WELCOME

TO

PRESENTATION ON

SUPERCRITICAL BOILER

BY

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5 X 660 MW

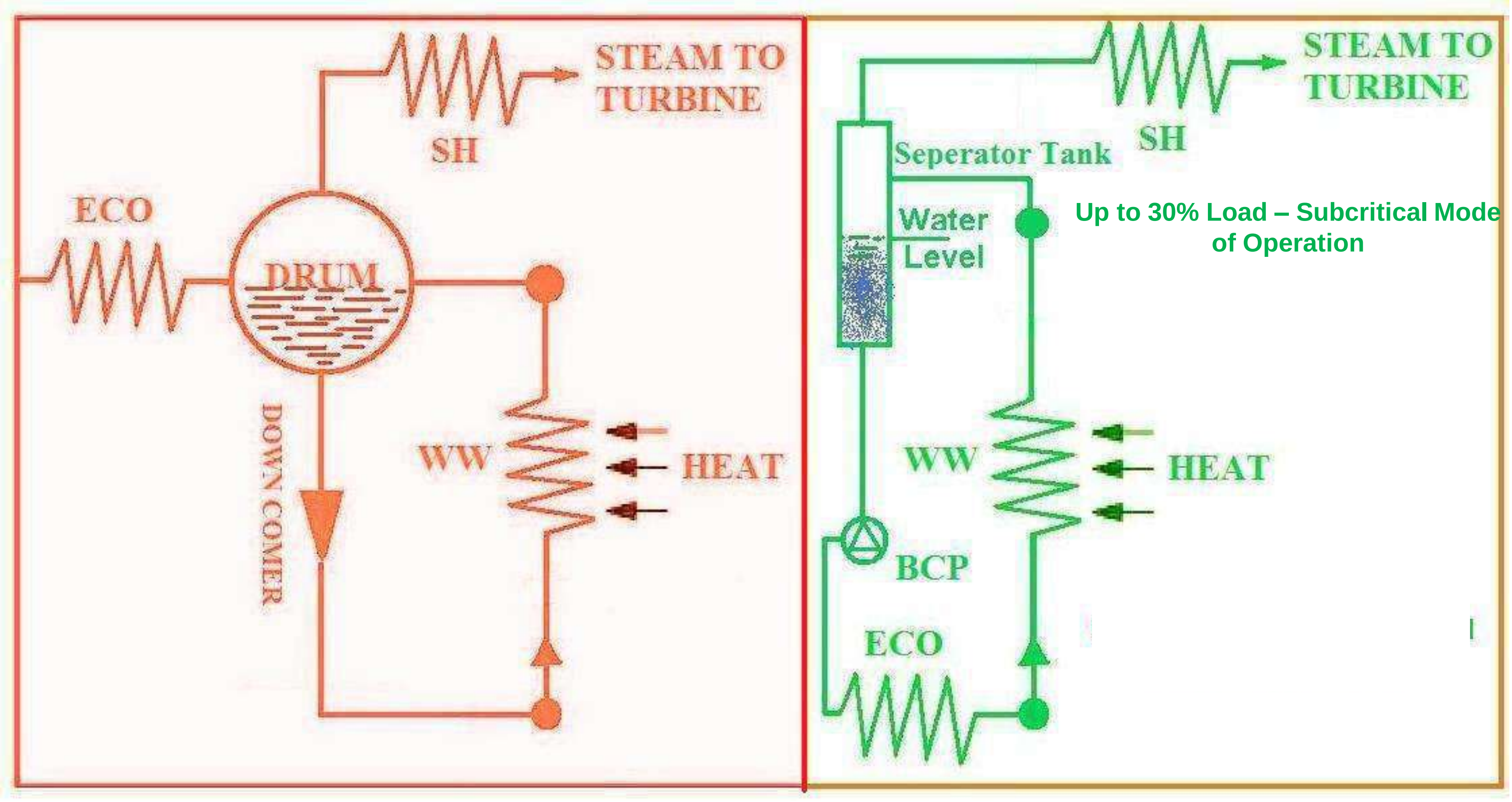
Introduction to Supercritical Technology

What is Supercritical Pressure ?

