Boiler - Protections, Emergencies and Losses

Kumar Rupesh
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Objectives and other details of modules

Duration – 90 + 75 minutes

Training aids

Power point Presentations

Reading Material

Objective

At the end of the session participants will be able to:

- **Describe various boiler protections**
- **List out events occurring at the time tripping of boiler**
- **Illustrate events associated with boiler emergencies**
- **Apply procedures prescribed for handling boiler emergencies**
- **Undertake planned boiler shutdown**
- **Describe reasons for boiler efficiency losses and components wise heat losses**
- **Calculate boiler efficiency**
- **Apply corrective action for reducing boiler losses**

Contents

- ❑ Boiler Protections
- ❑ Boiler Emergency
- ❑ Boiler Planned Shutdown
- ❑ Boiler Losses and Efficiency

Boiler Protections

Boiler Protections

Boiler Trip Conditions

- Both FD Fans Off
- All ID Fans Off
- ***Inadequate Waterwall Circulation***
- ***Loss Of Reheat Protection***
- Deaerator level Lo-Lo (-2134 mm 2 / 3 logic)
- All Boiler Feed Pumps Off
- Drum Level High-High (> + 250 mm, delay of 10 seconds)
- Drum Level Lo-Lo (< - 375 mm, delay 10 seconds)
- ***Elevation Power Failure For > 2 seconds***.
- Furnace Pressure High-High (> + 325 mmWC, 2 / 3 logic)
- Furnace Pressure Lo-Lo (< -250 mmWC, 2 / 3 logic)

Boiler Protections contd.

Boiler Trip Conditions

- ***Loss Of All Fuel***
- ***Unit Flame Failure***
- ***Loss Of Critical Power For > 2 seconds***
- ***Loss Of 220 V DC For > 2 seconds***
- ***Loss Of ACS Power > 2 seconds***
- ***Less than fire ball & loss of AC at any Elevation in service***
- Simulator Trip
- Air Flow < 30 %
- Both Emergency Push Buttons Pressed.

Boiler Protections – MFT actions

When the boiler trips the following events takes place:

- Boiler Trip red lamp comes on
- MFT A & B trip lamp comes on and reset lamp goes off
- Cause of trip memory can not be reset till the furnace purge is completed
- FD Fans Control is transferred to manual
- ID fans vane position is transferred to manual
- Pulverizers are tripped
- Coal feeders are tripped
- P A Fans are tripped and permit to start PA fan signal is removed.
- Cold air dampers opens to 100 % (TD – 300 Secs)
- HFO trip valve closes and the Oil elevation trip memory signal is established.
- All HFO Nozzle valves close
- Upper and Lower Fuel air damper opens
- Auxiliary air damper opens and control is transferred to manual
- Loss of all fuel trip protection disarms
- S/H and R/H spray block valves S-82 & R-31 closes and can not be opened unless furnace purge is completed
- Turbine Trips

Boiler Protections contd.

Inadequate Water Circulation (500 MW)

Condition-1: (Boiler Load > 60 %) And (Less Than Two Pumps ON OR Pump On And Differential Pressure < 10 Psi).

Condition-2: (Boiler Load < 60 %) And (no Pump ON OR Pump On And Differential Pressure < 10 Psi)

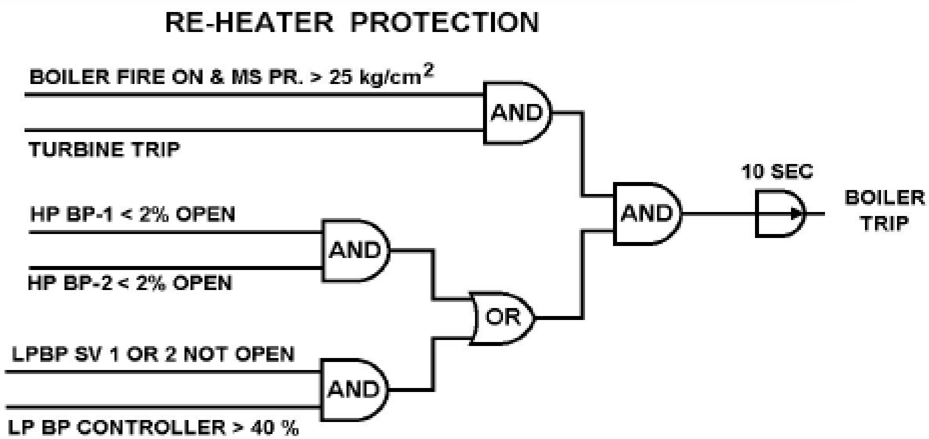
Reheat Protection (500 MW)

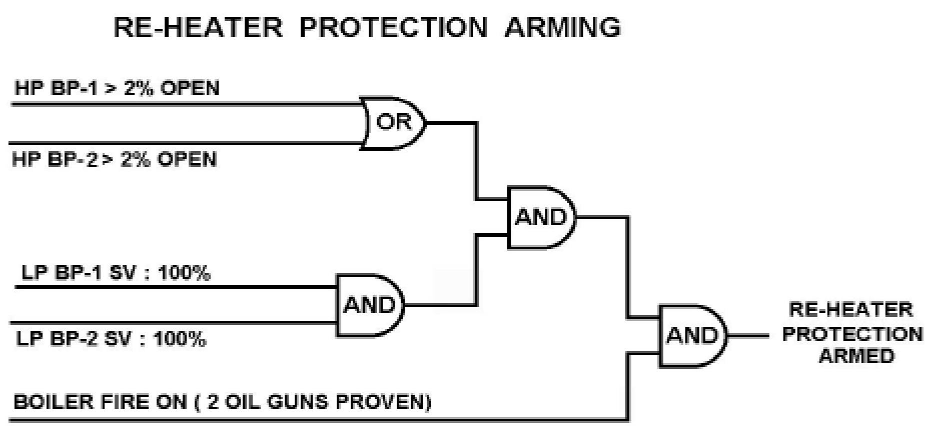
Condition-1: (Turbine Trip OR Generator Circuit Breaker Open)
AND (HP/ LP Bypass Opening <2%)

Condition-2: Turbine Working (HPCVs and IPCVs opening > 2%)
AND (Load Shedding Relay Operated)
AND (HP/ LP Bypass Opening <2%)

Condition-3: (Turbine not working AND Boiler Working i.e. 2 oil guns proven)
AND (HP/ LP Bypass Opening <2%)

Boiler Protections contd.





