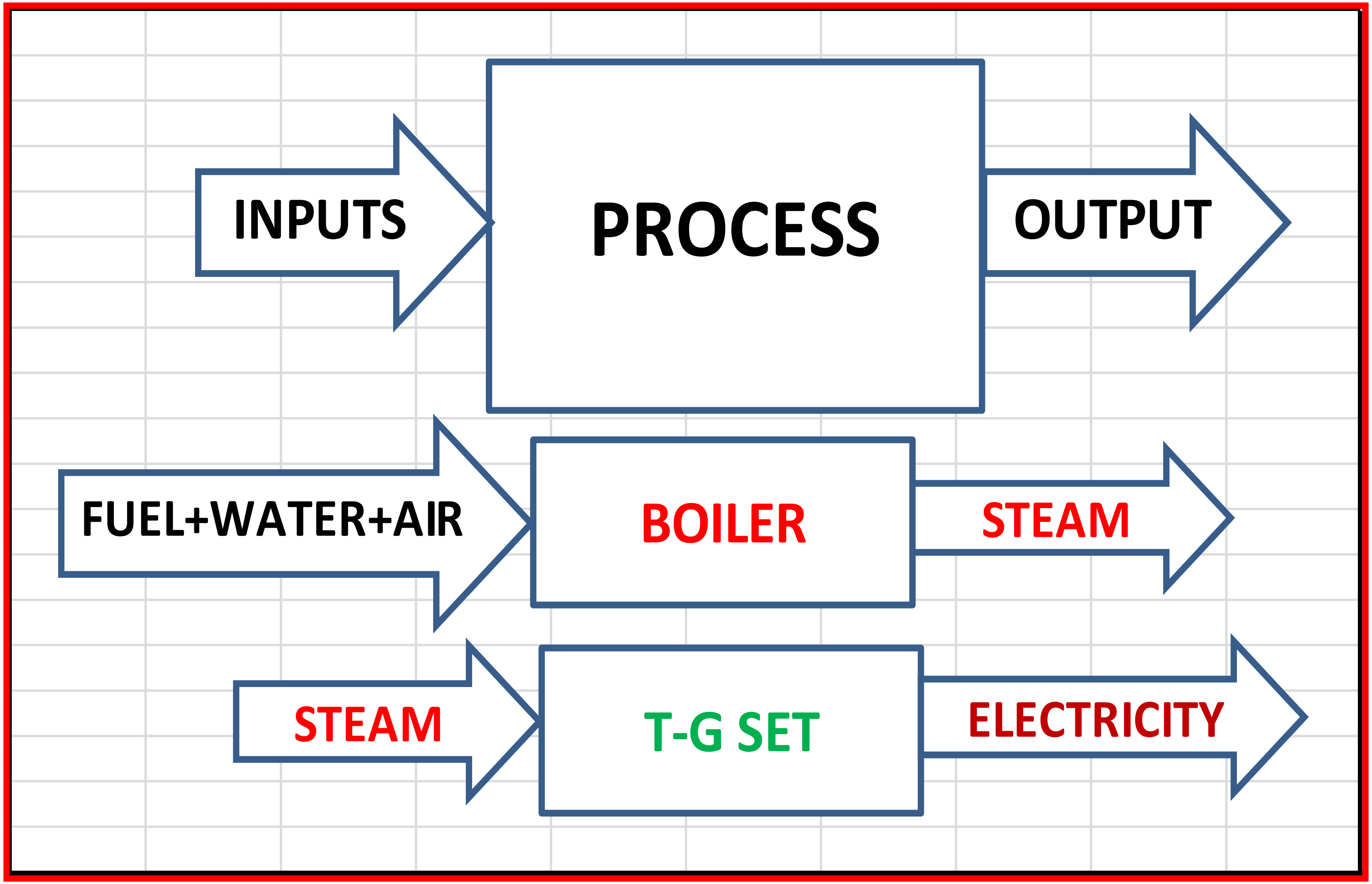
Steam Generator Design

PROCESSES


INPUTS
PROCESS
OUTPUT
FUEL+WATER+AIR
BOILER
STEAM
STEAM
T-G SET
ELECTRICITY

BOILER INPUTS & OUTPUTS

- FUEL – COAL – OIL – GAS
- CHP – OHP – Fuel GAS PLANT
- WATER – D.M. WATER
- COOLING WATER CYCLE.
- AIR – FANS- I.D. , F.D., P.A.
- OUTPUTS
- STEAM-
- GASES –
- ASH (B.A.+ F.A.)

PROCESS DESIGN

•Plant Size-Governing Factors-

•Land availability

•Water

•Fuel linkage

•Grid connectivity.

•Equipment Transportation logistics.

Suitable plant size can be fixed after considering above factors.

Main Elements of Power Plant

- BOILER- Furnace, Drum,Water walls, S/H, R/H, Eco, APH, ***Air & Gas*** Cycle. Ducting,ESP,***Chimney***
- Boiler Input :- Fuel + water + Air
- Coal Handling Plant-including Railway siding.
- D.M.Plant
- Boiler Output:-
- Flue Gas
- Ash Handling Plant
- Ash Dumping Pond.

Design Factors

- Functional capability. (Must be able to work as expected)
- Trouble free service
- Ease and Safety of O&M.
- Transportation Factor.
- Possible mis-handling.
- Factor of safety.

Coal Mills layout

- Mills in Front of the boiler- Coal mills are between the Turbine hall and the boiler.
- Very congested layout.
- Maintenance problems –Access difficulty.
- Dust problem in Turbine hall.
- Steam – Feed pipes are short.
- Gas ducting layout is simple and aerodynamic.

- Coal Mills in the back of the Boiler-
- Easy maintenance access.
- Dust problem in Turbine hall reduced.
- Steam – Feed pipes are longer.
- Gas duct between APH and ESP becomes complicated.
- Preferred layout.

Mills between two boilers

- As the length of a TG Set is much more than the width of a Boiler, lot of space remains between two boilers.
- Mills can be installed between two boilers to utilise this space.
- Compact mirror image layout.
- Separate drawings needed for each unit.
- Mostly used for smaller units.

BOILER DESIGN FACTORS

1. Capacity –Steam Flow Tons/Hour
2. Efficiency- 70% to 92 %(Depends on Type & size of Boiler)
3. Stoker / Pulverized / F.B.C./ C.F.B.C.
4. Steam Pressure – Sub Critical /Supercritical.
5. Steam Temperature
6. Flue gas outlet temperature
7. Fuel- Coal / Oil /Bio mass / Gas
8. Fuel Properties-Ash Fusion Temperature.
9. Redundancy for RELIABILTY
   (S/B coal mills/Pumps/Fans etc)

BOILER TYPES

1] **Stoker Fired**—Limited to 30 MW

1” size coal burns on grate.

grate size becomes too large for higher capacity.

Good coal essential. [C.V. > 4500 K.Cal/Kg]

2] **Pulverised Fuel--** 30-120-140-210-500-660 MW

Can handle poor quality coal .
No grate, Suspension Firing.
High combustion rate.
Fly-Ash problem.

DRY BOTTOM WET BOTTOM

Boiler types contd…

- 3] Fluidised Bed ---   5-10-30-60-100-200 MW
- Coal size is about 1/8th Inch.
- No Pulverisation, hence low fly-ash.
- Poor coals can be used.
- Ash is in slag form and handling is easier.

Boiler types contd…

- 4] Oil Fired—Gas-Fired [LNG]
- Only when Fuel oil/Gas was cheap, and available.
- No CHP, No AHP. NO Mills.
- Smaller size of the Boiler.

- For larger sizes and high combustion rates, P.F. boilers are preferred.
- We shall mainly discuss P.F. Boilers.

P.F. Steam Generator (Boiler) -Types

- Single pass -Tower Design - Height increases – Erosion in 2nd pass is avoided.
- Double pass – more conventional –most units are this type.
- Height is less so construction cost is less –also maintenance is easier.
- Coal mills –Location –
- Front - Rear - Sides.
- APH - Tubular or Rotary.

Main & Auxiliary Elements of Boiler

- BOILER- Furnace, Drum,Water walls, S/H, R/H, Eco, APH, ***Air & Gas*** Cycle. Ducting,ESP,***Chimney***
- Boiler Input :- Fuel + water + Air
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- D.M.Plant
- Boiler Output:-
- Flue Gas
- Ash Handling Plant
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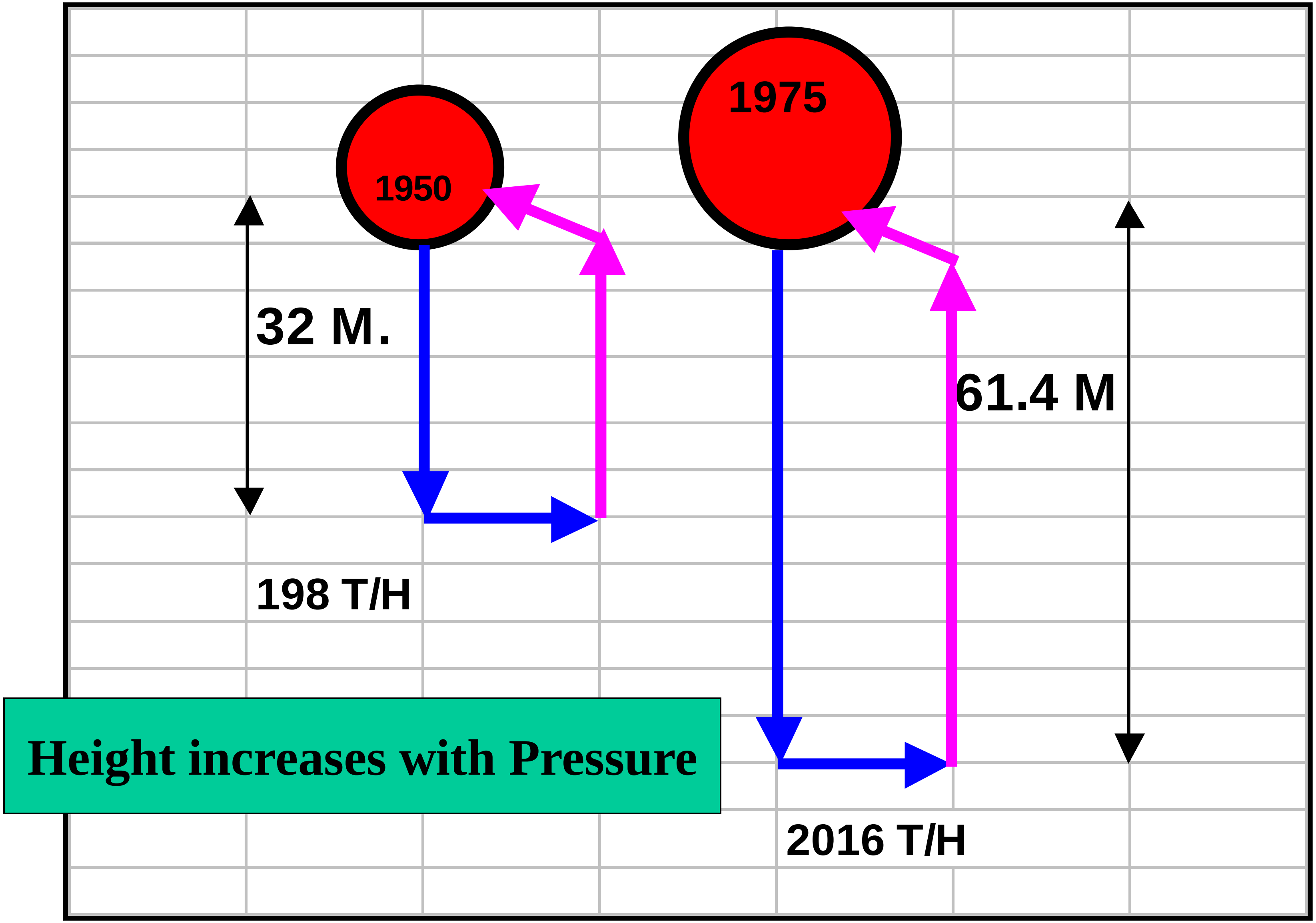
8. **Fuel Properties-Ash Fusion Temperature.**
9. **Redundancy for RELIABILTY(S/B coal mills/Pumps/Fans etc)**

Rising Sizes 1950 to 1975



What is to be designed ? ? ?

- Height of Boiler Drum.
- Depends upon design pressure.
- Furnace size for proper combustion i.e.
- Furnace width and depth.
- Distance between Neck and Highest Burner.
- Disposition of Super-heaters & Re-heaters
- Second pass heat transfer surfaces-
- Heat pick up in -
- LTSH and Economiser

Influence of FUEL & ASH

Once all other things are decided,the biggest factor to be considered is the influence of ASH on Boiler Design.

In India, many early units based on American/European design could not perform at design capacity as available coal was much inferior.

Now the practice in to INDIANIZE the design.

Example of Indianization

The 200/210 MW Boilers were of C.E.design.

In USA, for full load, only 3 coal mills were needed.

In India, we needed 4 mills in service with one s/b and one emergency s/b.

In practice many units run with 5 coal cycles in service.

This is due to lower GCV of coal used.

Influence of Fuel properties

1. Incombustible mineral matter (clay)is intimately mixed with combustible organic matter.
2. The mineral matter is the ASH.
3. Ash can be from 1% to 40 %.
4. 15-20% is Bottom Ash.
5. Rest is Fly Ash-collects in ESP.
6. Some ash deposits on heat transfer surfaces in the Boiler.

Boiler Slagging

- Ash has Basic and Acidic components.
- Slagging Index=R(b/a)=Ratio of Basic/Acidic components.
- This index for Bituminous Coals –0.2 to 0.4.
- For P.F. Boilers maximum value is 0.5.
- Slagging Index =R(b/a)
- $=(Fe_2O_3+CaO+MgO+K_2O+Na_2O) / (SiO_2+Al_2O_3+TiO_2)$

Alternate Index.

R'(b/a)=R(b/a) x % Sulphur

The basis for this is that part of Sulphur is pyrites(FeS).

When heated, its residue acts as a fluxing agent.

High values of R'(b/a) may cause severe slagging.

Ideal Situation

Coal from one source = **Slag tap design**.

Here, 85% ash deposits as running slag and is removed as Bottom Ash.

Advantages-

1. Reduced fouling in convection zone.
2. Smaller E.S.P.

Unfortunately coal comes from different sources and such slag-tap design is not possible.

ALTERNATIVE-Dry ash design.

Ash should ***not*** flow and ***sinter***.Should be easily removed by soot blowing.

Dry Ash Design.

1. Ash impacting on heat transfer surfaces should be below I.D.T.(Initial Deformation Temperature).
2. For this it is necessary to have –

   Short residence time.and

   Oxidizing atmosphere.(i.e. shortage of Oxygen)

   But the needs of **complete combustion** are exactly opposite.

   (Adequate residence time & proper excess air)

   In P.F. boilers, rise in CO content shows REDUCING conditions.(Incomplete combustion due lack of Oxygen)

   This happens at about 16 % Excess air.

   So Oxygen must be around 3.5 %.

Slagging Risks

1. Falling slag damages the hopper slope.
2. Bridging of NECK can occur.
3. In Front fired boilers, Slagging occurs around area cooled by secondary air
4. Burners not in service may be choked by slag.

Radiant S/H and R/H.

1. These are exposed to high radiant heat flux.
2. If ash temp.is above IDT, it will deposit here.
3. Thermal impedance increases.(due to ash layer)
4. This leads to higher ash surface temperature.
5. Results in sintering of ash deposits,and running slag ash.
6. If soot-blowing can not remove this, the deposits will increase.
7. Bridging may take place.

Precautions

- Spacing in radiant zone > 600 mm.
- If large deposits form, shut down & water jetting.
- Keep Platen metal temp. below 625 deg. C.

Convection Heating Surfaces.

Na, K, and Sulphur oxides can react to form alkali sulphates which deposit on the tubes.

Then fly ash forms a porous sintered deposit.

Corrosion then starts. There are whitish layers (50-70% sulphates) on tubes.

And the outer brown layers of fly ash get cemented by 20-40% pyro-sulphates.

Residual Fuel Oil

- **R.F.O. contains Vanadium, Sodium & Sulphur compounds.**
- **These can form large deposits in high temp. convection zone.**
- **Deposits increase corrosion.**
- **HENCE OIL FIRED BOILERS HAVE FINAL STEAM TEMP. BELOW 540 DEG. C.**
- **In high Calcium Coals (Ca>7%), insoluble calcium deposits can build-up on Economiser tube fins.**
- **Normal soot blowing is not effective.**
- **Special provisions are necessary.**

Conclusions

- A boiler can not be designed for all types of coal.
- Disposition & Configuration of heating surfaces depends upon fouling properties of fuel.
- Transverse pitch in Radiant S/H & R/H must be large enough to avoid blockage due to ash build-up.
- In this zone, ash temp. is above I.D.T.
- In convection zone, pitch is smaller but proper soot-blowing should be possible.

Conclusions-2

- Gas velocities must be within limits to control corrosion.
- Max. Flue gas velocity <15 Meters/Second.
- Pressure drop depends upon tube dia, tube spacing, No. of tubes –wide and deep.
- For Oil Fired Boilers-gas velocities can be higher as no ash erosion.
- But with Residual Fuel oils, the Na & V compounds cause tube fouling & corrosion.

Types of water walls

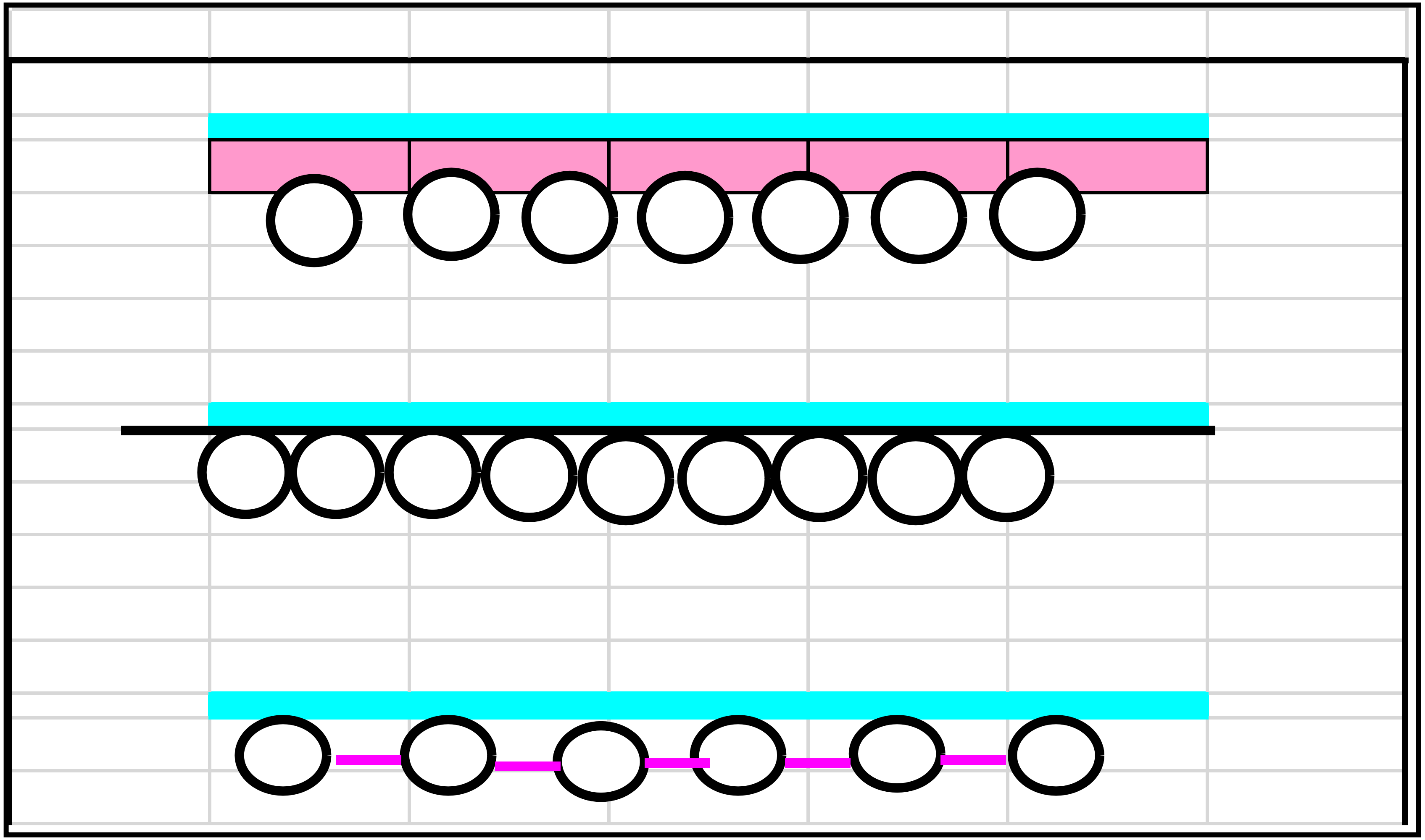
1. Gap between tubes-Refractory behind the tubes+Rock wool.(Partial Shielding)

2 .Tangent tubes-No Refractory, Skin casing+ Rock wool insulation.