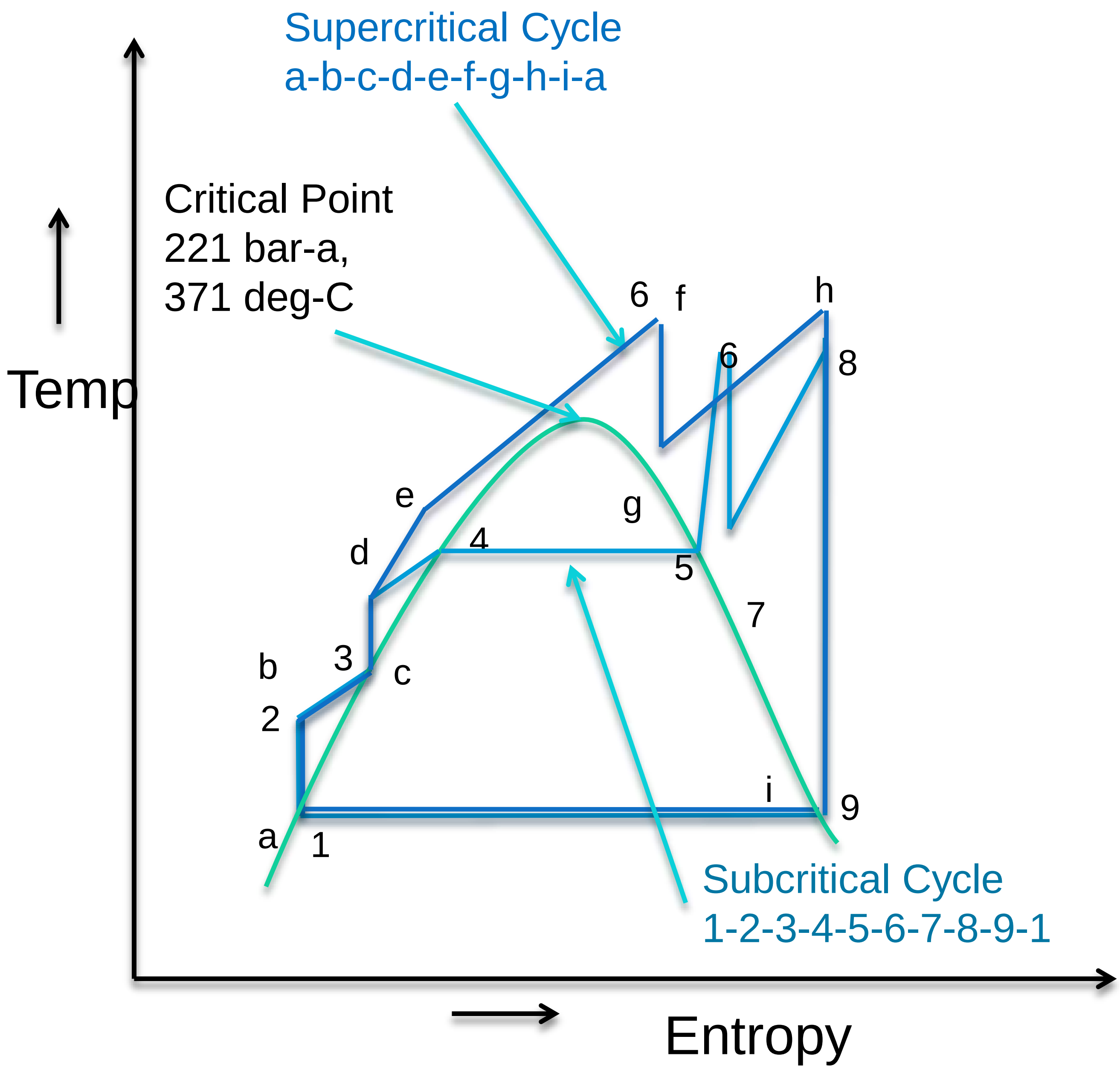
Critical point in water vapour cycle is a thermodynamic state where there is no clear distinction between liquid and gaseous state of water.

Water reaches to this state at a critical pressure above 221 bar and 374 ^{o}C.

