Boiler shutdown, emergencies, protections.

Boiler efficiency, losses and performance optimization

Dr. T K Ray
NTPC Limited

E-mail: rayt3@asme.org

Boiler normal shut down to cold

Steps for normal shut down to cold

Shut Down Procedure:

Turbine load reduction – To reduce the loading on turbine

Pulveriser shut down – To reduce the loading and take out the

puveriser from service

Load Reduction and HP/LP bypass operation

Turbine on barring gear

Shut down of air and flue gas system –

To stop ID fan and air preheater

To stop FD fans, scanner air fans

Shut down of turbine side auxiliaries –

To stop turbine lube oil pumps

To stop control fluid pumps

Steps for normal shut down to cold

Shut down of condensate system –

To stop the condensate pump which is in service

To stop the make pump

Shut down of circulation water system

To stop the circulating water pump

Shut down of fuel oil system

To stop the fuel oil pumps and associated system

Shut down of auxiliary steam system

To isolate the 16 ata steam header

Steps for normal shut down to cold

- **STEPS INVOLVED**

- Gradually reduce load on the reducing firing rate.

- MS/HRH steam temperature and MS pressure shall be reduced at the rate permitted by the turbine but not exceeding the rate of saturated steam temp drip of 83°C/hr, rate of load drop may be about 2MW/min.

- Carefully monitor the turbine condition and adjust the load temp, pressure drop rates such that HP/IP rotor differential expansion vibration etc are within the limit.

Steps for normal shut down to cold

- Load reduced to **160** MW, take HP heaters out of service.
- Load reduced to **150** MW approximate parameter at turbine inlet are:

  M.S. pressure=**120** $kg/cm^2(g)$

  M.S. temp=**520**°C

  HRH temp=**520**°C

Steps for normal shut down to cold

- While reducing the load check that following condition are maintained:
  Drum level is maintained on auto.
  SH and RH steam temp are maintained at set point .
  Furnace draft is maintained.
  Check the boiler expansion and contraction.

- At 40% mill load reduce the feeder speed to minimum and take upper elevation oil gun in service.

- When load on turbine is reduced to 100MW
  Temp=510°C
  Pressure=112kg/cm2

- At 100-90 MW take out one BFP from service.

Steps for normal shut down to cold

- Continue reduce the firing rate ,thus temperature and pressure will drop with drop in load.

- At 40% load take next upper elevation oil gun in service and take heavy oil gun in service.

- Prepare to take next upper elevation mill out and reduce feeder speed to minimum and stop feeder.

- Stop the mill after cooling down to 44°C and completely evacuating it see the load transferred on running mills.

Steps for normal shut down to cold

- Take heavy oil gun at lower elevation in service and take out next higher mill from service when loading on mill is reduce to 40%.
- At 70MW load MS temp=490°C RH steam temp=490°C MS pressure=105 kg/cm^2
- Take drum level control on manual and control drum level.
- Stop one PA fan after transferring full load on running PA fan.
- Stop lube oil pumps of tripped PA fan motor and bearing after all bearing temp reduced.
- Stop one FD fan corresponding to PA tripped.
- Check furnace draft and air flow before stopping FD fan and reduce load on this fan to minimum.
- Stop one ID fan corresponding to stopped FD fan . check furnace draft, transfer load from this ID fan to other and completely unload this ID fan before stopping it.
- Switch off supply of the ESP associated with tripped ID fan, carry out soot blowing of complete boiler.

Steps for normal shut down to cold

• At unit load 30% reduce air flow to 30%. Flow below 30%check the secondary air damper set point.

•Firing rate is reduced further and when load on mill is reduce to 40%,reduce feeder speed minimum and finally stop the feeder. Cool down mill to 44°C and shut down it.

• When load is reduce to 40MW take low load feed control valve and isolate main feed control valve .

• Switch off the supply to the field of ESP .

• Unit at 25-30MW with H.O. firing and change over auxiliary electrical supply from UATs to station transformer.

• Stop PA fan, check that seal air fan trips on interlock.

• Reduce load on unit to 5-7 MW

MS pressure boiler =90ksc

MS temp=465°C

RH steam temp=465°C

Steps for normal shut down to cold

•Trip the unit through MFT push buttons on FSSS console or through protections.

•Check that boiler fire is completely out ,check that all the flame scanners sense no flame and check boiler actually from peep hole and ensure that fire is completely out.

• Maintain 30% air flow and purge the boiler for at least five minute and check turbine bearing lubricating system.

•Check that all the feeders and mills are off ,break the vacuum when turbine speed comes to zero.

• Individual burner HO, atomizing air and steam nozzle valves and Igniters valves are closed.

•Check that Atemperation SH and RH isolating valve and its bypass valve are closed, close isolating valve of SH and Reheater spray control valves.

•Open Reheater vents and close CBD valves.

Steps for normal shut down to cold

- Close boiler main steam stop valves and their bypass valves.
- Open MS line drains valves open CRH and HRH line drains.
- Shut down HO system
- Top up the drum level up to +180 mm ,stop BFP.
- Stop hydrazine dosing pumps, stop phosphates dosing pumps if it is in service.
- Do not stop AP Heaters till flue gas temp at APH inlet is less than 205°C,air flow through furnace shall be controlled to effect the desired cooling rate and it can be controlled by:

  air flow through boiler

  opening SHH valve
- Boiler is to be forced cooled fast after shut down , keep ID fan and FD fan in service. Regulate air flow to effect desired rate of cooling ,open starting vent valve.
- Bring up drum level to +180mm when it drops to –180mm, start BFP for toping up the level. Stop BFP after words.
- Stop FD and ID fans when flue gas temp at APH inlet is reduced below 205°C and boiler is cooled.

Steps for normal shut down to cold

- If required stop APH otherwise keep them rotating , check that APH lube oil pump stop on interlock when oil temp goes below 40°C.
- When boiler water temp goes below 94°C, drain the boiler or preserve it according to the circumstances.