Boiler Protection - Loss of All Fuel

Loss of All Fuel Protection Arming (500 MW)

Any Elevation OIL nozzle valve not closed

AND MFT Reset (TD – 5 Secs)

Loss of All Fuel Protection (500 MW) – No Coal and No Oil

Loss of all fuel trip arming set

AND

All feeders off

AND

(HOTV not open) OR (All Elevation (AB,CD,EF,GH) backup trip) OR (All HO nozzle valves closed)

AND

(LOTV not open) OR (Elevation AB backup trip) or (All LO nozzle valves closed)

Less than Fireball and Loss of AC at any Elevation in Service

All feeders off

AND

Any Elevation (AB, CD, EF, GH) started & loss of 110 V AC (TD-2 sec)

Boiler Protection – Flame Failure

Flame Failure Trip Arming (500 MW)

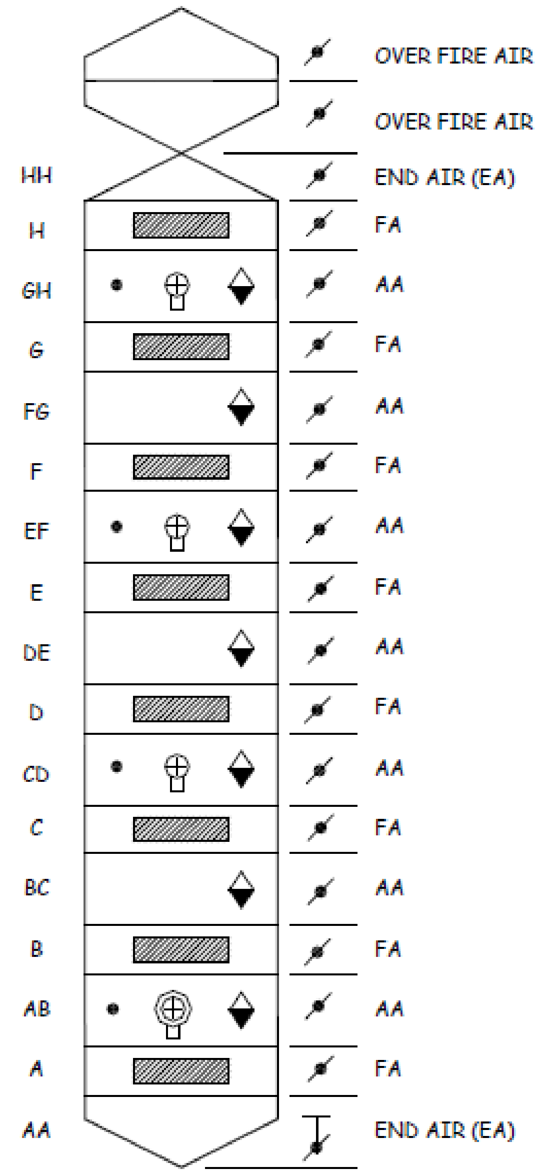
Any Feeder (A, B, C, D, E, F, G or H) Proven

Flame Failure Trip

Flame Failure Trip Protection Arming set
AND
All Elevations (A, B, C, D, E, F, G and H) Voted No Flame

Elevation A Voted No Flame

[(Elevation AB more than one nozzle valves not open)
AND
(Elevation AB Less than 2 Fire scanners sensing no Flame)]
OR
[Elevation AB Started and Loss of 110 V AC (TD- Secs)]
OR
[Feeder-A Not Proven]



Boiler Protection – Flame Failure contd.

Elevation B Voted No Flame

[Elevation BC Less than 2 Fire scanners sensing no Flame]

AND

[(Elevation AB more than one nozzle valves not open)

AND

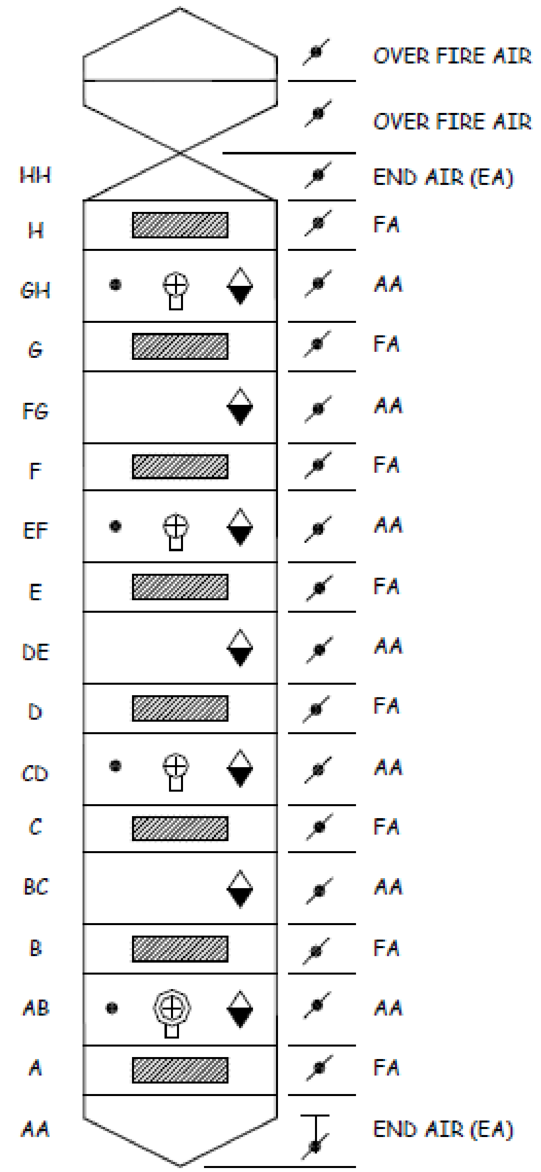
(Elevation AB Less than 2 Fire scanners sensing no Flame)]

