent swirl to produce combustion.





Classification of Boilers

(Based on Burner Arrangement)

Advantages of wall fired furnaces

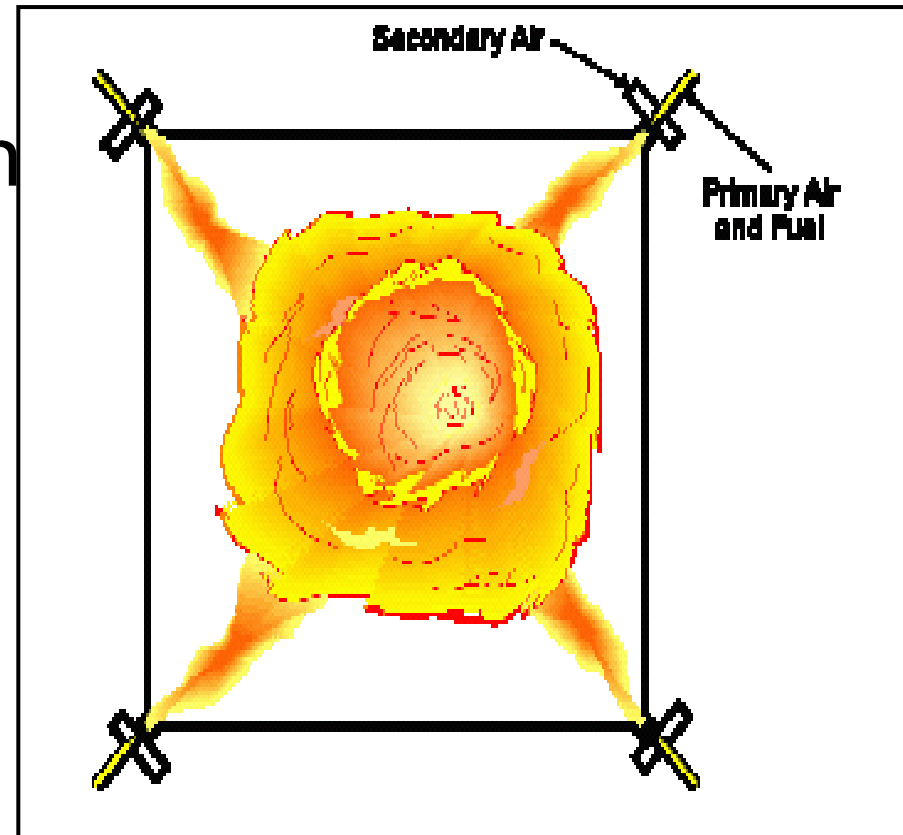
- ✓ stable flame in a single swirl burner,
- ✓ easy ignition of fuel/air mixture,
- ✓ fast mixing of fuel/primary air mixture and secondary air,
- ✓ considerable burn-out of fuel near the burner
- ✓ possibility of boiler operation with low load.

Classification of Boilers

(Based on Burner Arrangement)

1. Corner-fired (Tangential)

Burners are arranged vertically in four corners. Fuel from each burner is injected horizontally and at a tangent to the imaginary horizontal circle in the centre of furnace.