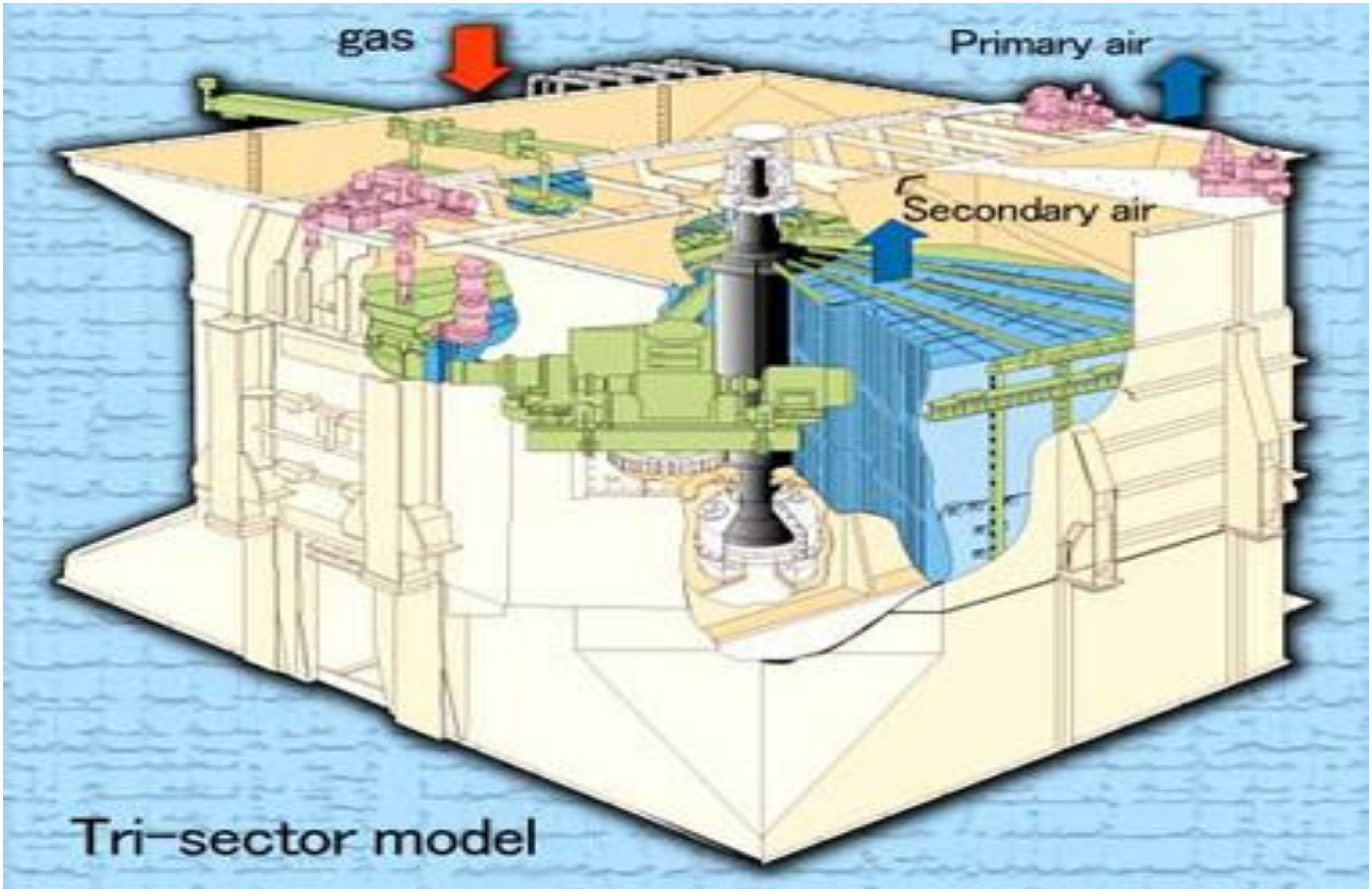
Emergencies in Boiler

- APH Fire
- Mill Fire
- Drum Level Hi / Lo
- Furnace Pres Lo / Hi
- Flame Failure
- Tripping of Mills
- ID Fan tripping
- FD Fan tripping
- PA fan tripping

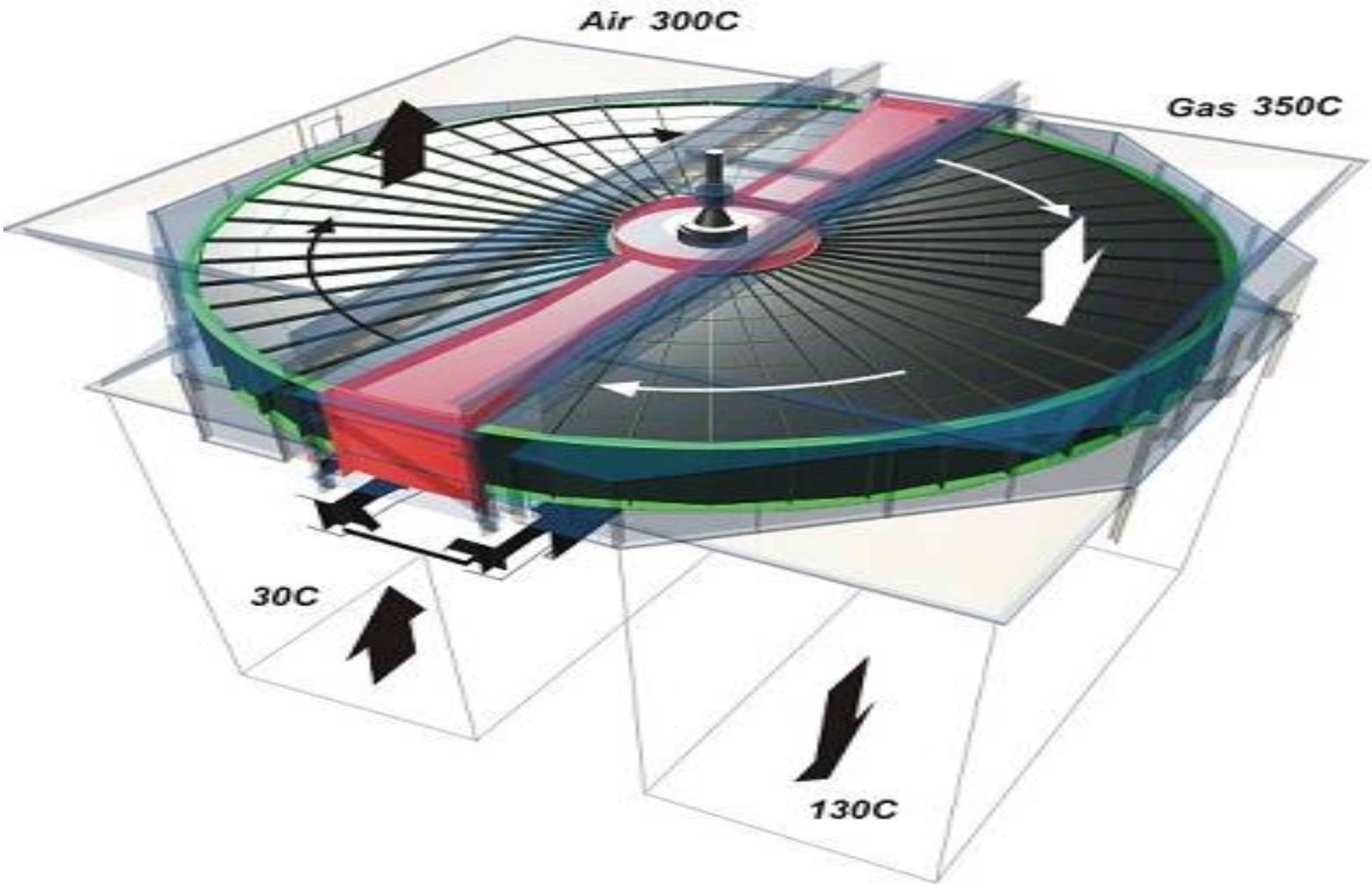
Emergencies in Boiler

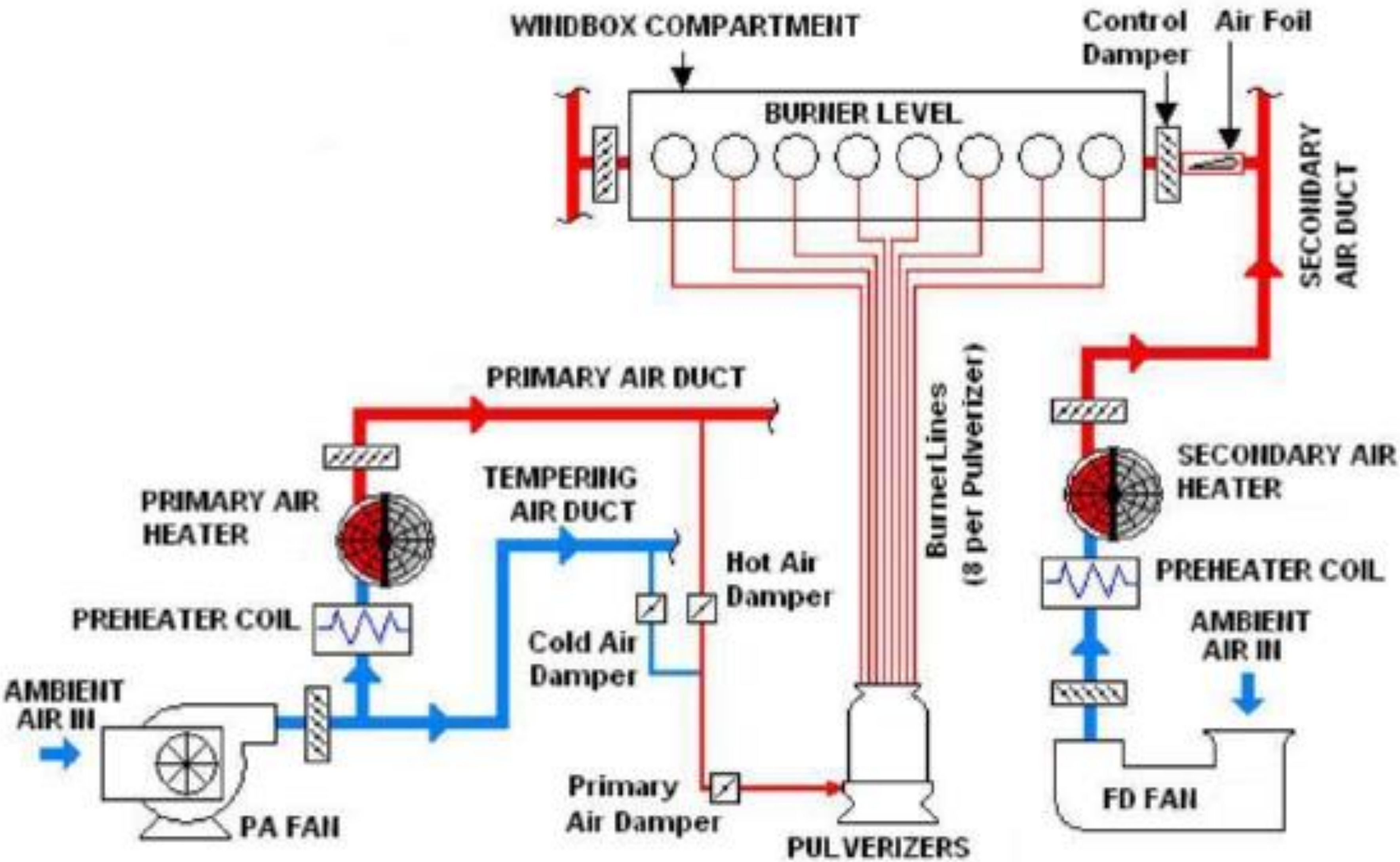
- APH tripping
- BA system Failure
- IA Failure
- CC Pump tripping
- Turbine tripping