3. Finned tubes-Similar to tangent tubes. Maintenance access to tube is easy.

   Erection is faster.

WATER WALLS



Furnace Ratings

Type of Firing	Opposed	Front	Corner	Corner	Oil Opposed
M.C.R. Load	660	500	500	350	660
No.of Furnace Chambers	2	1	2	2	2
Heat Release upto Nose-Projected area Kw/M2	551.9	544.7	502	433	753
Heat Release upto Nose-Volumetric Kw/M3	211	196.3	228	207	342
Plan Area MW/M2	5.7	5	5.05	5	8
Residence Time Seconds	2.4	2.5	2.29	2.28	****
Dist.from top burner to Nose	12.65M	13.4M	9.75M	11.12M	***
Platen Pitch	0.762M	0.616M	0.609	0.663	**

SIZE COMPARISON		
FUEL	OIL	COAL
HEIGHT	1	2
WIDTH	1	1,2
DEPTH	1	1.14

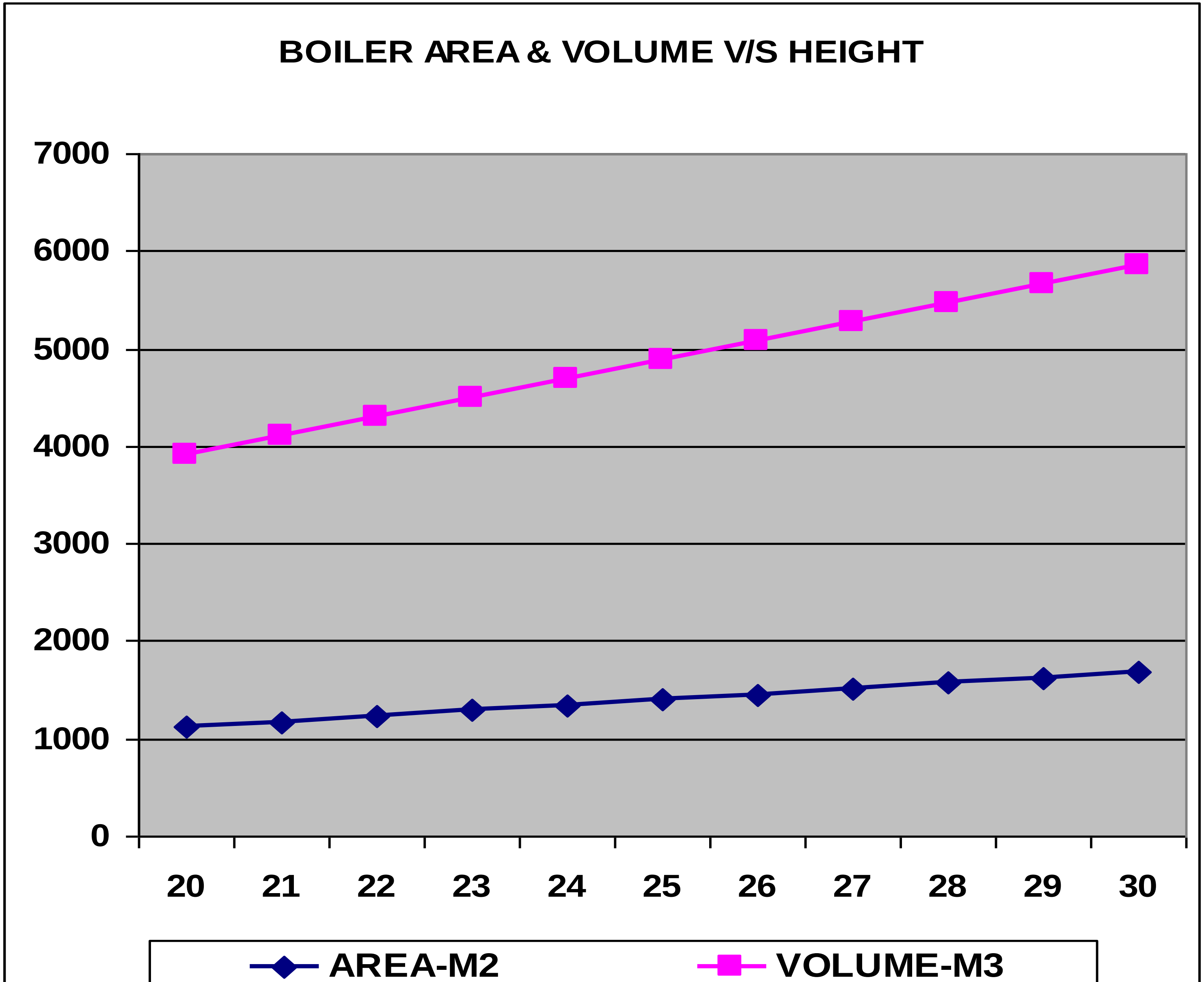
COAL furnace is bigger than OIL Furnace, because-

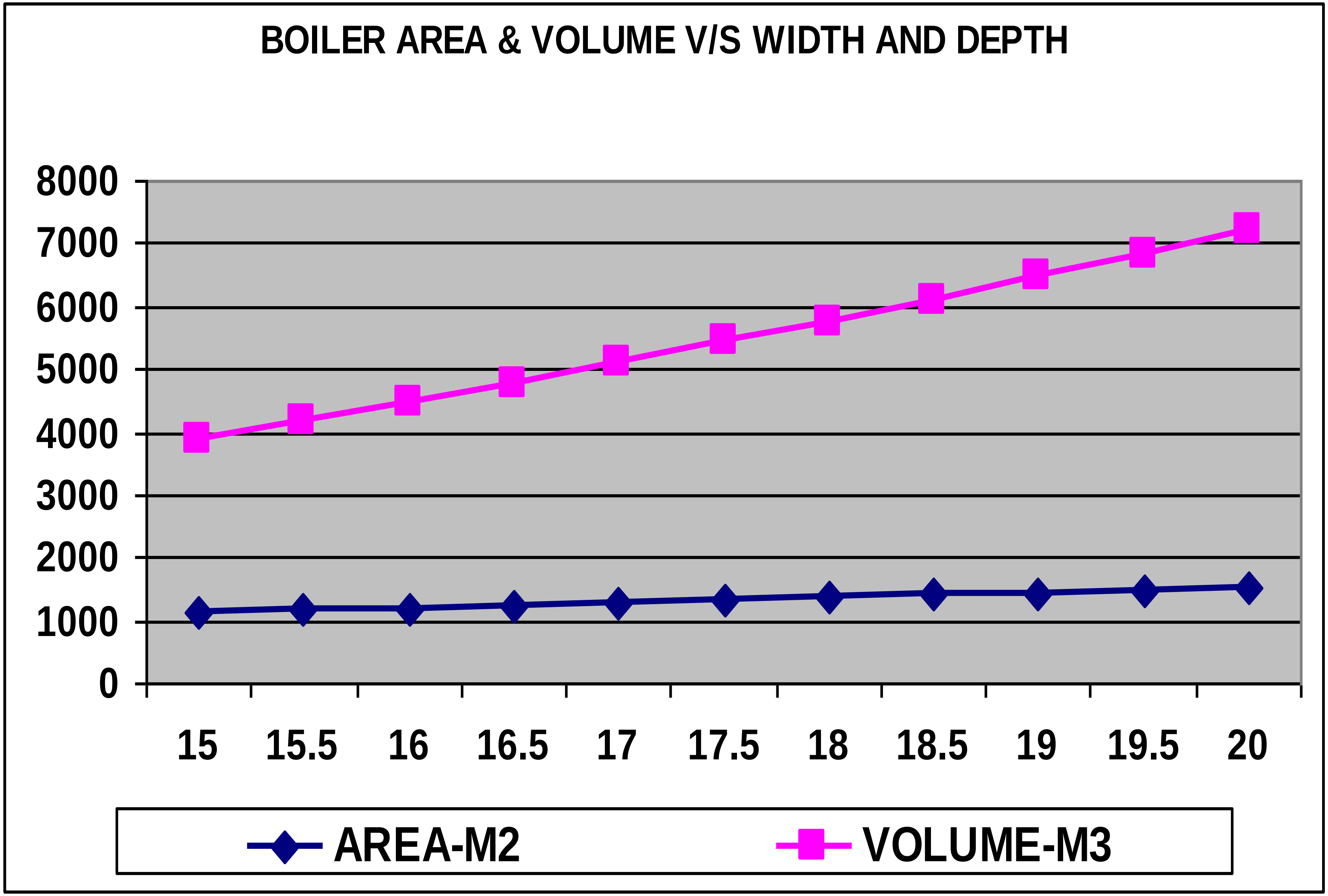
1]P.F. Particle burn out time is more.

2]Heat transfer is affected by ash deposits

Balance topics for Boiler Design

1. Furnaces
2. P.F.Burners-Types & Location
3. P.F.Milling Plant
4. Oil Burners-Types & Location
5. Arrangement of Oil Handling Plant.


BOILER AREA & VOLUME V/S HEIGHT
7000
6000
5000
4000
3000
2000
1000
0
20
21
22
23
24
25
26
27
28
29
30
AREA-M2
VOLUME-M3


BOILER AREA & VOLUME V/S WIDTH AND DEPTH
8000
7000
6000
5000
4000
3000
2000
1000
0
15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
AREA-M2
VOLUME-M3

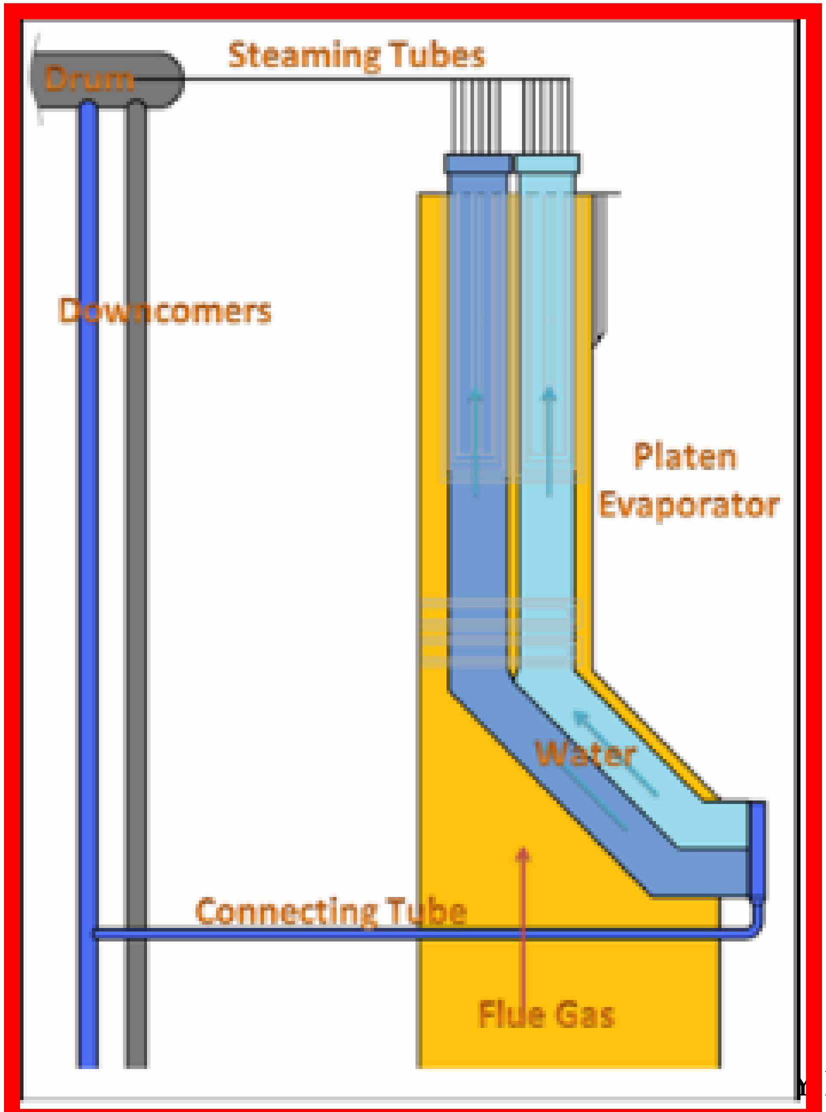
Matching Volume with Heating Surface

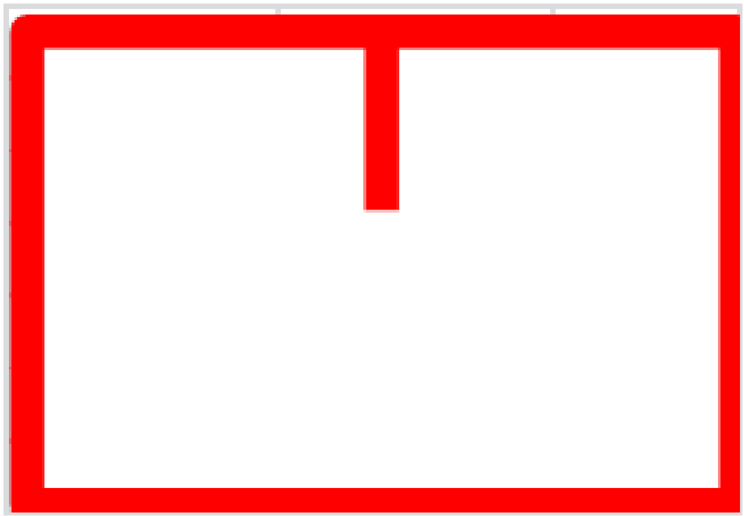
- As heating surface needs increase, the volume rises faster, which is not required.
- To add heating surface without increasing the volume , novel methods are used.

1. Water Platen – It is at the top of the furnace and water recirculates from drum. (like the water walls)
2. Partial Dividing wall on rear wall,

   for a front fired boiler.

Platen Evaporator –And Dividing Wall Schematic





CONDUCTION HEAT TRANSFER

Heat flow by conduction is given by

$$\mathbf{q = K*S*(t1-t2)/\ L}$$

Where q = heat flow in Kilo Calories per Hour

K = Thermal conductivity of metal of 1 cm thickness, K.Cal./Sq.Mtr/degC./Hr.

S = Heating surface in Sq.Meters.

L = Thickness of plate in CM.

K/L is expressed as CONDUCTANCE. And,

L/K is the RESISTIVITY.

Conductors & Insulators

Metals have high thermal conductivity and are used for heat transfer applications.

Certain materials have poor thermal conductivity and are used for Insulation (Rock wool, Glass wool , Magnesia.)

Liquids also conduct heat by conduction just like the metals.

Conductivity of FLUIDS is much less than the metals.

(Liquids & Gases transfer heat more by convection)

Gases –Thermal conductivity increases with temperature and is practically constant over the range of pressure in a boiler.

Hydrogen has comparatively high conductivity and is used for cooling of Generators.

CONVECTION

Convective Heat Transfer from a SOLID to a FLUID as in a Boiler,is expressed as –

q = U * S * (T1-T2)

Where,

U = Convection film conductance in K.Cal./ Sq.Mtr /Deg.C./Hr.

S = Heat Transfer Area in Sq.Mtrs.

(T1-T2) = Temperature difference between Hot surface and Bulk fluid .

Free Convection

When a fluid at rest is heated at one point, the temperature near that point rises and density reduces.

So hot fluid starts rising and colder fluid takes its place, and gets heated in turn.

This is FREE or NATURAL CONVECTION.

In Forced Convection, the fluid is moved by external driving force.

Water walls in a boiler may have heat transfer by Natural Convection or Forced Convection.

Heat loss from Boiler outer casing to ambient air is by Natural Convection

Forced Convection

Here the fluid is moved by external means like fans, pumps etc.

Most of Heat Transfer in a Boiler is of this type.

Some dimensionless numbers are important in Forced Convection.

1) Reynold's Number = (density x velocity x diameter) / absolute Viscocity.

The flow is LAMINAR when Reynold's No. is below 2000.

Above 12000 , the flow becomes turbulent.

Between 2000 to 12000, (transition zone), the degree of turbulence will vary.

The BOUNDRY LAYER THICKNESS reduces as flow becomes turbulent . This increases the HEAT TRANSFER.

Reynold's Number

$$\text{REYNOLD'S No.} = \frac{\rho \cdot V \cdot D}{\mu}$$

ρ = Fluid Density

V = Fluid Velocity

D = Pipe Diameter

μ = Absolute Viscosity

Prandtl Number

PRANDTL No. = $C_p \times \mu / K$

C_p = Sp. Heat at Constant Pr.

μ = Absolute Viscosity

K = Thermal Conductivity

It signifies the ability of the fluid to transfer heat.

Statnton Number

STANTON No. = $U_c / \rho \cdot V \cdot C_p$

U_c = Convective Film Coeff.

ρ = Fluid Density

V = Mean Velocity

C_p = Sp. Heat at Constant Pr.

Nusselt Number

NUSSELT No = $U_c \times D / K$

U_c = Convection film Conductance

D = Pipe diameter

K = Conductivity of fluid.

$$\text{NUSSELT No} = \frac{U_c \times D}{K}$$

$$= \left[\frac{U_c}{\rho \cdot V \cdot C_p}\right] \times \left[\frac{\rho \cdot V \cdot D}{\mu}\right] \times \left[\frac{C_p \cdot \mu}{K}\right]$$

$$= \left[\text{STANTON No.}\right] \times \left[\text{REYNOLD'S No}\right] \times \left[\text{PRANDTL No.}\right]$$

Radiant Heat Transfer

When Radiation is incident on a body –

1)Some radiation is ABSORBED –Absorptivity.(A)

2)Some radiation is Reflected –Reflectivity. (R)

3) Some radiation is Transmitted – Transmittivity (T).

And (A) + (R) + (T) = 1

Good absorbers are good emitters of radiation.

In thermal Equilibrium , Absorption = Emission.

A BLACK BODY absorbs ALL radiation incident upon it and hence, Reflectivity & Transmittivity of a black body is ZERO.

Radiation

Radiation emitted by a **Black Body** depends upon its Absolute Temperature and Surface area.

Stefan Boltzman Law-

$$q = \sigma . S . T^4$$

q – Rate of Heat Flow

σ – Stefan-Boltzman-Constant

S – Surface area of body

T – Absolute Temperature of the EMITTER

For bodies other than perfect black bodies, the heat transfer is given as

$$q = \sigma \cdot \epsilon \cdot S \cdot T^4$$

Where, ϵ is Emmissivity of the body.

For two PARELLEL PLANES

$$q = \sigma \cdot S \cdot (T_1^4 - T_2^4)$$

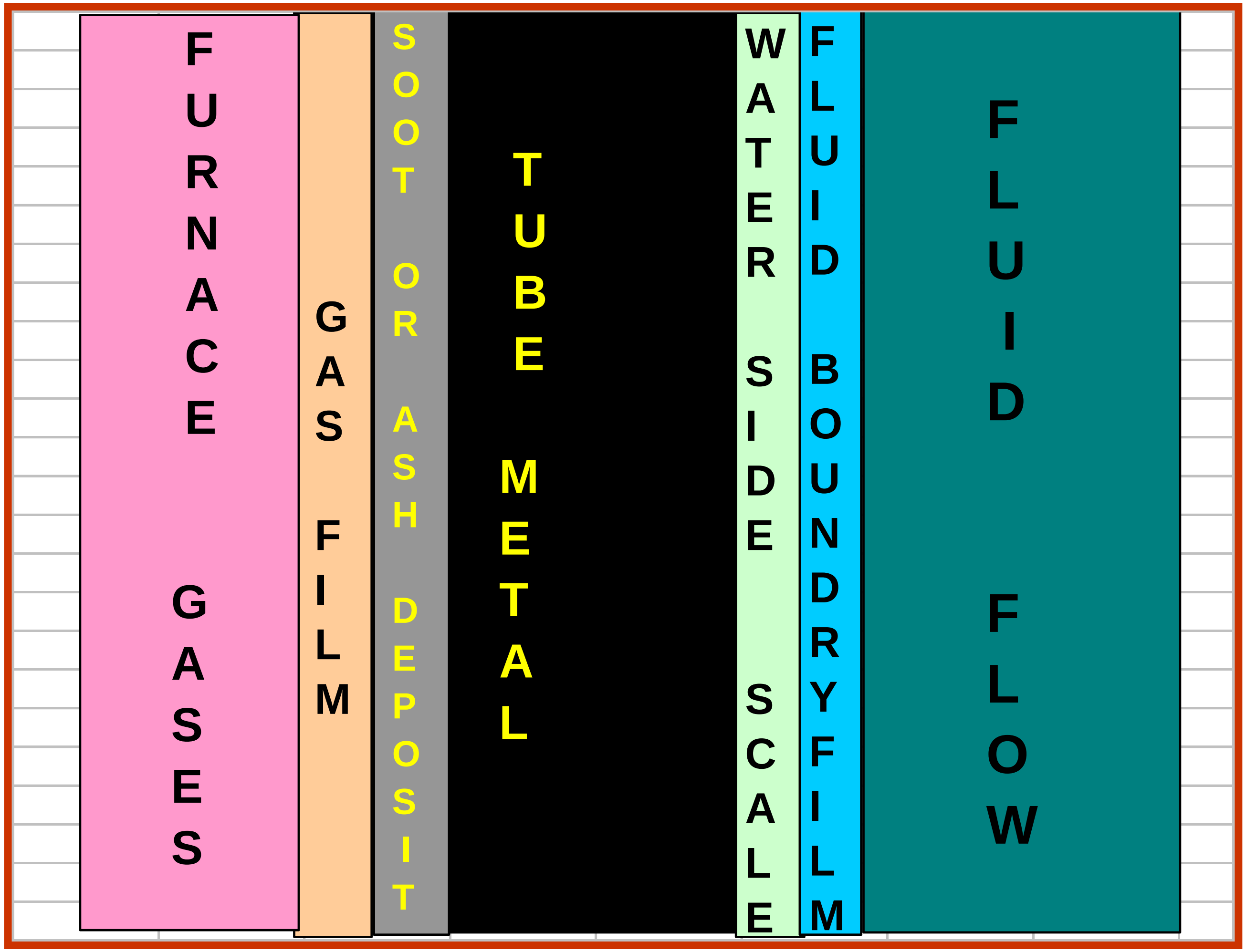
If the Planes are not Parellel, an Angle Factor is introduced.