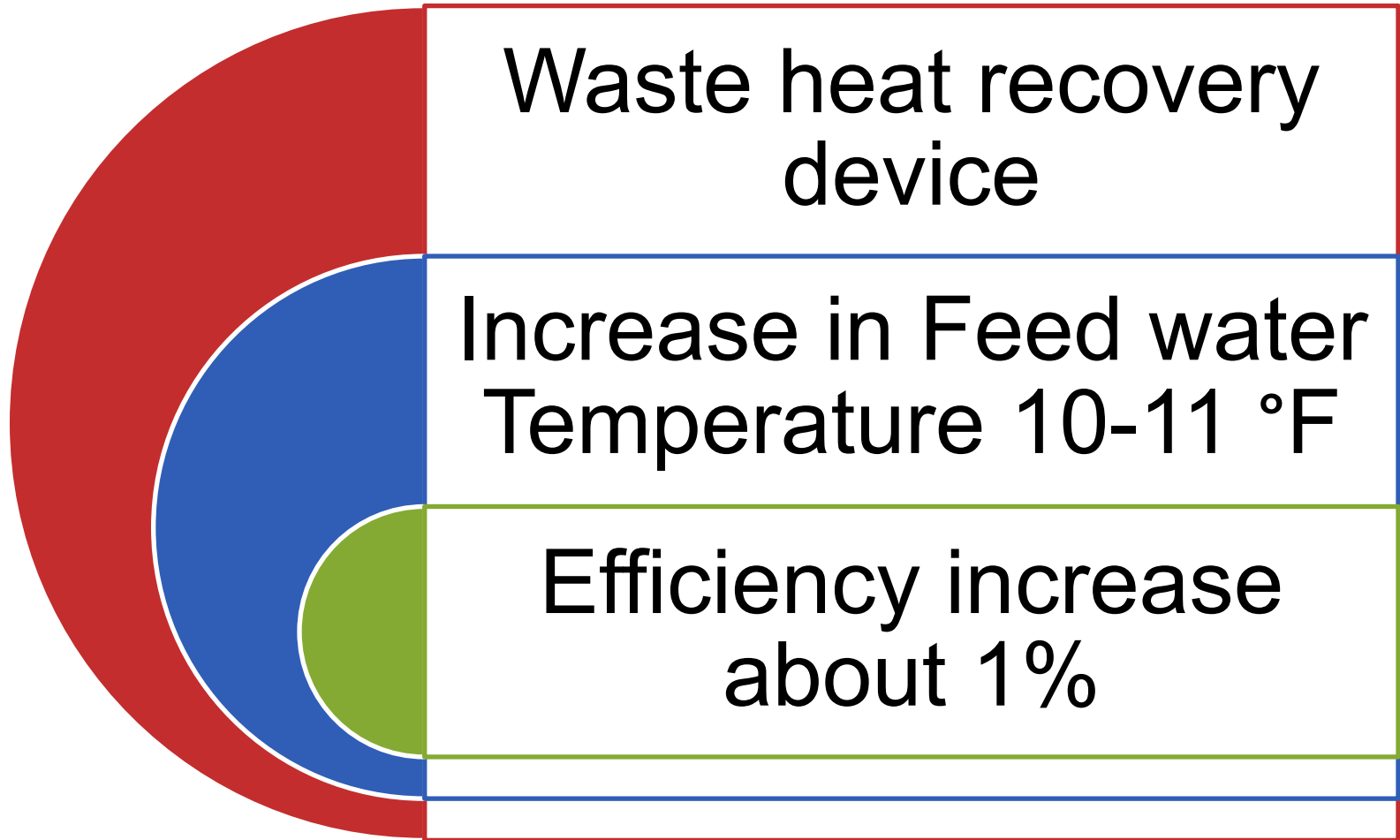
Classification of Boilers

(Based on Burner Arrangement)

Advantages of corner fired furnaces

- ✓ self-stabilization of fuel flames,
- ✓ delayed ignition of fuel/air mixture,
- ✓ staged mixing of fuel/primary air mixture and secondary air,
- ✓ efficient heat transfer to the boiler walls,
- ✓ tolerance of the fuel variation

Economizer



Boiler Drum

Uses

- ✓ To receive feed water
- ✓ Supply water to water wall tubes through down comers tube
- ✓ To separate water from steam
- ✓ To provide an outlet for steam on the top to the super heaters
- ✓ Temporary storage of water

Down Comer Tubes

Water carry from Steam Drum to Boiler at the bottom

Located away from the main heat source

Up Riser/ Water Wall/ Generation Tubes

Boiler Components

Absorb 50% of heat released during combustion process.

The only place for Steam generation

Super Heaters

Are Heat Exchangers

Receive saturated steam from steam drum and super heat it.