OR

[Elevation AB Started and Loss of 110 V AC (TD- Secs)]

OR

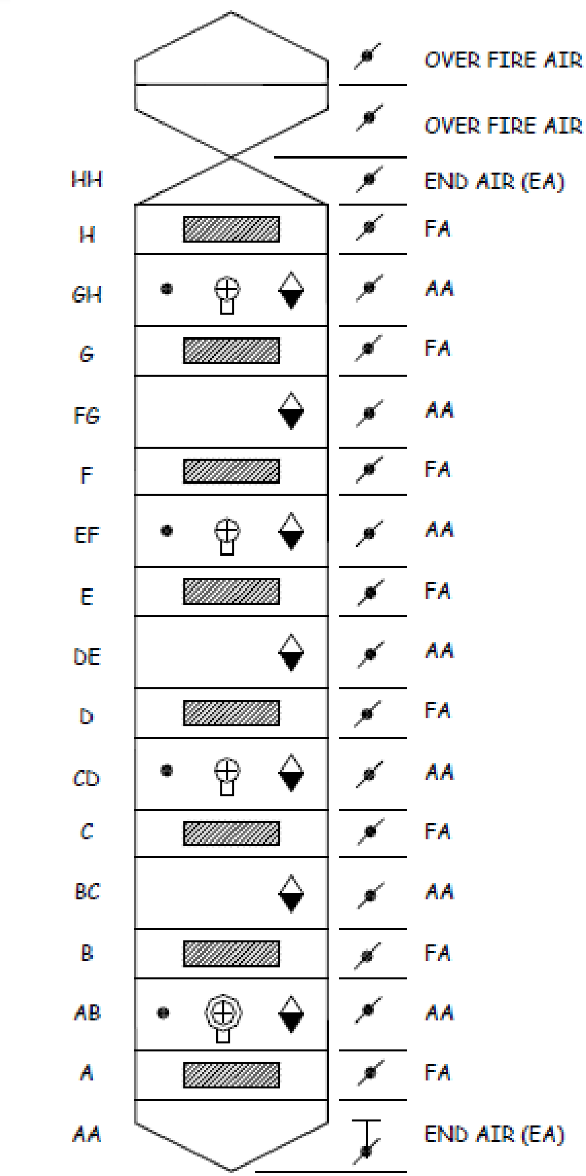
[Feeder-A Not Proven]



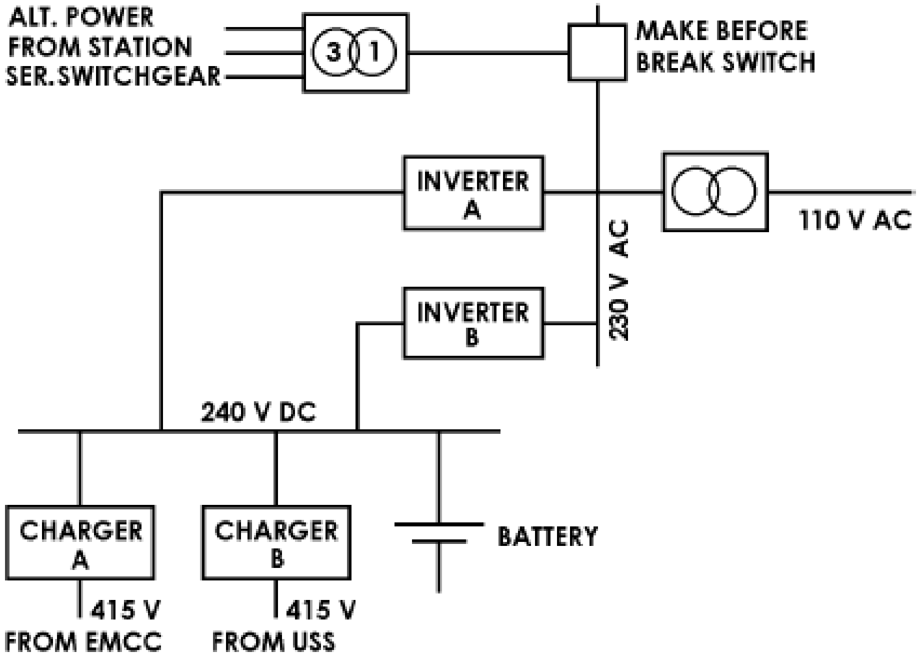
Boiler Protection – Flame Failure contd.

Elevation C Voted No Flame
[Elevation BC Less than 2 Fire scanners sensing no Flame]
AND
[(Elevation CD more than one nozzle valves not open)
AND
(Elevation CD Less than 2 Fire scanners sensing no Flame)]
OR
[Elevation CD Started and Loss of 110 V AC (TD- Secs)]
OR
[Feeder-C Not Proven]

Nearest Oil Elevation not proven
AND Nearest Scanners not proven
OR Coal Feeder not proven



FSSS Power Supply



FSSS Power Supply contd.