APH (Trisector type)

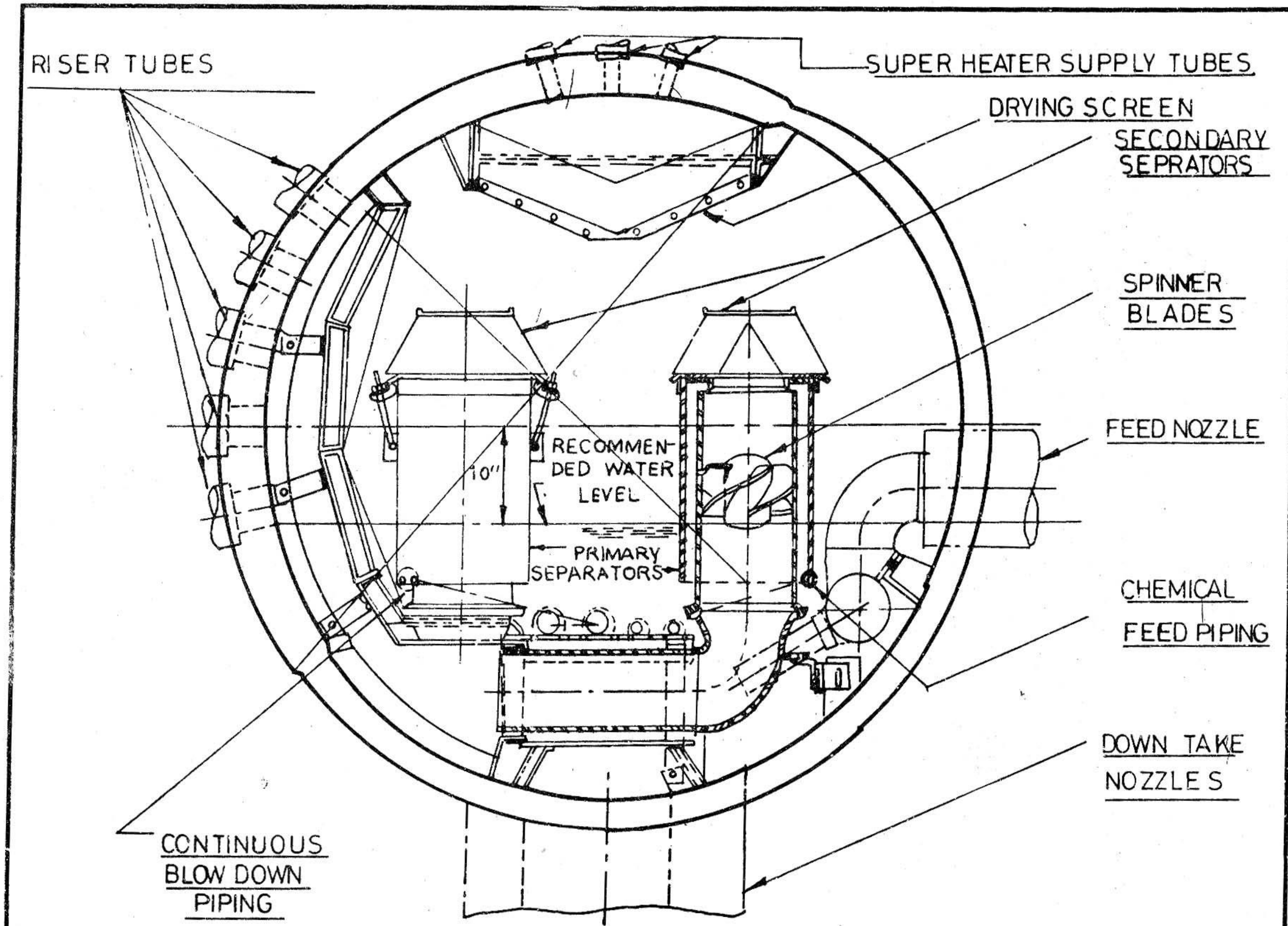


Regenerative APH




WINDBOX COMPARTMENT
Control Damper
Air Foil
BURNER LEVEL
SECONDARY AIR DUCT
PRIMARY AIR DUCT
Burner Lines (8 per Pulverizer)
SECONDARY AIR HEATER
TEMPERING AIR DUCT
PRIMARY AIR HEATER
Hot Air Damper
PREHEATER COIL
PREHEATER COIL
Cold Air Damper
AMBIENT AIR IN
AMBIENT AIR IN
Primary Air Damper
PA FAN
FD FAN
PULVERIZERS