- ✓ Increase the temperature and pressure of steam
- ✓ Increase the dryness of the steam

Super Heaters

Radiant Super Heater

Absorb heat by Radiation

- ✓ Steam temperature decreases as steam flow increases
- ✓ Temperatures can not be increased quickly

Super Heaters

Convection Super Heater

Absorb heat by convection
from flue gases
flowing over the tubes

- ✓ Steam temperature decreases as steam flow increases
- ✓ Temperatures can not be increased quickly

De-Super Heaters/ Attemperators

Located between two super heaters

Gets feed water from Feed Pump out let and spray it into super heater

- ✓ Avoids over heating of super heater tubes
- ✓ Maintain main steam Temperatures

Re Heater

Located in flue gas path like super heaters

Increase temperature of
steam exhausting from HP
Turbine

- ✓ Avoids early condensation of steam in IP and LP turbines

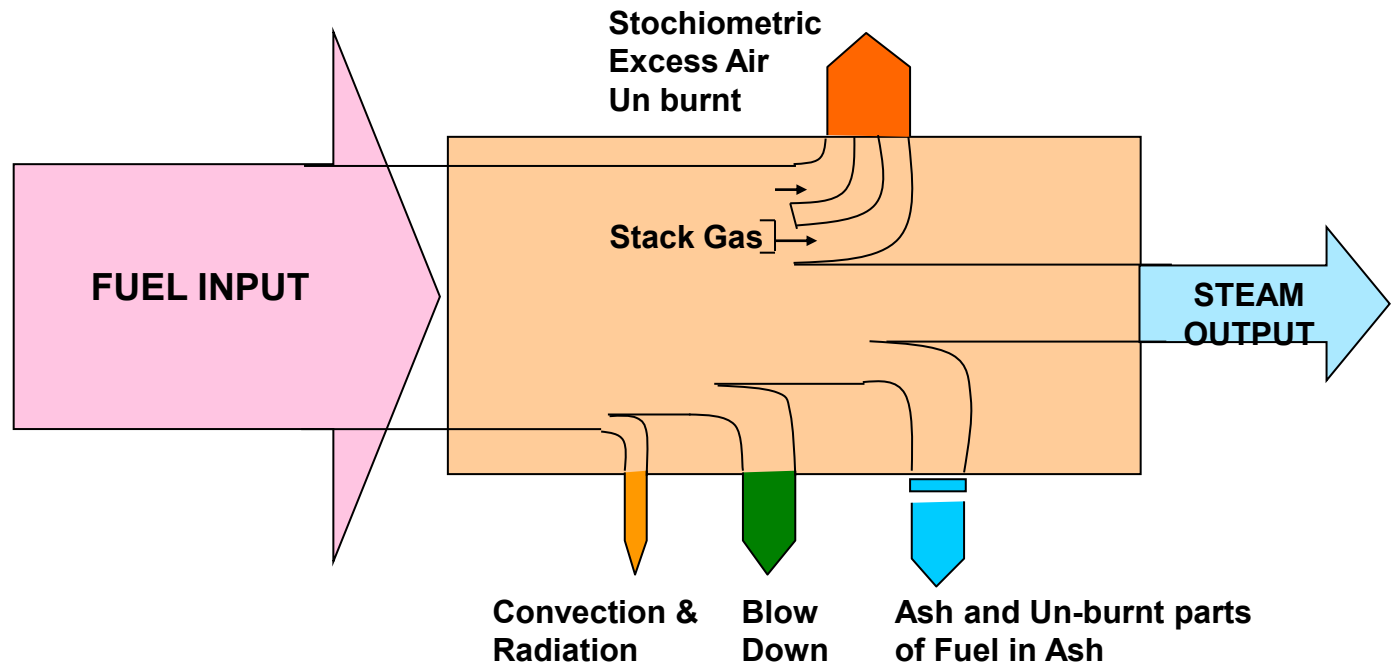
1. Boiler performance

- **Causes of poor boiler performance**
 - Poor combustion
 - Heat transfer surface fouling
 - Poor operation and maintenance
 - Deteriorating fuel and water quality
- **Heat balance: identify heat losses**
- **Boiler efficiency: determine deviation from best efficiency**