220 V AC Supply System

- Analogue Control System
- Annunciation
- Aux Relay Panel
- DAS
- Feeder Cabinet
- FSSS AC Supply
- HP Bypass Cabinet
- Hydrastep
- SADC

110 V AC Supply System

- Atomising Steam, HONVs, LONVs
- Flame Scanner Module
- Mill Discharge Valve
- Mill Feeder Control
- Mill Seal Air Damper etc.

FSSS Power Supply contd.

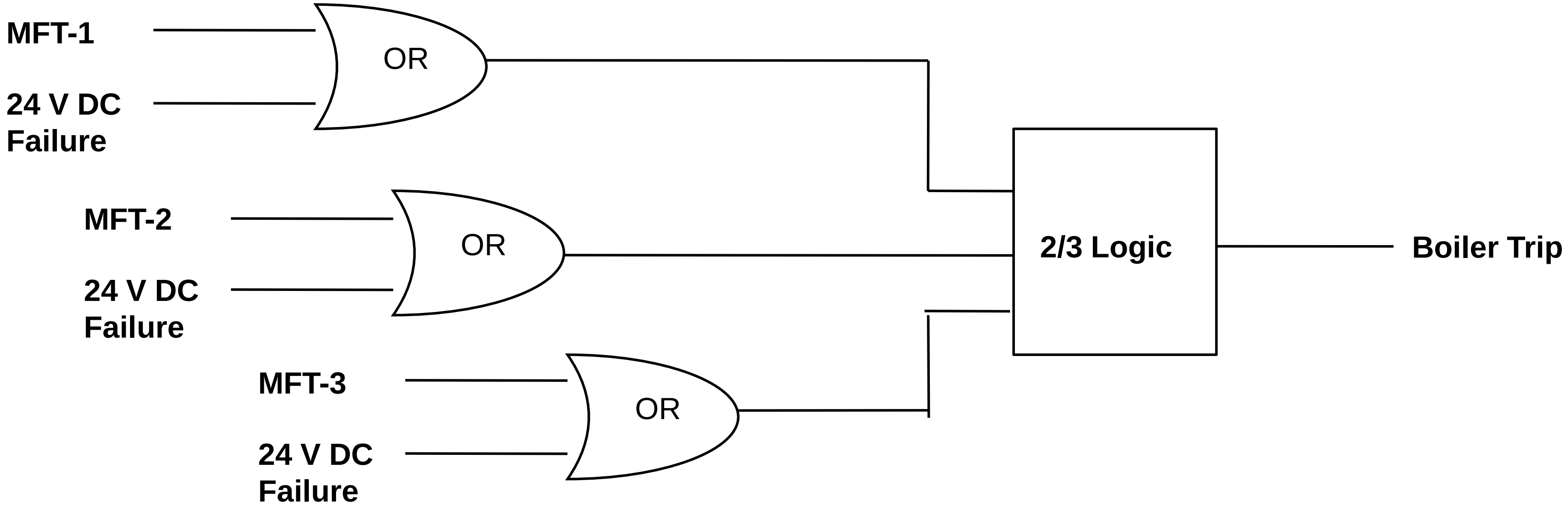
220 V DC Supply System

- HFO Trip Valve
- HFO Recirculation Valve
- Mill Motor Control
- Scanner Air Fan Discharge and Emergency Suction Damper etc.

Elevation Power Failure – 2 Secs – 110V AC power failure at respective elevations

Loss of Critical Power Failure – 2 Secs – 24 V DC Power failure (Hardwired)

MFT and 24 V DC Hardwired Integration



Boiler Emergencies and Shutdown

Boiler Emergencies – PA Fan Tripping

- **One PA Fan Tripping (2 X 50% configuration)**
- The discharge damper of tripped PA Fan takes time to close full. Due to fan tripping and running fan air short circuiting the PA Header pressure falls below expected.
- Take the running PA on manual and restrict its BP from overloading.
- Stop upper mills such that half of the running mills from bottom are in service.
- Immediately close the BP of fan tripped, Interconnecting damper of PA fans and CADs & HADs of mills stopped to reduce running fan demand.
- Take the oil support only after PA header pressure has recovered. An early action may result into furnace explosion due to high coal input and oil input simultaneously when PA header pressure recovers.
- Due to sudden pressure drop, drum level also surges violently. Maintain drum level properly.

Boiler Emergencies – ID Fan Tripping

- **One ID Fan Tripping (2 X 50% configuration)**
- The inlet gate/ damper of tripped ID Fan takes time to close full. Due to fan tripping and running fan air short circuiting the furnace pressure rises above expected.
- Take the running ID Fan on manual and restrict its IGV to avoid fan overloading.
- Stop upper mills one by one in sequence with a time delay of minimum 5 secs each such that half of the running mills from bottom are in service.
- Trip one of the FD Fans.
- Immediately close the IGV of fan tripped, the interconnecting damper and CADs & HADs of mills stopped to reduce running fan demand.
- Take the oil support only after furnace pressure has recovered. An early action may result into furnace explosion.
- Due to sudden pressure drop, drum level also surges violently. Maintain drum level properly.