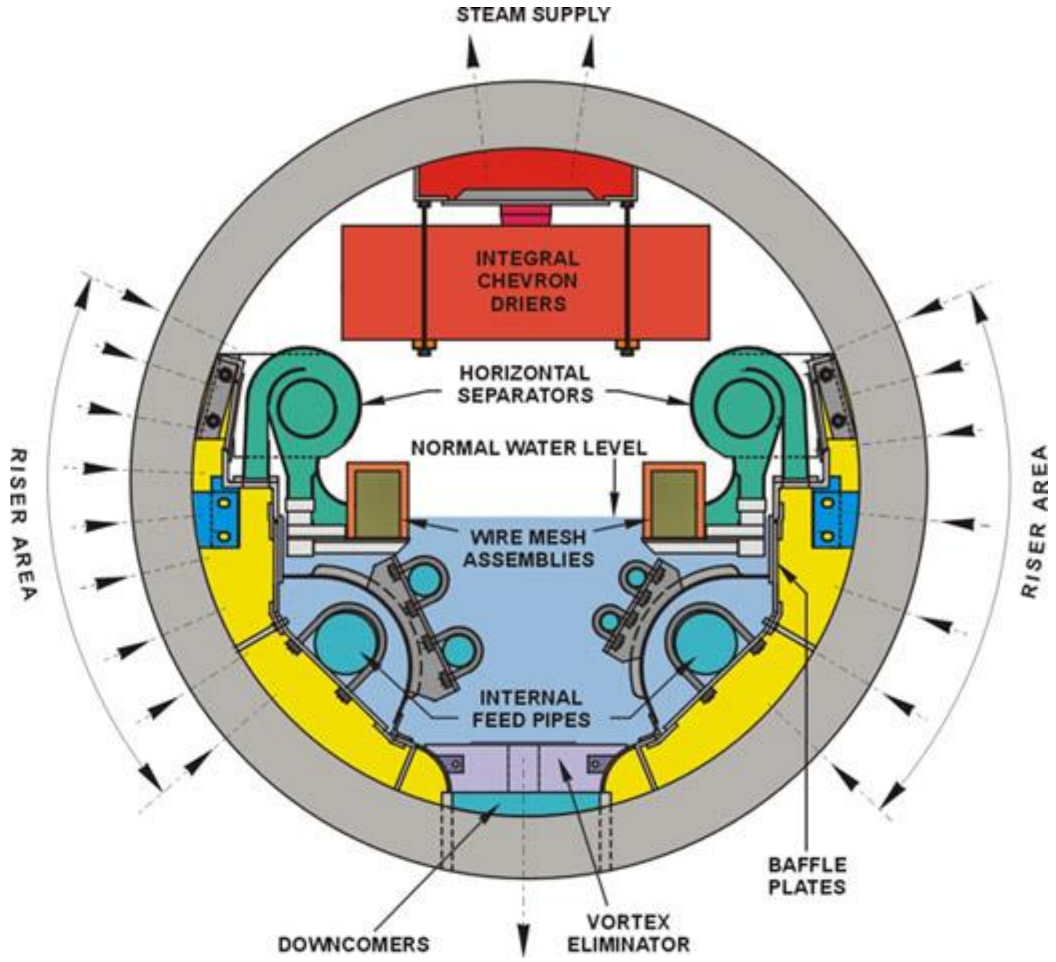
Drum Internals



Steam Drum Internals

The steam drum contains steam separating equipment and internal piping for distribution of chemicals to the water, for distribution of feedwater and for blowdown of the water to reduce solids concentration.

Drum Internals



Causes of boiler tripping

- **All ID fans off**

ID Fan Tripping Conditions

- Fan / motor /HC temp. > 85 deg.cel.
- HC oil temp at cooler inlet >100 deg.cel & outlet >75 deg. cel.
- Hydraulic coupling oil pressure < 0.5 ksc
- Discharge damper / gate does not open fully
- Electric protection trip
- Emergency push button pressed

- **All FD fans off**

FD fans Tripping Conditions

- No ID fan is running
- Fan / motor bearing temperature > 85 deg.cel.
- Discharge damper / gate does not open fully
- Shaft vibration high > 200 microns

- **Flame Failure Trip**
- **Loss of Fuel Trip**
- **Inadequate water wall circulation**

Trip Conditions of CC pumps

  - Discharge valves not open fully
  - Motor cavity temperature more than 55 deg.cel for more than 5 sec
  - Electric protection trip
  - Emergency push button pressed
  - DP across pump < 10 psi.

- **Furnace Pressure Very High (+325 mmwc)**

  Cause of high furnace pressure

  - Tripping of ID fans
  - mal-operation of regulating vanes of fans
  - closing of damper from flue gas side
  - Unstable flame due to improper combustion

- **Furnace Pressure Very Low(-325 mmwc)**

  Cause of low furnace pressure

  - Tripping of FD fans
  - closing of damper from air side
  - Sudden tripping of mills
  - mal-operation of regulating vanes of fans

- **Drum Level Very High (> + 250 mm, > 10 sec)**

  Causes of Drum Level High

  - **Mal-operation of FRS**
  - **Over feeding**
  - **Sudden decreasing of firing rate**
  - **Tripping of CC pumps**
  - **Opening of the bypass**

- **Drum Level Very Low (< - 375 mm, > 5 sec)**

  Causes of Drum Level Low

  - **Tripping of BFPs**
  - **Mal-operation of FRS**
  - **Sudden closing of turbine control valves**
  - **Sudden releasing of coal from the choked mills**

- **All BFP Trip (>10 sec)**

Trip Conditions of TDBFP

  - **Lubricating oil pressure < 1 ksc**
  - **Exhaust steam pressure > 0.7 ksc**
  - **Live steam pressure >10 ksc**
  - **Governing oil pressure < 4.5 ksc**
  - **Exhaust steam temperature > 120 deg.cel**
  - **Axial shift > 0.7 mm**
  - **Eccentricity > 200 micron**
  - **Bearing temperature > 105 deg.cel.**
  - **Turbine speed > 6330 rpm**
  - **Seal quench water pressure < 10 ksc**
  - **Suction and discharge differential temperature of main pump >16 deg.cel**
  - **Emergency trip from UCB**
  - **Emergency trip from LCB**

Trip Conditions of MDBFP

- Lubricating oil pressure < 0.8 ksc
- Suction and discharge differential temperature of main pump >15 deg.cel
- Working oil pressure < 2.2 ksc
- Working oil temperature > 130 deg.cel
- Suction valve closed
- Seal quench water pressure < 10 ksc

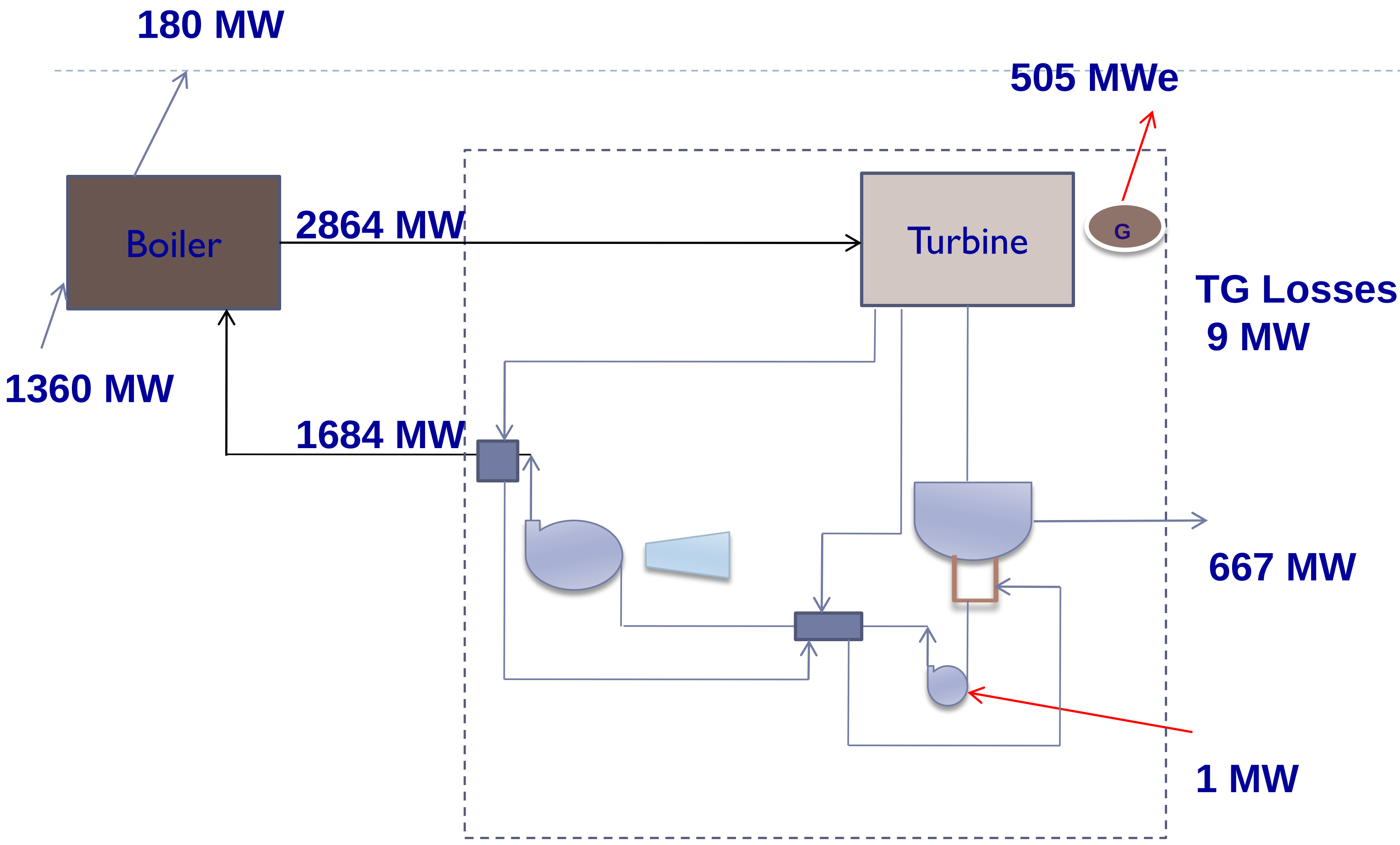
- **Reheat protection**
- **Emergency trip**
- **Air flow less than 30%**
- **All secondary air preheater off**
- **Loss of 220V DC (>2 sec)**
- **Loss of 110V AC (>2 sec)**
- **Loss of critical control supply (15V AC)(> 2 sec)**