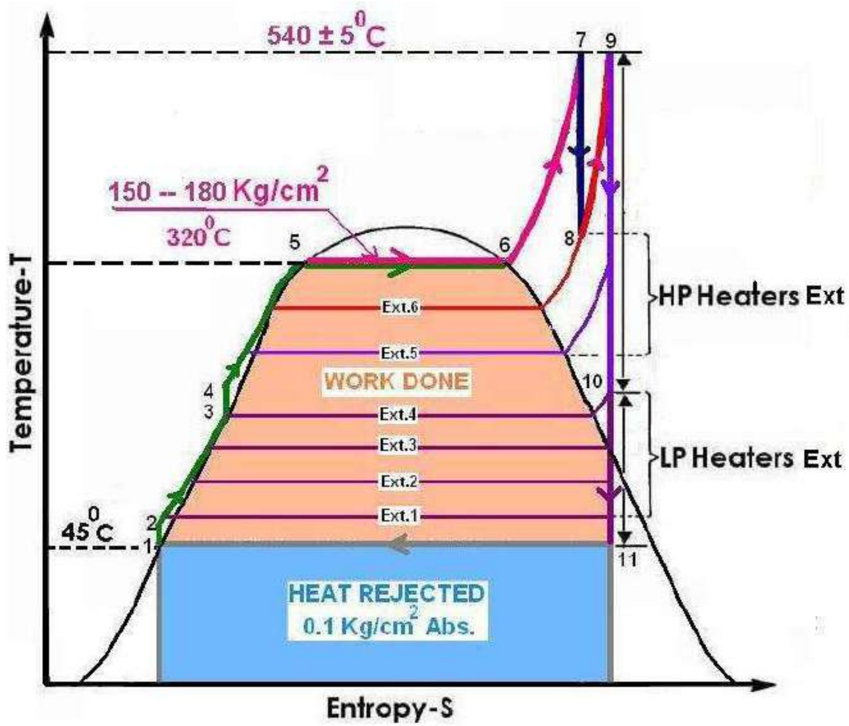
Natural Circulation Vs. Once Through System



Subcritical / Supercritical Cycle



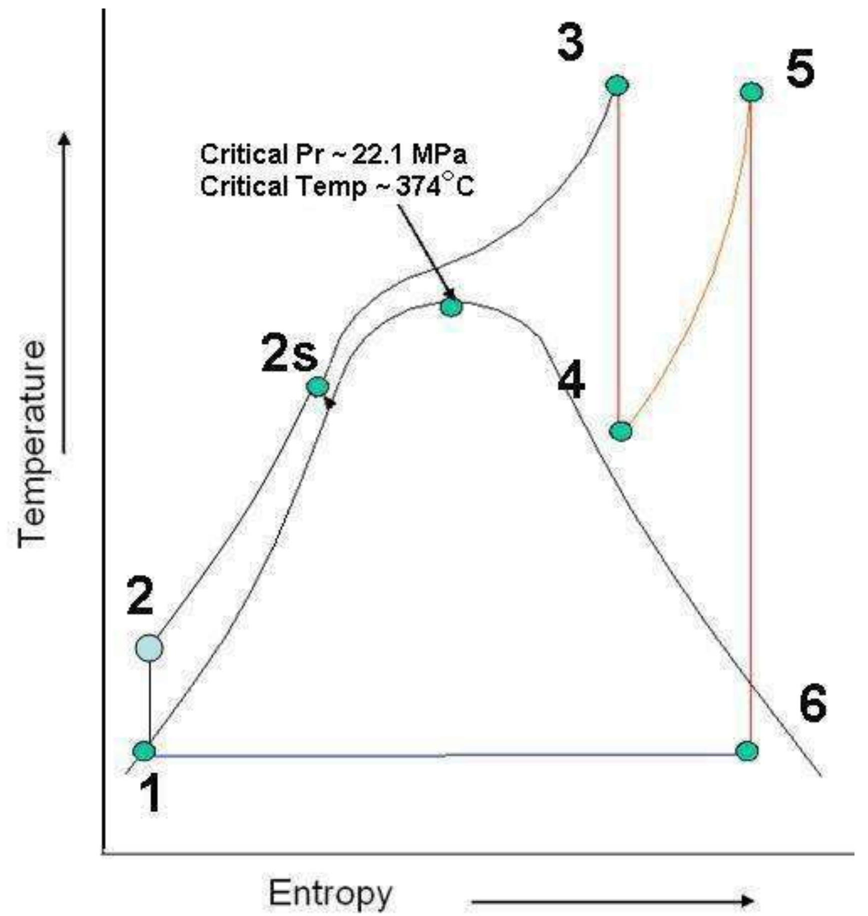
Rankine Cycle Subcritical Unit



- 1 - 2 > CEP work
- 2 - 3 > LP Heating
- 3 - 4 > BFP work
- 4 - 5 > HP Heating
- 5 – 6 > Eco, WW
- 6 – 7 > Superheating
- 7 – 8 > HPT Work
- 8 – 9 > Reheating
- 9 – 10 > IPT Work
- 10–11 > LPT Work
- 11 – 1 > Condensing