1. Boiler performance

Heat Balance

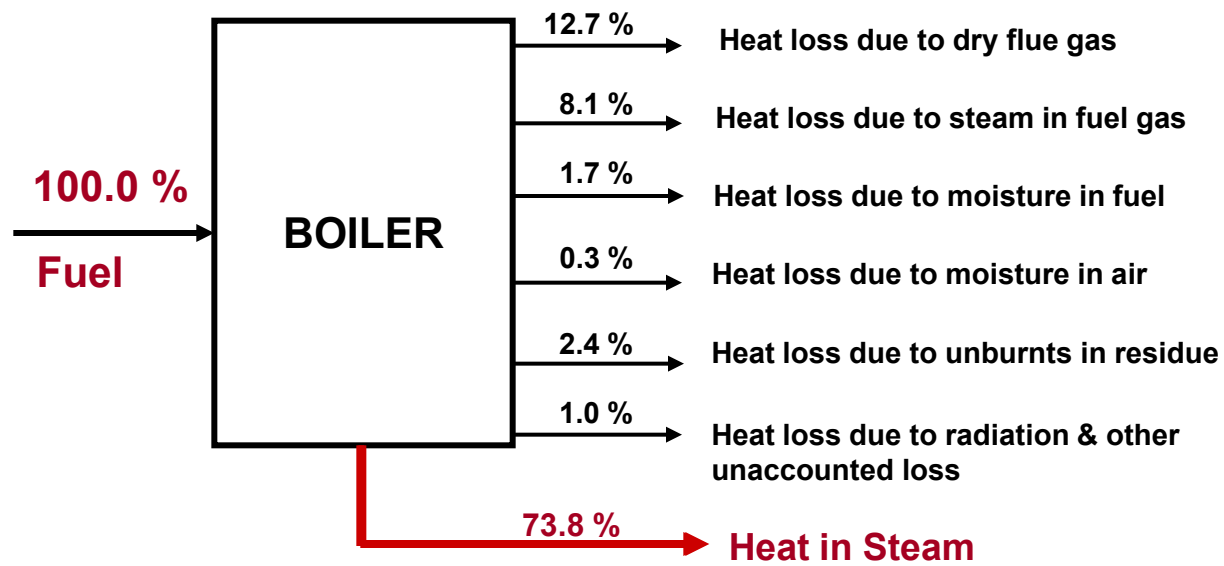
An energy flow diagram describes geographically how energy is transformed from fuel into useful energy, heat and losses



1. Boiler performance

Heat Balance

Balancing total energy entering a boiler against the energy that leaves the boiler in different forms



1. Boiler performance

Heat Balance

Goal: improve energy efficiency by reducing *avoidable* losses

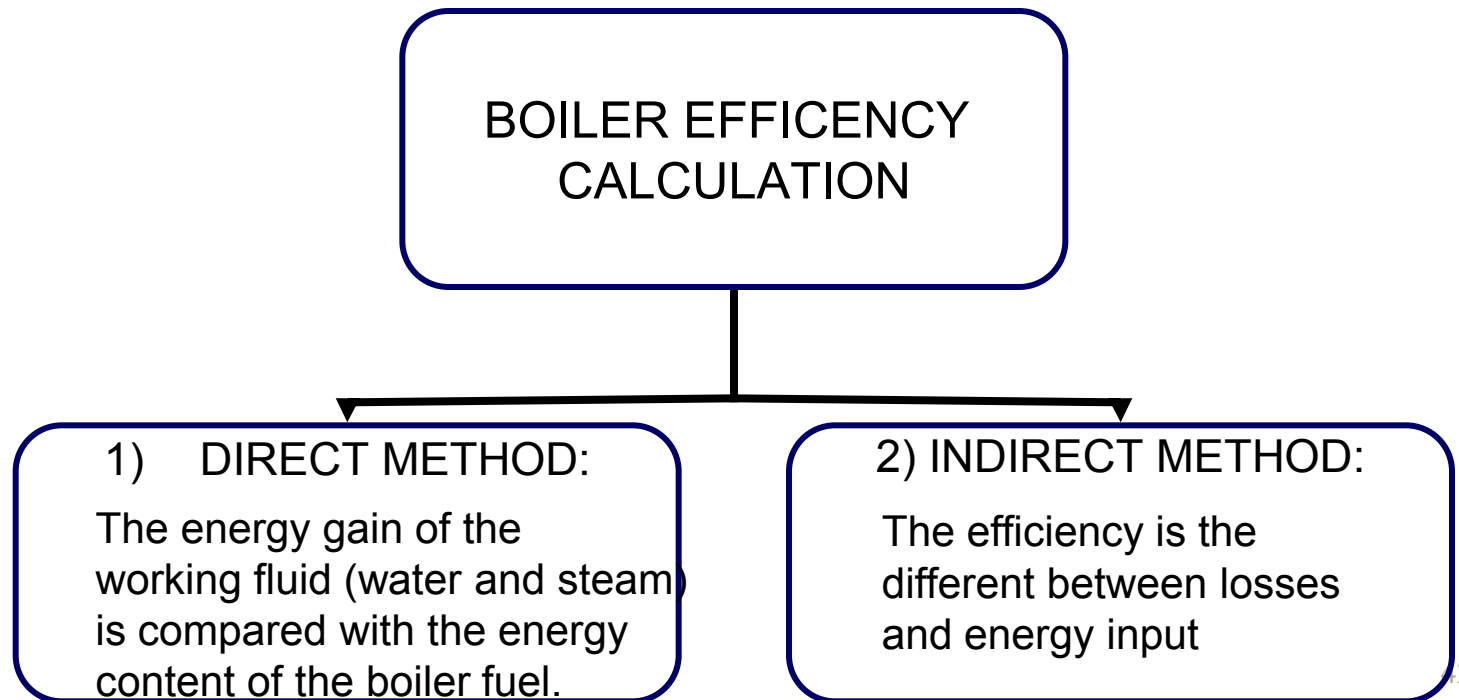
Avoidable losses include:

