Petroleum Conservation Research Association- profile

Emergence of PCRA

■ 1973	:	Oil Crisis World Over
■ Study Team	:	Engineers from IOC, NPC, DGTD estimated huge oil conservation potential in Industries & STUs
■ Study Results	:	Conservation Potential of 20 - 30%
■ 6th JAN'76	:	Petroleum Conservation Action Group (PCAG) formed
■ 10th AUG'78	:	PCAG Reconstituted as "Petroleum Conservation Research Association" (PCRA) and registered as a society under MOP&NG

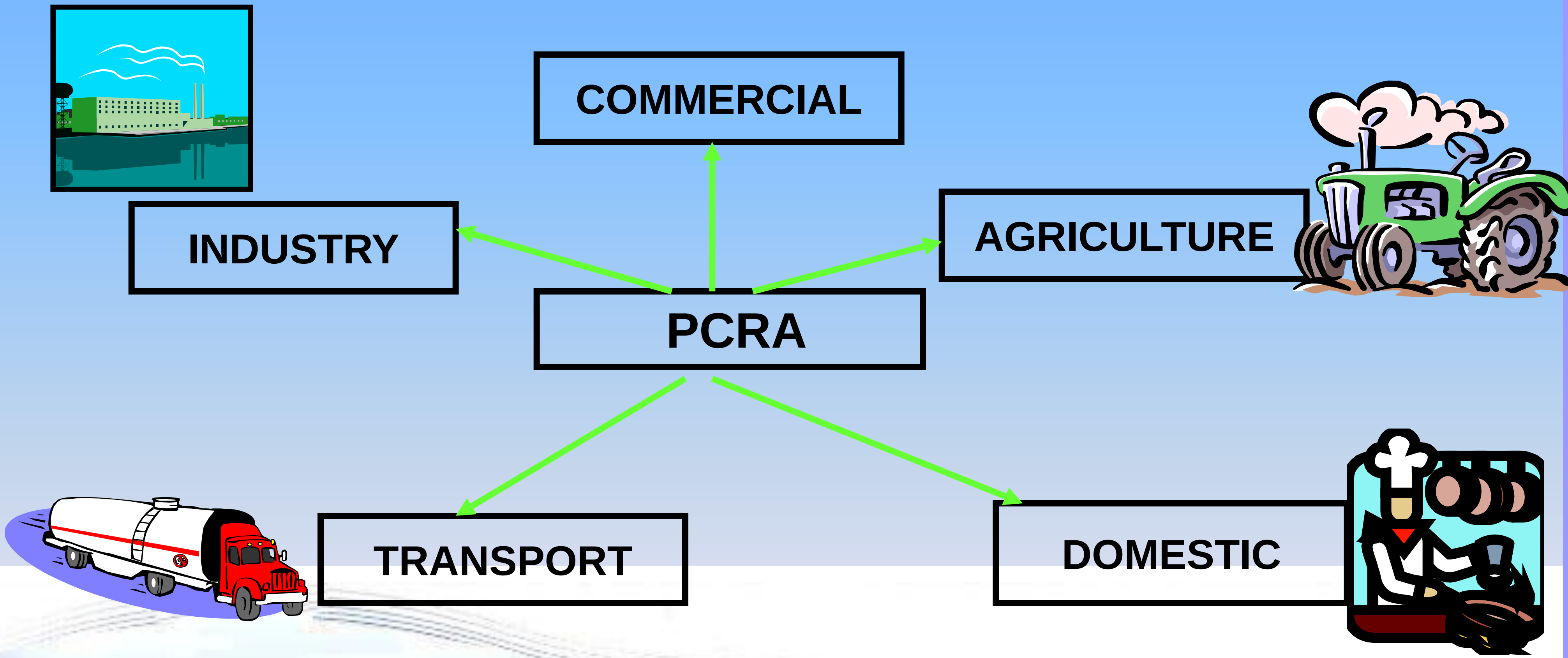
About PCRA

PETROLEUM CONSERVATION RESEARCH ASSOCIATION (PCRA) is a society under MOP&NG

Primary Objective:

- Create awareness among all sectors
- Special focus on Domestic sector

SECTROAL APPROACH



1. Fuels and Combustion

Introduction to Fuels

- Different type of fuels such as liquid, solid and gas are available for firing in boilers and furnaces.
- What is the criteria for selecting the fuel type?
  - Availability
  - Storage & handling
  - Pollution
  - Cost of fuel
  - Fuel properties

Properties of Liquid Fuels and its impacts

- **Density:** $\frac{\text{mass of the fuel}}{\text{volume of the fuel}}$

At a reference temperature typically 15°C. (kg/m^3.)

- **Specific gravity:** $\frac{\text{weight of a given volume of oil}}{\text{weight of the same volume of water}}$

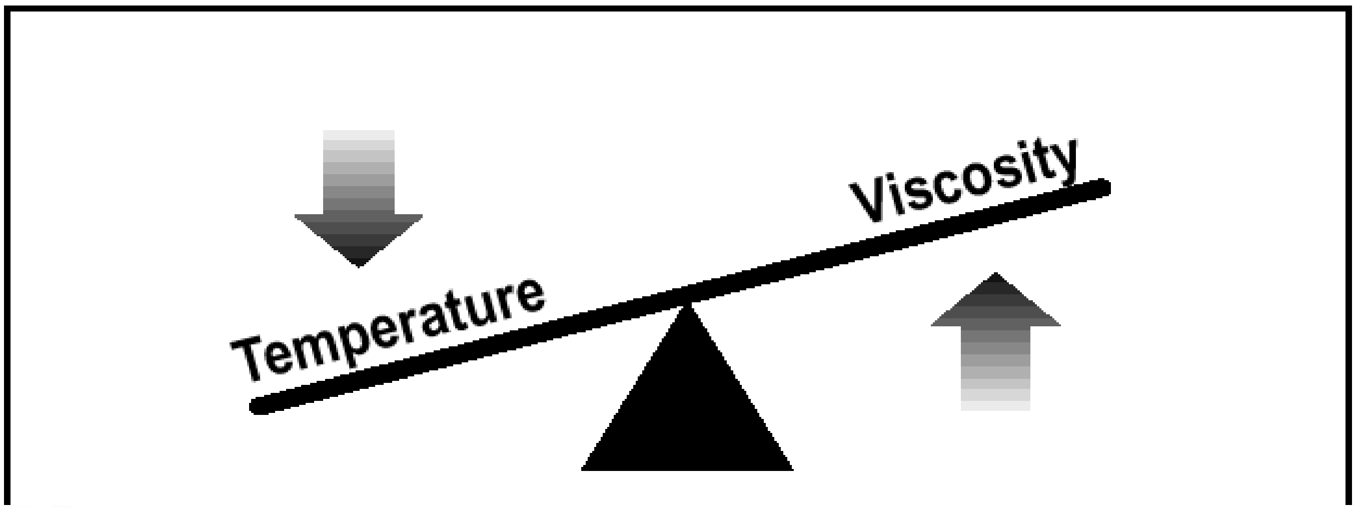
at a given temperature.

- If specific gravity is more, heating value is less.

e.g Light Oil =0.85-0.87, Furnace oil=0.89-0.95, L.S.H.S=0.88-0.98

Viscosity

- Internal resistance to flow of fluid
- Viscosity influences the degree of pre-heat required for handling, storage and satisfactory atomization



Specific Heat

- Specific heat is the **amount of kcals** needed to raise the temperature of 1 kg of oil by $1^{o}C$. The unit of specific heat is $kcal/kg^{o}C$. It varies from 0.22 to 0.28 depending on the oil specific gravity.

It helps to quantify how much steam or electrical energy required for preheating.

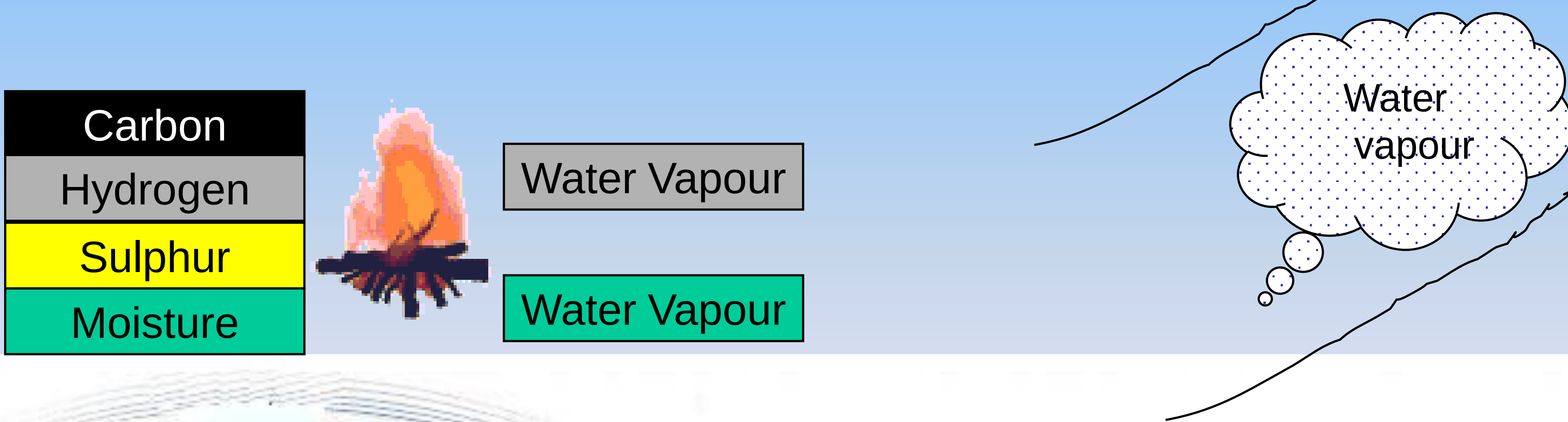
Flash Point & Pour Point

- **Flash Point:** The lowest temperature at which the fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it. Ex.Flash point for furnace oil is 66^{o}C.

- **Pour Point: T**he lowest temperature at which it will pour or flow when cooled under prescribed conditions. It is a very rough indication of the lowest temperature at which fuel oil is readily pumpable.

Calorific Value

- The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value.
- The difference being the *latent heat of condensation of the water vapour* produced during the combustion process.



GCV – 10,500 Kcal/kg

NCV – 9800 Kcal/kg

Typical calorific values of fuels

The calorific value of coal varies considerably depending on the ash, moisture content and the type of coal while calorific value of fuel oils are much more consistent.