Results of Boiler Trip Command

- **Close of HOTV**
- **Close of HONV**
- **Trip all feeders**
- **Trip all mills**
- **Close attemperation block valves**
- **Close all hot air gates**
- **Trip all PA fans**
- **Open all cold air dampers**

Boiler efficiency and losses

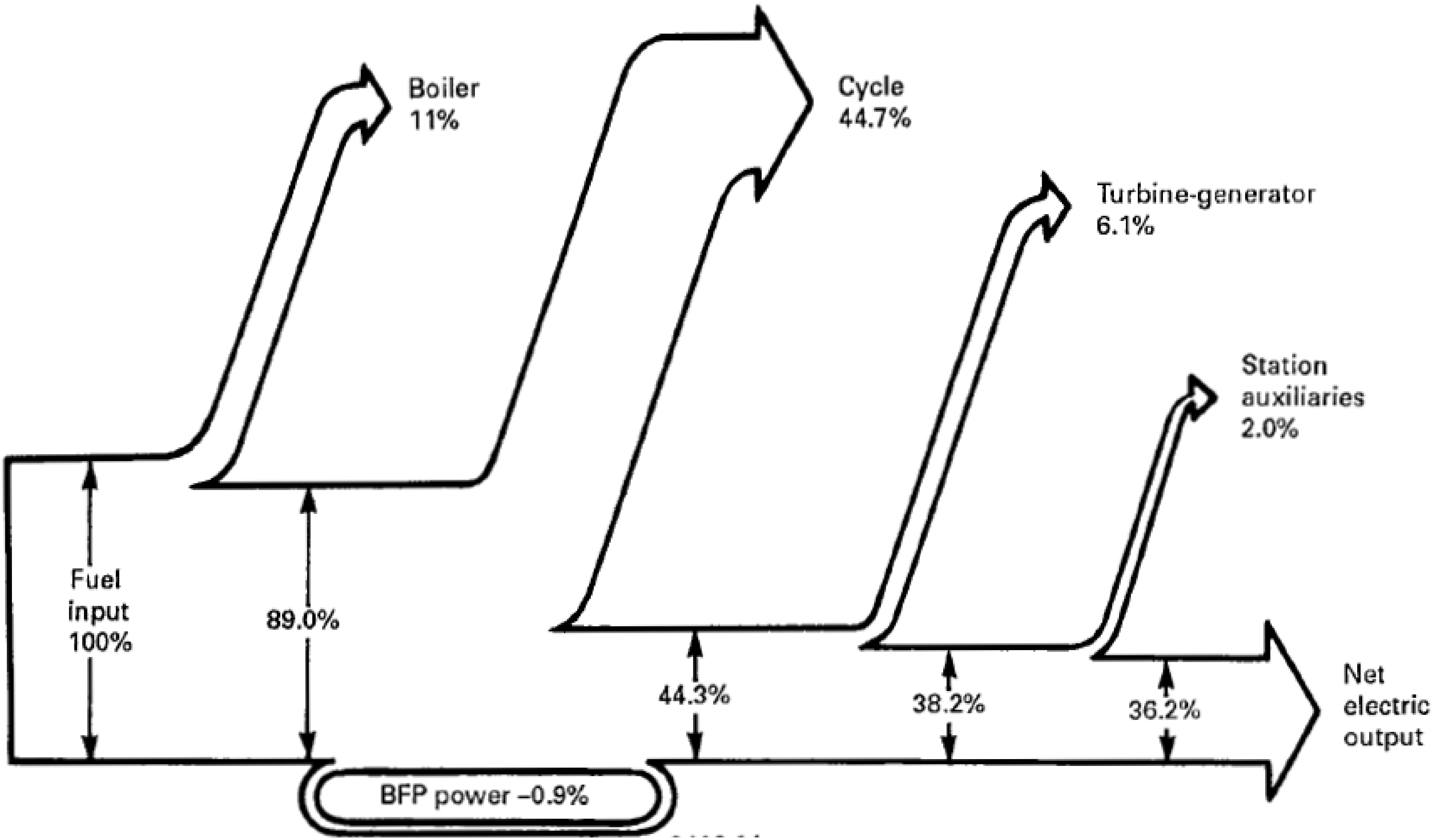
Energy flows



Unit Heat Rate

- Unit HR (test) =(Test GTCHR)/(Test Boiler Efficiency)
- Unit HR (Cor.) =(Cor. GTCHR)/(Cor. Boiler Efficiency)
- GTCHR is corrected to design CW inlet temp.
  - ASME PTC 6: Steam Turbines, PTC 6A
- Boiler Efficiency is corrected to
  - design ambient condition, Coal quality
    - ASME PTC 4, PTC 4.2 (Pulverizers), PTC 4.3 (Air Heaters)

Typical plant losses



Boiler Efficiency determination

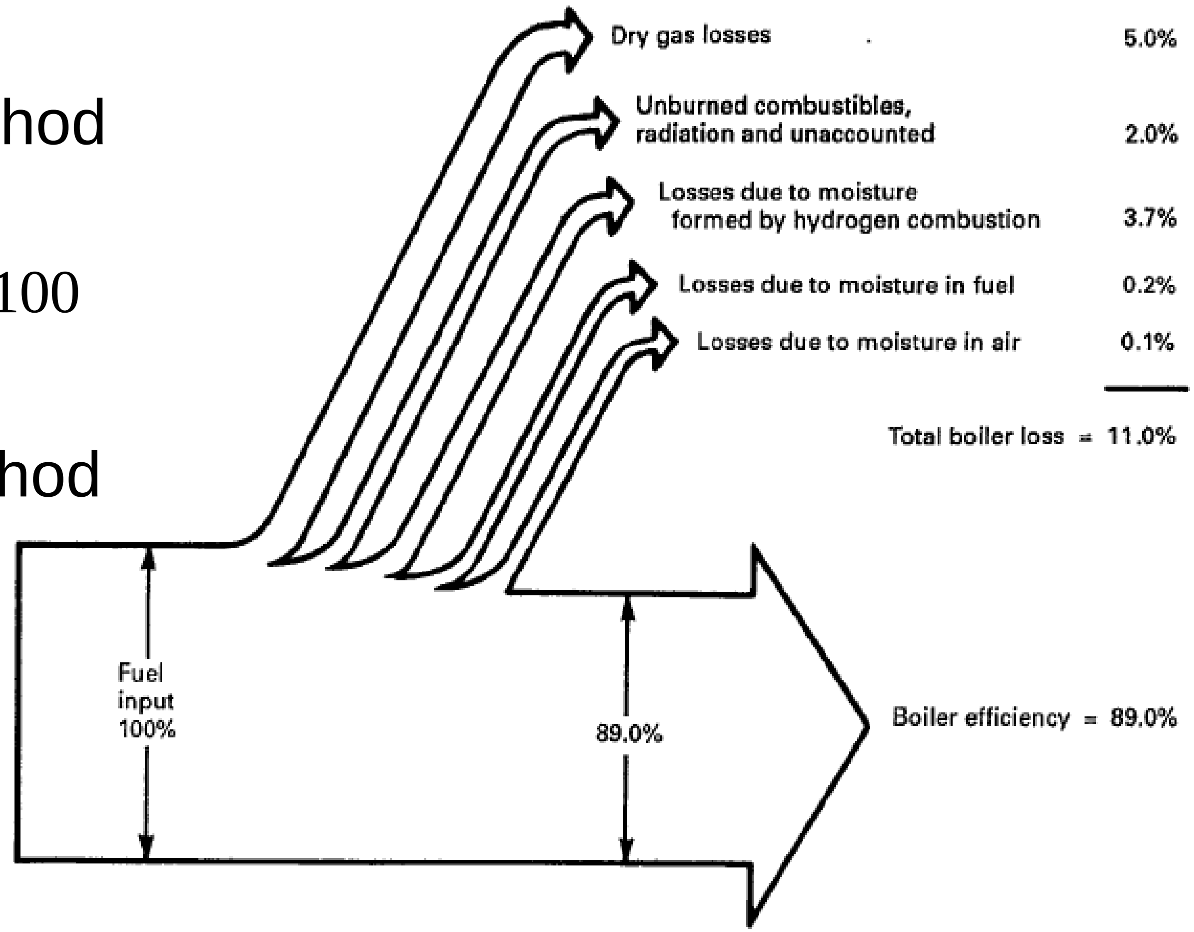
The % of heat input to the boiler absorbed by the working fluid