- **Stack gas losses (excess air, stack gas temperature)**
- **Losses by unburnt fuel**
- **Blow down losses**
- **Condensate losses**
- **Convection and radiation**

1. Boiler performance

Boiler Efficiency

Thermal efficiency: % of (heat) energy input that is effectively useful in the generated steam



1. Boiler performance

Boiler Efficiency: Direct Method

$$\text{Boiler efficiency } (\eta) = \frac{\text{Heat Input}}{\text{Heat Output}} \times 100 = \frac{Q \times (h_g - h_f)}{Q \times \text{GCV}} \times 100$$

h_g -the enthalpy of saturated steam in kcal/kg of steam

h_f -the enthalpy of feed water in kcal/kg of water

Parameters to be monitored:

- Quantity of steam generated per hour (Q) in kg/hr
- Quantity of fuel used per hour (q) in kg/hr
- The working pressure (in kg/cm²(g)) and superheat temperature (°C), if any
- The temperature of feed water (°C)
- Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel

1. Boiler performance

Boiler Efficiency: Direct Method

Advantages

- Quick evaluation
- Few parameters for computation
- Few monitoring instruments
- Easy to compare evaporation ratios with benchmark figures

Disadvantages

- No explanation of low efficiency
- Various losses not calculated

1. Boiler performance

Boiler Efficiency: Indirect Method

$$\text{Efficiency of boiler } (\eta) = 100 - (i+ii+iii+iv+v+vi+vii)$$

Principle losses:

- i) Dry flue gas
- ii) Evaporation of water formed due to H_2 in fuel
- iii) Evaporation of moisture in fuel
- iv) Moisture present in combustion air
- v) Unburnt fuel in fly ash
- vi) Unburnt fuel in bottom ash
- vii) Radiation and other unaccounted losses

1. Boiler performance

Boiler Efficiency: Indirect Method Required calculation data

- Ultimate analysis of fuel (H_2 , O_2 , S, C, moisture content, ash content)
- % oxygen or CO_2 in the flue gas
- Fuel gas temperature in $^{\circ}C$ (T_f)
- Ambient temperature in $^{\circ}C$ (T_a) and humidity of air in kg/kg of dry air
- GCV of fuel in kcal/kg
- % combustible in ash (in case of solid fuels)
- GCV of ash in kcal/kg (in case of solid fuels)

1. Boiler performance

Boiler Efficiency: Indirect Method

Advantages

- Complete mass and energy balance for each individual stream
- Makes it easier to identify options to improve boiler efficiency

Disadvantages

- Time consuming
- Requires lab facilities for analysis

2. Boiler Blow Down

- Controls 'total dissolved solids' (TDS) in the water that is boiled
- Blows off water and replaces it with feed water
- Conductivity measured as indication of TDS levels
- Calculation of quantity blow down required:

$$\text{Blow down (\%)} = \frac{\text{Feed water TDS} \times \% \text{ Make up water}}{\text{Maximum Permissible TDS in Boiler water}}$$