Fuel Oil	**Calorific Value (Kcal/Kg)**
Kerosene	- 11,100
Diesel Oil	- 10,800
L.D.O	- 10,700
Furnace Oil	- 10,500
LSHS	- 10,600
Indian coal	- 4000 to 6000

Sulphur Content

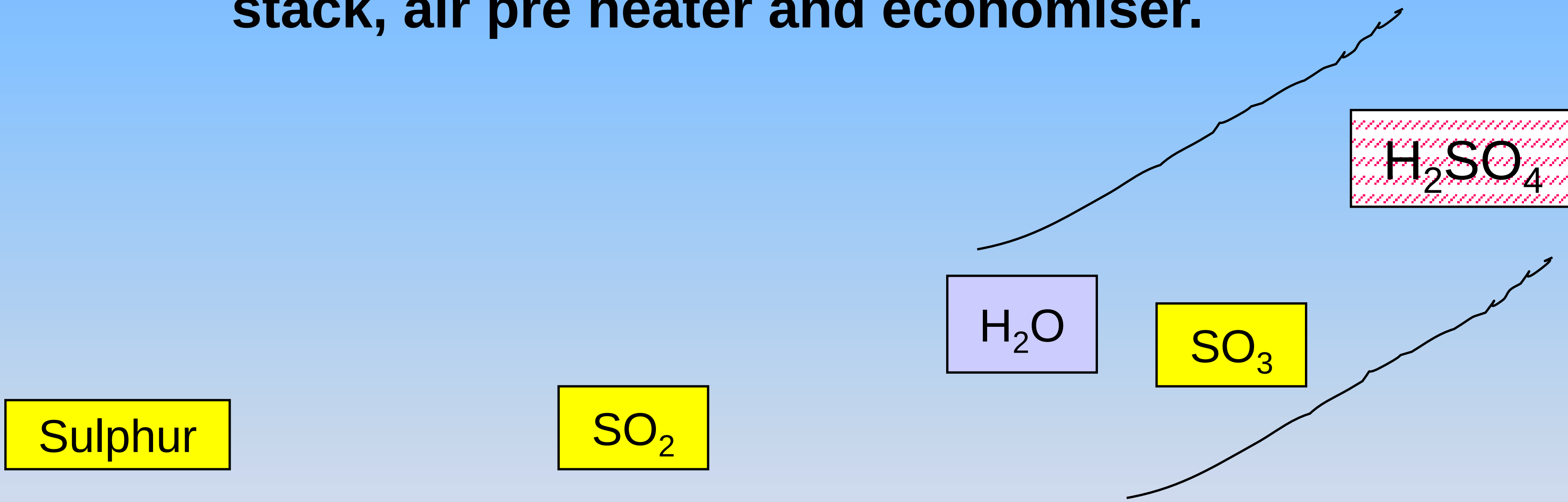
Depends mainly on the source of the crude oil and to a lesser extent on the refining process. The normal sulfur content for the residual fuel oil (heavy fuel oil) is in the order of 2-4 %.

Fuel oil	**Percentage of Sulphur**
Kerosene	0.05—0.2
Diesel Oil	0.3 – 1.5
L.D.O	0.5 – 1.8
Heavy Fuel Oil	2.0 – 4.0
LSHS	< 0.5

Disadvantage of sulphur

risk of corrosion

Cold end corrosion in cool parts of the chimney or stack, air pre heater and economiser.



Important properties of fuel oil

Typical Specification of Fuel Oils

Properties	Fuel Oils		
	Furnace Oil	L.S.H.S.	L.D.O.
Density (Approx. kg/litre at 15^0C)	0.89-0.95	0.88-0.98	0.85-0.87
Flash Point (^{0}C)	66	93	66
Pour Point (^{0}C)	20	72	18
G.C.V. (Kcal/kg)	10,500	10,600	10,700
Sediment, % Wt. Max.	0.25	0.25	0.1
Sulphur Total, % Wt. Max.	Upto 4.0	Upto 0.5	Upto 1.8
Water Content, % Vol. Max.	1.0	1.0	0.25
Ash % Wt. Max.	0.1	0.1	0.02

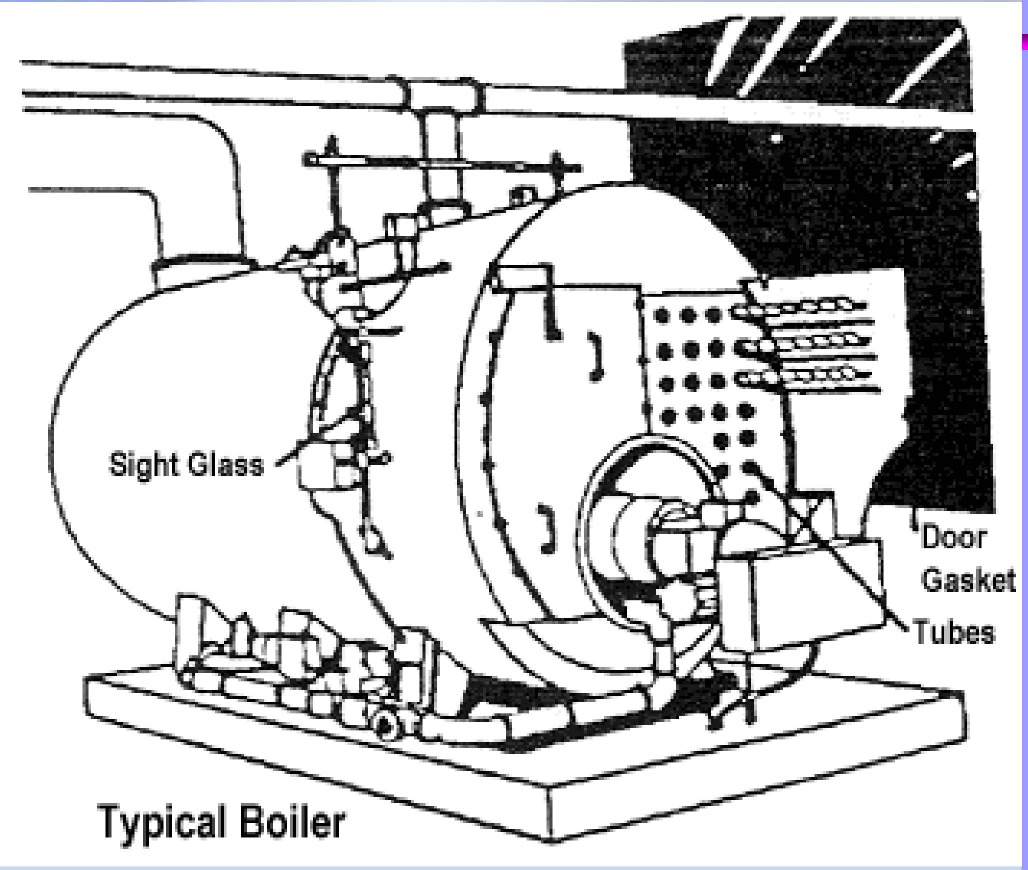
Storage of Fuel oil

- Hazardous to store furnace oil in barrels.
- Stored in cylindrical tanks
  - either above or below the ground.
- Storage capacity
  - - at least 10 days of normal consumption.
- Periodical cleaning of tanks
  - annually for heavy fuels and every two years for light fuels.
- leaks
  - from joints, flanges and pipelines must be attended at the earliest.
  - **LOSS OF EVEN ONE DROP OF OIL EVERY SECOND CAN COST YOU OVER 4000 LITRES A YEAR**
- Fuel oil
  - should be free from contaminants such as dirt, sludge and water before it is fed to the combustion system.

Introduction to Boiler

- Enclosed Pressure Vessel
- Heat generated by Combustion of Fuel is transferred to water to become steam
- Process: Evaporation

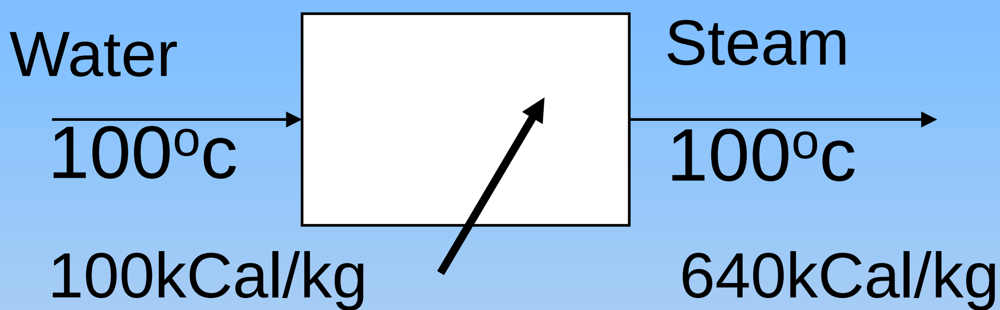
- Steam volume increases to 1,600 times from water and produces tremendous force
- Boiler to be extremely dangerous equipment. Care is must to avoid explosion.



What is a boiler?

What is F&A 100^{O}C ?

MCR(Maximum Continuous Rating):10TPH(F&A100^{o}C)
Rated Working Pressure :10.54 kg/cm^{2}(g)



What is the amount of steam generated at 10**kg/cm^{2}(g) ?**

Enthalpy of steam(sat) at 10 kg/cm^{2}(g) pressure:665 K.Cal/kg

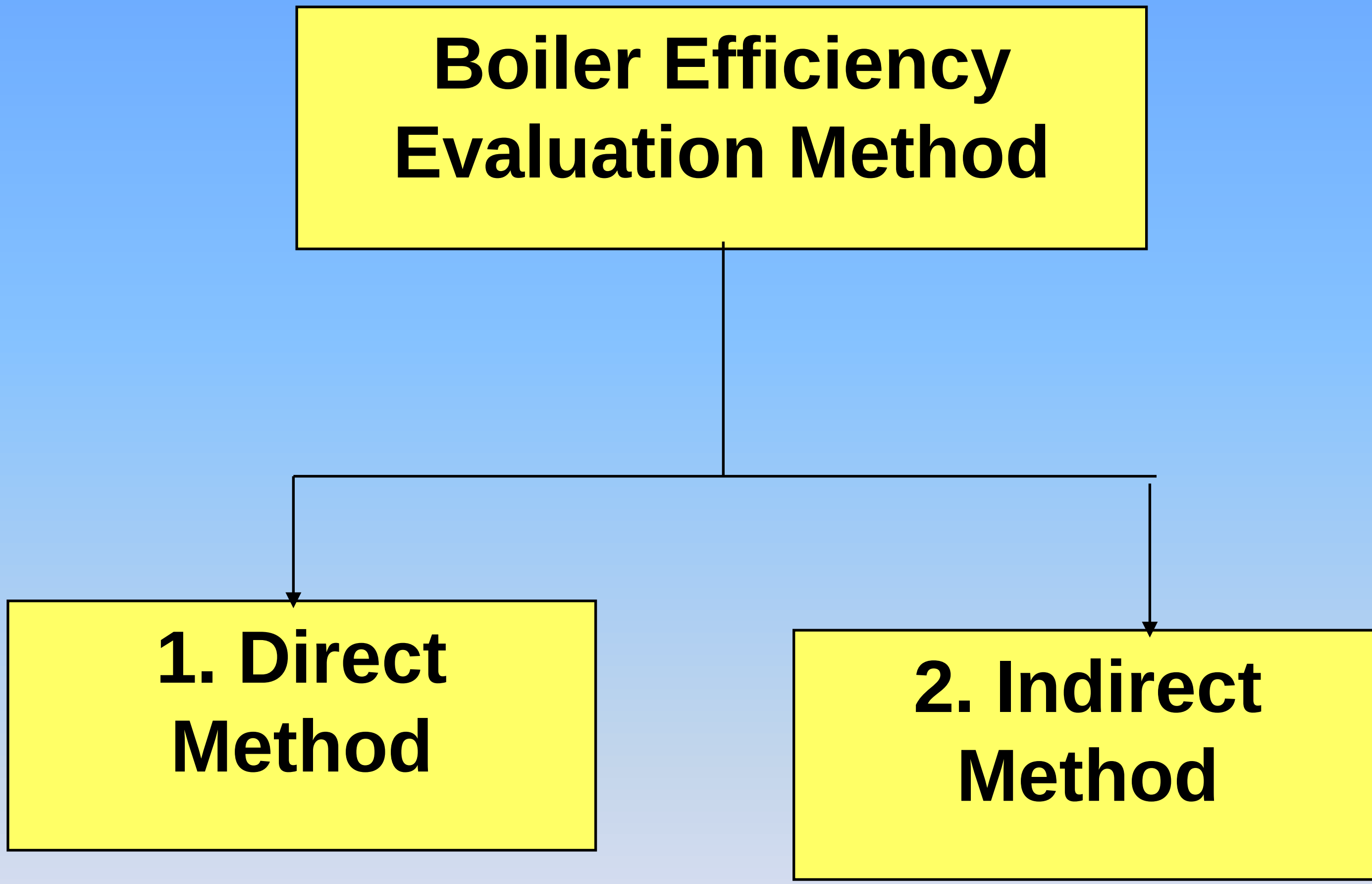
Feed water temperature : 85^{0}

$$\frac{10\ \text{TPH} \times 540\ \text{kCal/kg}}{(665-85)\ \text{kCal/kg}} = 9.31\text{TPH}$$

Fuels used in Boiler

S. No	Solid	Liquid	Gaseous	AgroWaste
1	**Coal**	HSD	NGas	Baggase
2	**Lignite**	LDO	Bio Gas	Pith
3		Fur.Oil		Rice Husk
4		LSHS		Paddy
5				Coconut shell
6				Groundnutshell

2.4 Performance Evaluation of Boilers



Which method is better? Why?