Rankine Cycle Supercritical Unit

- 1 - 2 > CEP work
- 2 – 2s > Regeneration
- 2s - 3 > Boiler Superheating
- 3 – 4 > HPT expansion
- 4 – 5 > Reheating
- 5 – 6 > IPT & LPT Expansion
- 6 – 1 > Condenser Heat rejection

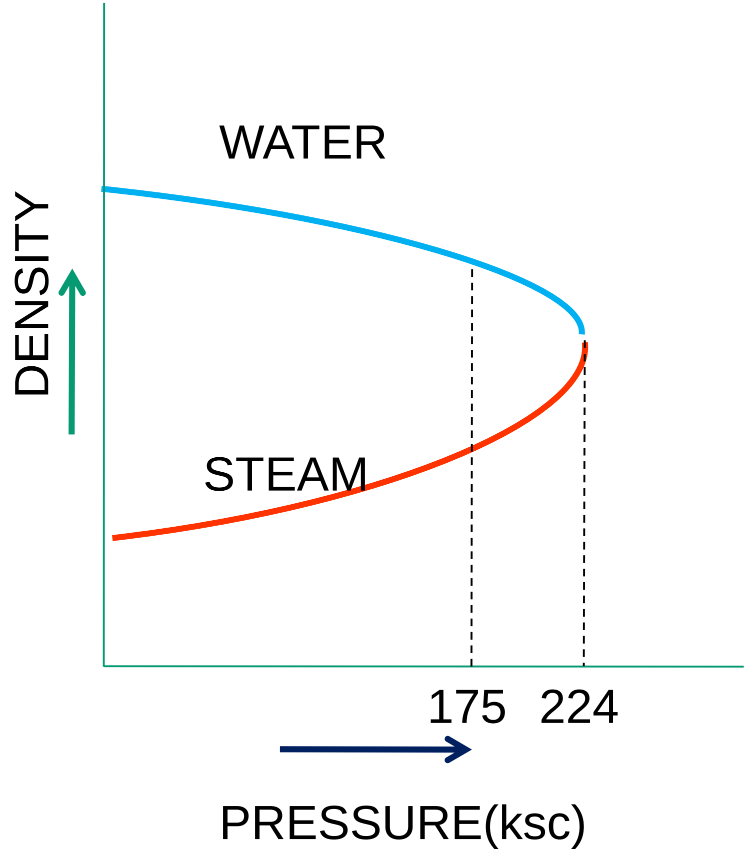


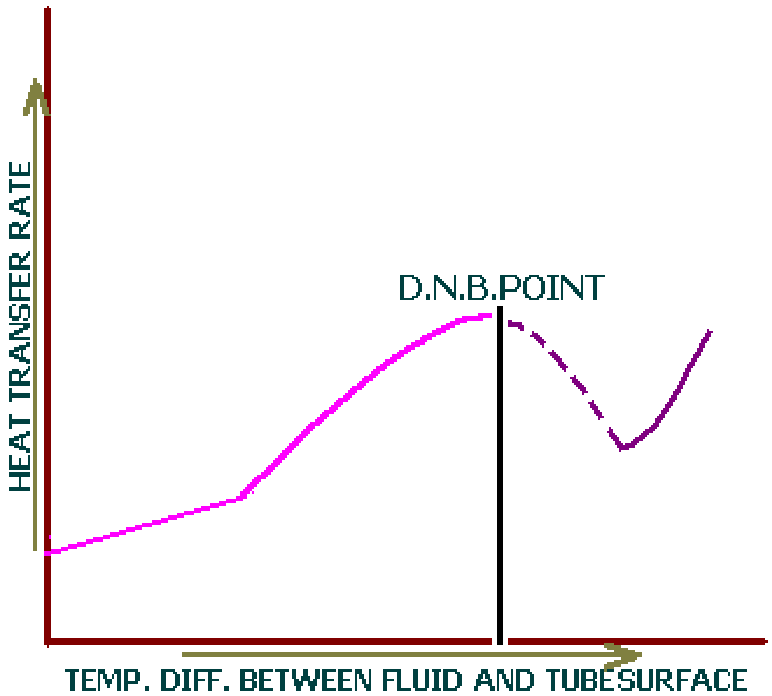
VARIATION OF LATENT HEAT WITH PRESSURE

Absolute Pressure (Bar)	Saturation Temperature (°C)	Latent Heat (K J/Kg.)
50	264	1640
150	342	1004
200	366	592
221	374	0