Heat Transfer From Furnace to Fluid

The HEAT of the flue gases passes through –

Gas film,ash layer,Tube thickness,scale,fluid boundary layer –

to the FLUID on other side



Arrangement of Heating Surfaces

In a Boiler, there may be –

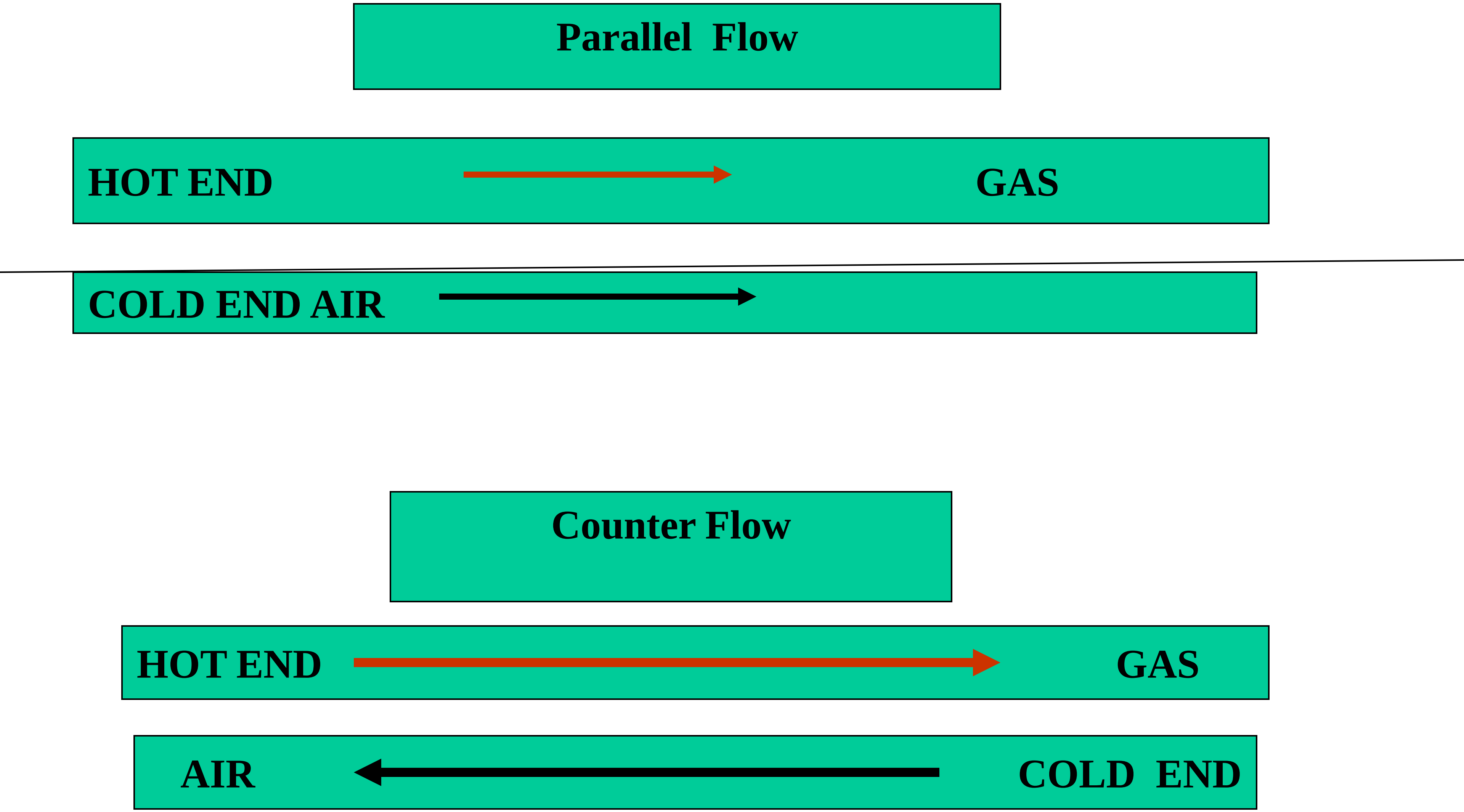
1. Parallel Flow – Flue gas and Fluid flow in the same direction.
2. Counter Flow – They flow in opposite directions.
3. Cross Flow – Gas flows ACROSS the fluid flow.

Efficiency of heat transfer is highest in COUNTER FLOW.

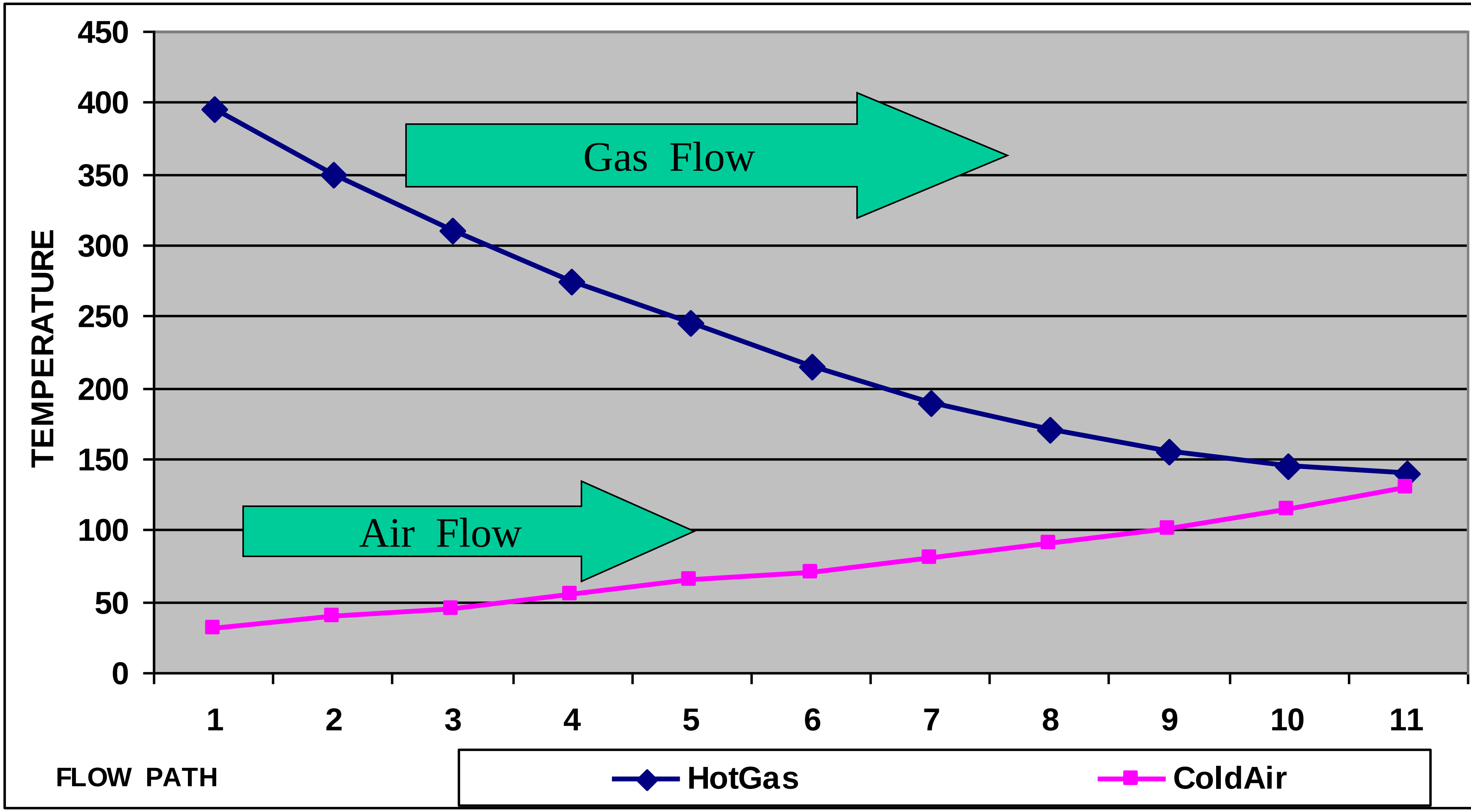
The maximum temperature of Cold side can be higher then Minimum temperature on Hot side.

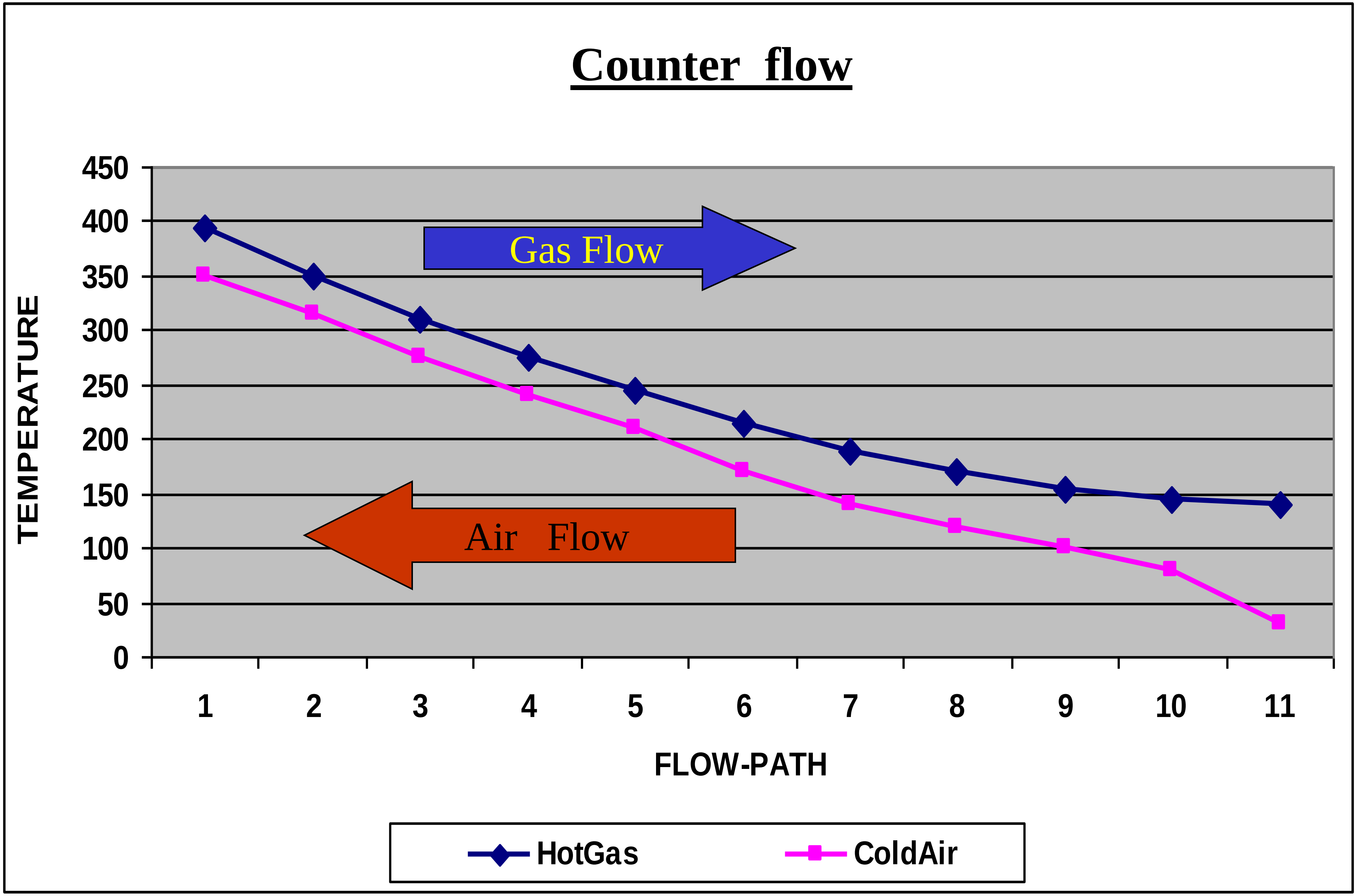
This is not possible in Parallel Flow.

Heat Transfer –Parralel Flow & Counter Flow.

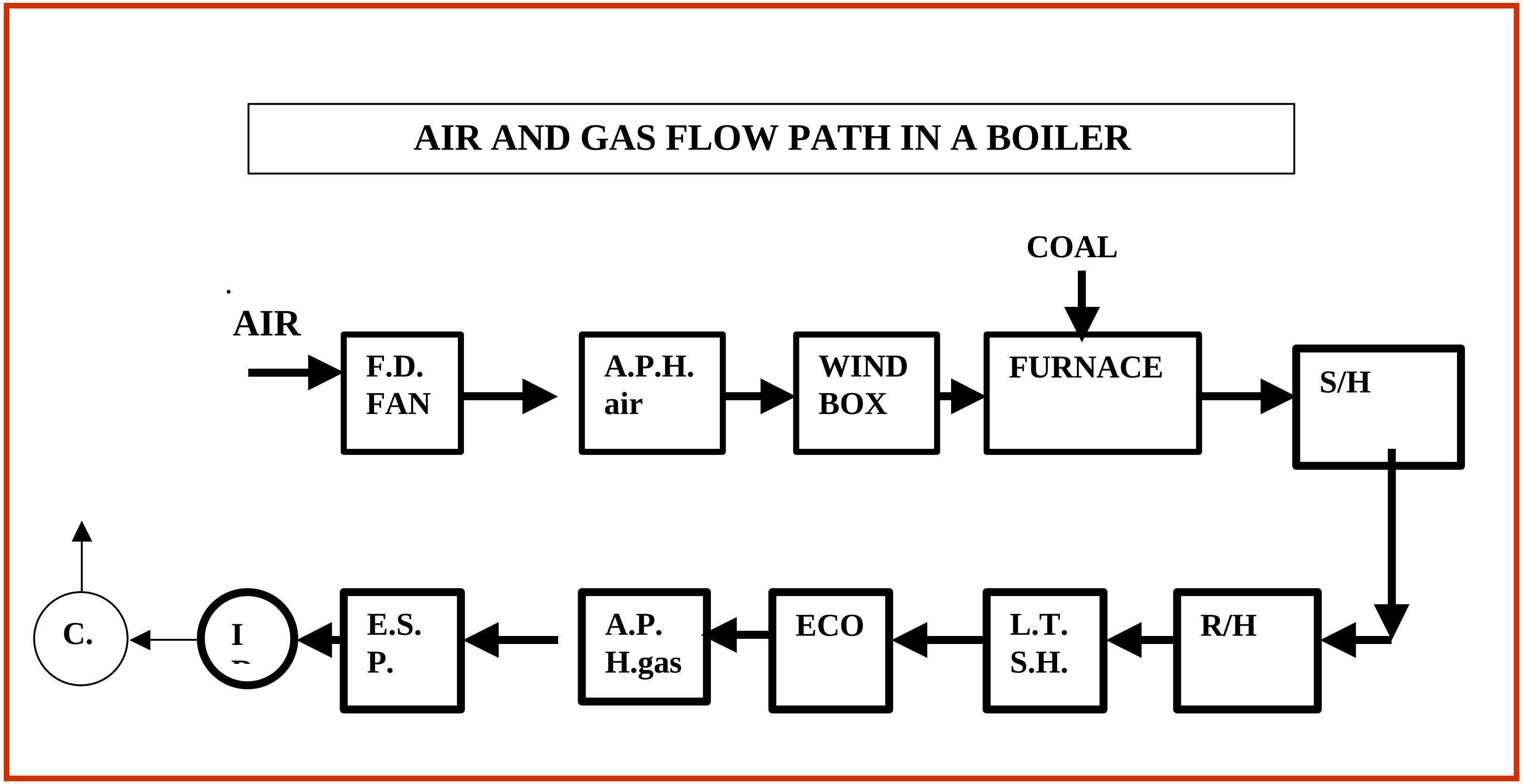


PARALLEL FLOW




Counter flow
Gas Flow
Air Flow
TEMPERATURE
450
400
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
FLOW-PATH
HotGas
ColdAir

AIR&GAS FLOW-PATH



Lanes & Heat Absorption

Lanes in Tube Banks may reduce heat absorption.

Lanes act as BYPASS for the hot gases.

Overall heat transfer decreases but due to higher mass flow through the Lanes, higher heat absorption takes place in adjacent tubes.

Overheating of Superheaters and Steaming in Economiser can occur.

Hence Lanes are avoided.

When a tube coil fails (Tube Leakage) and has to be plugged.

The failed coil should be left in place to avoid lane formation

Insulation & Heat Loss

This is like Heat Transfer through a composite wall.

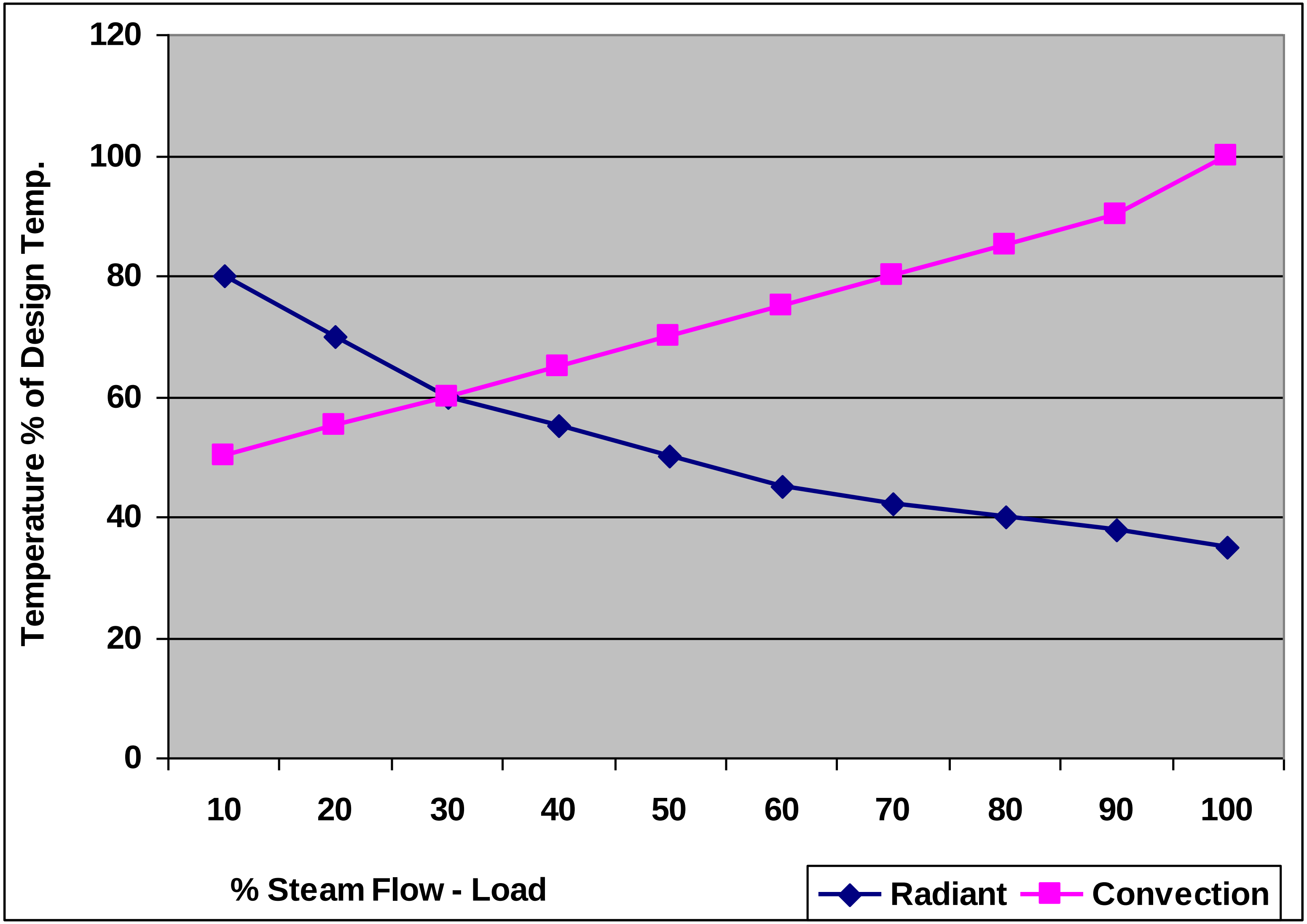
Thicker Insulation will reduce loss but will increase the cost.