2. Boiler Blow Down

Boiler Blow Down

Two types of blow down

- **Intermittent**
 - Manually operated valve reduces TDS
 - Large short-term increases in feed water
 - Substantial heat loss
- **Continuous**
 - Ensures constant TDS and steam purity
 - Heat lost can be recovered
 - Common in high-pressure boilers

2. Boiler Blow Down

Boiler Blow Down

Benefits

- Lower pretreatment costs
- Less make-up water consumption
- Reduced maintenance downtime
- Increased boiler life
- Lower consumption of treatment chemicals

3. Boiler Feed Water Treatment

- **Quality of steam depend on water treatment to control**
 - Steam purity
 - Deposits
 - Corrosion
- **Efficient heat transfer only if boiler water is free from deposit-forming solids**

3. Boiler Feed Water Treatment

Boiler Feed Water Treatment Deposit control

- To avoid efficiency losses and reduced heat transfer
- Hardness salts of calcium and magnesium
 - Alkaline hardness: removed by boiling
 - Non-alkaline: difficult to remove
- Silica forms hard silica scales

3. Boiler Feed Water Treatment

Boiler Feed Water Treatment

Internal water treatment

- Chemicals added to boiler to prevent scale
- Different chemicals for different water types
- Conditions:
 - Feed water is low in hardness salts
 - Low pressure, high TDS content is tolerated
 - Small water quantities treated
- Internal treatment alone not recommended

3. Boiler Feed Water Treatment

Boiler Feed Water Treatment

External water treatment:

- Removal of suspended/dissolved solids and dissolved gases
- Pre-treatment: sedimentation and settling
- First treatment stage: removal of salts
- Processes
 - a) Ion exchange
 - b) Demineralization
 - c) De-aeration
 - d) Reverse osmoses

3. Boiler Feed Water Treatment

External Water Treatment

a) Ion-exchange process (softener plant)

- Water passes through bed of natural zeolite or synthetic resin to remove hardness
- Base exchange: calcium (Ca) and magnesium (Mg) replaced with sodium (Na) ions
- Does not reduce TDS, blow down quantity and alkalinity

b) Demineralization

- Complete removal of salts
- Cations in raw water replaced with hydrogen ions

3. Boiler Feed Water Treatment

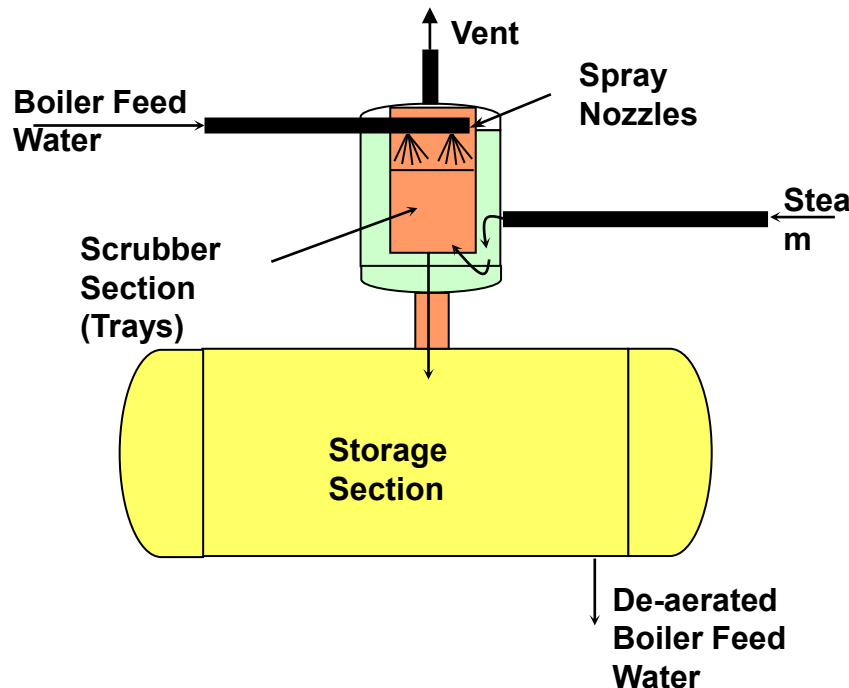
External Water Treatment

c) De-aeration

- **Dissolved corrosive gases (O_2 , CO_2) expelled by preheating the feed water**
- **Two types:**
 - *Mechanical de-aeration:* used prior to addition of chemical oxygen scavengers
 - *Chemical de-aeration:* removes trace oxygen