(i) Input /output method

$$\eta = \frac{\sum(\dot{m}_e h_e - \dot{m}_i h_i)}{H_f + B} * 100$$

(ii) Heat Loss method

$$\eta = 100 - \frac{L}{H_f + B} * 100$$



Parameters required for evaluation of Boiler Efficiency

- AH inlet and exit FG O_2 / CO_2 /CO
- AH inlet and exit FG temp
- Primary / Secondary air temp at AH inlet
- Dry/Wet bulb temperatures
- Ambient pressure, bar (abs)
- Proximate Analysis & GCV of Coal
- Combustibles in Bottom Ash and Fly ash

Boiler Losses	Typical values
Dry Gas Loss	4.56
Unburnt C Loss	1.50
Hydrogen Loss	3.29
Moisture in Fuel Loss	2.53
Moisture in Air Loss	0.12
CO Loss	0.04
Radiation/Unaccounted Loss	0.89
Total Heat Loss	12.93
Heat credit	0.44
Boiler Efficiency	**87.51**

DFG Loss (kJ/kg of fuel) =

$$[\frac{100}{12(CO_2+CO)}(\frac{C}{100}+\frac{S}{267}-C_{in\_A})]*30.6(T_{fg}-T_{air})$$

Seigert formula: **DFG Loss (%) =** $\frac{K(T_{fg}-T_{air})}{\%CO_2}$

$$T_{fg}=\frac{A_L*C_{pa}*(T_{fgt}-T_{air})}{C_{pg}*100}+T_{fgt}$$

$$CO_{2\_out}=\frac{90*CO_{2\_in}}{A_L+90}$$

$$A_L=\frac{CO_{2\_in}-CO_{2\_out}}{CO_{2\_out}}*0.9*100$$

$$=\frac{O_{2\_out}-O_{2\_in}}{21-O_{2\_out}}*0.9*100$$

O_2 in / CO_2 in measured, A_L known

K ~0.63 for bituminous coal

Combustible in Ash Loss

- Unburnt carbon loss (kJ/kg of fuel) =

$$\frac{cA}{100} * 33820$$

C= % of carbon in ash

- A= Mass of ash kg/kg of fuel
- Carbon burnt to CO_2 =33820 kJ/kg (8077 kcal/kg)
- Compute Boiler efficiency loss % due to C in Ash

Wet Flue Gas Loss (kJ/kg of fuel) =

$$\frac{M+9H}{100}[1.88(T_{fg}-25)+2442+4.2(25-T_{air})]$$

Moisture in combustion air loss (kJ/kg fuel)=

$$M_a * h * 1.88 * (T_{fg} - T_{air})$$

h =kg moisture per kg dry air

M_a =Dry air for combustion kg/kg of fuel

$$M_a = \frac{3.034 N_2}{CO_2 + CO}[\frac{C}{100} + \frac{S}{267} - C_{in\_A})$$

N_2, CO_2, CO=% volume in dry gas
C, S=% in fuel

Incomplete gas (CO) loss (kJ/kg fuel)=

$$\frac{12}{28}*[\frac{7CO}{3(CO_2+CO)}*(\frac{C}{100}+\frac{S}{267}-C_{in\_A})]*23717$$

23717 kJ/kg = CV of burning 1 kg of carbon in CO to CO_2

CO_2, CO=% volume in dry gas

C, S=% in fuel

Heat credit

Heat Credit due to Coal Mill Power

$= [MP * 859.86 * 100] / [Coal_{FLOW} * GCV * 1000]$

Coal Flow Rate $Coal_{FLOW}$ Tons/Hr

Total Coal Mill Power MP kWh

GCV of Coal Kcal/Kg

Probable measurement errors and resulting errors in efficiency calculations

Parameter	Measurement error, %	Error in calculated SG Efficiency, %
Heat value (coal)	±0.50	±0.03
Orsat analysis	±3.00	±0.30
Exit FG temp	±0.50	±0.02
Inlet air temp	±0.50	±0.00
Ult. anal. of coal (C)	±1.00	±0.10
Ult. anal. of coal (H)	±1.00	±0.10
Fuel moisture	±1.00	±0.00

Unburnt Carbon Loss (Controllable)

- $C_{unburnt}$ is a measure of effectiveness of comb. process
- $C_{unburnt}$ includes the unburned constituents in FA and BA
- Focus to be on FA due to uncertainty in repeatability and representativeness
- +50 PF fineness fractions to be $< 1\%$

Influencing Factors - Unburnt Carbon Loss

- **Type of mills** and firing system
- Furnace **size**
- PF **fineness** (Pulveriser problems)
- Coal FC/VM ratio, coal **reactivity**
- Insufficient **excess air in combustion zone**
- **Air damper** / register settings
- Burners design / condition
- Burner **balance** / worn orifices
- Primary Air Flow / Pressure

Coal particle size distribution

- If 1-2% is +50 in BS mesh sieve (300 μm), most of this coarse coal will not burn and end up in C in BA
  - It also frequently causes slagging around the burners
- If -200 mesh (75 μm) fineness is poor, results in high C in FA
- If the coal is not properly ground, the distribution to the burners may not be even
  - Resulting in air-fuel imbalances at one or more burners

Fuel line balance

- Mill discharge pipes offer different resistances to the flows due to unequal lengths and different geometry/layouts.
- Fixed orifices are put in shorter pipes to balance velocities, dirty air / PF flows.
  - The sizes of the orifices are normally specified by equip. supplier
  - Variable/adjustable orifices
- Dirty air flow distribution should be within +/- 5%
- Coal distribution within +/- 10% of the mean value