Regulation requires that the insulation must be adequate to keep the outer surface temperature below 49 deg.C.

Calculation of heat loss by radiation and convection is very complex.

Standard tables based on past data are therefore used to estimate this loss and it is called Radiation Heat Loss.

Radiant & Convection Superheaters



Effect of Excess Air

Excess air **cools** the Furnace. **Reduces** Slagging.

Heat Transfer to **Radiant** S/H and W/W s **reduces**.

But, due to higher mass flow, the **gas velocity increases** and heat transfer in **Convection** Zone **increases.**

S/H temperature can be controlled by excess air.

BUT, the dry flue gas loss will increase.

Re-circulation of flue gas ***after*** economiser to the Furnace will give the same result.

Loss of efficiency due to excess air is avoided by re-circulation of Flue gases.

Combustion System & Fans

From the composition of fuel we can calculate the air required for combustion.

For example 1 Kg of Carbon needs 11.54 Kg of AIR for theoretical combustion.

Similarly air required for other constituents of coal can be calculated.

By adding the excess air we know the total air required.

Add the weight of fuel and we get the gas flow.

Boiler Efficiency

B.S.2885 –1974 and ASME Power Test Code 4.1 define the method to determine efficiency of a Boiler.

Gross Efficiency = Output / Input.

Output = Heat energy absorbed by the working fluid.

Input = Chemical energy in the fuel.

Fuel input measurement is very difficult and is possible only for the existing units.(Used for Acceptance Test)

So, Heat Loss method id adopted.

Efficiency = 100% - % Losses.

BOILER LOSSES.

1. Dry Flue gas loss.
2. Loss due to absorption of latent heat by the moisture in fuel (surface +Inherent)
3. Loss due to formation of H2O by burning of H2 in fuel.
4. Moisture in air loss.
5. Loss due to un-burnt fuel.
6. Loss due to sensible heat in boiler rejects (ash).
7. Radiation Loss.
8. Unaccounted loss + manufacturer margin.

Fan sizing

Fans are needed to supply combustion air to the furnace and also to take away the flue gases.

Centrifugal & Axial fans are used,\.

A fan imparts boost energy to a gas to raise its pressure.

The rise in pressure is utilised for movement of the gases.

Fan performance is given by Flow x Head characteristic.

To Select a Fan

We need to know –

1. Air / Gas Flow (Kg / Hr , or Cub.Meter / Second)
2. Density – Kg./Cub.Meter.(Function of temperature & Pressure)
3. System resistance (Head loss)

System resistance is calculated by aerodynamic studies for losses in the ducts and other parts of the boiler.Recommended gas / air velocities are assumed for sizing the ducts.

Important Fans

1) F. D. 2) I.D.3) P.A.;and 4) Gas Re-circulation fans.

There are many more fans but these are the crucial fans for the boiler.

FORCED DRAFT FAN – Supplies atmospheric air at ambient temperature for combustion to the furnace.

It can be sized to overcome all the boiler path resistance.(Forced Draft).

Or, Just to put the air in the furnace (Balanced Draft).

System resistance includes loss in –

Ducts, APH and Wind box.

Speeds vary from 600 to 1500 RPM.

Boiler & Fans - Schemetic

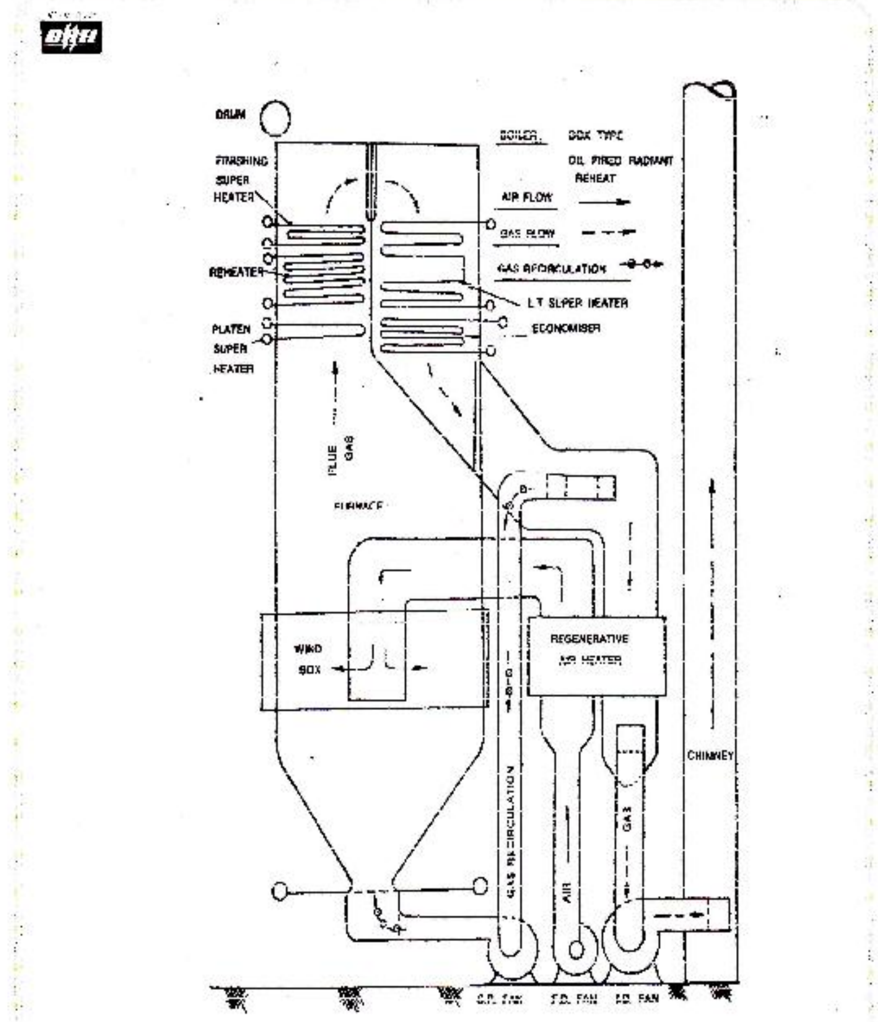


FIG. IV-1 TYPICAL SCHEME OF FANS IN BOILER

Induced Draft Fans

I.D. Fans are used only for balanced draft boilers.

They literally suck the gases out of the furnace through the various heating surfaces and put them in the Stack.

They handle Dirty flue gases at 125 deg.C. to 200 deg.C.

System resistance includes losses in the Furnace, S/H.s, R/H.s , Eco., APH, ducts and ESP.

If ESP performance is poor, ID Fans erode fast.

The design must take care of some erosion.

Primary Air Fan

P.A. fans are used in Coal Fired Boilers only.

Cold PA Fan takes air from atmosphere and sends it through the APH to coal mills for lifting and transporting the fuel to furnace.

Hot PA Fan takes hot air from APH outlet and send it to coal mills for similar action.

Usually there are two Cold PAF for all the mill but,

Hot PAF is separate for each mill.

PAFs are similar to FDFs but the discharge pressure is much higher.Centrifugal fans are used.

System resistance for Cold & Hot PAFs.--?

Gas Re-Circulation Fans

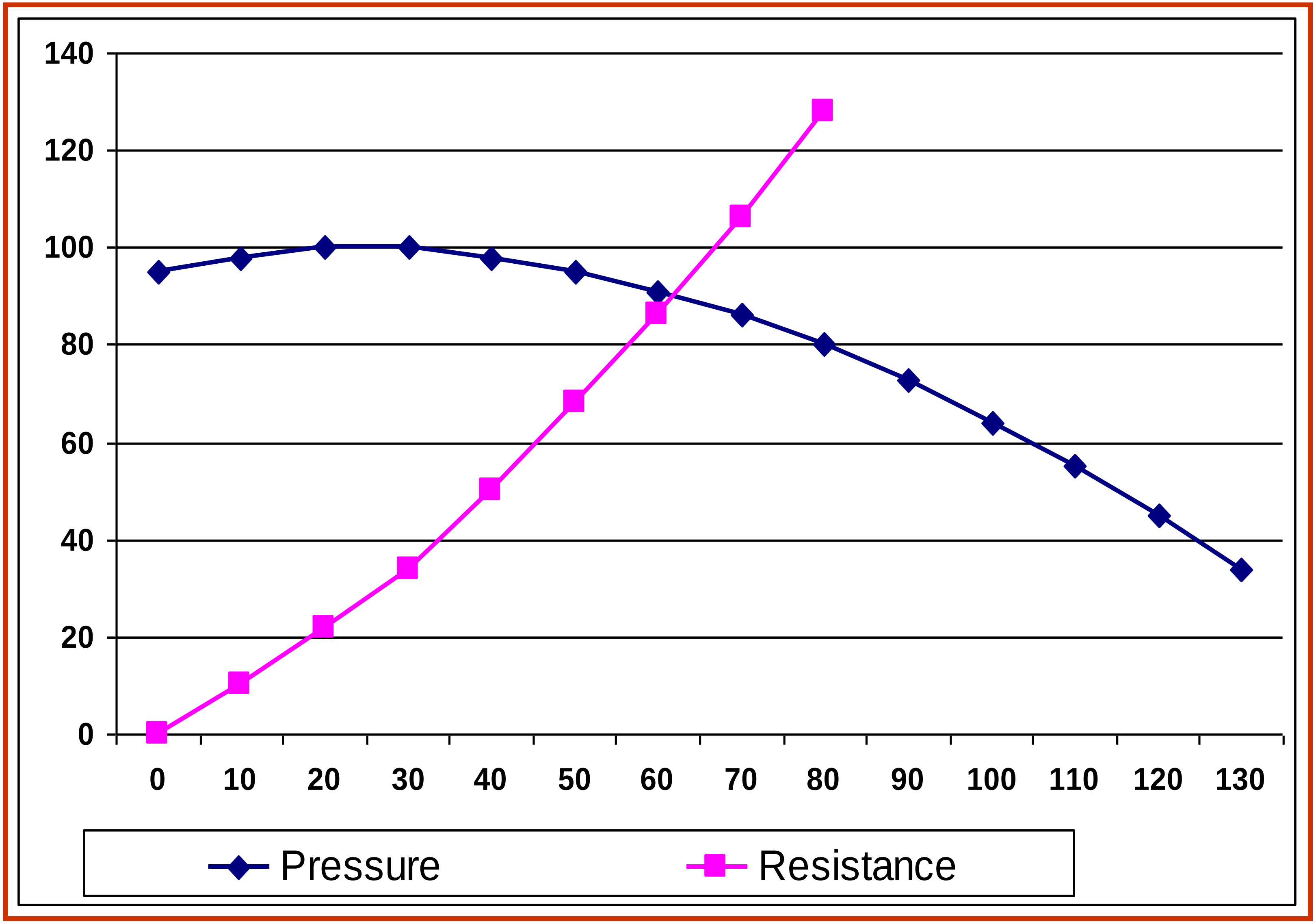
These are sized to circulate a part of Dirty flue gases(300-425 deg.C.) from ECO outlet back to furnace.

Speed – 600 – 1000 RPM.

If the fan stops, it will be exposed to 1200 deg.C. and may get totally damaged.

Proper protection has to be provided.

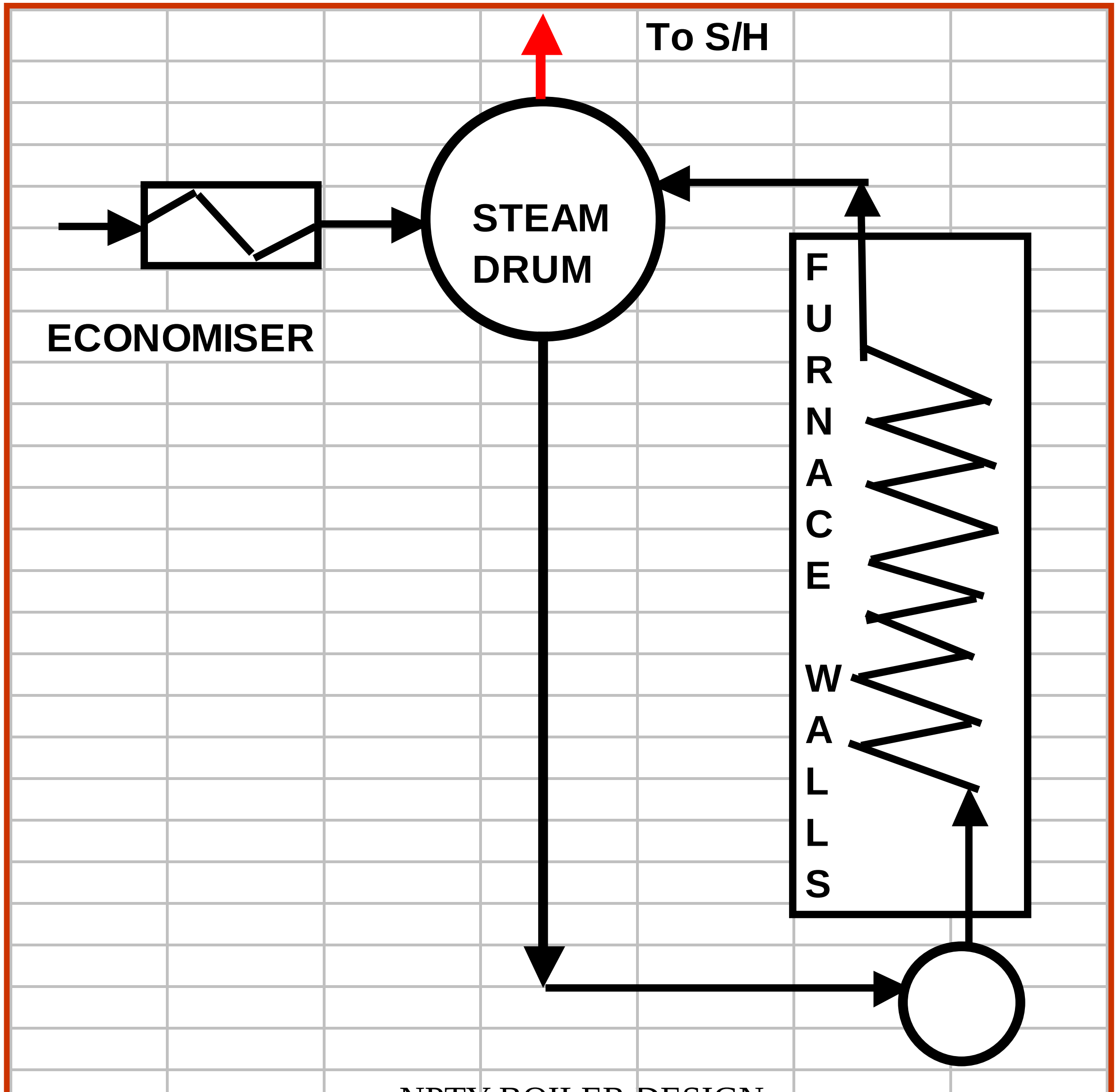
Flow V/s Pressure Characteristic of a Fan.



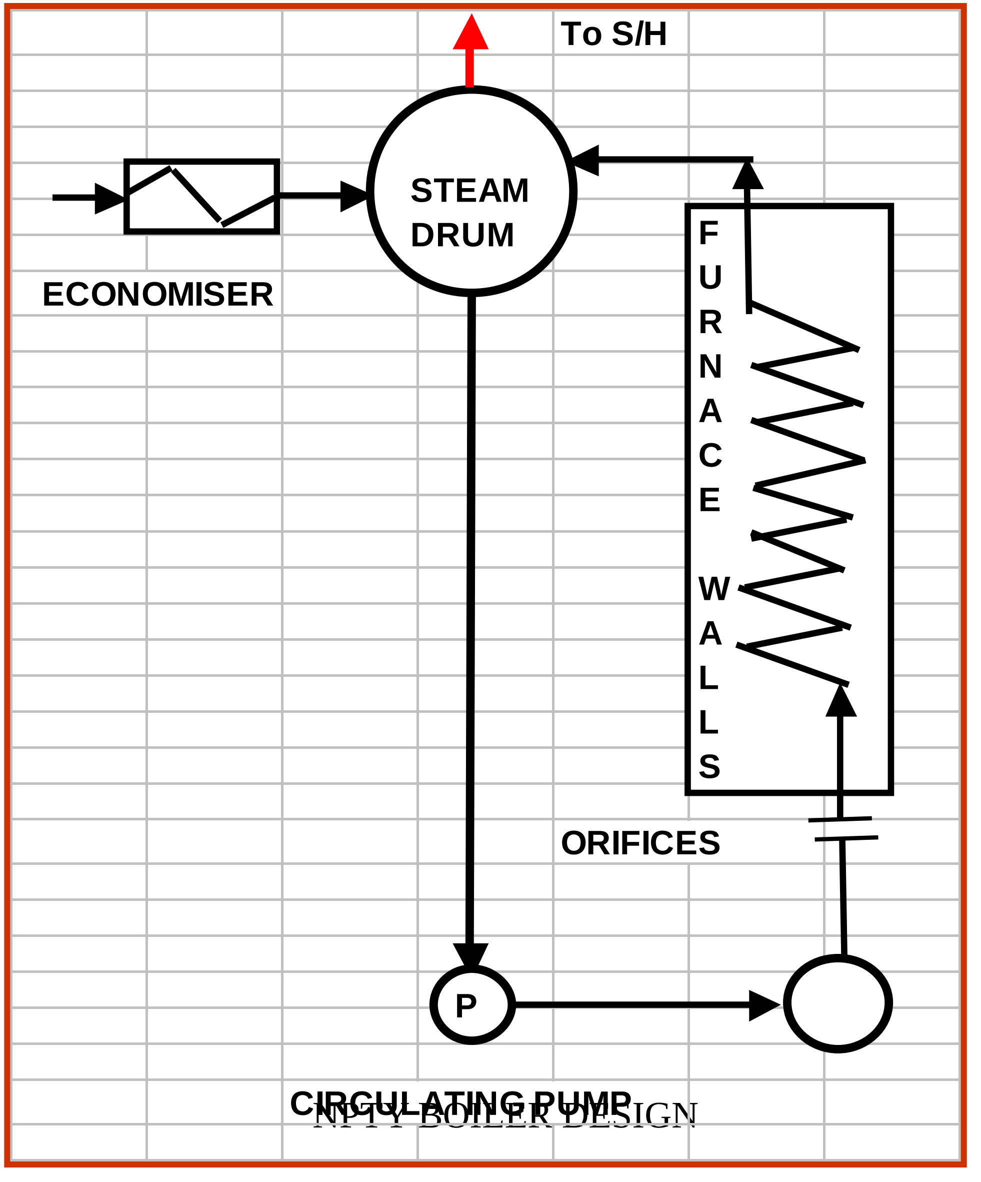
Boiler Circulation Systems

1. Natural Circulation.for Sub-critical Boilers.(Thermo Siphon)
2. Assisted Circulation.- Beyond 175 Kg/Cm2 pressure to overcome frictional head loss in W/W tubes.Circulating pumps at the base of down comers.
3. Combined Circulation – Super-critical boilers. There is no phase change.These are Once Through Systems.But at lower loads, circulation is necessary.