Boiler Emergencies – HPHs Group Bypass

- **HPHs group bypass**
- The HPHs extraction steam may amount to 8-10% of full load steam flows. Expansion of this amount of steam in turbine leads to sudden load shoot up.
- As sensible heat is no more added in HPHs, this shall be added in Economiser and Water Wall. Thus lower heat is available for steam evaporation.
- This results into lower heat evaporation. Also, there is higher FG heat consumption in water wall. Out of these competing features, former dominates and SH and RH steam temperatures rise rapidly.
- Also, due to very high heat consumption in Economiser, PA temperature pick-up in APH is low and its difficult to maintain Mill outlet temperature.
- Drum Pressure also drops rapidly due to lower evaporation. This results into lower BFP discharge Pressure.
- Increase SH and RH spray to maximum. Also, increase ΔP across FRS for higher BFP pressure and hence spray.
- Bring burner tilt to lowest position. Take-out the highest mill out of service.
- When temperature stabilises, higher coal than condition before disturbance shall be required to restore load.

Boiler Emergencies – others

- **Lower Mill Tripping**
- It has similar effects on MS and RH temperature as HPHs tripping. The action should be taken accordingly.
- **MS Pressure TX going out of order**
- As MS flow incorporates pressure and temperature correction, a sudden loss of MS Pressure TX (one used for pressure compensation), results into lower MS flow measured by the system.
- The three element drum level control reduces the FW flow in response. Thus, BFPs start unloading and the drum level drops fast.
- If analyzed in time, take BFPs in manual and restore the flow to suitable value.
- **N-1 mills to N mills operation**
- Assume that a lower number of mills are operating near full load and additional mill is taken in service.
- Generally, bowl mills operating at full load have choking tendency. Before cutting in the new feeder, it is advisable to clear the choking of one mill at a time.
- Reducing coal flow in all mills and simultaneous command to extra feeder pumps excess coal in Boiler and all the pressures rise rapidly. This may result into safety valve operation, HP/ LP bypass operation, vacuum deterioration etc.

Planned Boiler Shutdown - Sequence

Planned Boiler Shutdown (in conjunction with Turbine operations)

- Reduce Loading of TG set to 75% with two pulverizers withdrawn.
- Reduce Loading of TG set below 50% with HP-LP bypass in operation with three pulverizers withdrawn
- Remove one ID, one FD and one PA fan
- Reduce Loading of TG set to 25% with two pulverizers and AB/ CD oil elevation in service
- Reduce loading of TG set to 10-15% with one pulverizer and AB & CD Oil elevation in service
- Trip Turbine and put on barring gear
- Take Boiler under shutdown
- Boiler cooling and Shutdown of Air & Flue gas system

Planned Boiler Shutdown - Pulverizer Shutdown

Pulverizer shutdown

- Take top mill feeder in manual and reduce it to minimum.
- Close the HAG and HAD and open CAD full.
- Close bunker silo gate. When mill outlet temperature drops rapidly, stop mill feeder. The other mills may be loaded if Fuel master is on Auto.
- Wait till pulverizer grinding current reduces to minimum. Mill bowl DP and outlet temperature comes down indicating emptying of mill.
- Open the tramp iron gate to remove any rejects.
- Stop pulverizer. Close Fuel Air Damper.
- Close CAD full.
- Close Pulverizer seal air valve (may close on interlock). Close pulverizer discharge valve.

Planned Boiler Shutdown - Load Reduction

Load Reduction to 75%

- Load gradient shall not be more than recommended by OEM. Generally it is 5MW/min for planned shutdown.
- Reduce the Unit master demand gradually to 75% if in CMC. If in manual, put machine in load controller, reduce mill firings and withdraw two pulverizers one by one.
- Reduce the throttle steam pressure also to 75% of rated value.
- Withdraw HPHs by closing the extraction steam valves. Drum pressure increases first then comes down.
- Reduce AVR set point if required.
- Take attemperation control in manual and increase sprays slightly to bring down MS and HRH temperatures for turbine cooling. Also lower burner tilt.
- MSP and Reheat Pressure also drops.
- ESV and CV surface temperature and mean temperature starts dropping.
- HP casing and shaft temperatures also start dropping.

Note: If the unit is withdrawn for short duration, MST and HRH temperature should not be dropped very low.

Planned Boiler Shutdown - Load Reduction contd.

Load Reduction below 50% with HP-LP Bypass in service

- Keep machine in pressure controller, and reduce firing further. Take another mill out of service.
- Withdraw one set of ID, FD and PA fans.
- Reduce the throttle steam pressure also to 50% of rated value. Both load and MS/ HRH pressure, MST, HRHT and valves & shaft temp keeps dropping.
- Reduce AVR set point if required.
- Take machine on load controller mode.
- Put HP bypass set point near throttle pressure set point.
- Put LPBP also on auto with fix set point slightly below sliding set point.
- Reduce load set point. As throttle pressure tries to increase, HPBP opens. As HRH pressure increases above sliding set point LPBP also opens.
- Take CD or AB Oil elevation and withdraw another Mill.
- For load < 20%, withdraw LPHs. UAT to Station C/O to be carried out.
- Take AB oil elevation and withdraw another mill.

Note: If the unit is withdrawn for short duration, MST and HRH temperature should not be dropped very low.

Planned Boiler Shutdown - Fans withdrawal

Withdrawal of one set of ID, FD and PA

- Transfer the furnace pressure controller to manual. Unload one of the ID fans and load other through IGV. Stop one fan. Ensure that discharge damper closes on auto. Stop the lube oil pump only after bearing temperature comes to normal.
- Transfer the PA header pressure controller to manual. Unload one of the PA fans and load other through BP. Stop one fan. Ensure that discharge damper closes on auto. Stop the lube oil pump only after bearing temperature comes to normal.
- Transfer the oxygen controller to manual. Unload one of the FD fans and load other through BP. Stop one fan. Ensure that discharge damper closes on auto. Stop the lube oil pump only after bearing temperature comes to normal.
- After, killing of Boiler two ID and FD fans running is not recommended as Boiler cooling becomes very fast and drum top-bottom temperature difference exceeds 50 Deg C.