Efficiency Calculation by Direct Method

Example:

Type of boiler: Coal fired Boiler

Heat input data

Qty of coal consumed :1.8 TPH

GCV of coal :3200K.Cal/kg

Heat output data

- Qty of steam gen : 8 TPH
- Steam pr/temp:10 kg/cm^2(g)/180^{0}C
- Enthalpy of steam(sat) at 10 kg/cm^2(g) pressure :665 K.Cal/kg
- Feed water temperature : 85^0 C
- Enthalpy of feed water : 85 K.Cal/kg

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Boiler efficiency (η): $= \dfrac{Q \times (H - h)}{(q \times GCV)} \times 100$

Where **Q** = Quantity of steam generated per hour (kg/hr)

H = Enthalpy of saturated steam (kcal/kg)

h = Enthalpy of feed water (kcal/kg)

q = Quantity of fuel used per hour (kg/hr)

GCV = Gross calorific value of the fuel (kcal/kg)

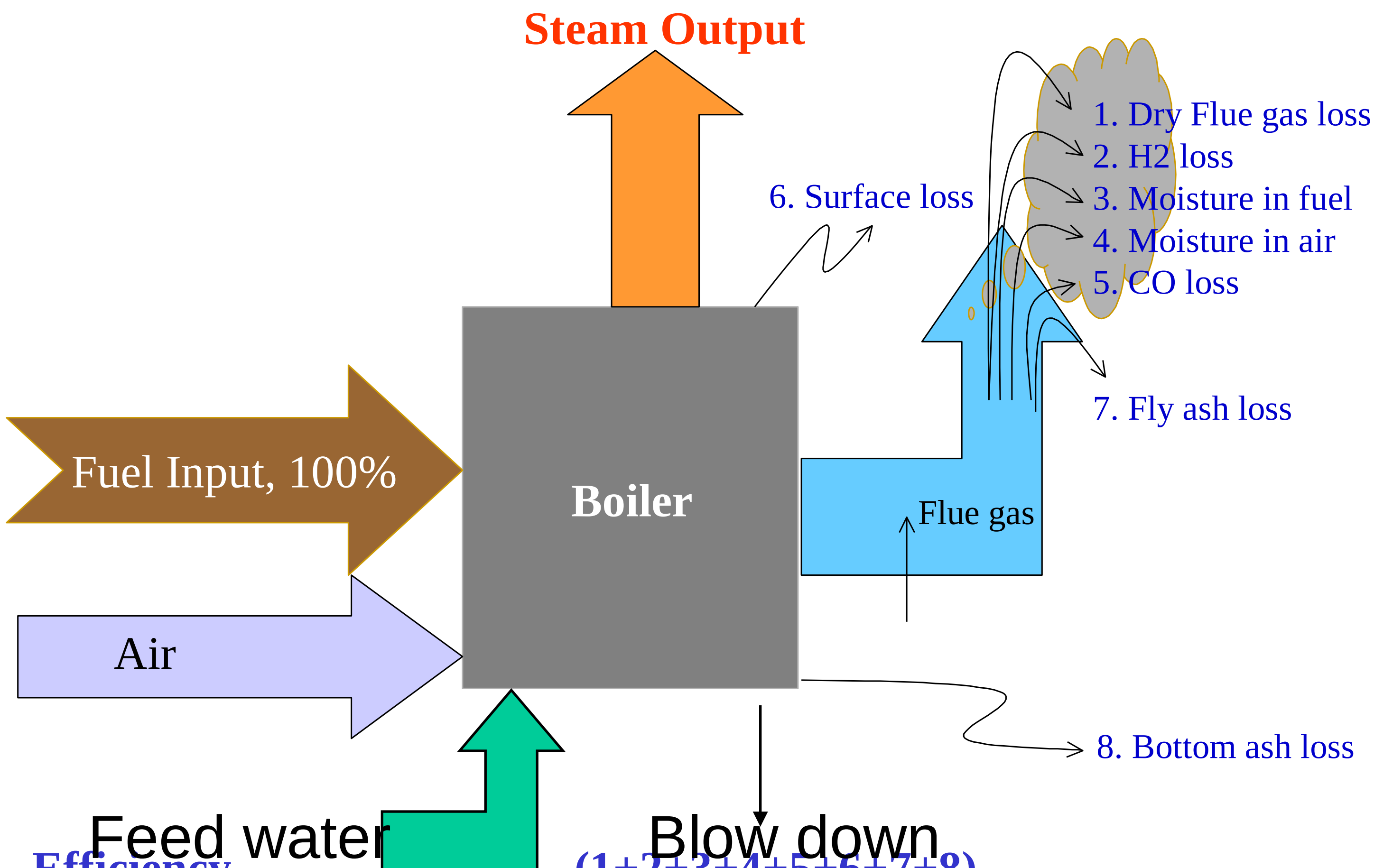
Boiler efficiency (η)= $\dfrac{8\ TPH \times 1000 Kg/T \times (665 - 85) \times 100}{1.8\ TPH \times 1000 Kg/T \times 3200}$

= 80.0%

Evaporation Ratio = 8 Tonne of steam/1.8 Ton of coal

= 4.4

What are the losses that occur in a boiler?



Efficiency = 100 – (1+2+3+4+5+6+7+8)

(by In Direct Method)

Example: Indirect Method

The following are the data collected for a typical oil fired boiler. Find out the efficiency of the boiler by indirect method and Boiler Evaporation ratio.

Ultimate analysis of Oil

C : 84.0 % , H_2: 12.0 %, S: 3.0 % , O_2: 1.0 %

GCV of Oil : 10200 kcal/kg

Steam Generation Pressure : 7kg/cm^2(g)-saturated

Enthalpy of steam : 660 kCal/kg

Feed water temperature : 60^{o}C

Percentage of Oxygen in flue gas : 7

Percentage of CO_2 in flue gas : 11

Flue gas temperature (T_f) : 220 ^{0}C

Ambient temperature (T_a) : 27 ^{0}C

Humidity of air : 0.018 kg/kg of dry air

Solution

Step-1: Find the theoretical air requirement

$$[(11.6xC)+\{34.8x(H_2-O_2/8)\}+(4.35xS)]/100$$

=[(11.6 x 84) + [{34.8 x (12 – 1/8)} + (4.35 x 3)]/100 kg/kg of oil
=14 kg of air/kg of oil

Step-2: Find the %Excess air supplied

Excess air supplied (EA) = $\frac{O_2\%}{21-O_{2\%}} x100$ = $\frac{7\%}{21-7} x100$ = 50%

Step-3: Find the Actual mass of air supplied

Actual mass of air supplied /kg of fuel = [1 + EA/100] x Theoritical Air (AAS)
= [1 + 50/100] x 14
= 1.5 x 14
= 21 kg of air/kg of oil

Step-4: Estimation of all losses

i. Dry flue gas loss

Percentage heat loss due to dry flue gas = $\frac{m \, x \, C_p \, x \, (T_f - T_a)}{GCV \, of \; fuel} \, x \, 100$

m= mass of CO_2 + mass of SO_2 + mass of N_2 + mass of O_2

$$m = \frac{0.84 \, x \, 44}{12} + \frac{0.03 \, x \, 64}{32} + \frac{21 \, x \, 77}{100} + \left((21 - 14) \, x \, \frac{23}{100} \right)$$

m = 21 kg / kg of oil

$$\frac{21 x 0.23 x (220 - 27)}{10200} \, x \, 100$$

= 9.14 %

Alternatively a simple method can be used for determining the dry flue gas loss as given below.

Percentage heat loss due to dry flue gas = $\frac{m \, x \, C_p \, x \, (T_f - T_a)}{GCV \, of \, fuel} \, x \, 100$

Total mass of flue gas (m) = mass of actual air supplied + mass of fuel supplied **= 21 + 1=22**

%Dry flue gas loss = $\frac{22 \, x \, 0.23 \, x \, (220 - 27)}{10200} \, x \, 100 = 9.57\%$

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ii. Heat loss due to evaporation of water formed due to H_2 in fuel

$$= \frac{9 \text{ x } H_2 \text{ x } \{584 + C_p (T_f - T_a)\}}{\text{GCV of fuel}} \; x \; 100$$

Where, H_2 – percentage of H_2 in fuel

$$= \frac{9 \text{ x } 12 \text{ x } \{584 + 0.45 (220 - 27)\}}{10200} \; x \; 100$$

= 7.10%

iii. Heat loss due to moisture present in air

$$= \frac{AAS \; x \, humidity \; x \, C_p \; x \, (T_f - T_a)}{GCV \; of \; fuel} \; x \, 100$$

$$= \frac{21 x 0.018 x 0.45 x (220 - 27)}{10200} \; x \, 100 = 0.322$$

iv Heat loss due to radiation and other unaccounted losses

For a small boiler it is estimated to be 2%

Boiler Efficiency

i. Heat loss due to dry flue gas 9.14%

ii. Heat loss due to evaporation of water formed due to H_2 in fuel: 7.10 %

iii. Heat loss due to moisture present in air 0.322%

iv. Heat loss due to radiation and other unaccounted los : 2%

Boiler Efficiency = 100- [9.14+7.10+0.322+2]

= 100 – 18.56 = 81 (app)

Evaporation Ratio = Heat utilized for steam generation/Heat addition to the steam

= 10200 x 0.81/ (660-60)

= 14.11

Conservation Measures in Boilers

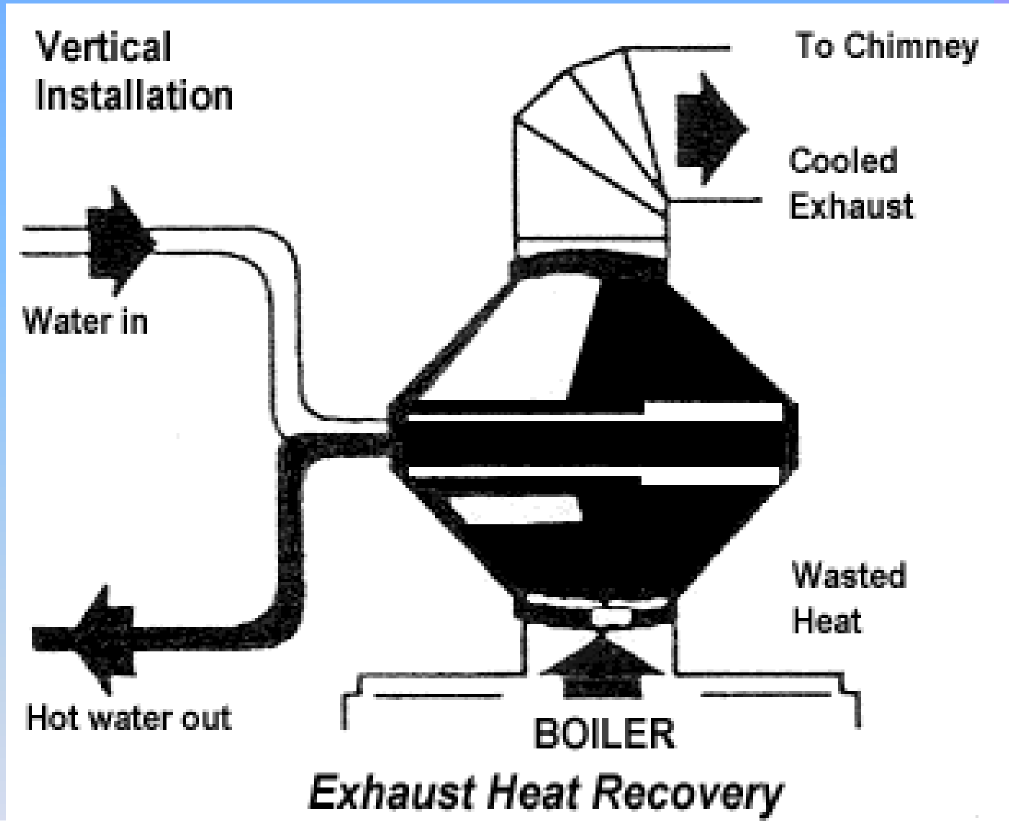
1. Reduce Stack Temperature

- Stack temperatures greater than 200°C indicates potential for recovery of waste heat.
- It also indicate the scaling of heat transfer/recovery equipment and hence the urgency of taking an early shut down for water / flue side cleaning.