Natural (Thermal Circulation)

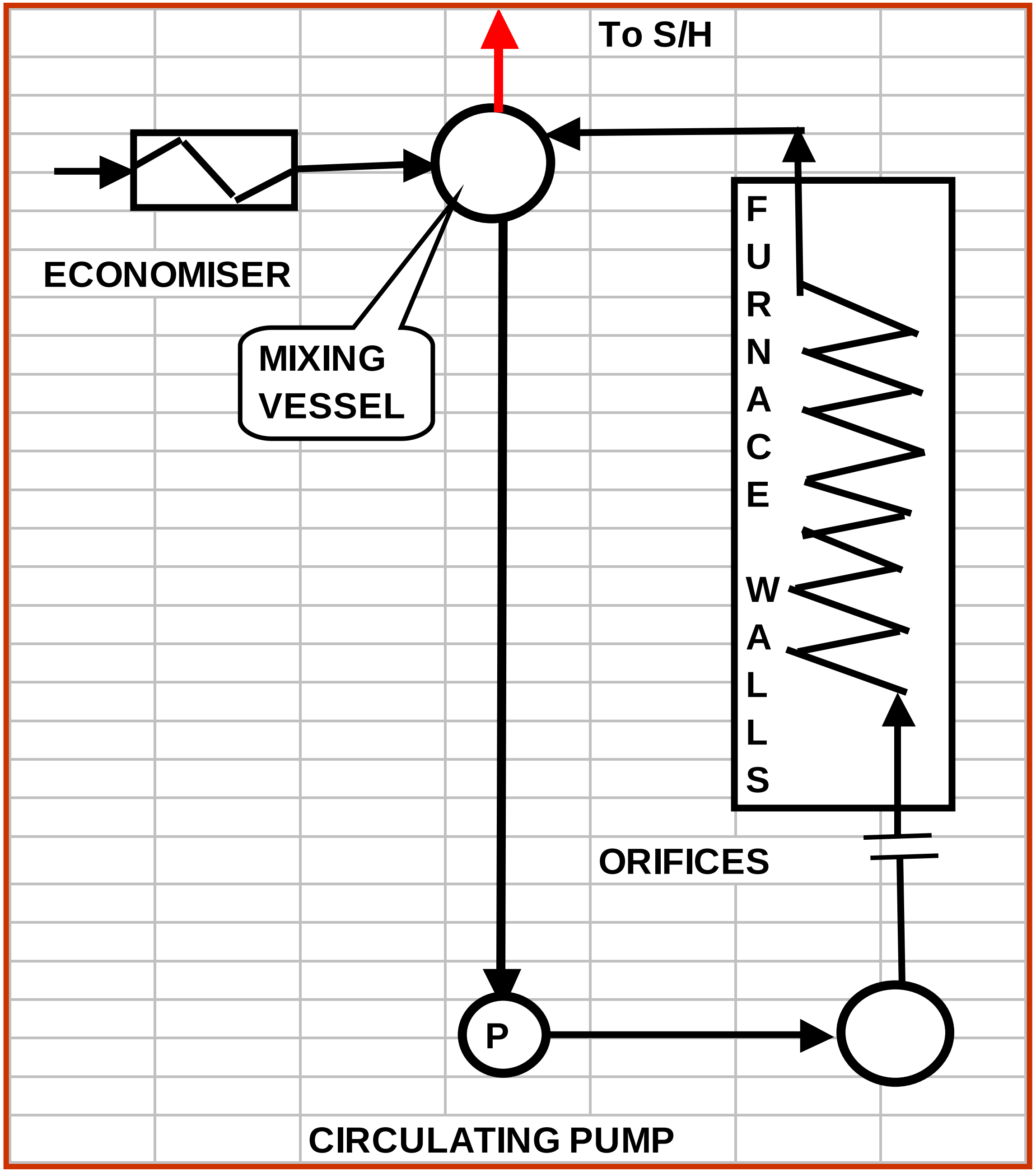


ASSISTED CIRCULATION



Once Through – Super critical Boilers

Note that the DRUM is replaced by a Mixing Vessel (which is much smaller)



Boiling Types

Nucleate Boiling.- Tube metal temperature is slightly above the water temperature.Bubbles formed at surface soon collapse.

When saturation temperature is reached water boils (Steam bubbles do not collapse.)

Now the tube metal temperature is slightly above the saturation temperature.

Film Boiling.

D.N.B. – Departure from Nucleate Boiling

When heat flux is too high, the bubbles formed in nucleate boiling combine and a film of superheated steam is formed on the inner side of W/W tubes.

As this film is a bad thermal conductor, tube metal temperatures rise. Overheating can occur.

Water Cooled Furnace

Modern high capacity boilers have water-cooled furnace. Thus Furnace is designed not only for Combustion but also for Heat Transfer.

Advantages : -

1. No refractory and its maintenance.
2. Heat absorption in W/W.s reduce furnace exit gas temperature.Less ash / soot deposit on S/H and convective heat transfer surfaces.
3. Higher heat loading is possible as heat transfer & combustion is simultaneous.Hence less surface area is required.

Furnace design aspects

1. Adequate height for Natural Circulation.
2. Size of furnace and location of burners – No flame impingement.
3. Uniform heat transfer on all furnace walls.
4. Furnace shape to ensure that gas flow “Fills” the furnace and to provide maximum heat absorption.
5. Provision for ash removal.
6. Furnace to withstand static load, furnace pressure load, wind and seismic loads.
7. Thus furnace must be well supported but must be free to expand due to heating.

Furnace Types – Dry Bottom

Dry Bottom – Suitable for non – slagging coals. The fusion temperature of ash is much above the maximum furnace temperature.

Hopper at the bottom of the furnace is formed by sloping the front & rear walls.

The neck is about 1.0 –1.5 meters.

This reduces the loss due to water evaporation.

The slope also cools the ash sliding over it.and picks up additional heat.

High silica content in most Indian coals,so ash fusion temperature is high and Dry Bottom furnace is suitable.

Furnace Types – Slag Type

There are normally two furnaces.

Primary furnace with high combustion rate.

The molten slag passes on to the ash hopper.

Hot flue gas passes through the secondary furnace, which is similar to dry bottom furnace.

Molten slag is chilled and crushed for easy disposal.

Ash has to flow, so coal with low melting point ash can be used.

To get high temperature in the primary furnace, it is made smaller but with high combustion rating.

As the slag is removed from the furnace itself, heat transfer surfaces remain comparatively cleaner.

Oil flame is more emissive than coal flame.

Higher absorption by water walls , so greater heat transfer loading is possible.

Compared to coal fired furnace, only 65 % volume is adequate for oil fired furnace.

Furnace is closed at the bottom as no ash removal is necessary.

Duel fired furnace must be designed for COAL, as the volume for oil firing will be inadequate.

Furnace Water Walls Construction

1. Partially Shielded – Gap of about one tube dia between tubes.The gaps are filled with refractory.
2. Tangent Tubes – Tubes touching each other. No Gap.No refractory.

   Difficulty in tube repairs.
3. Membrane Tubes – About 12 mm strip joins adjacent tubes.

   Faster erection, Ease in tube repairs.

   Good furnace sealing.

Provision for Expansion

Walls must be free to expand.

They are supported at the top so that all expansion is downward.

A 40 Meter high wall may expand by 125 mm due to the temperature change.

For lateral supports, buck stays are used which do not restrict the down ward expansion of tubes.

Super heaters & Re heaters

Radiant S/H or R/H can SEE the flame and heat transfer is mainly by Radiation.

Convection heating surfaces can not SEE the flame.

The heat transfer is by Convection.

Temperature is higher in Radiant Zone and the S/H coils are placed wider apart than in the convection zone.

This avoids bridging of tubes.

In a single coil, the gap between adjacent tubes in minimum.

De - Superheater

As seen earlier, Radiant Superheat will fall with rise in load and Convective Superheat will rise with load.

So, they are in series so that S/H temperature control is easier.

Even then some De – Superheating is required.

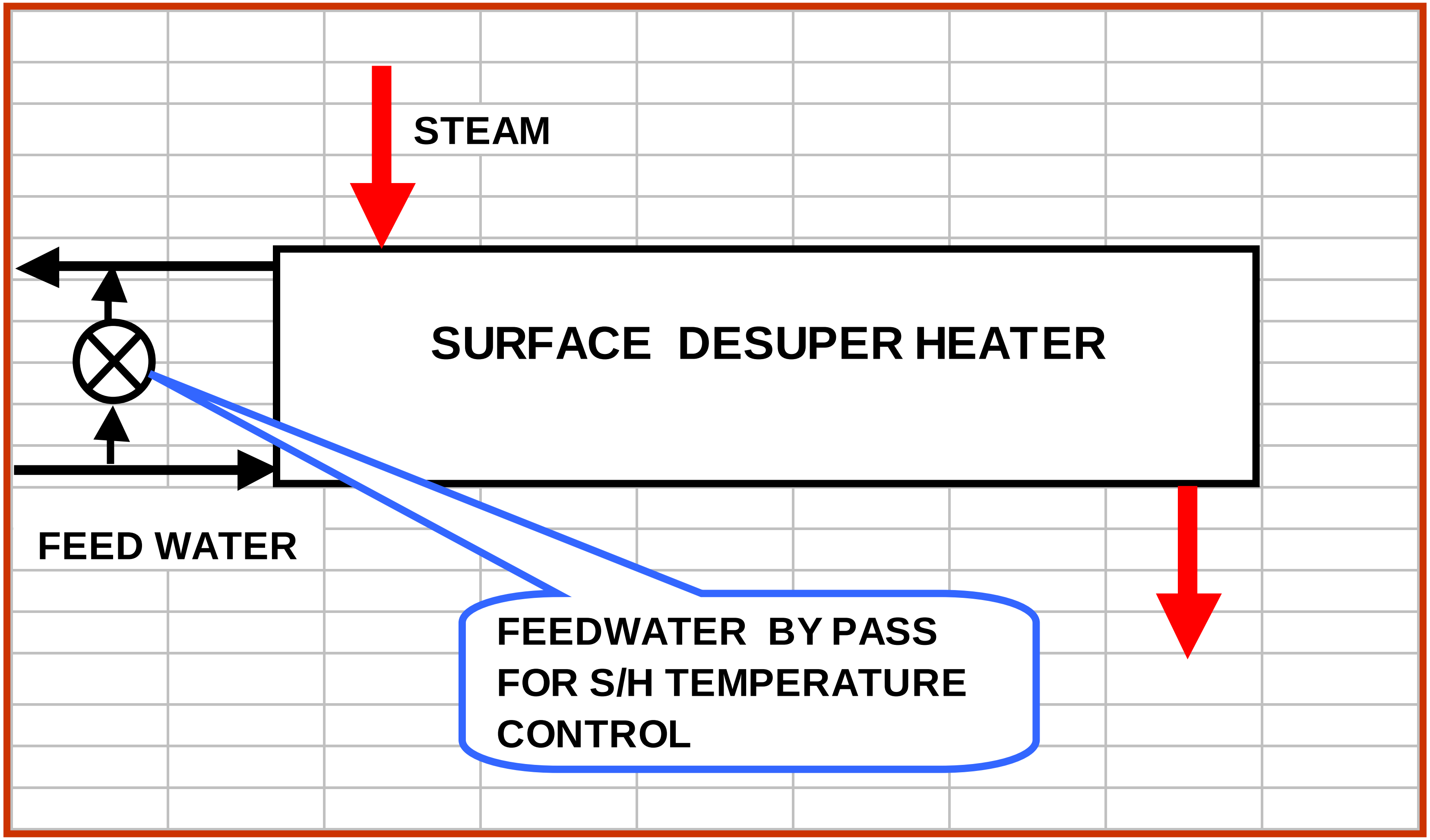
De-super-heater may be spry type or surface type.

In surface type feed water flow is controlled to maintain the S/H temperature.

No contamination of steam but these are bulky and pressure drop is more.

Spray reduces efficiency , especially in R/H.

SURFACE DESUPERHEATER - SCHEMETIC



Supports

S/H or R/H can be vertical and supported from the top which is a simple arrangement.

This is Pendant arrangement and is not drainable.

They can be horizontal also. Here supports are needed to avoid sagging of tubes and yet maintain the freedom of expansion.

Horizontal S/H , R/H is drainable.

Radiant S/H and R/H is pendant type.

The reheater is place din high gas temperature zone.

So, less heating surface is required and the pressure drop is less.

In – line OR Staggered tubes.

Staggered tubes need less heat transfer area.

But, pressure drop is more and cleaning of tubes is not effective.

Hence are used in oil/gas fired boilers.

In – line tubes are preferred for coal fired boilers.

Heating surfaces can be arranged in –

Parallel flow –Only for water walls.

Counter flow – Mostly used.

Cross flow.- For LTSH and Economiser.

In counter flow temperature of cold medium can be raised above the lowest temperature of hot medium.

S/H – R/H STAGES ?

Generally these are in 3 stages –

L.T. S/H OR L.T.R/H.

PRIMARY S/H

SECONDARY or FINAL S/H.

The headers and their supports are not in the boiler.

These are placed above the boiler roof and are not in the flue gas path.

De-Superheater is located between LTSH and Primary S/H.

ECONOMISER

Waste heat from the boiler heats incoming feed water. So the name “Economiser”

Now Feed heaters also heat the feed water and hence less surface area is needed for the Economiser.

Also the residual heat after the economiser can be used to pre-heat the incoming air in the APH.

Modern boilers have both, the economiser and the APH.

Economiser coils are generally horizontal in the 2nd pass of the boiler and it is after the LTSH. Proper supports to prevent sagging of tubes are provided.

Re-circulation is provided to protect the tubes when feed flow is not there as during start-up.

Economiser outlet temperature.

Early designs kept eco. Out let temperatures well below the saturation temperature.(about 50 deg.C.below).

This was to preclude flashing in the Eco.

However, now the Eco. Outlet feed water temperature is just 15-20 deg.C.below the saturation temperature.

As Eco is a Forced flow section, flashing is not likely.

Water rises up in the Eco, so that any steam bubble will rise up and will not cause a steam – lock.

After the economiser, the flue gas path takes a turn and ash hoppers are provided below the Eco.

Provision for soot blowing.

Tubes may be plain or with welded fins.

They may be in-line or staggered.

Staggered formation gives more turbulence and less heat transfer area is needed,but draft loss is more and soot-blowing is not effective.

In-line arrangement need about 20% more area but draft loss is less and soot blowing is simpler.

Fuel Oil Burner system – Fundamentals.

Large boilers deal with high rate of mass and energy flow.

Operator response may not be fast enough.

So, automation, safety interlocks, and remote control is necessary.

Fuel burning system must supply a ***Controllable*** and ***Uninterrupted*** fuel supply to the furnace and ***burn it as fast as it enters.***

Fuel will ignite when heated to ignition temperature.

Fuel must not accumulate in the furnace.

All fuel must be burnt and made inert as soon as it enters the furnace.

Factors for Ignition Energy

1. Location of Ignition energy.(Central or on side wall across the main fuel flow)
2. Quantity of ignition energy.
3. Fuel Quality,(Volatile matter, moisture, ash etc.)
4. Fuel parameters (Temperature,viscosity,)
5. Combustion air parameters.(temperature)
6. Fuel air distribution .
7. Air / Fuel ratio.
8. Main fuel (Coal) burner flow rate.

Ideal auxiliary Ignition System requirements

1. Measure the ignition energy required & supplied.
2. Be close to main fuel flow.
3. Control the auxiliary fuel flow.
4. Flame proving system.
5. Automatic run back when flame is lost.
6. Interlock with main fuel admission.

   Such a system can also be used a “flame prover” for the associated main flame.

When the ignition system is proven in service, Main fuel can be admitted and controlled as combustion is ensured.

Light – up Protection and Safety

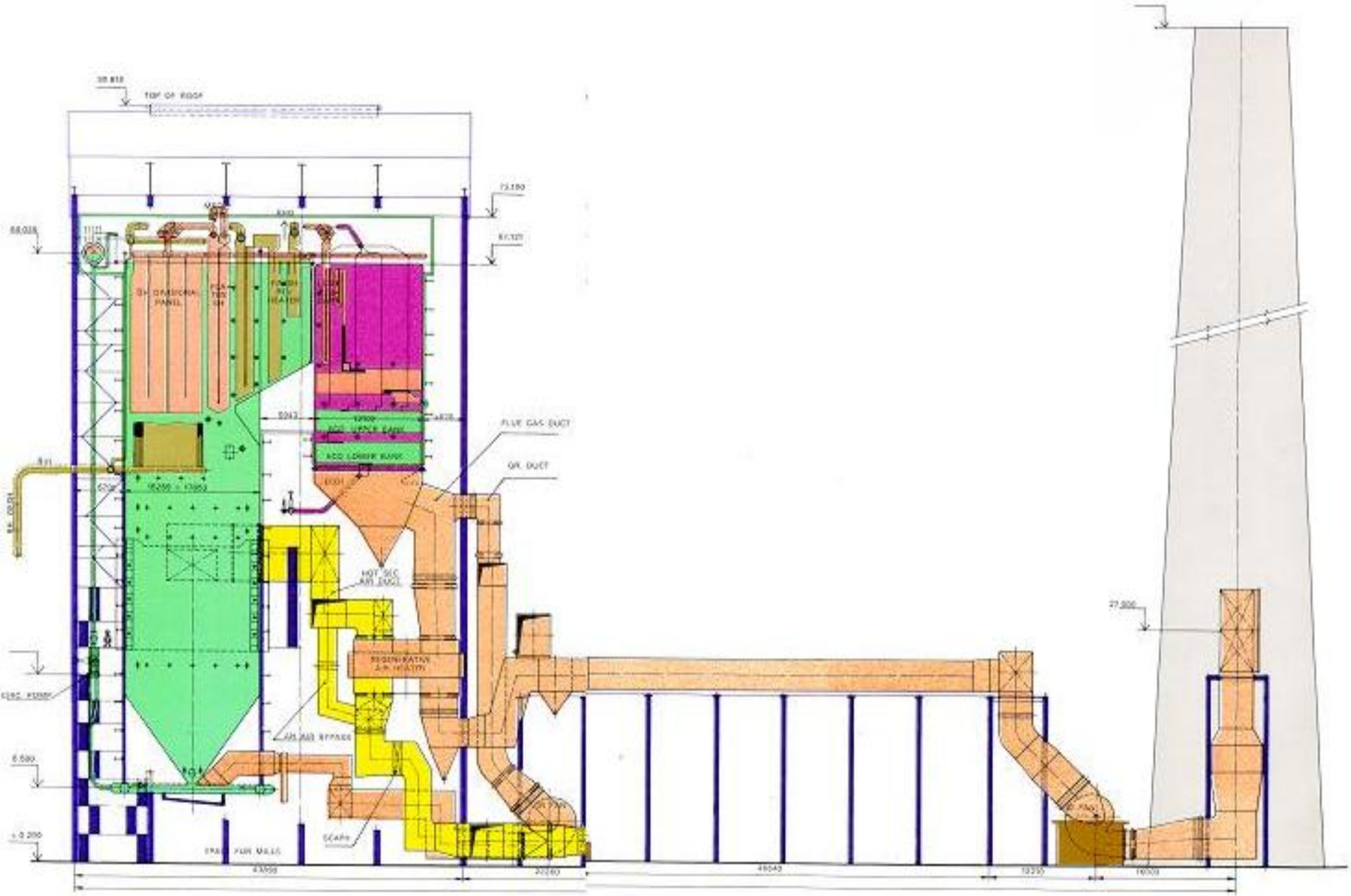
The remote , manual light – up philosophy depends on-

1. Interlocking &Monitoring all firing permissives.
2. Air rich burner & Furnace (30 % air flow)
3. For all fuels, sufficient ignition energy is ensured.

   Ignition and Burner Management System is covered in FSSS.

It ensures that an auxiliary can start only when it is safe and the system is ready for it.

Similarly fuel admission is allowed only when system is ready and it is safe to admit fuel.


TOP OF ROOF
FLUE GAS DUCT
GR. DUCT
ECO UPPER BANK
ECO LOWER BANK
HOT SEC AIR DUCT
REGENERATIVE AIR HEATER
CIRC. PUMP
SCAPH
SPACE FOR MILLS

BOILER

"BOILER" MEANS ANY CLOSED VESSEL EXCEEDING 22.75 Litres IN CAPACITY WHICH IS USED FOR GENERATING STEAM UNDER PRESSURE.

- IBR

BOILER CODES

Boiler Codes have been written by various nations in the past century to ensure safety of personnel and to avoid loss of property. Boiler codes cover the whole gamut of activities including Design, Fabrication, Testing, Construction and Operation. The various aspects of IBR Regulations are consolidated against major items like drum, headers, lines & links, etc. The following codes have been used widely.

1. IBR 1950
2. ASME Section-I
3. BS 1113
4. DIN TRD 300.

TYPES OF BOILERS

(A) BASED ON APPLICATION :

1. UTILITY Boilers are large capacity steam generators used purely for electrical power generation.

2. INDUSTRIAL Boilers are small capacity boilers intended for use in the process industries.

Types of Boilers.......contd

(B) BASED ON CONSTRUCTION:

1. Vertical Package- VP
2. Vertical Recovery-V2R
3. Vertical Unit 40-VU40
4. Vertical Unit 60-VU60
5. Modular Unit-MU
6. 2 Pass Single Arch
7. 2 Pass Double Arch
8. Close couple
9. Box Type
10. Tower Type

Types of Boilers……contd

(C) BASED ON FUEL:

1. OIL FIRED
2. OIL AND COAL FIRED
3. BLACK LIQUOR (For Paper Mills)
4. BAGGASE (Stoker Fired)

Types of Boilers…….contd

(D) BASED ON TYPE OF FIRING:

1. WALL FIRING
2. CORNER TANGENTIAL FIRING
3. STOKER

Types of Boilers……contd

(E) BASED ON NO. OF DRUMS:

1. SINGLE DRUM
2. BI- DRUM
3. NO DRUM (Vertical Separator)

Types of Boilers……contd

(F) BASED ON CIRCULATION:

1. NATURAL

2.1 FORCED Circulation (Pump)

2.2 CONTROLLED Circulation (+Orifice)

2.3 CC+ (Pump + Orifice + Rifled Tubing)

3. Once Through

BOILER PARAMETER:

(A) UTILITY BOILERS

1. Main Steam Flow – T/Hr.
2. Main Steam Pressure – Kg/Sq.cm.(g)
3. Main Steam Temperature - ºC
4. Reheater Flow – T/Hr.
5. Reheater Pressure – Kg/Sq.Cm.(g)
6. Reheater Temperature - ºC

(B) INDUSTRIAL BOILERS:

Steam Flow – T/Hr.

(C) HEAT RECOVERY UNITS:

Fuel Used – T/Day.