Planned Boiler Shutdown - Firing Shutdown

Boiler Shutdown

- Withdraw the last pulverizer. Ensure that all Fuel Air Dampers are closed.
- Stop the running PA fan. Keep the lube oil pump running till the bearing temperature comes down. Ensure that discharge dampers of both the fans open on auto. Stop seal air fans.
- Bring burner tilt to horizontal position.
- Adjust air to 30-40%.
- Remove CD oil gun elevation. The scavenzing should take place in gun withdrawal sequence.
- Remove AB oil guns. As the 4th nozzle valve closes, Boiler MFT operates on loss of all fuel.
- Ensure that LOTV and HOTV closes.
- Start furnace purge cycle and complete furnace purging.
- Do not drain the Boiler immediately.
- If fast boiler cooling is required, leave one ID and FD in service. Maintain the air flow such that Drum top – bottom temp difference maintains below 50 Deg C.

Planned Boiler Shutdown - Air and FG system shutdown

Boiler Shutdown

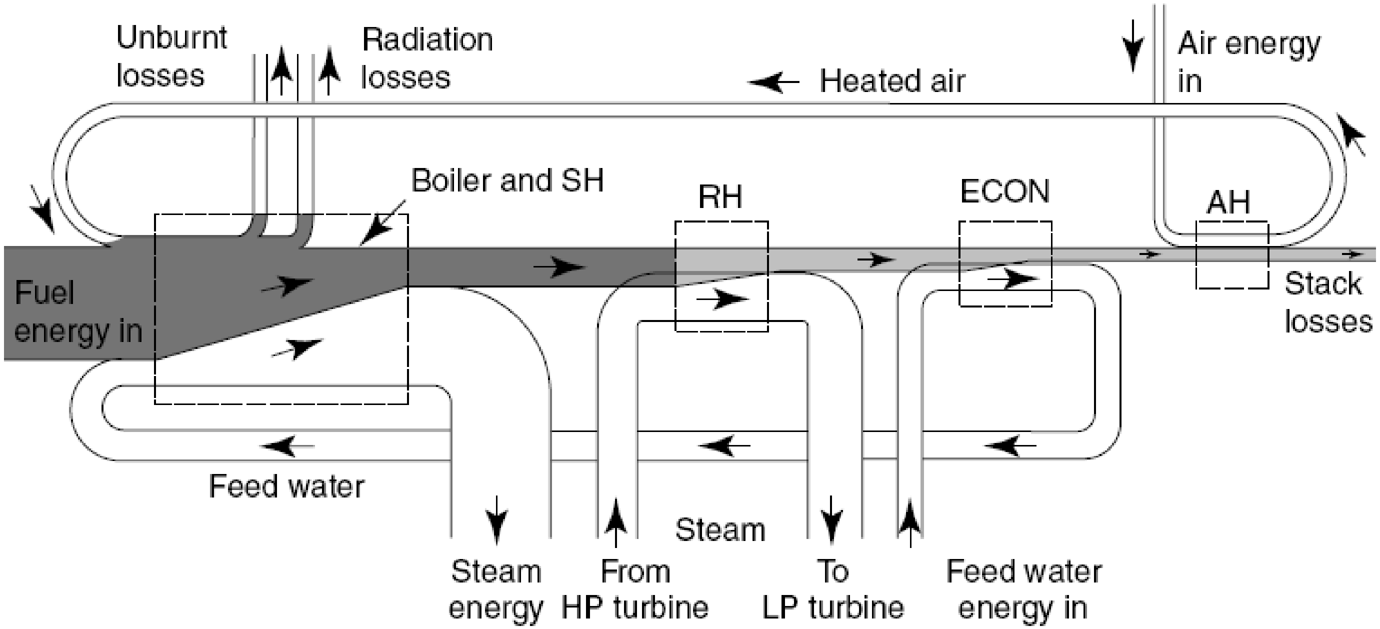
Note: Boiler draining is advisable only after Drum top-bottom temperature difference is below 50 Deg C and Drum top and bottom metal temperature drops to < 110 Deg C.

Air and Flue Gas System Withdrawal

- Reduce the FD fan BP to minimum and stop FD Fan. Stop the lube oil pump only after the bearing temperature comes to normal. Discharge damper of both the fans open full on auto.
- Scanner Air Fan emergency suction damper from atmosphere opens on Auto.
- Reduce the ID fan IGV to minimum and stop ID Fan. Stop the lube oil pump only after the bearing temperature comes to normal. Discharge damper of both the fans open full on auto. This helps in natural cooling of furnace.
- When FG temperature at APH inlet falls below 120 Deg C, stop APHs. Keep FG and Air side dampers at APH inlet and outlet open for natural air circulation.
- Stop SCAPH steam supply if in service.
- ESP fields can be withdrawn.
- Scanner Air fan to be stopped only when Furnace is sufficiently cooled.

Boiler Losses and Efficiency

Boiler Losses - Overview



Heat Inputs, Outputs, and Loss

Heat Inputs	Heat Outputs	Heat Loss
Fuel Air	SH steam RH steam	Stack Unburnt Radiation Unaccountable

Boiler Efficiency Calculation – Important Aspects

Important Aspects

GCV (Gross Calorific Value) basis vs. NCV (Net Calorific Value) basis Calculation:

NCV = GCV – 578(m + 9 H_2) kcal/kg

where, m is mass of moisture/ kg of fuel and H2 is mass of Hydrogen/ kg of fuel

(As, $H_2 + \frac{1}{2} O_2 = H_2O$, i.e. 1 g of hydrogen produces 9 g of water)

578 kcal/kg is the latent heat of vaporization of moisture

- When calculation is done on GCV basis, it is the total fuel heat which is considered for evaluation. It gives the pessimistic figure of boiler efficiency as the heat carried away by moisture is system requirement and not due to inefficacy of heat transfer surfaces. But, for ascertaining the fuel requirement for specified quantity of steam, this methodology must be adhered to.