3. Boiler Feed Water Treatment

External Water Treatment



Mechanical de-aeration

- O_2 and CO_2 removed by heating feed water
- Economical treatment process
- Vacuum type can reduce O_2 to 0.02 mg/l
- Pressure type can reduce O_2 to 0.005 mg/l

3. Boiler Feed Water Treatment

External Water Treatment

Chemical de-aeration

- Removal of trace oxygen with scavenger
- Sodium sulphite:
 - Reacts with oxygen: sodium sulphate
 - Increases TDS: increased blow down
- Hydrazine
 - Reacts with oxygen: nitrogen + water
 - Does not increase TDS: used in high pressure boilers

3. Boiler Feed Water Treatment

External Water Treatment

d) Reverse osmosis

- **Osmosis**

- Solutions of differing concentrations
- Separated by a semi-permeable membrane
- Water moves to the higher concentration

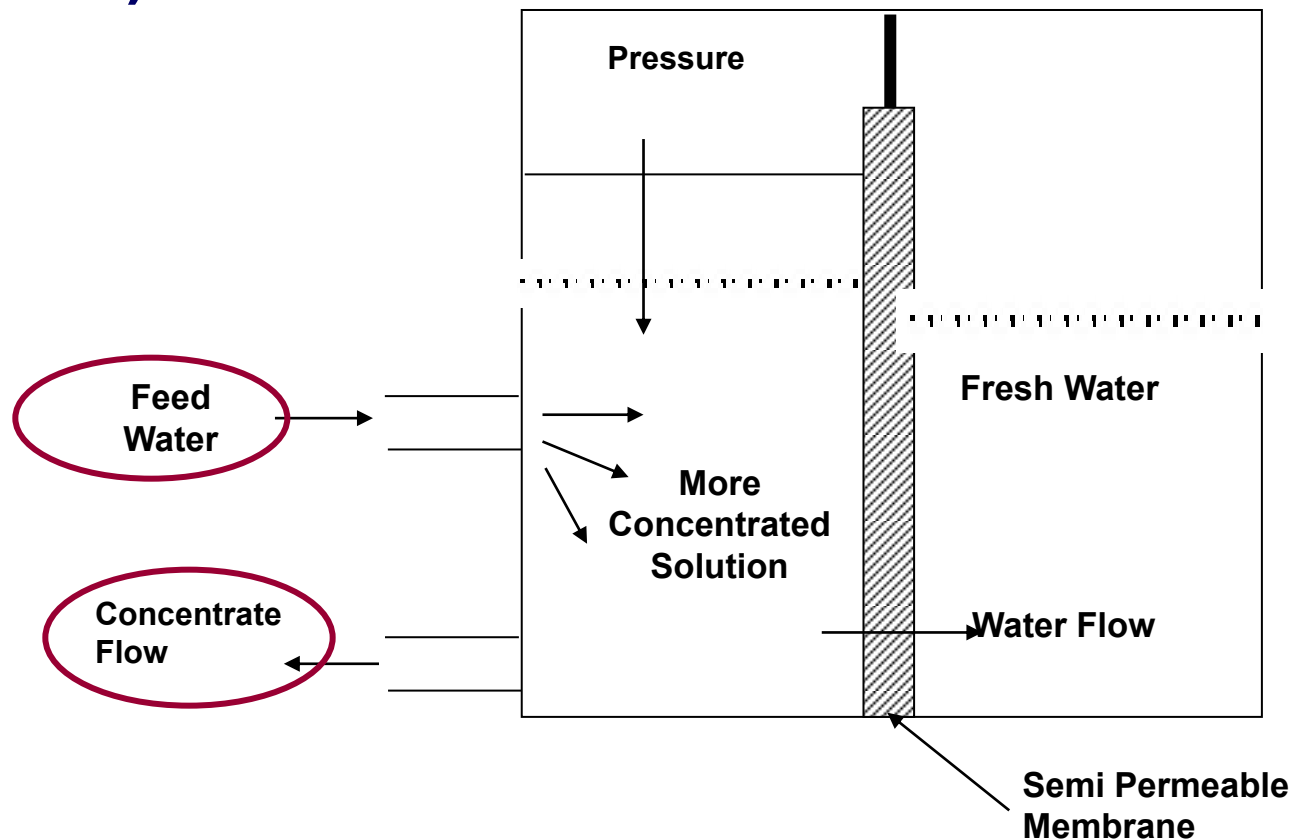
- **Reversed osmosis**

- Higher concentrated liquid pressurized
- Water moves in reversed direction

3. Boiler Feed Water Treatment

External water treatment

d) Reverse osmosis



Introduction

Type of boilers

Assessment of a boiler

Energy efficiency opportunities

Energy Efficiency Opportunities

Types of Boilers

1. **Stack temperature control**
2. **Feed water preheating using economizers**
3. **Combustion air pre-heating**
4. **Incomplete combustion minimization**
5. **Excess air control**
6. **Avoid radiation and convection heat loss**
7. **Automatic blow down control**
8. **Reduction of scaling and soot losses**
9. **Reduction of boiler steam pressure**
10. **Variable speed control**
11. **Controlling boiler loading**
12. **Proper boiler scheduling**
13. **Boiler replacement**

Energy Efficiency Opportunities

1. Stack Temperature Control

- Keep as low as possible
- If $>200^{\circ}\text{C}$ then recover waste heat

2. Feed Water Preheating Economizers

- Potential to recover heat from $200 - 300^{\circ}\text{C}$ flue gases leaving a modern 3-pass shell boiler

3. Combustion Air Preheating

- If combustion air raised by $20^{\circ}\text{C} = 1\%$ improve thermal efficiency

Energy Efficiency Opportunities

4. Minimize Incomplete Combustion

- **Symptoms:**
 - Smoke, high CO levels in exit flue gas