PRESSURE PARTS

(A) BASED ON CONFIGURATION :

1. HEADERS
2. PANELS
3. COILS
4. CONNECTING LINKS
5. SUPPORTS & SUSPENSIONS

(B) BASED ON SYSTEM :

1. ECONOMISER SYSTEM
2. CIRCULATION SYSTEM
3. SUPERHEATER SYSTEM
5. REHEATER SYSTEM

PRESSURE PARTS

(WITH RESPECT TO ARRANGEMENT)

PERFORMANCE PARAMETERS:

1. SIZE (Diameter)
2. SIZE (Thickness)
3. MATERIAL (Specification)
4. TRANSVERSE SPACING (ST)
5. LONGITUDINAL SPACING (SL)
6. HEATING SURFACE AREA
7. No. OF ELEMENTS
8. No. OF ASSEMBLIES

Pressure Parts .....contd

9. INLET / OUTLET CONNECTION REQUIREMENTS
10. FURNACE WIDTH
11. FURNACE DEPTH
12. EXTENDED PASS DEPTH
13. BACKPASS DEPTH
14. HOPPER ANGLE
15. ARCH CONFIGURATION
16. COIL / BANK DEPTH

Pressure Parts …..contd

DETAIL DESIGN REQUIREMENTS:

IBR REQUIREMENT (Strength Calculations)

MANUFACTURING REQUIREMENTS

HEAT TREATMENT REQUIREMENTS

TRANSPORT LIMITATIONS (ODC)

STRESS ANALYSIS REQUIREMENTS:

- GUIDES ,SUPPORTS & SUSPENSIONS
- THERMAL EXPANSION
- FLEXIBILITY OF COMPONENTS
- DISTANCE OF TOP HEADERS ABOVE ROOF
- BUCKSTAY SPACING

ARRANGEMENT REQUIREMENTS:

- INTERFERANCE FREE ARRGT./ ROUTING OF RISERS / PIPES / LINKS
- WELD ACCESSIBILITY
- TAKING CARE OF LAYOUT REQUIREMENTS (Ex. Matching Components
- TAKING CARE OF PERFORMANCE, DETAIL DESIGN & STRESS ANALYSIS ASPECTS

DRUM AND DRUM INTERNALS:

CIRCULATION SYSTEM:

The circulation system of water through the furnace water wall is due to either natural circulation or controlled circulation.

Natural circulation boilers employ the effect of density differences between water and steam to produce circulation.

At higher pressures and height of the boiler where density difference is not adequate the difference is augmented by a pump effecting Controlled circulation.

DRUM

- To provide space for separation of steam from steam water mixture.

- To house the internals required for steam separation such as Feed water distribution system, Turbo separators, Separating chamber, Screen driers etc.

- To provide a water storage for preventing the starvation of tubes during operation.

- Drum diameter and length should be sufficient to provide accessibility for installation and inspection. Thickness of drum is determined to meet the stresses induced due to internal pressure, self weight and external loads.

DRUM INTERNALS:

- Separation of water from steam water mixture.
- Removal of bubbles entering into the downcomer which will affect the density of fluid and circulation by providing vortex breakers.
- Mixing and distributing the feed water.
- Adding chemicals.
- Facilitating blow down.

FURNACE / BACK PASS WALLS:

Normally for boiler furnace enclosures membrane wall construction (fusion welded panels) is adopted in place of tangent tube construction which is not leak proof and increases the erection work.

Back pass enclosures are formed by fin welded panels with wider pitch because the flue gas temperature is less compared to furnace.

SUPERHEATER AND REHEATER:

These heating surfaces are in the form of coils which are made by bending the tubes in cold or hot condition. The superheater is composed of four basic sections.

The platen section is located directly above the furnace in front of the furnace arch. It absorbs heat mainly by radiation.

The pendant spaced section is located in back of the screen wall tubes. The mode of heat transfer is convection.

The horizontal section of the superheater (LTSH) is located in the rear gas pass above economiser.

The steam cooled wall sections form the side, front and rear walls and roof of the vertical gas pass.

<u>Desuperheaters: for </u>Steam temperature control are provided in

1.superheater connecting links

2.cold reheat line

to permit reduction of steam temperature when necessary to maintain the final temperatures.

❖ The desuperheaters used in the reheater system is meant for emergency condition.

❖ The reheat steam temperature is controlled mainly by tilting burners.

Reheater

The reheater - Single stage – 2 Sections

Front & rear pendant vertical spaced.

The front section located between the rear water wall hanger tubes and the super-heater platen section.

The rear section is located between water wall screen and rear wall hanger tubes.

SPACERS FOR SH & RH:

Spacer are used to maintain pitches along and across coil assemblies.

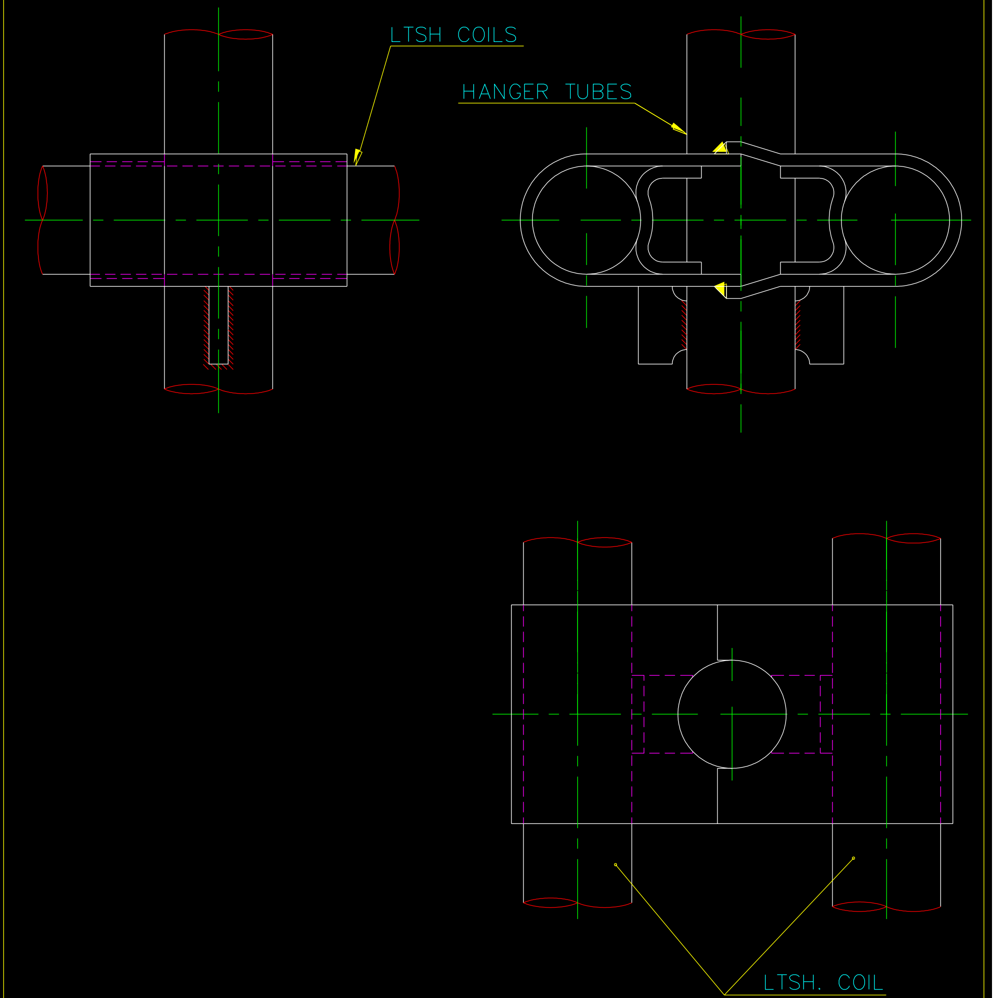
1. Transverse spacers and alignment tie.

2. Fluid cooled spacers or mechanical spacer bar are used as transverse spacers.

3. Flexible connector and alignment bands are used as alignment ties. to maintain pitch between tubes in the same assembly.

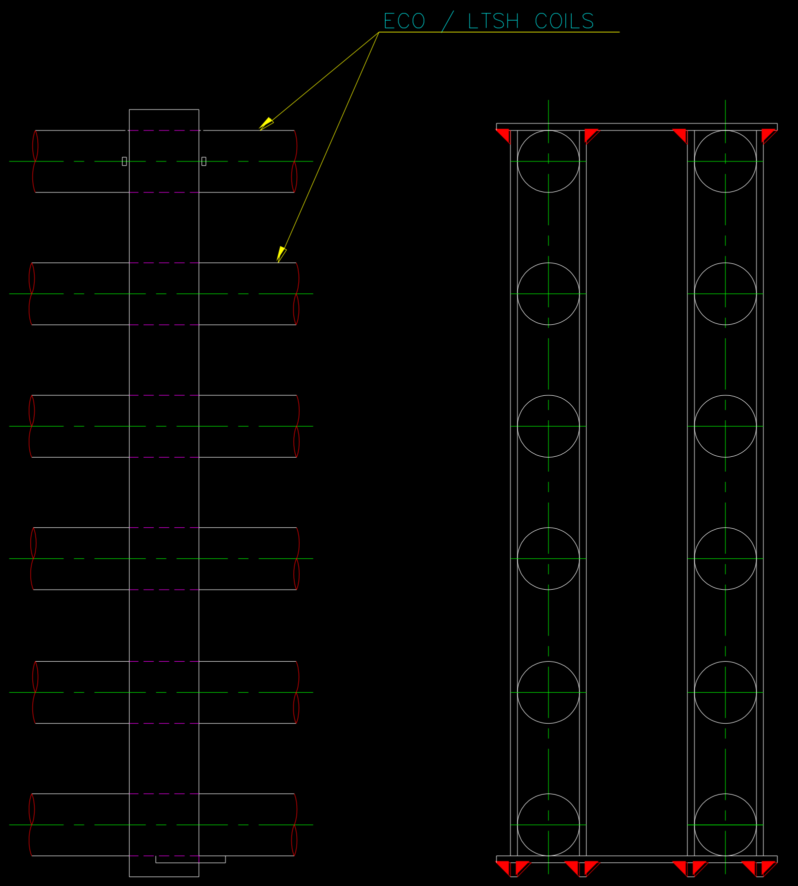
SUPPORTS & SUSPENSIONS FOR SH & RH:

1. Vertical Assemblies are suspended from the ceiling.
2. In pendant assemblies the tie lugs are welded in between tubes at the top row to transfer the load from centre to end terminals.
3. The horizontal superheaters are supported by economiser hanger tubes through strap supports.
4. The pendant coils are suspended by high crown supports. The high crown plates are welded on either side of seal band and the load is transferred through end bar.
5. The headers will be independently supported from the ceiling through tie rod assemblies with or without variable spring hangers as the case may be.



TYPICAL SUPPORTING ARRGT. OF LTSH COILS

(STRAP SUPPORT)



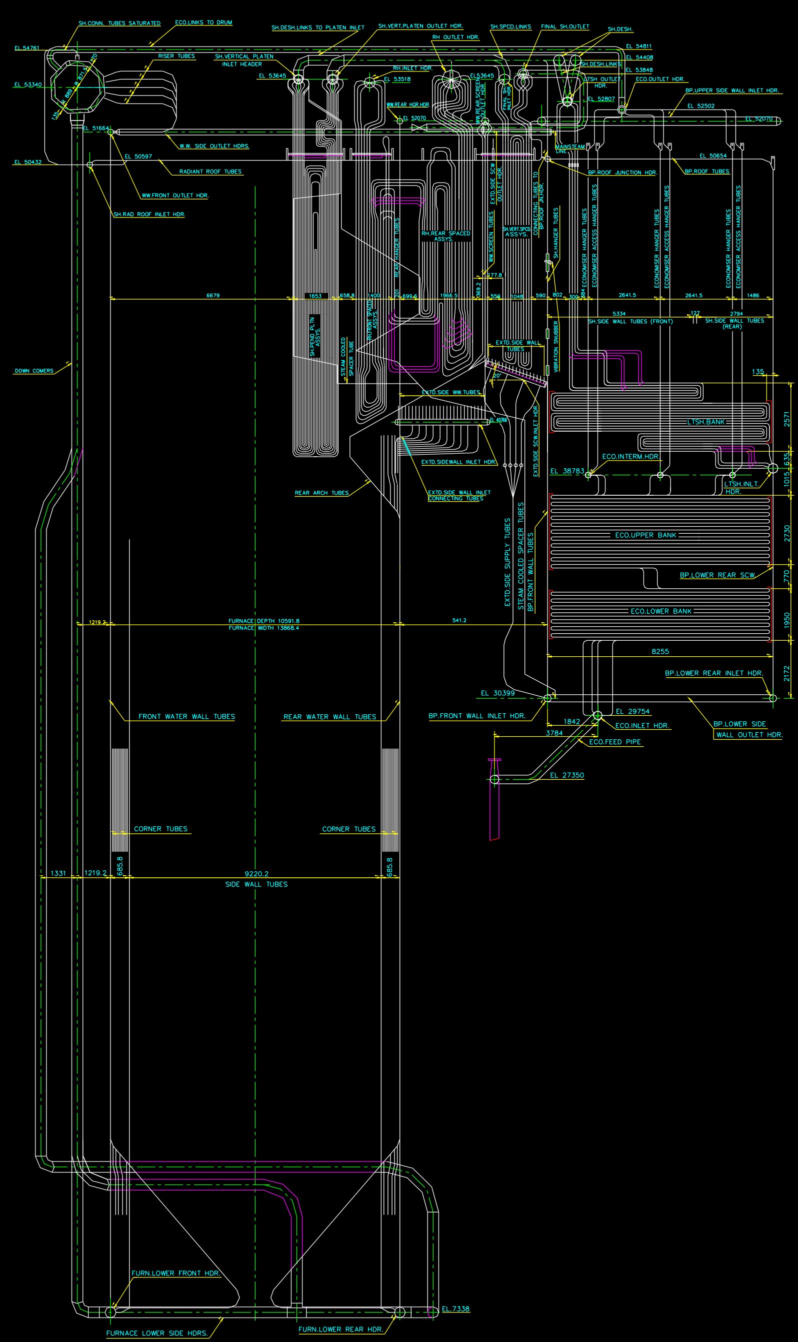
ALIGNMENT BAND

(FOR ECO / LTSH)

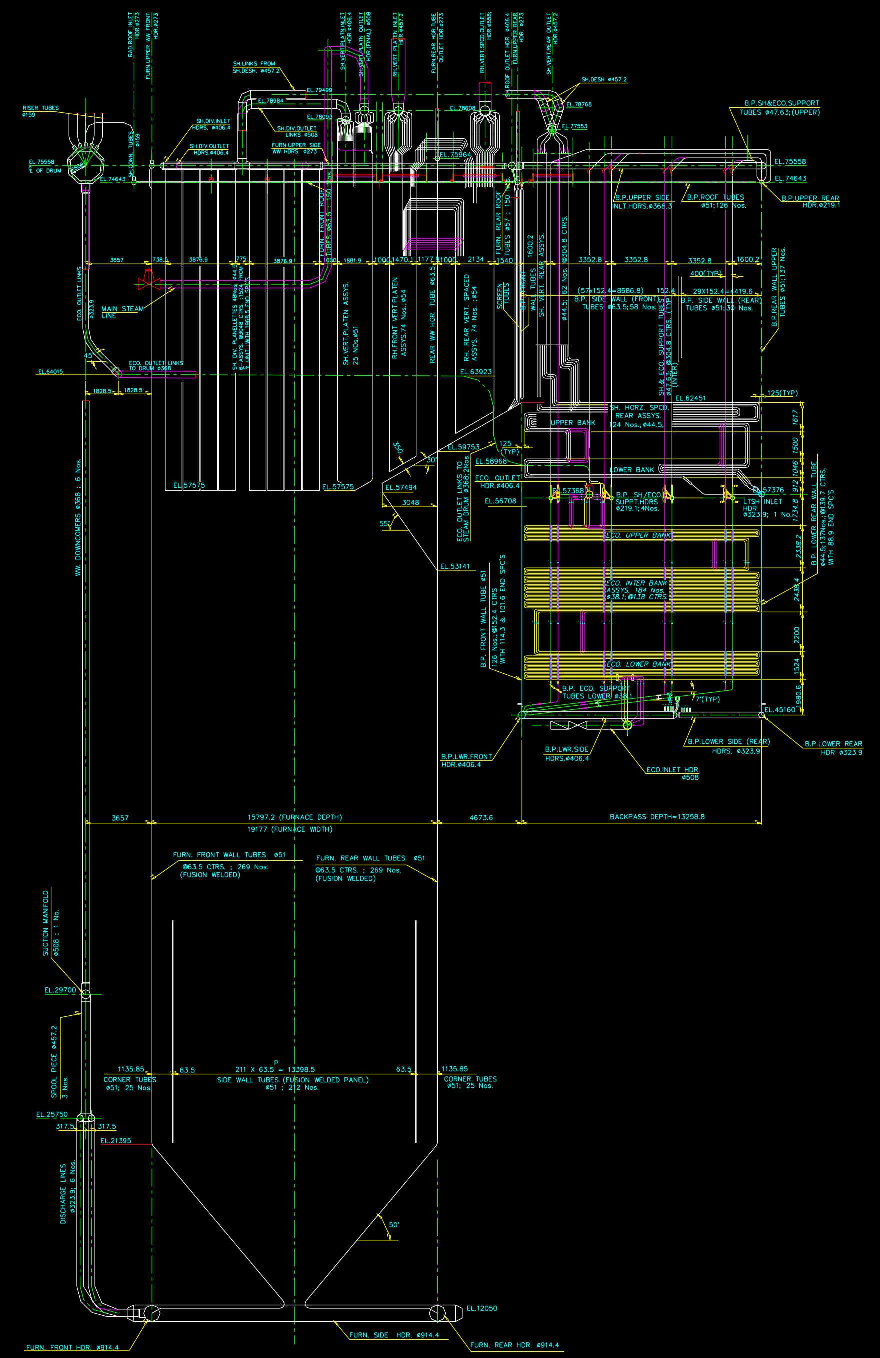
Pressure Parts Arrangement Comparison of 250 MW and 500 MW Boilers

- Circulation
  - Circulating Pump
  - Down comer Connections
  - Lower Ring header with Orifice Plates
- Divisional Panellette Super Heater
- Extended Pass
  - Split Extended pass
  - Steam Cooled side wall for Extended Pass
- Steam Cooled Eco. / LTSH Hangers
- Rifled Tubings in WaterWalls
- Wall Reheater (Presently not followed)

TYPICAL 210 MW/250 MW BOILER



TYPICAL 500 MW BOILER



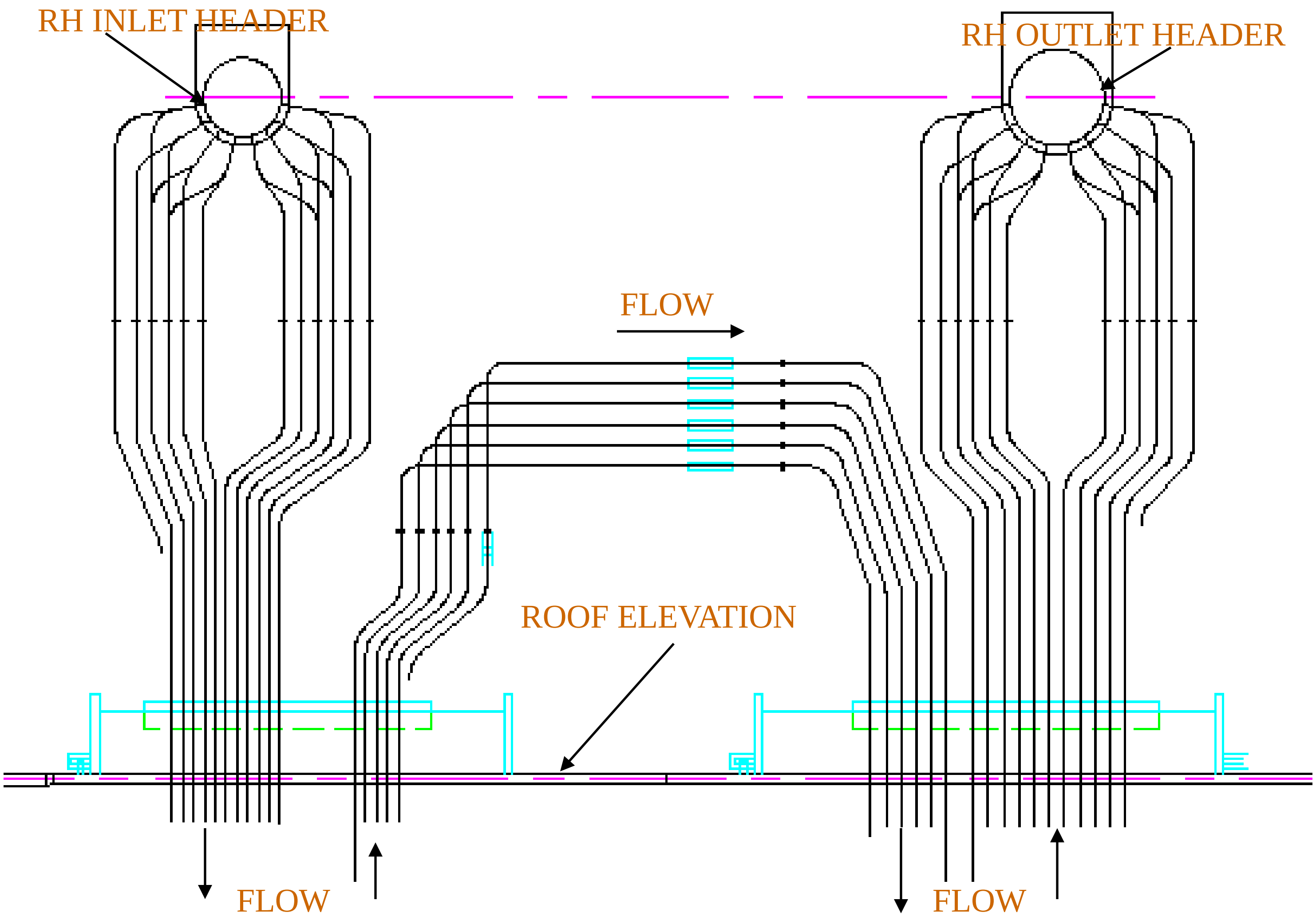
RECENT CHANGES IN 500MW

TO MEET THE REQUIREMENT OF PERFORMANCE THE FOLLOWING MODIFICATIONS ARE CARRIED OUT IN SOME OF OUR BOILERS:

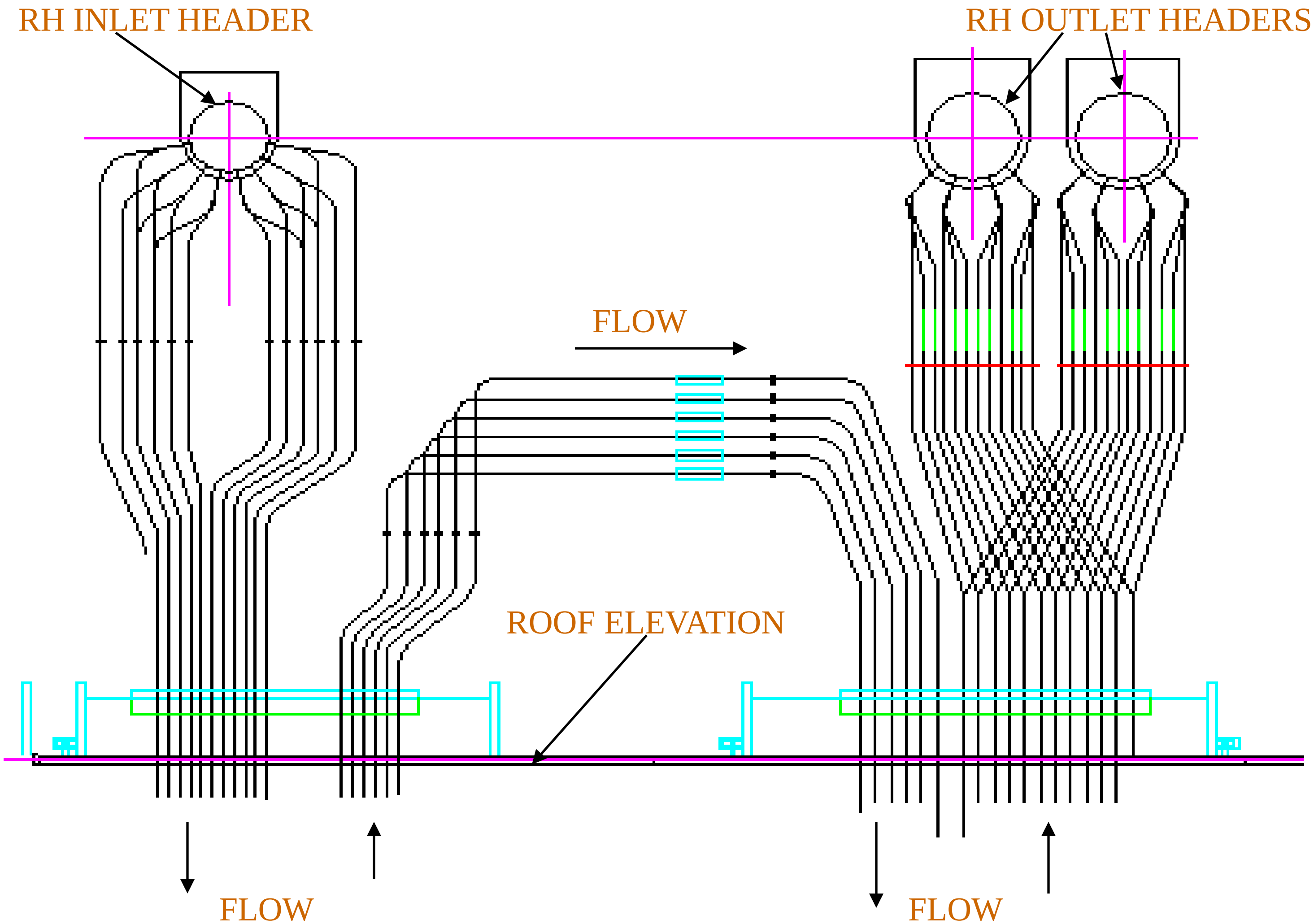
- TWIN REHEATER OUTLET HEADERS
- DESUPER HEATER CRISS-CROSS LOCATION CHANGED FROM LTSH OUTLET TO DIVISIONAL PANEL OUTLET
- WALL SUPER HEATER ADDITION IN VINDHYACHAL
- WALL REHEATER REMOVAL

Modifications for Performance Improvement and Site Feed Back

- Twin Header for Reheater
- Two Stage reheater Arrangement
- Elimination of Downcomer Buckstay Interference
- Introducing mixing header for Divisional Panel
- Wall reheater addition

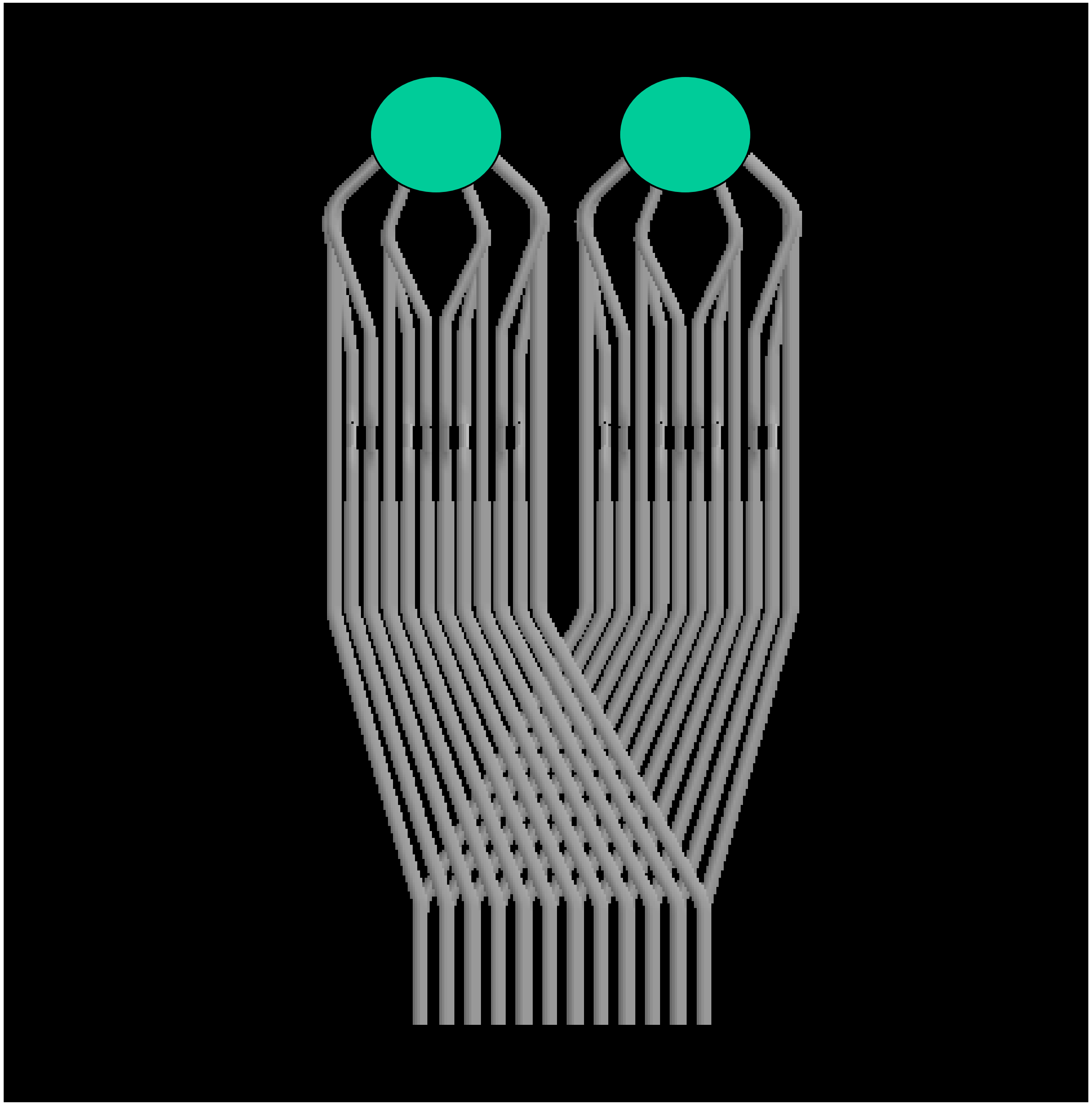


EXISTING ARRANGMENT



PROPOSED SAIYAMESE ARRANGMENT

SAIYAMESE HEADER

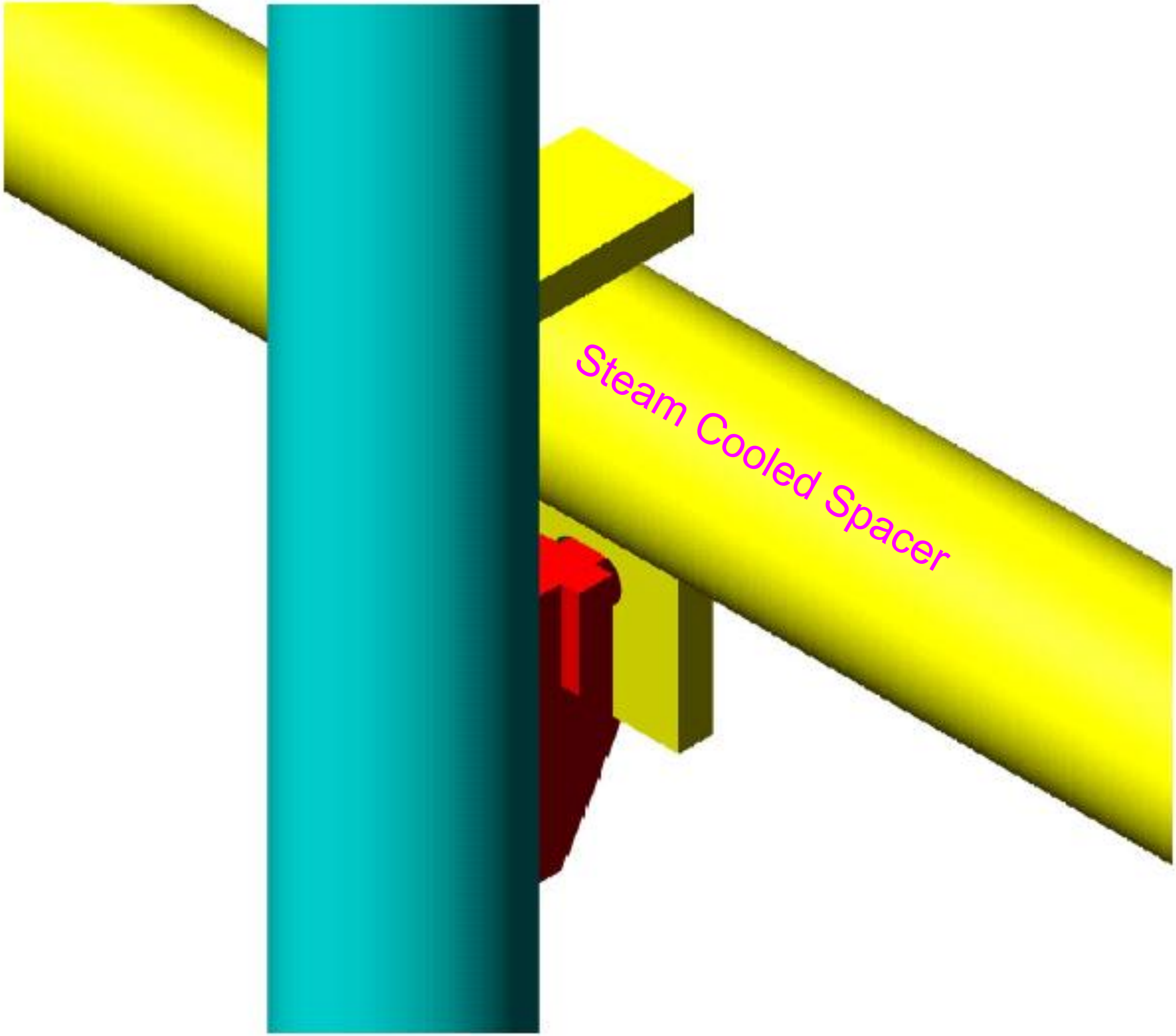


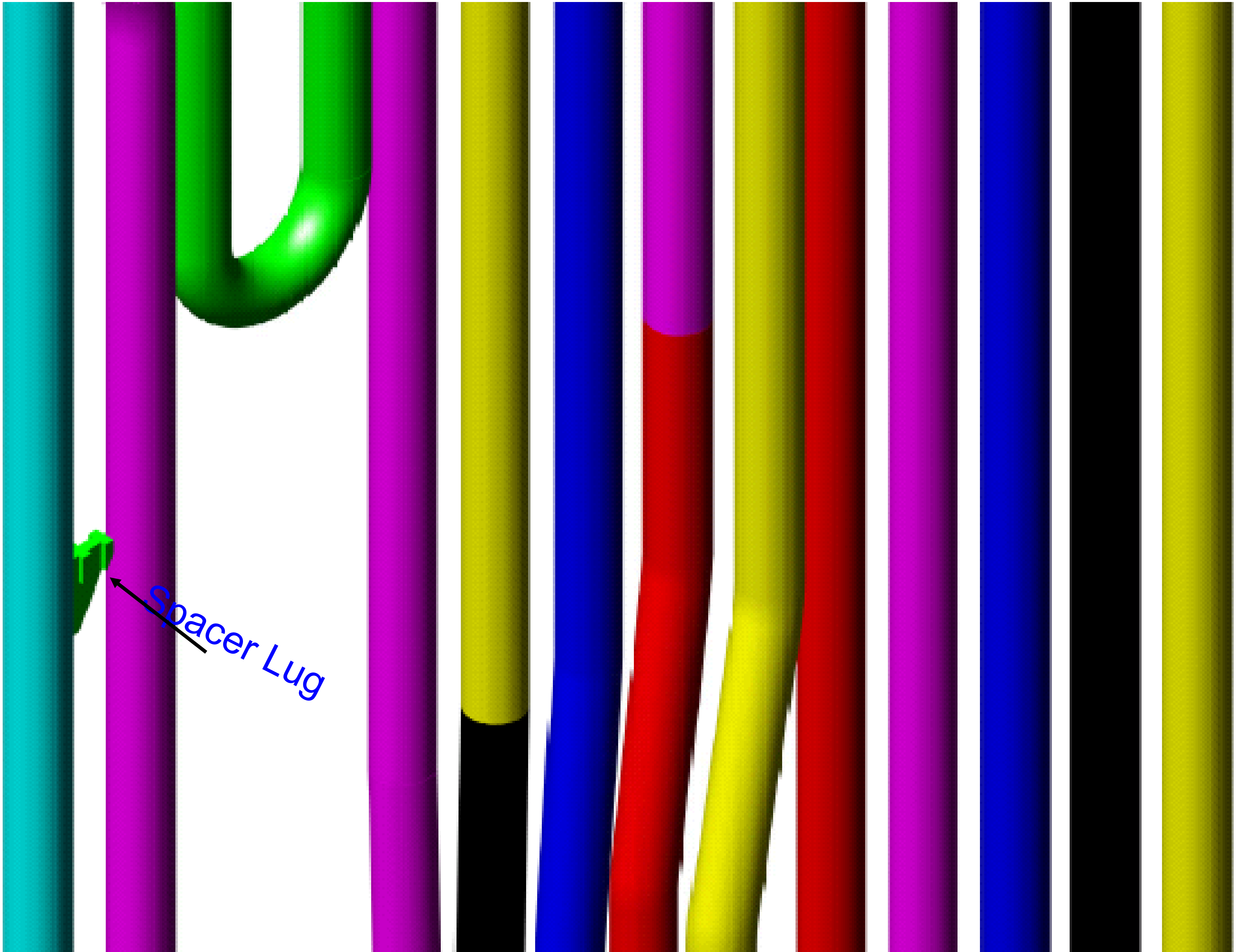
TO AVOID LEFT TO RIGHT TEMPERATURE UNBALANCE

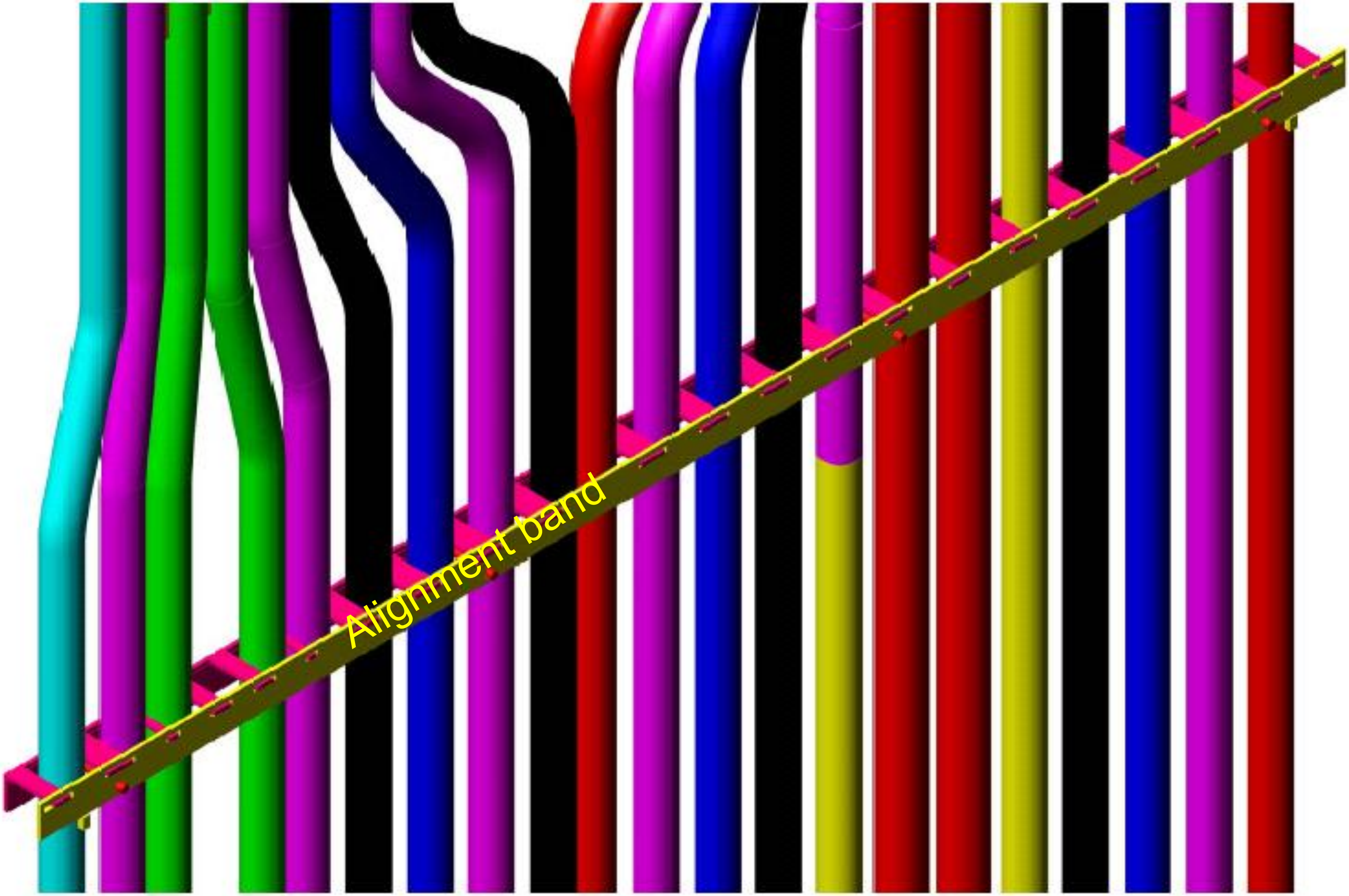
RIHAND & RAMAGUNADAM REHEATER OUTLET HEADER NIPPLE ARRGMT.