- When calculation is done on NCV basis, it is the available heat which is considered for evaluation. It gives the correct picture of Boiler efficiency.

Boiler Efficiency Calculation – Important Aspects

Important Aspects

Input-Output method vs. Heat Loss method:

- Input-Output (or Direct method as per BS) gives Gross Boiler Efficiency as (net Output/ Total Input). The net out put is measured by steam flow and steam enthalpy – FW Flow and FW enthalpy.
- Heat Loss Method (or Indirect method as per BS) gives gross boiler efficiency as (100 – Heat Loss/ Total Input). The heat losses are measures by measuring various temperatures, pressures, % by weight, heating value of ash etc.
- As the direct method of efficiency measurement involves measurement of steam flow which inherently can not be too accurate, its accuracy is lower. Further, the sensitivity of inaccuracy in direct method has larger effect. E.g. in a Boiler of 80% efficiency, a 2% error on parameter measurement reflects 1.6% error in final result whereas it reduces to 0.4% for Indirect method.
- For both of the methods the Calorific value of the coal should be fairly constant throughout the testing.
- The direct method being simple and cost effective is used for day-to-day assessment of Boiler condition. The indirect method is cost intensive and is used as acceptance test for Boilers.

Boiler Losses – components and calculation

Heat Loss Method Components and Calculation

Components:

I. Stack Losses

a. Dry gas loss (Ldg)

b. Moisture Loss (Lm)

c. Humidity Loss (Lh)

II. Unburnt Loss (Lub)

III. Radiation Loss (Lr)

IV. Unaccountable Loss (Lu)

I. Stack Loss is a measure of how well the exit gases are cooled and flue gas quantities are maintained. The dry gas loss covers 70-80% of total losses, moisture loss varies from 8-20% of total losses and Humidity losses are < 0.1%.

Boiler Losses – components and calculation contd.

Dry Gas Loss (Ldg)% on GCV basis = $$\frac{W_g (T_g - T_a) \times C_p \times 100}{GCV}$$

Dry Gas Loss (Ldg)% on NCV basis = $$\frac{W_g (T_g - T_a) \times C_p \times 100}{NCV}$$

Where,

W_g = weight of gas leaving the system in kg/ kg of fuel burnt (not fired)

W_h = weight of moisture in air in kg/ kg of fuel burnt

T_g = temperature of flue gas leaving the system in 0 C

T_a = temperature of air entering the system in 0 C

C_p = mean specific heat of gas between Tg and Ta

Moisture Loss (Lm)% on GCV basis = $$\frac{(9\,H_2 + m) \times (H_s - h_a) \times 100}{GCV}$$

Moisture Loss (Lm)% on NCV basis = $$\frac{(9\,H_2 + m) \times (H_s - h_a - 578) \times 100}{NCV}$$

H_2 = percentage hydrogen in fuel by weight

m = percentage moisture in fuel by weight

H_s = Enthalpy of steam at T_g and 1 psia is equal to 578 kcal/kg

h_a = enthalpy of water at T_a in kcal/ kg

Boiler Losses – components and calculation contd.

Humidity Loss (Lh)% on GCV basis = $\dfrac{\mathbf{W_h \times (H_s - h_a) \times 100}}{\mathbf{GCV}}$

Humidity Loss (Lh)% on NCV basis = $\dfrac{\mathbf{W_h \times (H_s - h_a) \times 100}}{\mathbf{NCV}}$

W_h= percentage hydrogen in fuel by weight

H_s = Enthalpy of steam at T_g and 1 psia is equal to 578 kcal/kg

h_a = enthalpy of water at T_a in kcal/ kg

II. **Unburnt Loss** is a measure of how well the fuel is burnt in the firing equipment for the excess air chosen. Efficiency of heat release of firing equipment is measured by the amount of carbon burn-up.

Carbon burn-up (Cb) = $\dfrac{\textbf{(100 - \% carbon in the residue)}}{\textbf{\% total carbon at inlet}}$

The unburnt loss (Lub)% on GCV basis = $\dfrac{\textbf{Percent ash in fuel X } \mathbf{C_a} \textbf{ X 80.78}}{\mathbf{GCV}}$

The unburnt loss (Lub)% on NCV basis = $\dfrac{\textbf{Percent ash in fuel X } \mathbf{C_a} \textbf{ X 80.78}}{\mathbf{NCV}}$

Where, Ca = % of combustible in fly ash and bottom/ bed ash

Boiler Losses – components and calculation contd.