22^{o} C reduction in flue gas temperature increases boiler efficiency by 1%

2. Feed Water Preheating using Economizer

- For an older shell boiler, with a flue gas exit temperature of 260ºC, an economizer could be used to reduce it to 200ºC, Increase in overall thermal efficiency would be in the order of 3%.
- Condensing economizer(N.Gas) Flue gas reduction up to 65ºC



6ºC raise in feed water temperature, by economiser/condensate recovery, corresponds to a 1% saving in fuel consumption

3. Combustion Air Preheating

- Combustion air preheating is an alternative to feedwater heating.

- In order to improve thermal efficiency by 1%, the combustion air temperature must be raised by 20 ^{o}C.

4. Complete Combustion

$C + O_2 \rightarrow CO_2$ + 8084 kCals/kg of Carbon

$2C + O_2 \rightarrow 2\,CO$ + 2430 kCals/kg of Carbon

$2H_2 + O_2 \rightarrow 2H_2O$ + 28,922 kCals/kg of Hydrogen

$S + O_2 \rightarrow SO_2$ + 2,224 kCals/kg of Sulphur

loss due to incomplete combustion,CO: 8084-2430=5654

5. Control excess air

for every 1% reduction in excess air ,0.6% rise in efficiency.

The optimum excess air level varies with furnace design, type of burner, fuel and process variables.. **Install oxygen trim system**

Table 2.5 Excess air levels for different fuels

Fuel	Type of Furnace or Burners	Excess Air (% by wt)
Pulverised coal	Completely water-cooled furnace for slag-tap or dry-ash removal	15-20
	Partially water-cooled furnace for dry-ash removal	15-40
Coal	Spreader stoker	30-60
	Water-cooler vibrating-grate stokers	30-60
	Chain-grate and traveling-gate stokers	15-50
	Underfeed stoker	20-50
Fuel Oil	Multi-fuel burners and flat-flame	10-30
Wood	Dutch over (10-23% through grates) and Hofft type	20-25
Bagasse	All furnaces	25-35
Black liquor	Recovery furnaces for draft and soda-pulping processes	5-7

6. Radiation and Convection Heat Loss

depends on

- difference in temperature between the surface and the surroundings.
- Surface area
- The heat loss from the boiler shell is a fixed energy loss, irrespective of the boiler output.

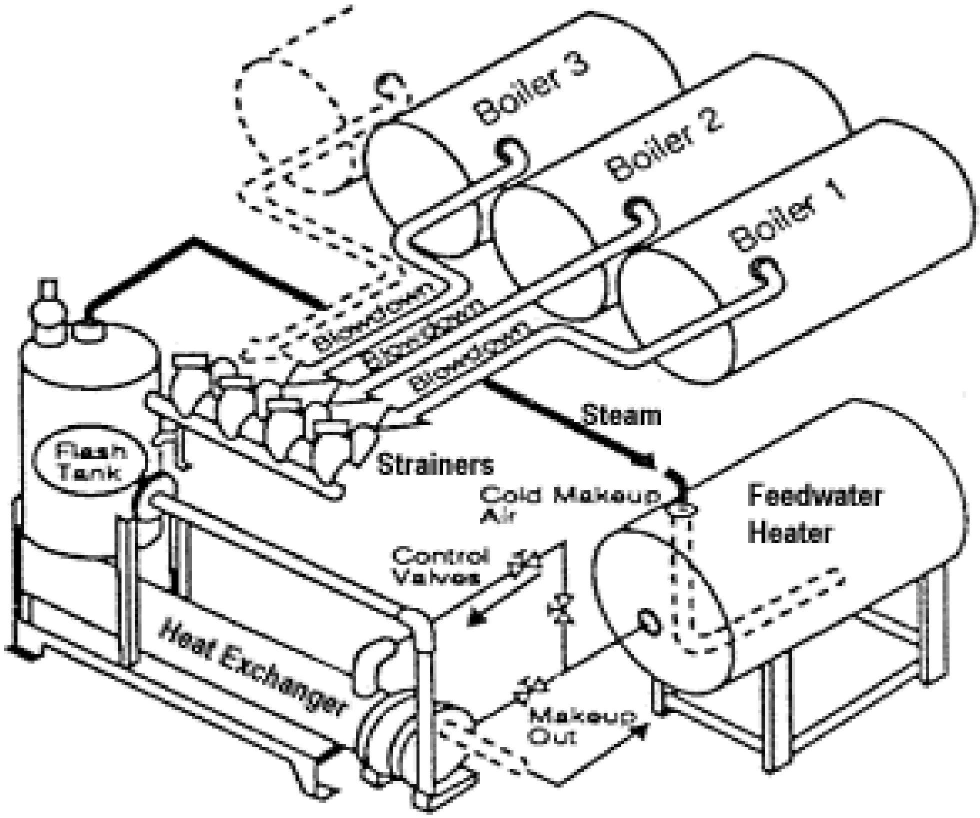
Note : 1.5% loss at full rating, will increase to around 6% at 25 percent output.

7. Automatic Blowdown Control

- Uncontrolled continuous blowdown is very wasteful.
- Automatic blowdown controls can be installed that sense and respond to boiler water conductivity and pH.
- A 10% blow down in a 15 kg/cm^2 boiler results in 3% efficiency loss.

Blowdown Heat Recovery

- **Efficiency Improvement - Up to 2 percentage points.**
- Blowdown of boilers to reduce the sludge and solid content allows heat to go down the drain.
- The amount of blowdown should be minimized by following a good water treatment program, but installing a heat exchanger in the blowdown line allows this waste heat to be used in preheating makeup and feedwater.
- Heat recovery is most suitable for continuous blowdown operations which in turn provides the best water treatment program.



Blowdown Heat Recovery System

8. Reduction of Scaling and Soot Losses

- Soot buildup on tubes acts as an insulator against heat transfer.
- Elevated stack temperatures ndicate excessive soot buildup or scaling on the water side.
- High exit gas temperatures at normal excess air indicate poor heat transfer performance.
- When the flue gas temperature rises about 20^{o}C above the temperature for a newly cleaned boiler, it is time to remove the soot deposits

Cleaning

- Incorrect water treatment, poor combustion and poor cleaning schedules can easily reduce overall thermal efficiency

- However, the additional cost of maintenance and cleaning must be taken into consideration when assessing savings.

•Every millimeter thickness of soot coating increases the stack temperature by about 55^{o}C. 1 mm of soot can cause an increase in fuel consumption by 2.5%.

•A 1mm thick scale (deposit) on the water side could increase fuel consumption by 5 to 8%

9. Reduction of Boiler Steam Pressure

- Lower steam pressure leads to reduction in the flue gas temperature which reduces dry FG loss.
- Steam is generated at pressures normally dictated by the highest pressure / temperature requirements for a particular process.
- Adverse effects, such as an increase in water carryover from the boiler owing to pressure reduction, may negate any potential saving.
- Pressure should be reduced in stages, and no more than a 20 percent reduction should be considered.

10. Variable Speed Control for Fans, Blowers and Pumps

Generally, combustion air control is effected by throttling dampers fitted at forced and induced draft fans. Though dampers are simple means of control, they lack accuracy, giving poor control characteristics at the top and bottom of the operating range.

If the load characteristic of the boiler is variable, the possibility of replacing the dampers by a VSD should be evaluated.

11. Effect of Boiler Loading on Efficiency

- Below 50% load, most combustion appliances need more excess air to burn the fuel completely which increases the sensible heat loss.
- Below 25% this effect becomes huge and should be avoided
- Optimum efficiency occurs at 65-85% of full loads

- If all the above measures fail to improve the boiler efficiecy…………………

12. Boiler Replacement

Boiler plants have a useful life of well over 25 years, hence following must be carefully studied.

- Long-term fuel availability
- Company growth plans.
- Financial and engineering factors.

Steam Utilization

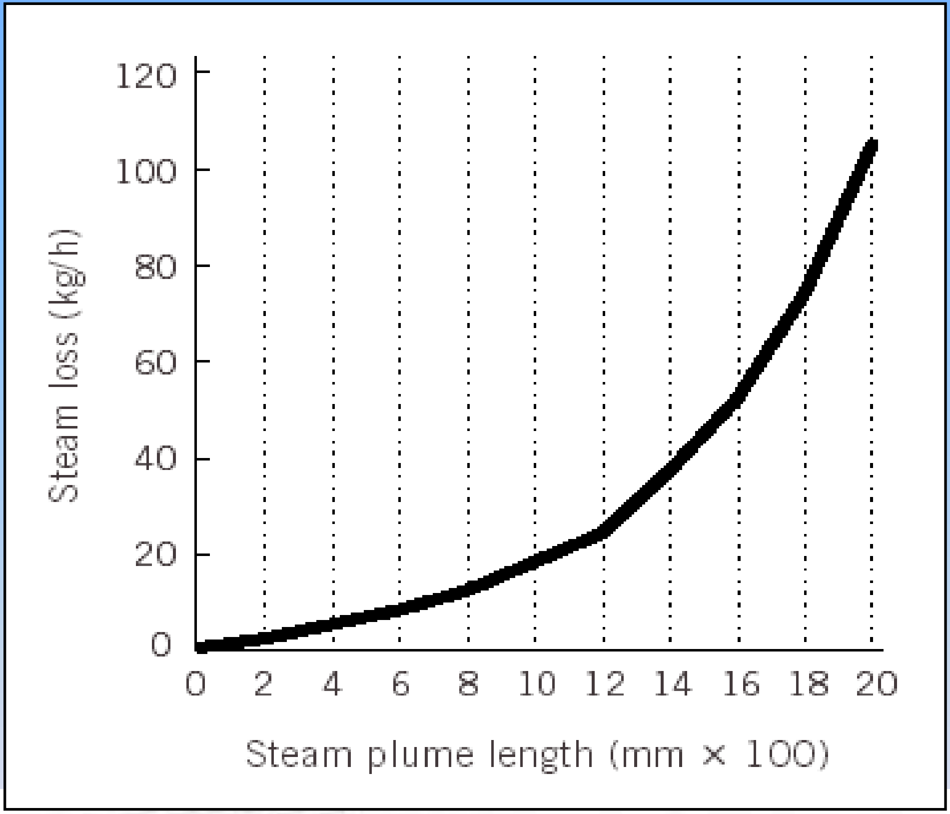
STEAM SYSTEM

Why steam is popular mode of heating?