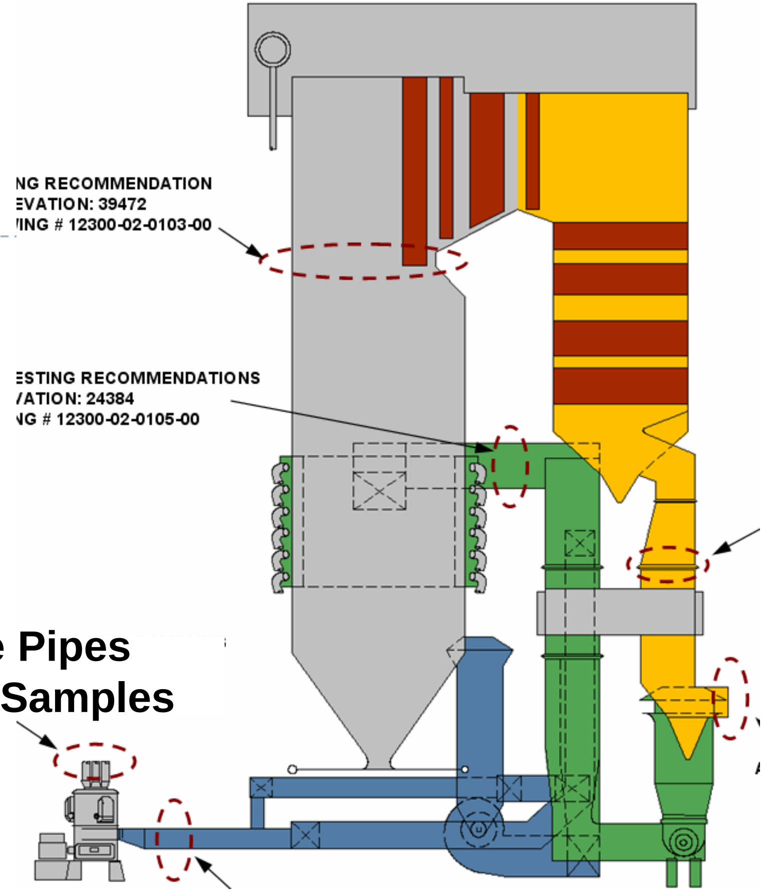
Dry Gas loss reduction requires

- Boiler operation at optimum excess air
- Cleanliness of boiler surfaces
- Reduction of tempering air to mill
- Reduction in air ingress
- Cleaning of air heater surfaces and proper heating elements / surface area

The Diagnostic Tests

- Representative & accurate performance data
- RCA , Identify reasons for inefficiency
- Verify online FB

- **Dirty Airflow Tests**
- **Iso-kinetic Coal Sampling**
- **PA Flow Calibration**
- **Clean Airflow Tests**
- HVS
- Furnace Exit HVT
- Air In-Leakage survey
- Insulation survey
- Furnace temperature survey
- Boiler Efficiency Tests
- AH Performance Tests



- Turbine Cycle Heat Rate Test
- Turbine Cylinder Efficiency Test
- Condenser Performance Test
- Condenser Air in-leak Test
- Heater Performance Test