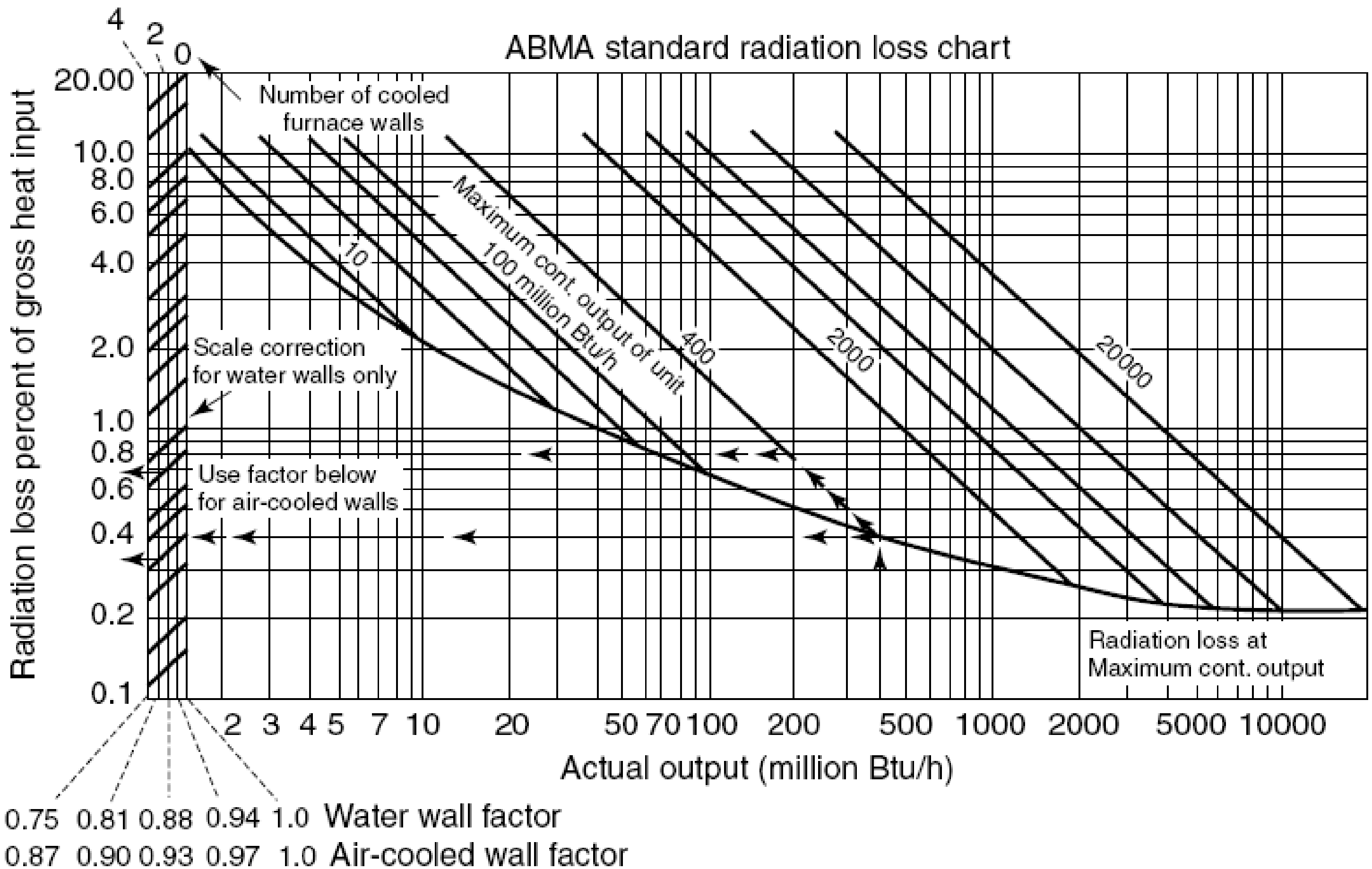
III. **Radition Loss** is a comprehensive measure of losses caused by radiation and convection conductance for Boiler, ducting and milling plant. This can be calculated on actual basis with respect to reference temperatures. Alternatively, it can be derived from radiation loss curve given by ABMA (American Boiler Manufacturer's Association).

The radiation losses are below 1% and become smaller as the boiler size and water cooled surfaces increase.

There are limitation of the ABMA graph but it is very popular due to its convenience and low value of radiation loss. For example, the loss is not based on surface area of boiler but the evaporation capacity. Thus, a compact oil fired boiler of same capacity as PF fired boiler shall have same radiation loss.

IV. **Unaccountable Loss** cannot be exactly quantified and are small enough to be combined as a reasonable value. They usually comprise of losses like heat loss in ash, unstated instrument tolerances and errors, any other immeasurable losses etc. Generally it is agreed before the test itself.

Boiler Losses – components and calculation contd.



Note: The losses are based on assumption of surface to ambient temperature difference as 27 ^{0}C and the air velocity of 0.5 m/sec.

Boiler Losses – Controlling measures

Optimization – Lowering the losses and Auxiliary Consumption

I. Stack Loss Reduction

- Minimum exit FG temperature avoiding low temperature gas corrosion. Larger surface area for heat recovery at lower temperatures are required.
- Minimum excess air without compromising combustion with traces of CO. This requires careful metering.
- Reduce Air infiltration through leakages to reduce weight of exit flue gas
- Reduce gas bypassing the banks due to excessive gap between coils
- Regular Soot Blowing

II. Unburnt Loss Reduction

- Maintain there Ts – Time, Temperature, Turbulence
- Proper Coal Fineness
- Proper secondary air control

III. Radiation Loss Reduction

- Proper insulation such that surface temperature is about 20-25 ^{0}C above ambient.

IV. Fan Power Reduction

- Optimum gas velocity – Optimum pressure drop – Optimum Fan head
- Optimum Excess Air

Boiler Losses – Controlling measures contd.

Optimization – Lowering the losses and Auxiliary Consumption

Fan Power Reduction contd.

- Highest Efficiency – Axial Flow for clean application and Careful design for operating point matching best efficiency point
- Use of VFDs and VHCs for low load condition savings
- Low margins on head and flow

V. Pump Power Reduction

- Careful design for operating point matching best efficiency point
- Low margins on head and flow
- Use of VFDs and VHCs for low load condition savings

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Thank You