- Highest specific heat and latent heat

  (water 1000 cal/kg C, Hg 33, alcohol 570)
- Highest heat transfer coefficient
- Easy to control and distribute
- Cheap and inert

1. Avoiding Steam Leakages



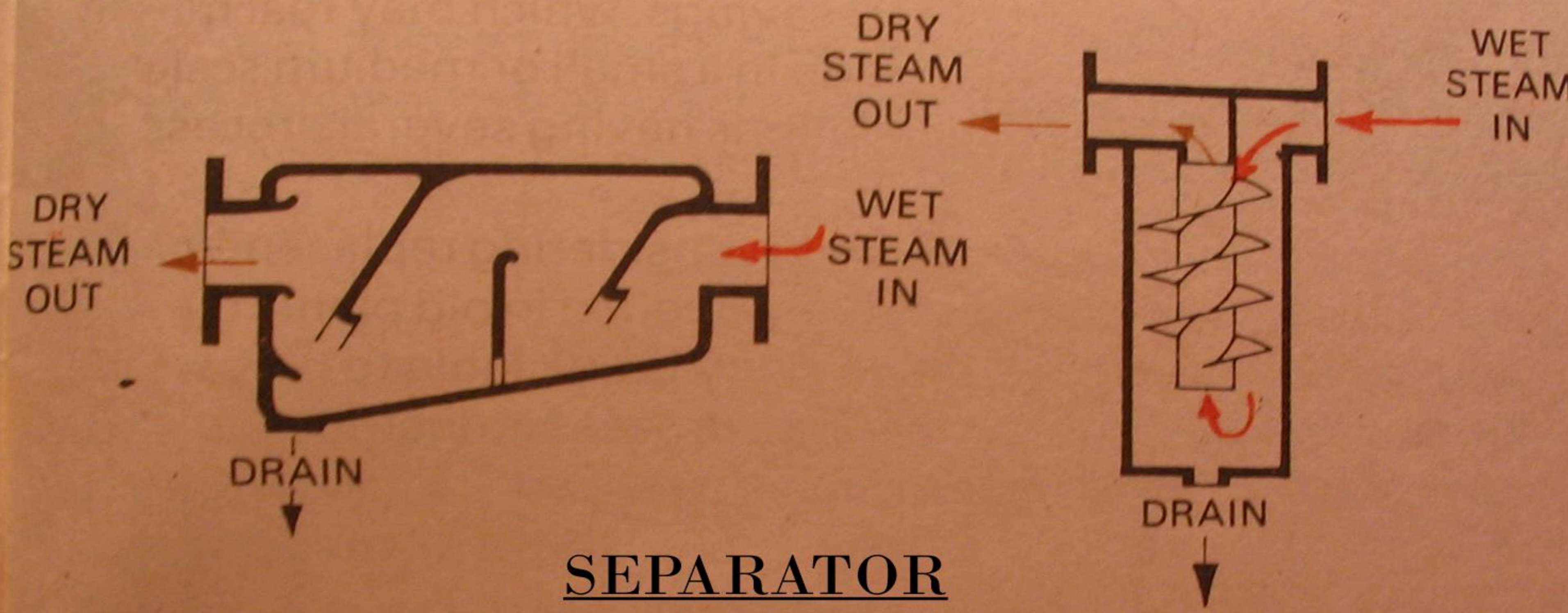
Example

Plume Length = 700 mm

Steam loss = 10 kg/h

2. Providing Dry Steam for Process

- **The best steam** for industrial process heating is the dry saturated steam.
- **Wet steam** reduces total heat in the steam. Also water forms a wet film on heat transfer and overloads traps and condensate equipment.
- **Super heated steam** is not desirable for process heating because it gives up heat at a rate slower than the condensation heat transfer of saturated steam

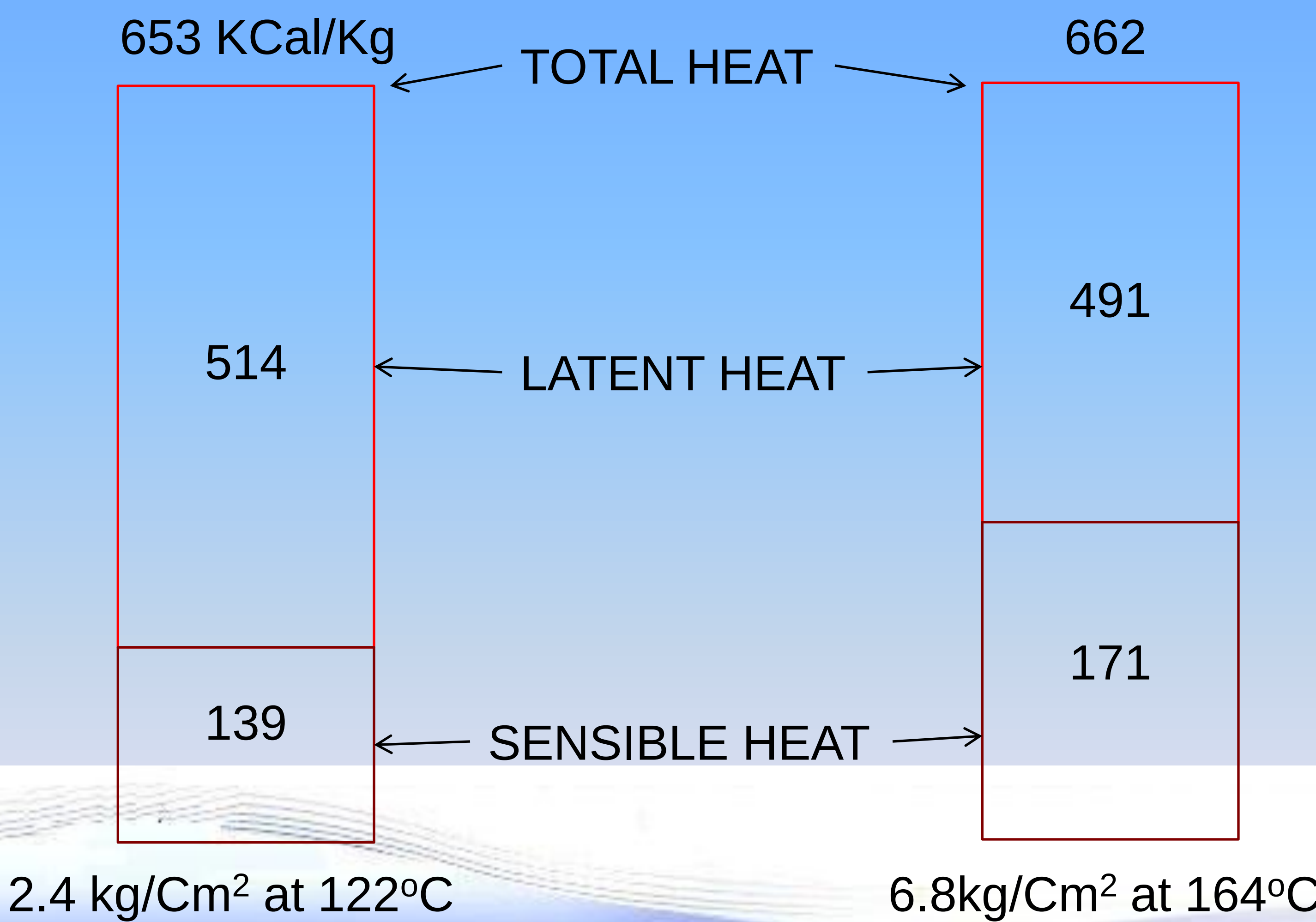

DRY
STEAM
OUT
WET
STEAM
IN
DRAIN
DRY
STEAM
OUT
WET
STEAM
IN
DRAIN

SEPARATOR

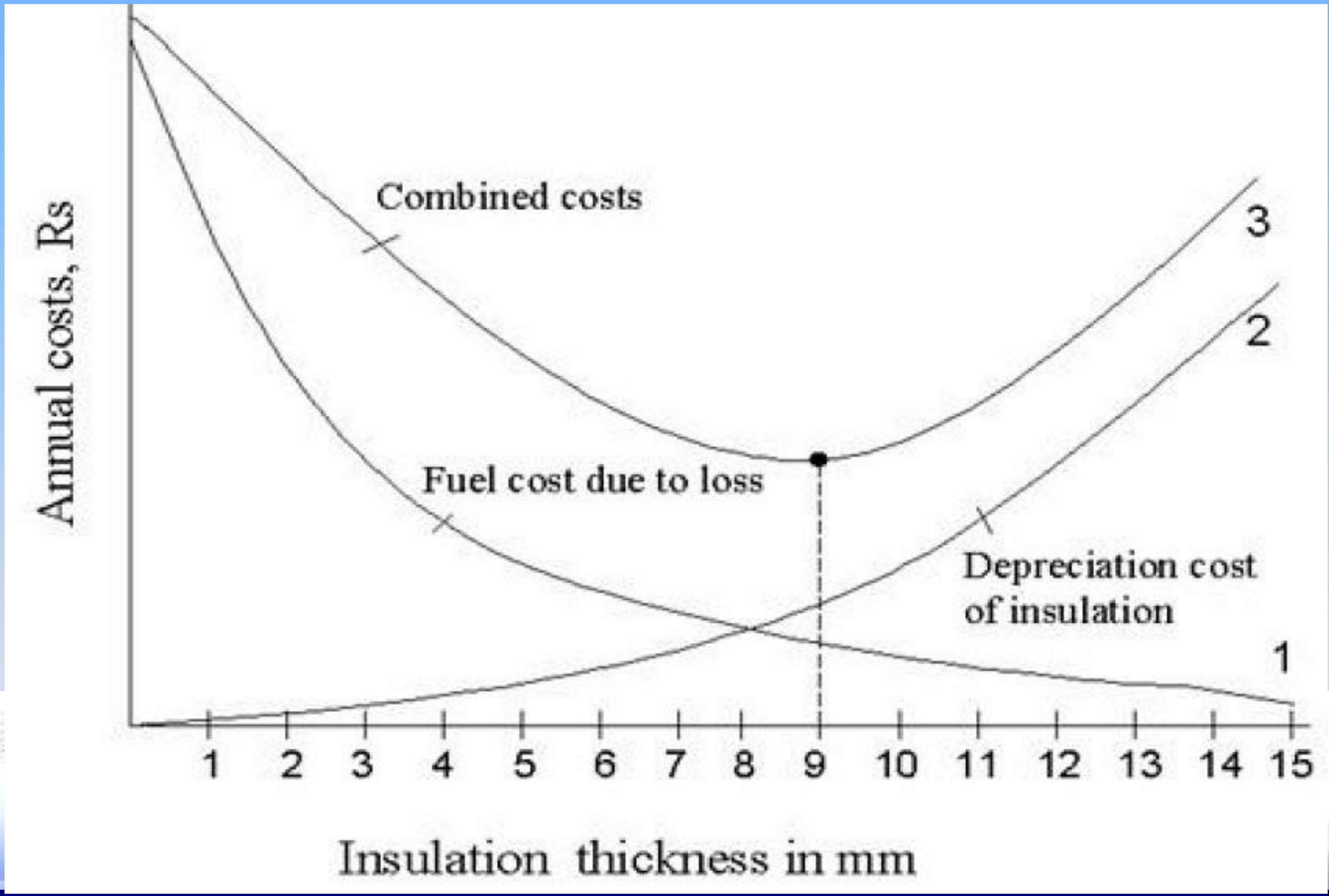
3. Utilising Steam at the Lowest Acceptable Pressure for the Process

- the latent heat in steam reduces as the steam pressure increases (next slide)
- but lower the steam pressure, the lower will be its temperature
- Therefore, there is a limit to the reduction of steam pressure