Divided Back pass and Horizontal Coils

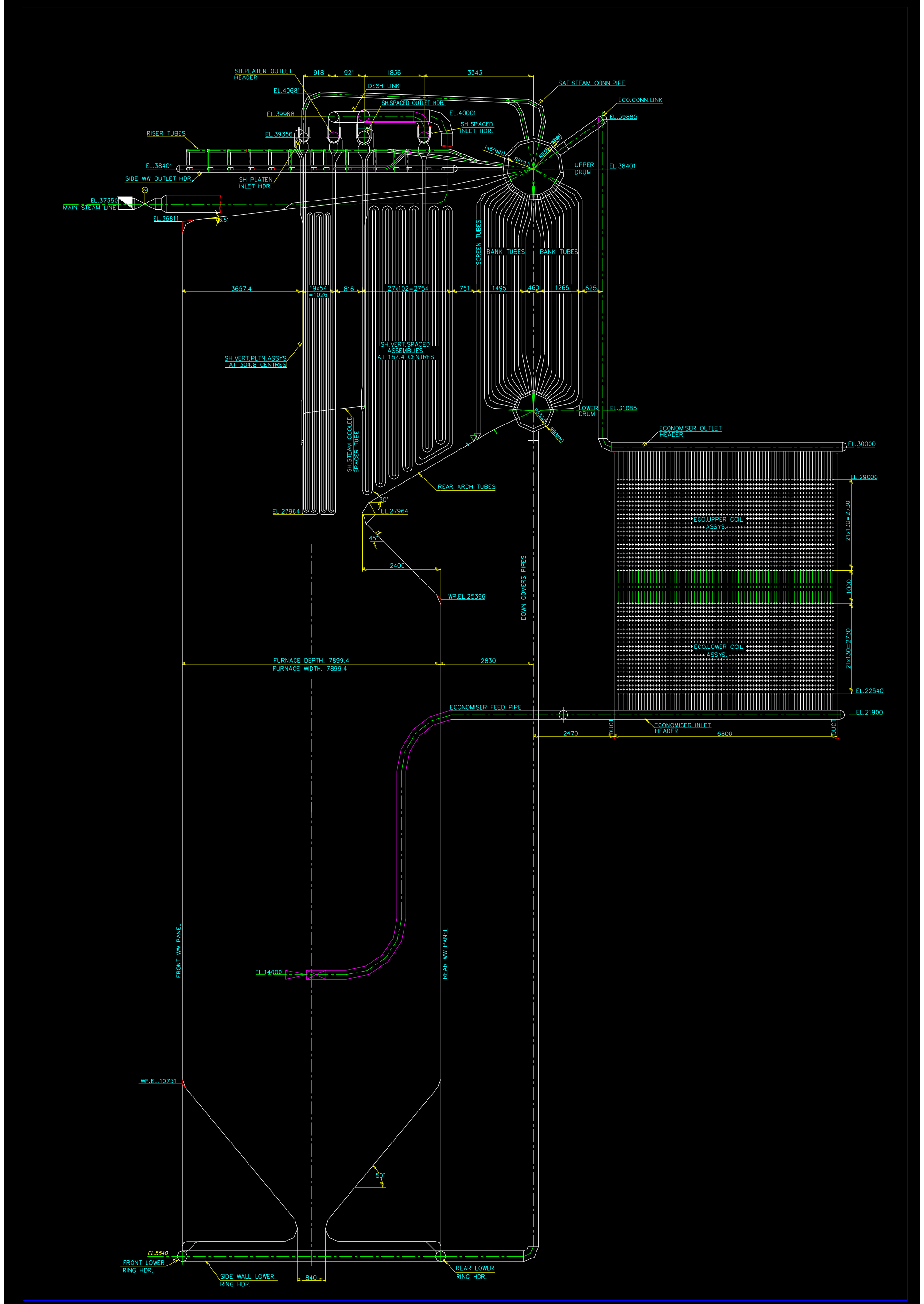
- Back pass depth 9144 and 9144 mm
- Back pass width = 23926.8 mm (Equal to Furnace Width)
- Steam cooled center wall (fin welded panel) divides the back pass
- Radial Distributor supplies steam to all back pass walls
- All coils are supported by steam cooled hangers
- LTRH coils placed in the first partition and LTSH in the second partition
- Eco first Stage in first Partition; Eco second stage in second partition below LTRH and LTSH coil banks respectively
- Flue gas biasing dampers are placed below eco inlet headers


Steam Cooled Spacer


Spacer Lug

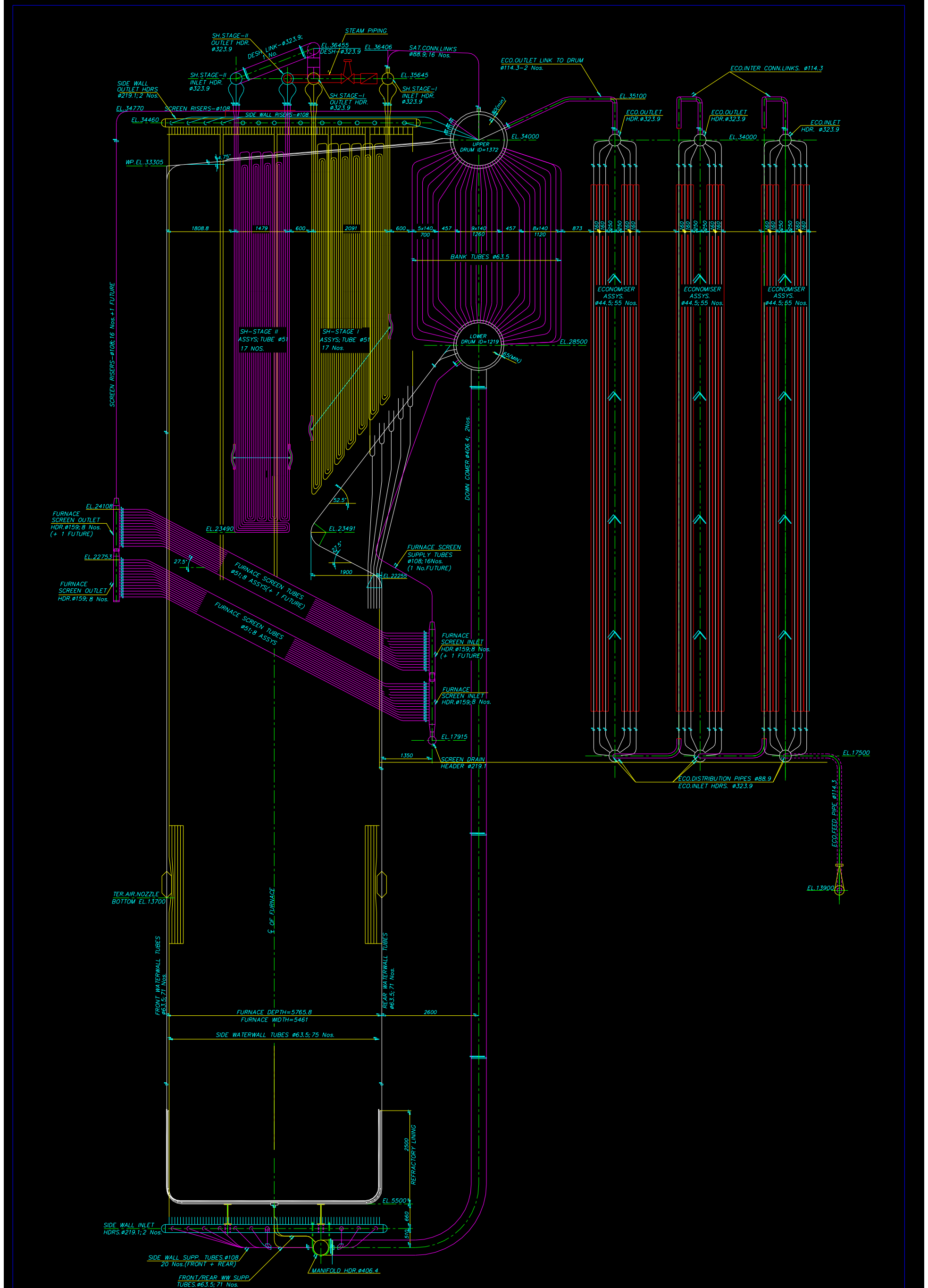

Alignment band

TYPICAL VU-40 BOILER



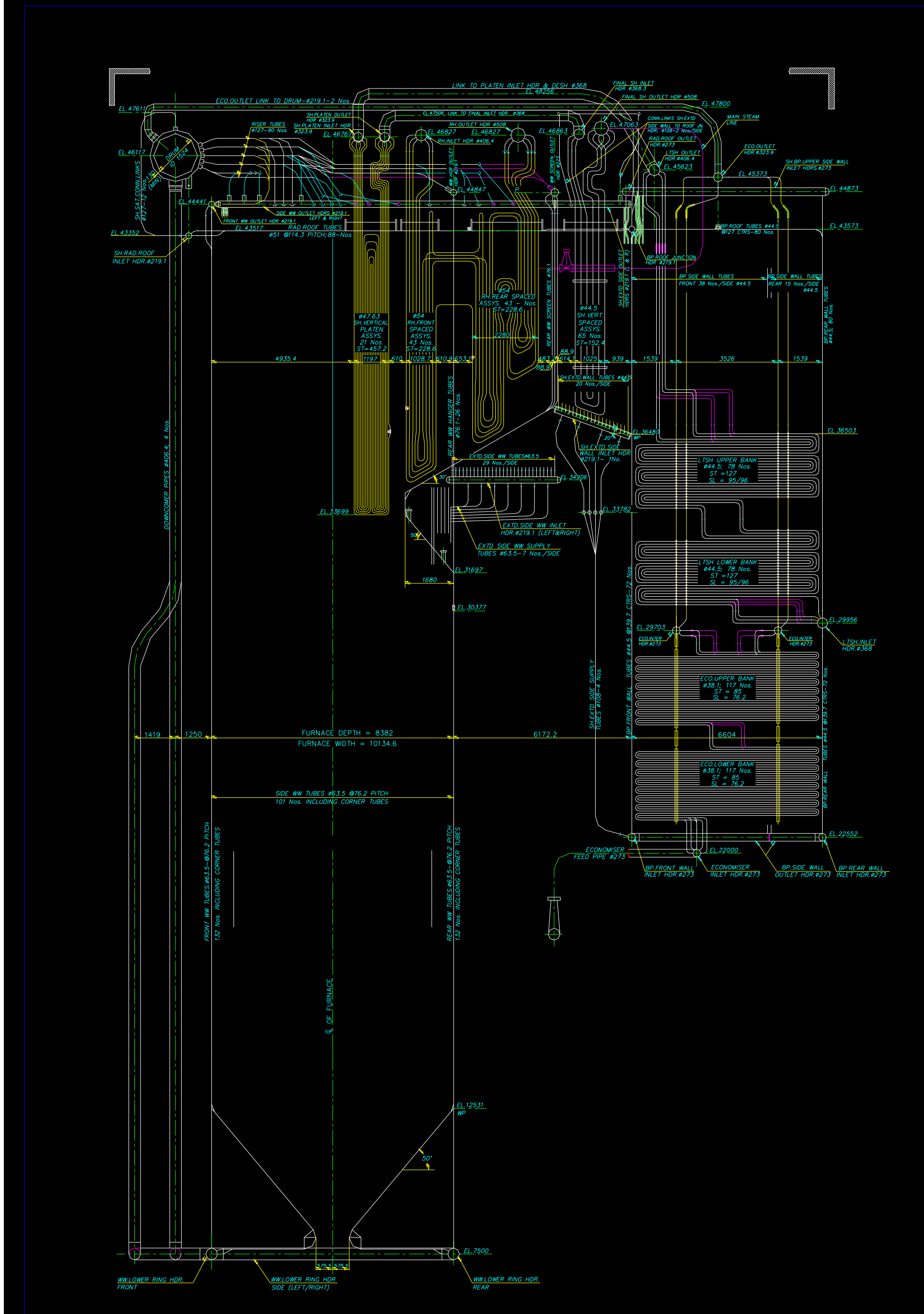
BACK

TYPICAL RECOVERY BOILER



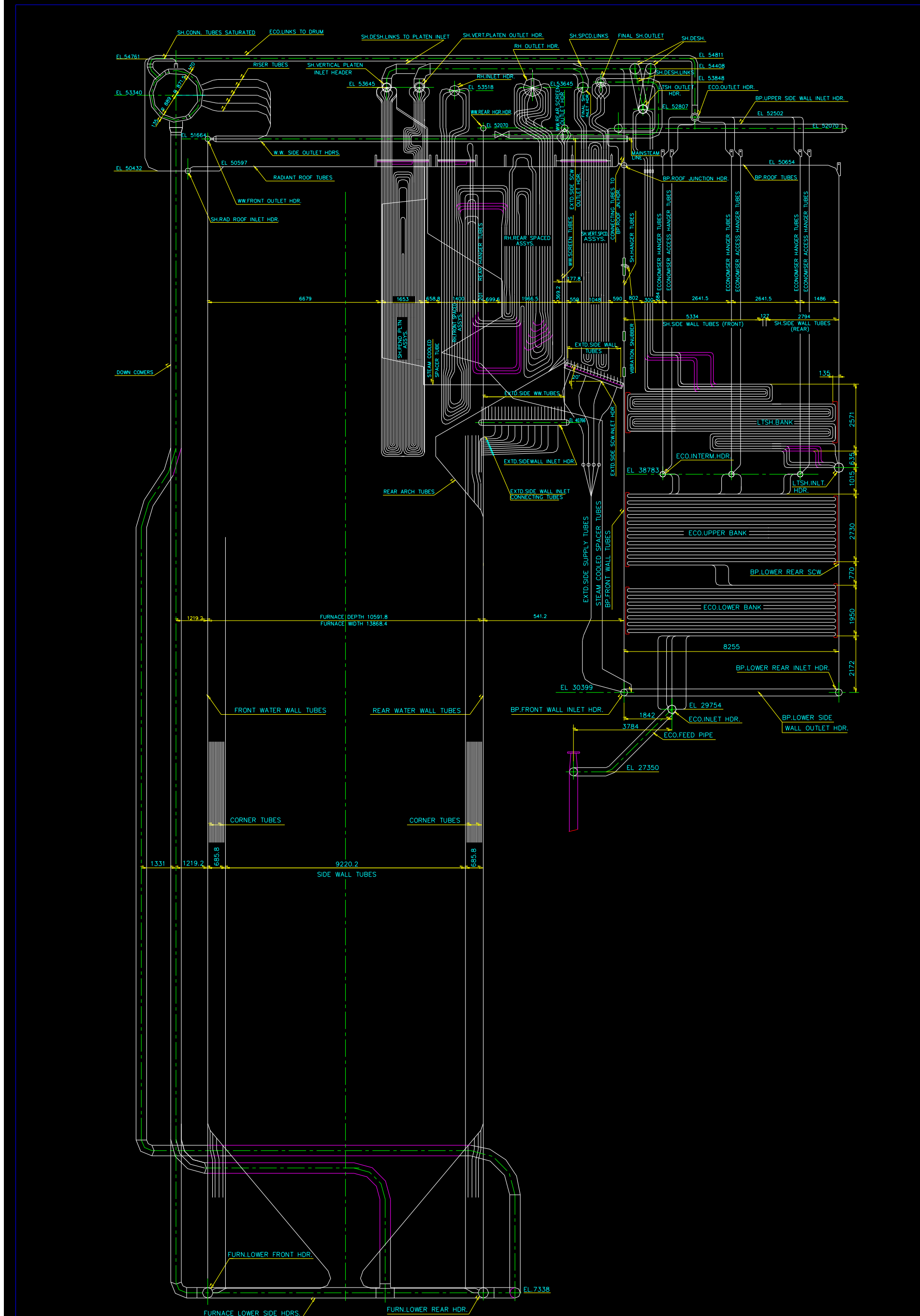
BACK

TYPICAL 120 MW BOILER



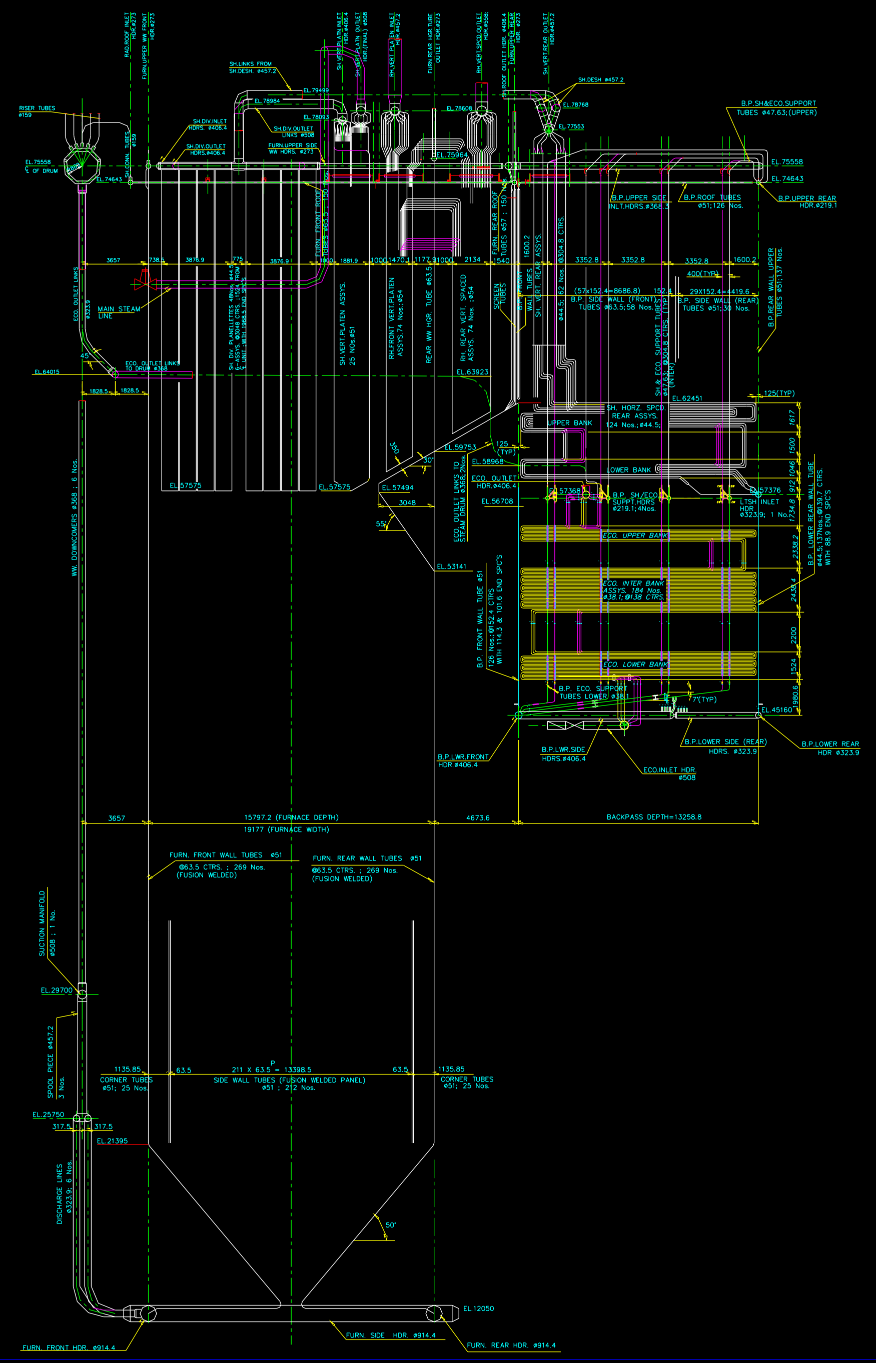
BACK

TYPICAL 210 MW/250 MW BOILER



BACK

TYPICAL 500 MW BOILER



BACK

Economiser System

Sl. No.	Description		Material	Design Temp. °C
1.	Economiser	Coils	SA 210 Gr A1	326
		Headers	SA 106 Gr C	398

Circulating System

Sl. No.	Description		Material	Design Temp. °C
1.	Drum		SA 299	368
2.	Waterwalls	Tubes	SA210 Gr C	398
		Headers	SA 299, SA106 Gr C	370

Roof & Steam Cooled walls

Sl. No.	Description		Material	Design Temp. °C
1.	Roof	Tubes	SA 213 T11	413
		Headers	SA106 Gr C	368
2.	SC walls	Tubes	SA210 Gr C	405
		Headers	SA106 Gr C	368 -394

Superheater System

Sl. No.	Description		Material	Design Temp. °C
1.	LTSH	Coils	T11	404 - 477
		Headers	SA106 Gr. C SA335 P12	394 -452
2.	Div. Panelette	Coils	T11, T22, T91	409 - 535
		Headers	SA335 P12	420 - 496
3.	Platen	Coils	T22, T91, TP347H,	478 - 600
		Headers	SA335 P12 SA335 P22	489 - 572

Reheater System

Sl. No.	Description		Material	Design Temp. °C
1.	RH	Coils	T11, T22, T91, TP347H,	351 - 589
		Headers	SA106 Gr C SA335 P22	361 - 590