- **Causes:**
 - Air shortage, fuel surplus, poor fuel distribution
 - Poor mixing of fuel and air
- **Oil-fired boiler:**
 - Improper viscosity, worn tops, carbonization on dips, deterioration of diffusers or spinner plates
- **Coal-fired boiler:** non-uniform coal size

Energy Efficiency Opportunities

5. Excess Air Control

- Excess air required for complete combustion
- Optimum excess air levels varies
- 1% excess air reduction = 0.6% efficiency rise
- Portable or continuous oxygen analyzers

Fuel	Kg air req./kg fuel	%CO ₂ in flue gas in practice
Solid Fuels		
Bagasse	3.3	10-12
Coal (bituminous)	10.7	10-13
Lignite	8.5	9 -13
Paddy Husk	4.5	14-15
Wood	5.7	11.13
Liquid Fuels		
Furnace Oil	13.8	9-14
LSHS	14.1	9-14

Energy Efficiency Opportunities

6. Radiation and Convection Heat Loss Minimization

- Fixed heat loss from boiler shell, regardless of boiler output
- Repairing insulation can reduce loss

7. Automatic Blow Down Control

- Sense and respond to boiler water conductivity and pH

Energy Efficiency Opportunities

8. Scaling and Soot Loss Reduction

- Every 22°C increase in stack temperature = 1% efficiency loss
- 3 mm of soot = 2.5% fuel increase

9. Reduced Boiler Steam Pressure

- Lower steam pressure
 - = lower saturated steam temperature
 - = lower flue gas temperature
- Steam generation pressure dictated by process

Energy Efficiency Opportunities

10. Variable Speed Control for Fans, Blowers and Pumps

- Suited for fans, blowers, pumps
- Should be considered if boiler loads are variable

11. Control Boiler Loading

- Maximum boiler efficiency: 65-85% of rated load
- Significant efficiency loss: $< 25\%$ of rated load

Energy Efficiency Opportunities

12. Proper Boiler Scheduling

- Optimum efficiency: 65-85% of full load
- Few boilers at high loads is more efficient than large number at low loads

13. Boiler Replacement

Financially attractive if existing boiler is

- Old and inefficient
- Not capable of firing cheaper substitution fuel
- Over or under-sized for present requirements
- Not designed for ideal loading conditions

Types of Boilers



**THANK YOU
FOR YOUR ATTENTION**