➢ **Boiler Tuning & Optimization**

Boiler Performance Optimization

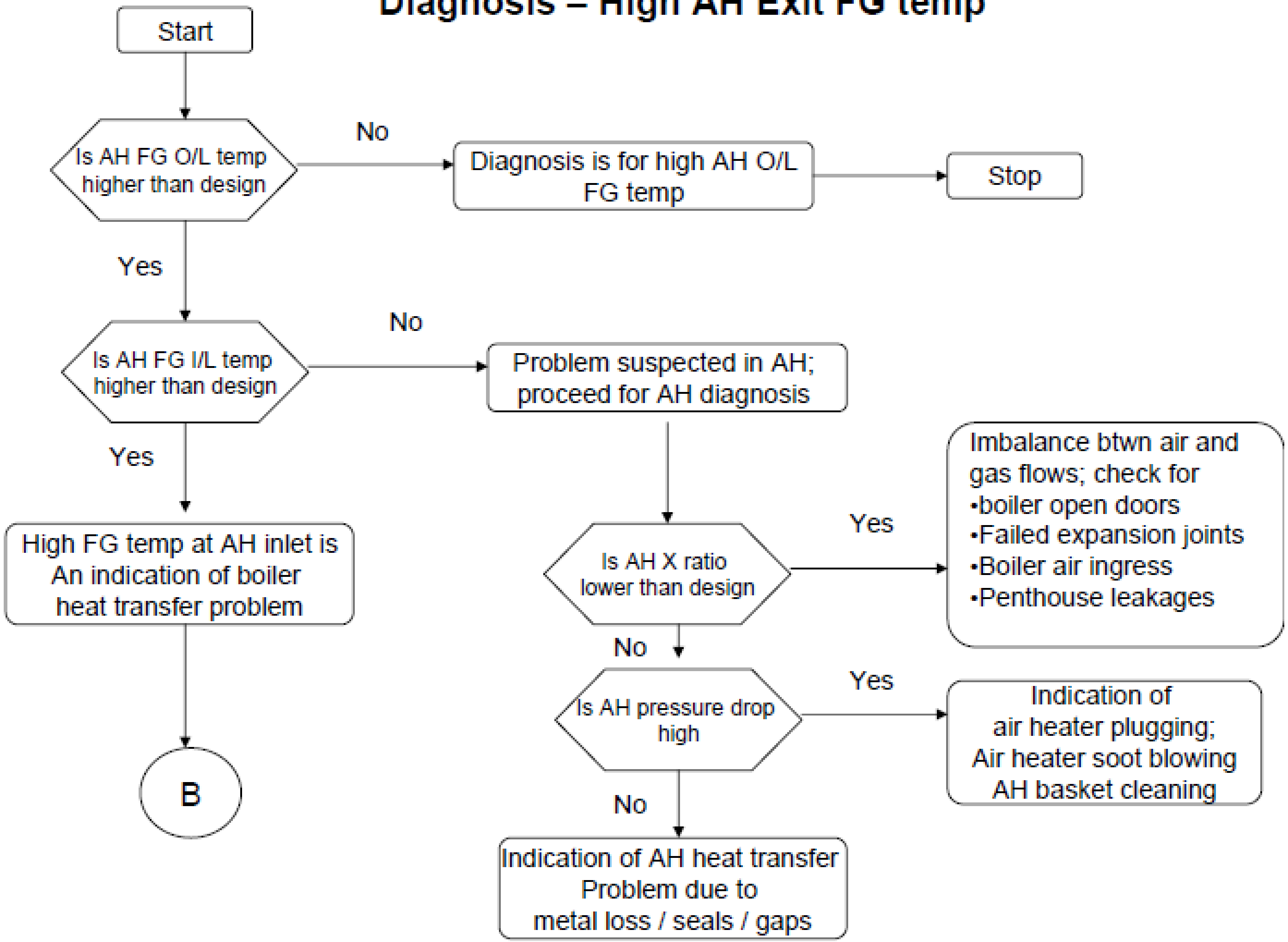
Reduction in Dry Gas loss

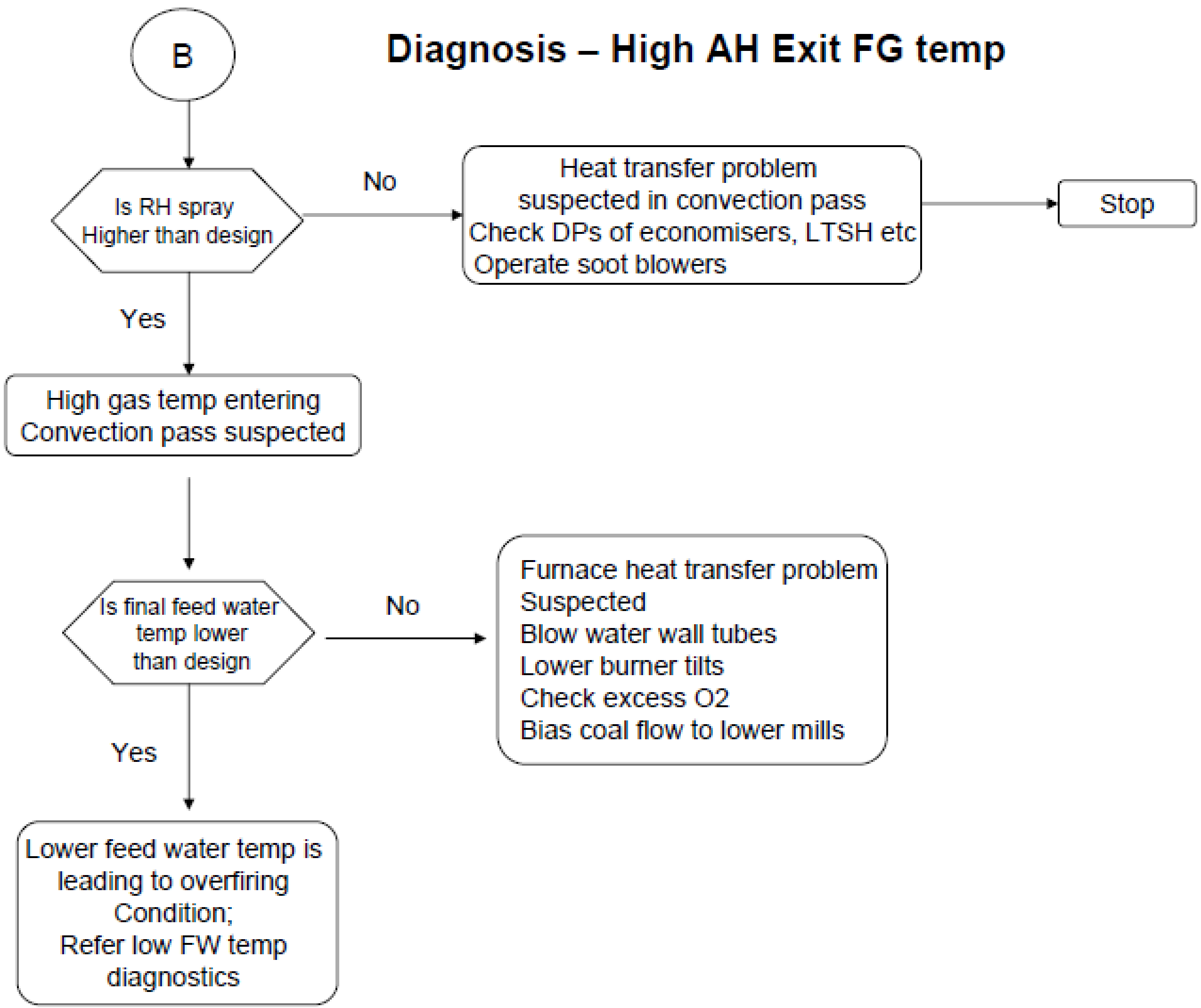
Factors affecting furnace Heat Transfer include Furnace wall condition, Combustion Heat release rate, Emissivity, absorptivity and thermal conductivity of deposits, Ash dust loading, Pulverised fuel fineness, Mill Combination (Top, Middle, Bottom), Air regime for combustion etc.

- Operation at optimum excess air – Hi O_2 ~ Hi DFG
- Cleanliness of boiler surfaces – Dirty tubes ~ Hi EGT
- Cleaning of air heater surfaces and proper heating elements
- Reduction of tempering air to mill
- Reduction in air ingress
- Representative Measurements
- Design Considerations - Additional Heat transfer area

Typically 20-22 C increase in exit gas temperature ~ 1% reduction in boiler efficiency.

Diagnosis – High AH Exit FG temp

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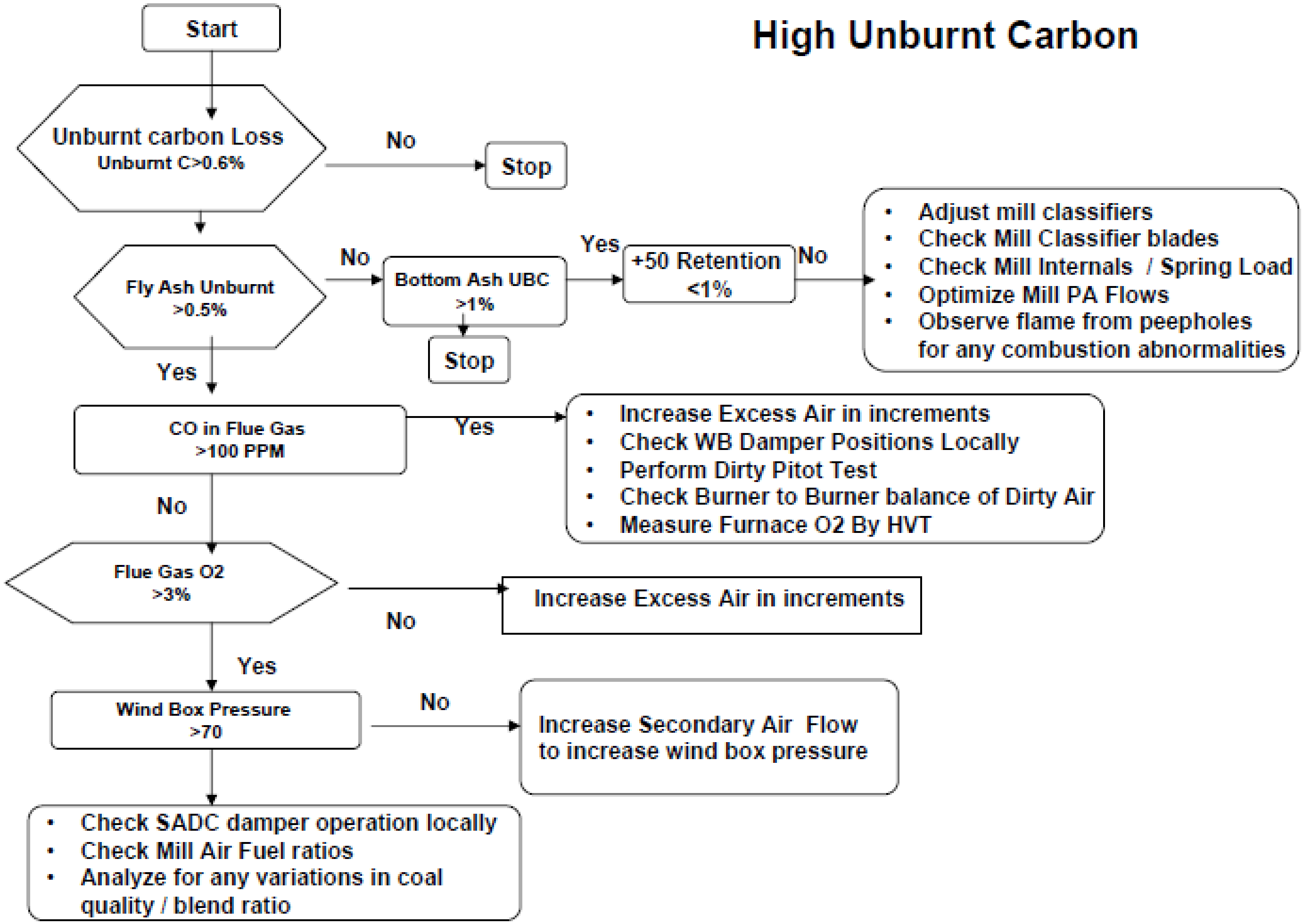
Diagnosis – High AH Exit FG temp
Is RH spray Higher than design
No
Heat transfer problem suspected in convection pass
Check DPs of economisers, LTSH etc
Operate soot blowers
Stop
Yes
High gas temp entering Convection pass suspected
Is final feed water temp lower than design
No
Furnace heat transfer problem Suspected
Blow water wall tubes
Lower burner tilts
Check excess O2
Bias coal flow to lower mills
Yes
Lower feed water temp is leading to overfiring Condition;
Refer low FW temp diagnostics

Unburnt Carbon Loss (Controllable)

The amount of unburnt is a measure of effectiveness of combustion process in general and mills / burners in particular.
Influencing Factors

- Type of mills and firing system
- Furnace size
- Coal FC/VM ratio, coal reactivity
- Burners design / condition
- PF fineness (Pulveriser problems)
- Insufficient excess air in combustion zone
- Air damper / register settings
- Burner balance / worn orifices
- Primary Air Flow / Pressure

High Unburnt Carbon



AUXILIARY POWER CONSUMPTION

Major auxiliaries Consuming Power in a Boiler are FD fans, PA fans, ID fans and mills. Reasons for higher APC include

- Boiler air ingress
- Air heater air-in-leakage
- High PA fan outlet pressure
- Degree of Pulverisation
- Operation at higher than optimum excess air

Thanks

rayt3@asme.org