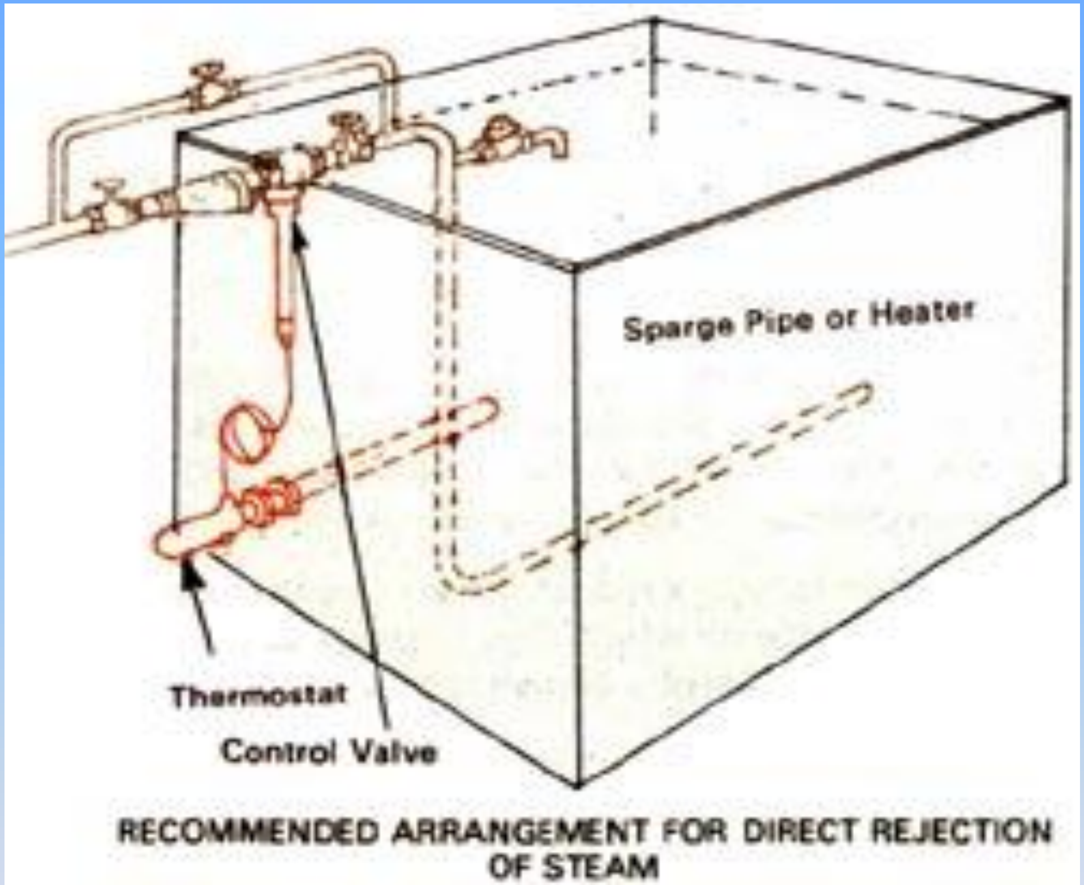
Latent Heat of Steam



Economic Thickness of Insulation (ETI)

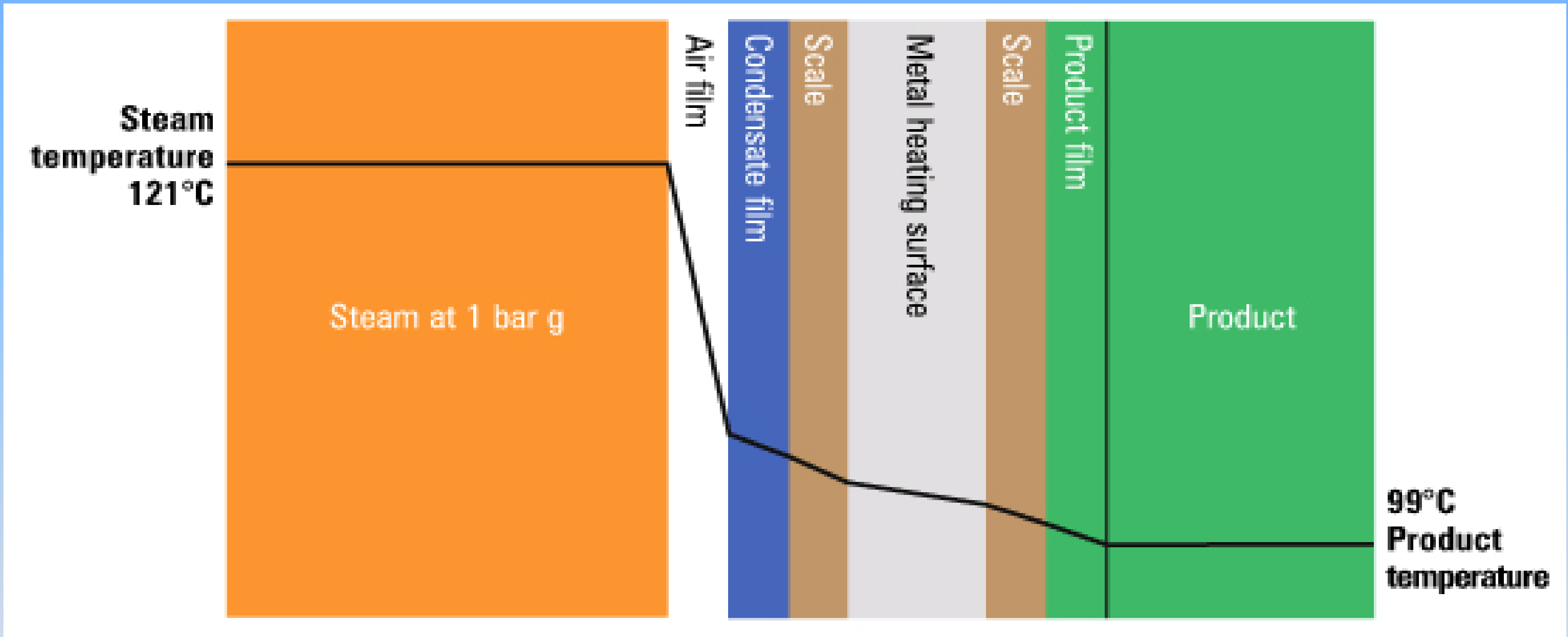


5. Proper Utilization of Directly Injected Steam



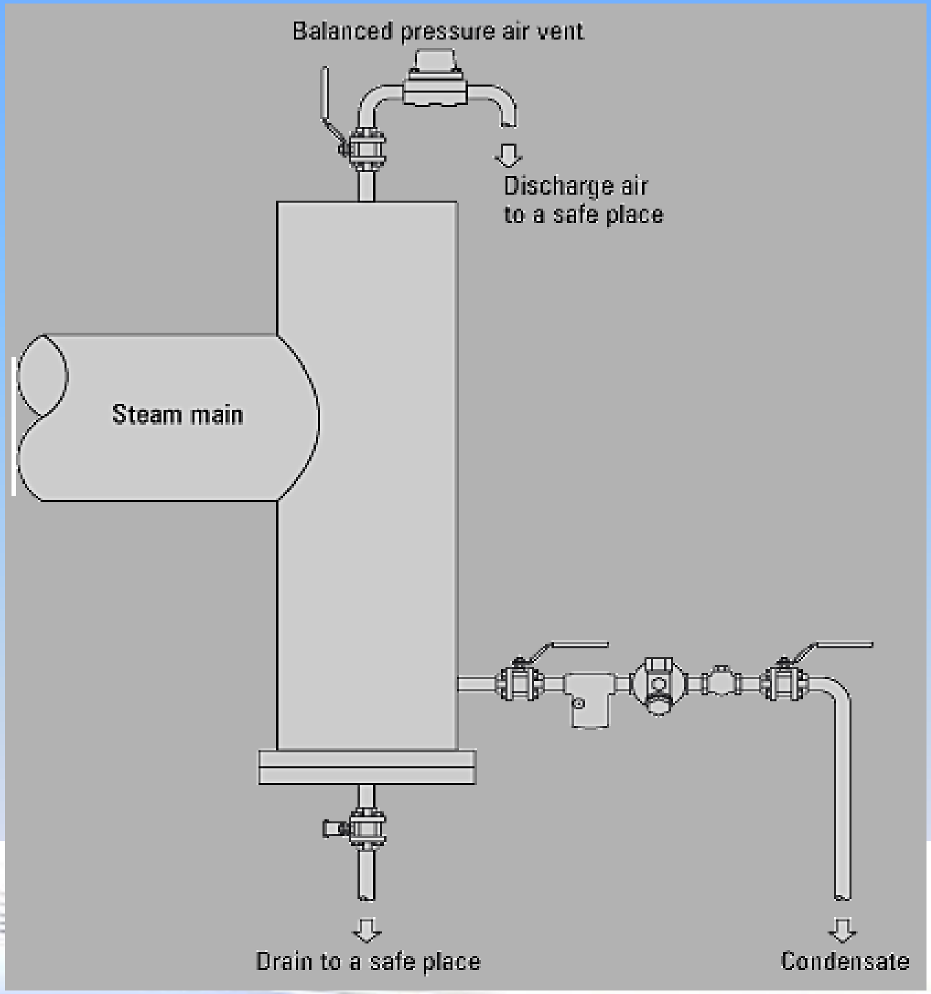
Direct Injection of Steam

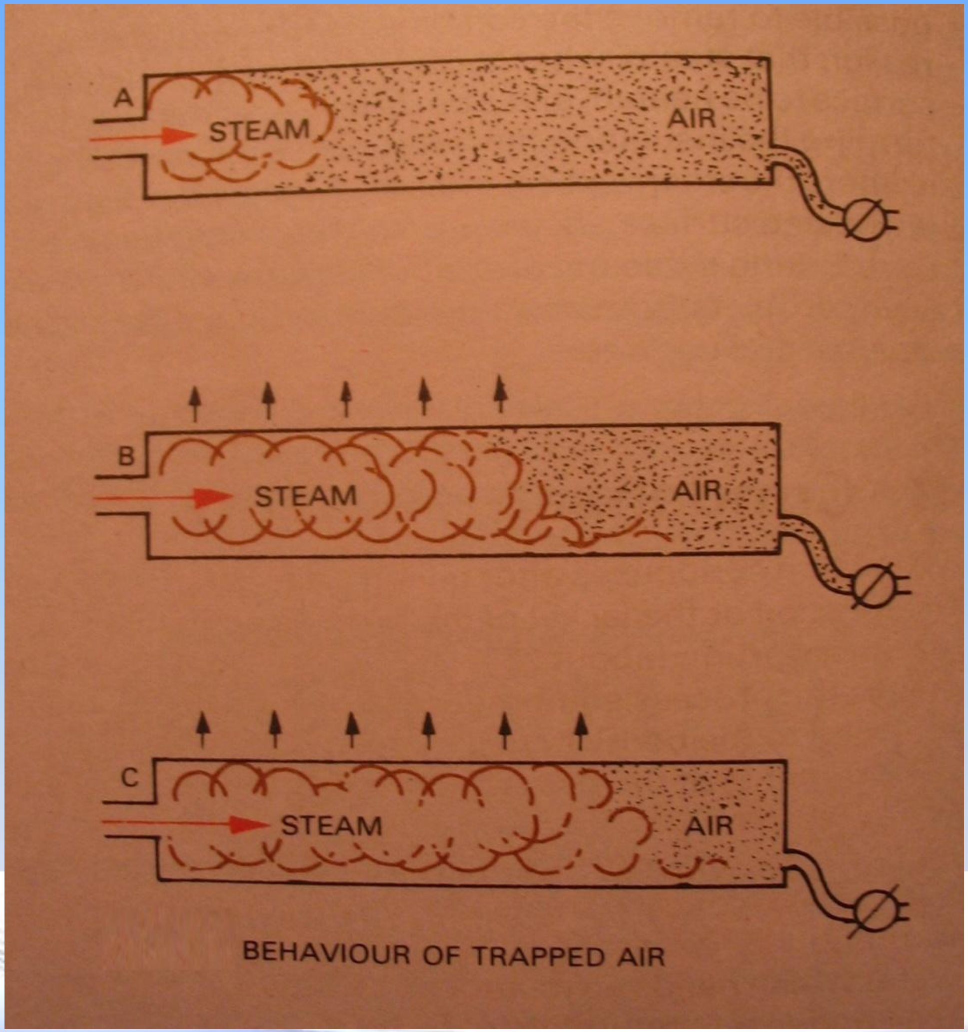
6. Minimising Heat Transfer Barriers



0.25mm air film equals 330mm copper wall

7. Proper Air Venting




A
STEAM
AIR
B
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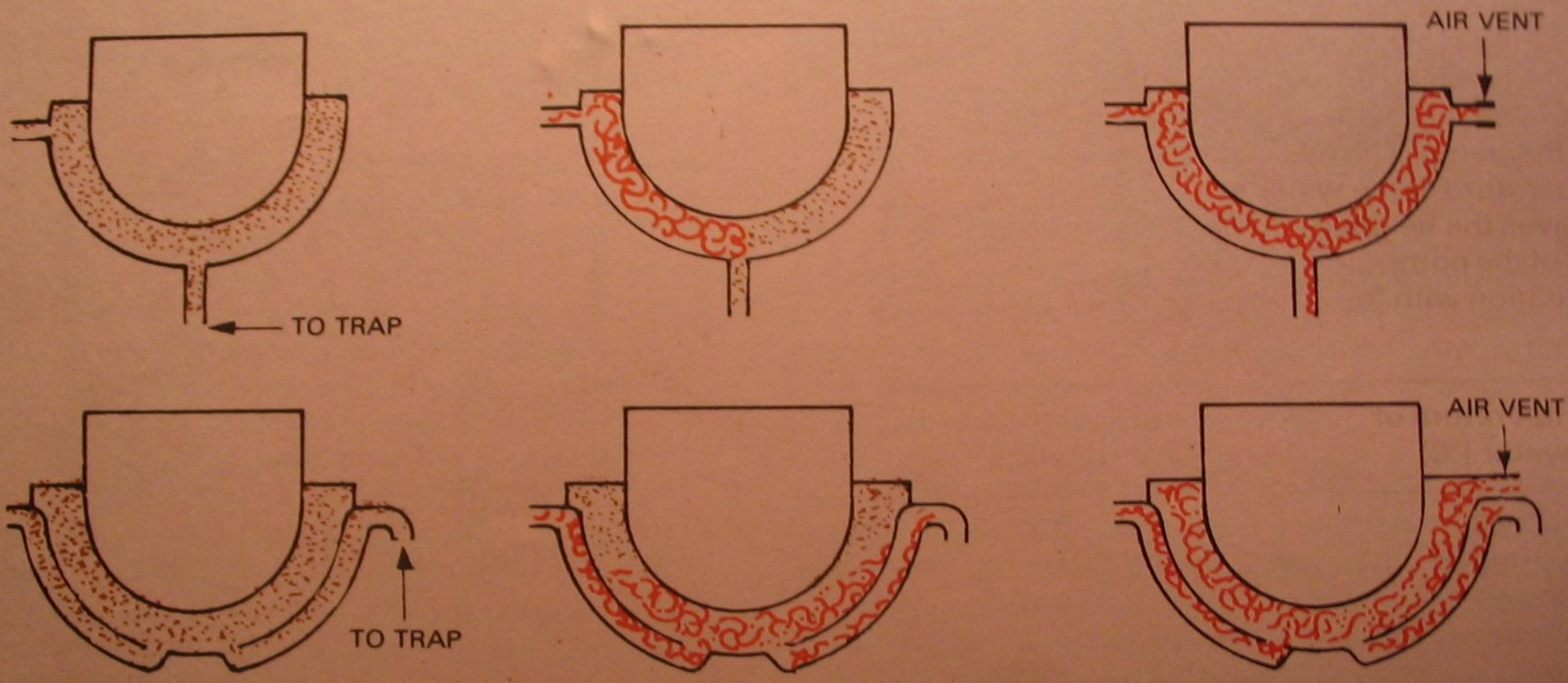
STEAM
AIR
BEHAVIOUR OF TRAPPED AIR

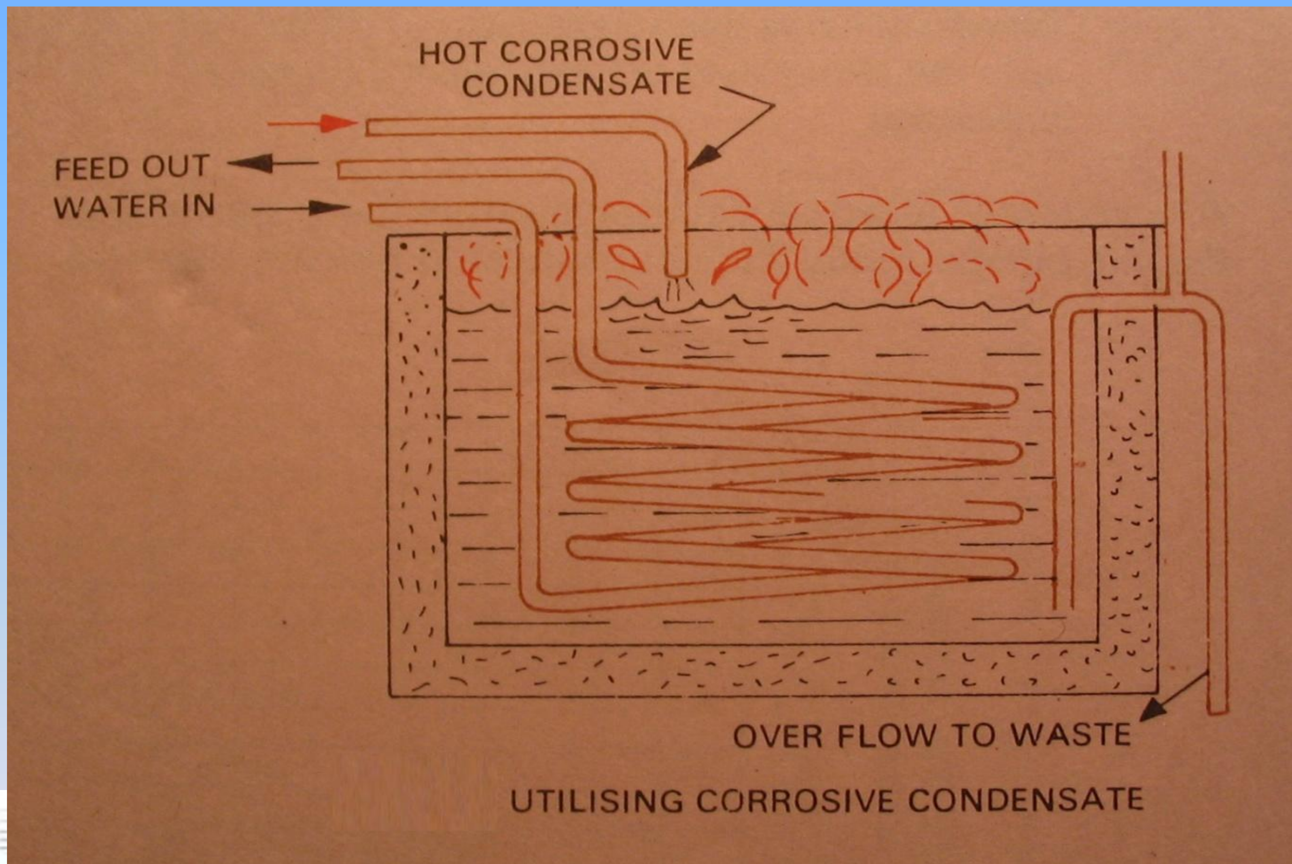


AIR VENTING OF STEAM JACKETED BOILING PANS

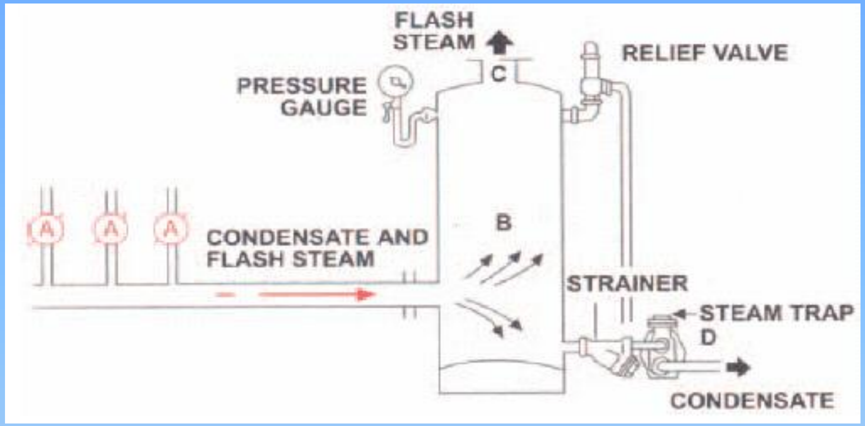
8. Condensate Recovery

- For every 6^0C rise in the feed water temperature, there will be approximately 1% saving of fuel in the boiler
- Condensate too hot – feed pump cavitation
- Get flash steam to meet economiser temp.
- Local use for very large plants
- Corrosive condensate

Scheme for corrosive condensate



9. Flash Steam Recovery

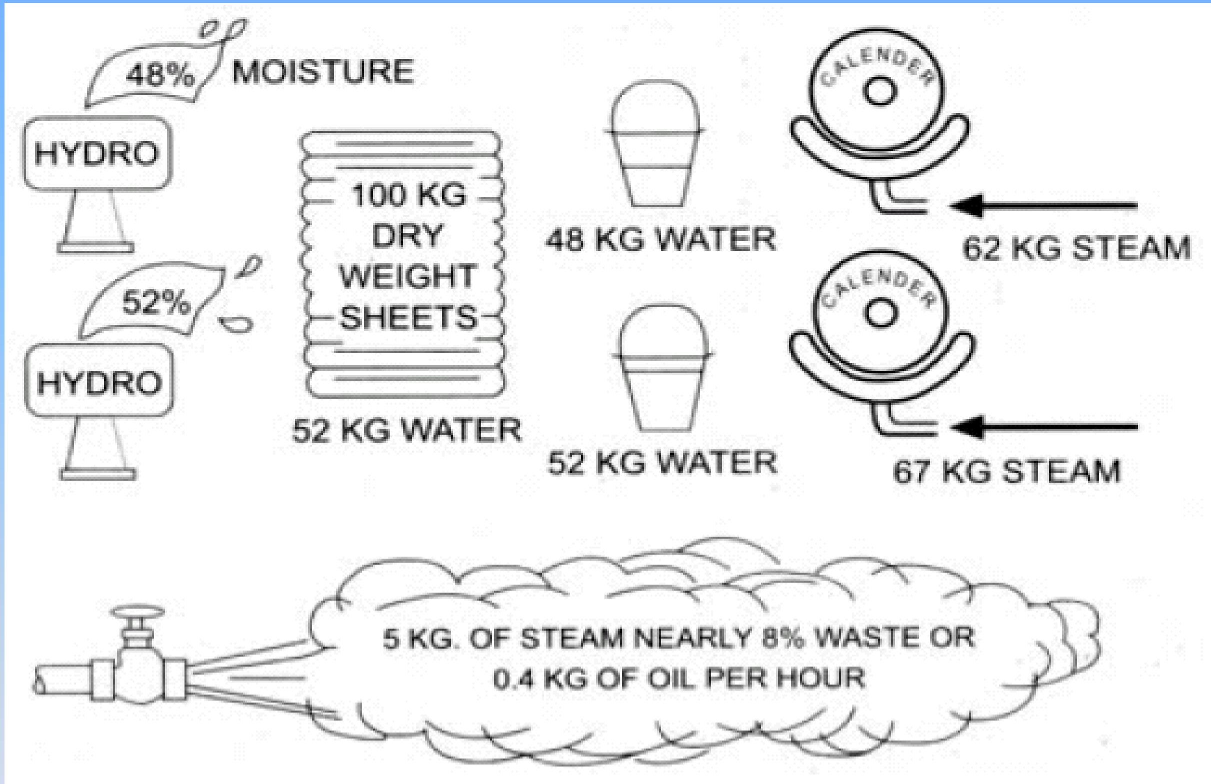


Flash steam available % = $(S_1 — S_2)/L2$

S_1 is the sensible heat of higher pressure condensate.
S_2 is the sensible heat of the steam at lower pressure (at which it has been flashed).

L_2 is the latent heat of flash steam (at lower pressure).

10. Reducing the Work to be done by Steam



11. Proper pipe sizing

If smaller, high pressure drop & steam starvation

If larger, higher installation cost & higher radiation loss

12. STEAM TRAPS

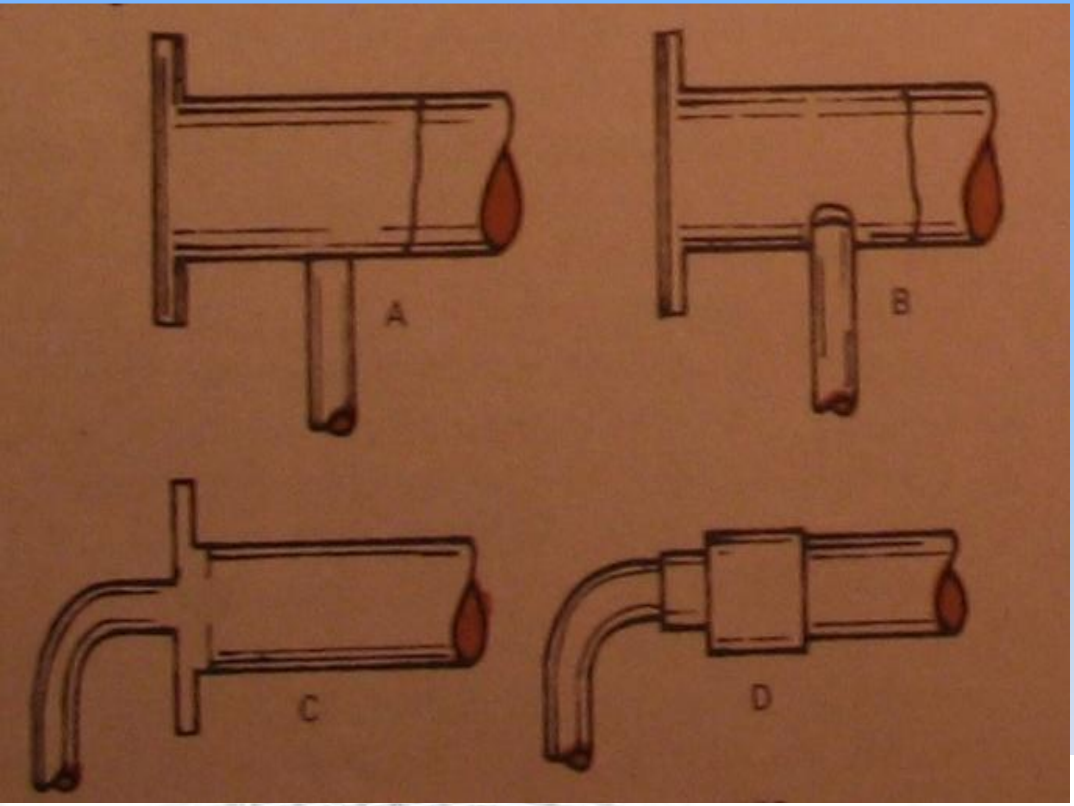
- Works by sensing difference between condensate & steam

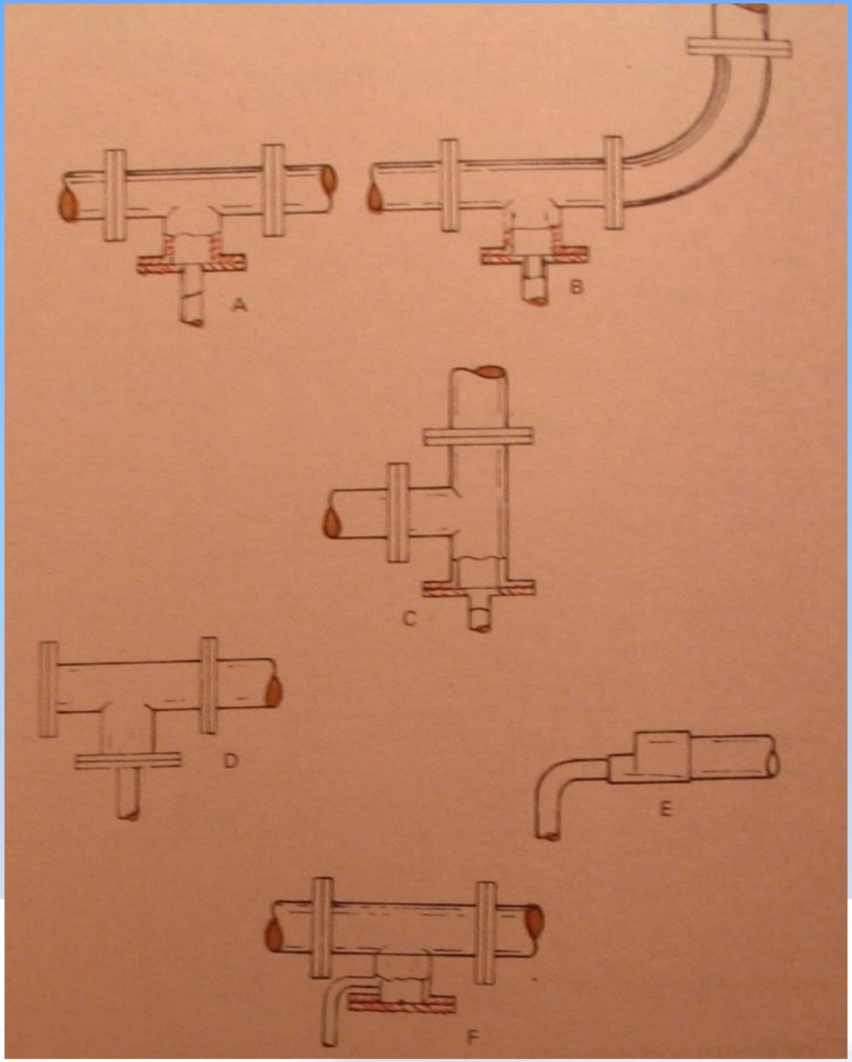
Classification :

1. Mechanical Traps – Operates on diff. in densities.
2. Thermostatic Traps – Operates on diff. in temps.
3. Thermodynamic Traps – Operates on diff. in flow properties

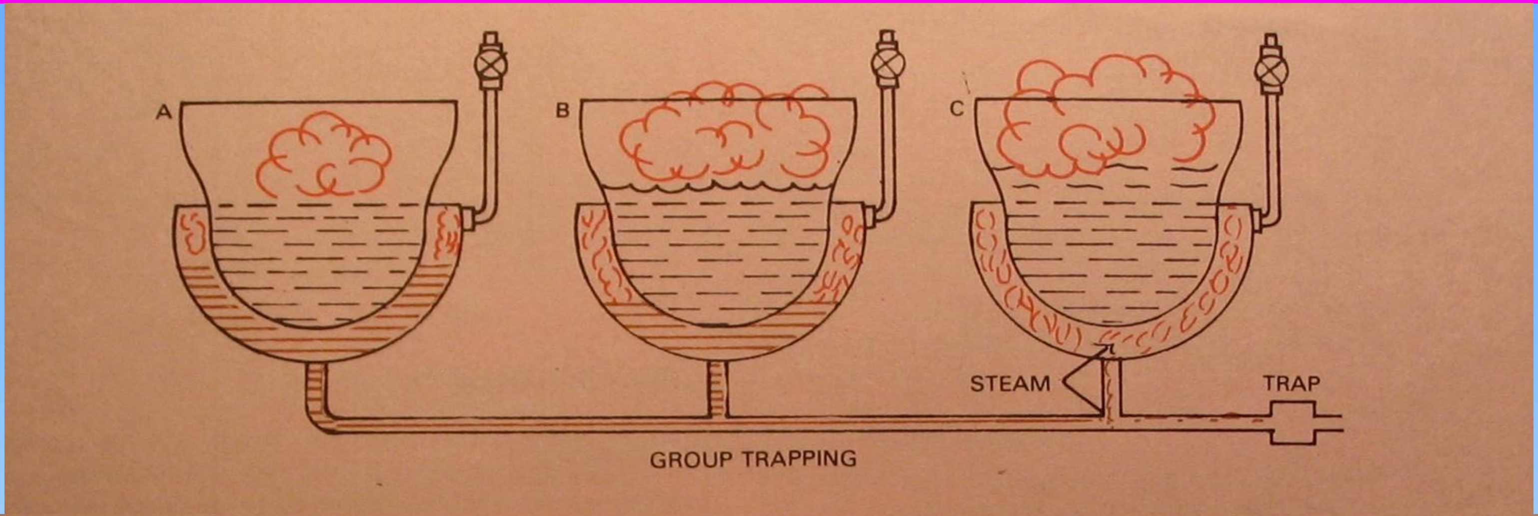
Important Points : Drain point, Pipe sizing, Air Binding, Dirt, Group vs individual trapping and Water Hammering.

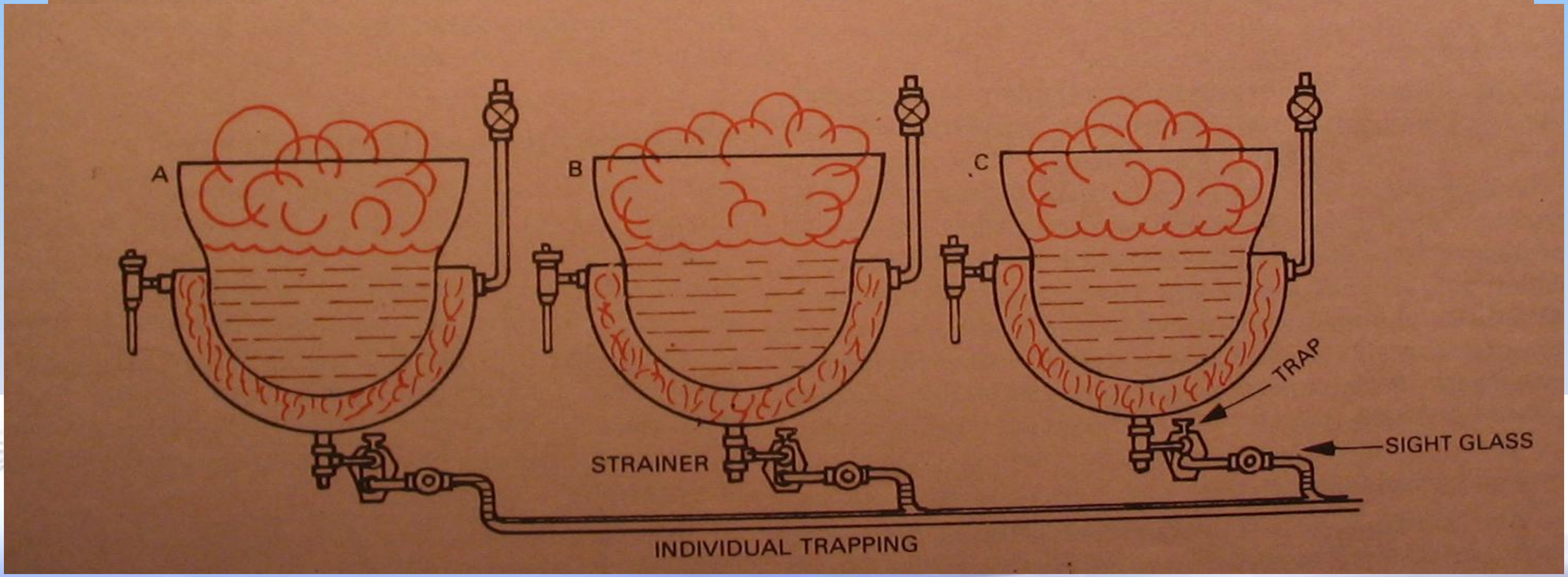
Drain Points





Group Trapping





Dirt