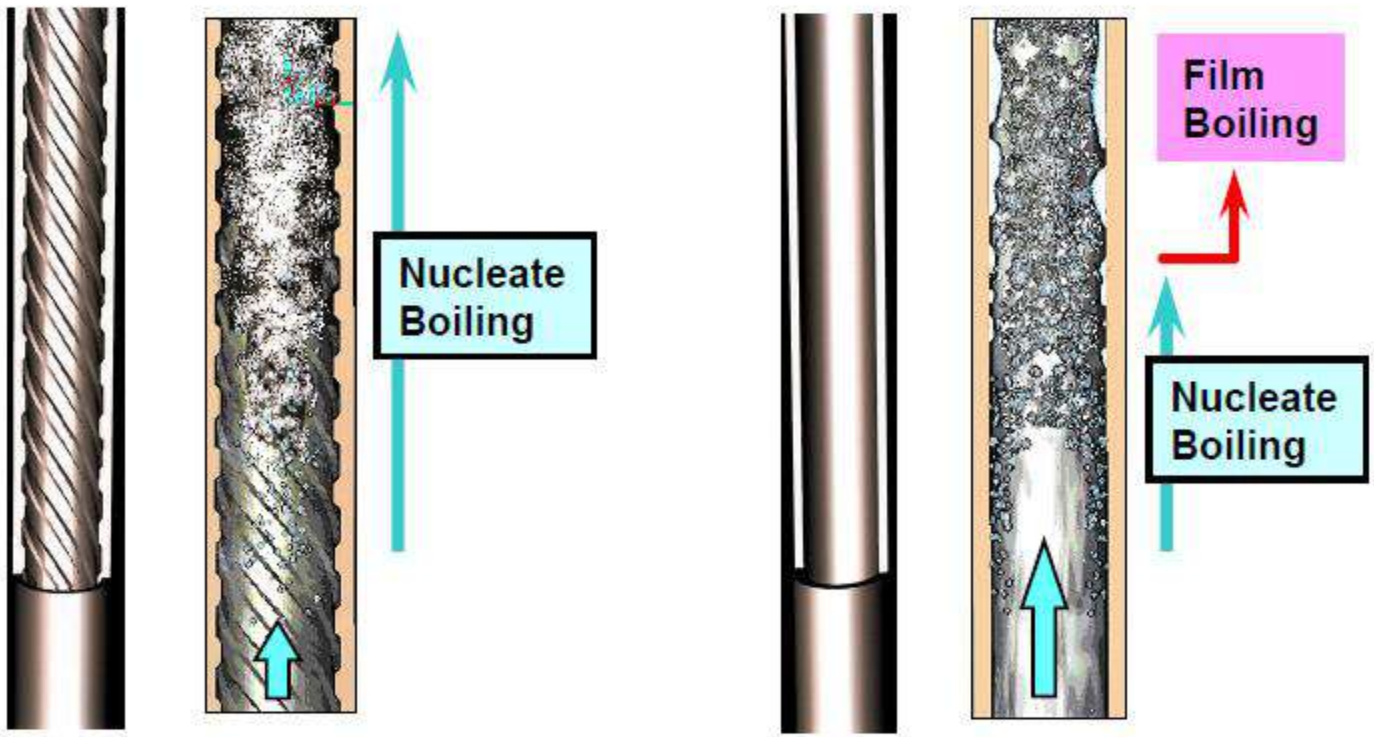
Departure from Nucleate Boiling

Nucleate boiling is a type of boiling that takes place when the surface temp is hotter than the saturated fluid temp by a certain amount but where heat flux is below the critical heat flux. Nucleate boiling occurs when the surface temperature is higher than the saturation temperature by between 4^{0}C to 30^{0}C.



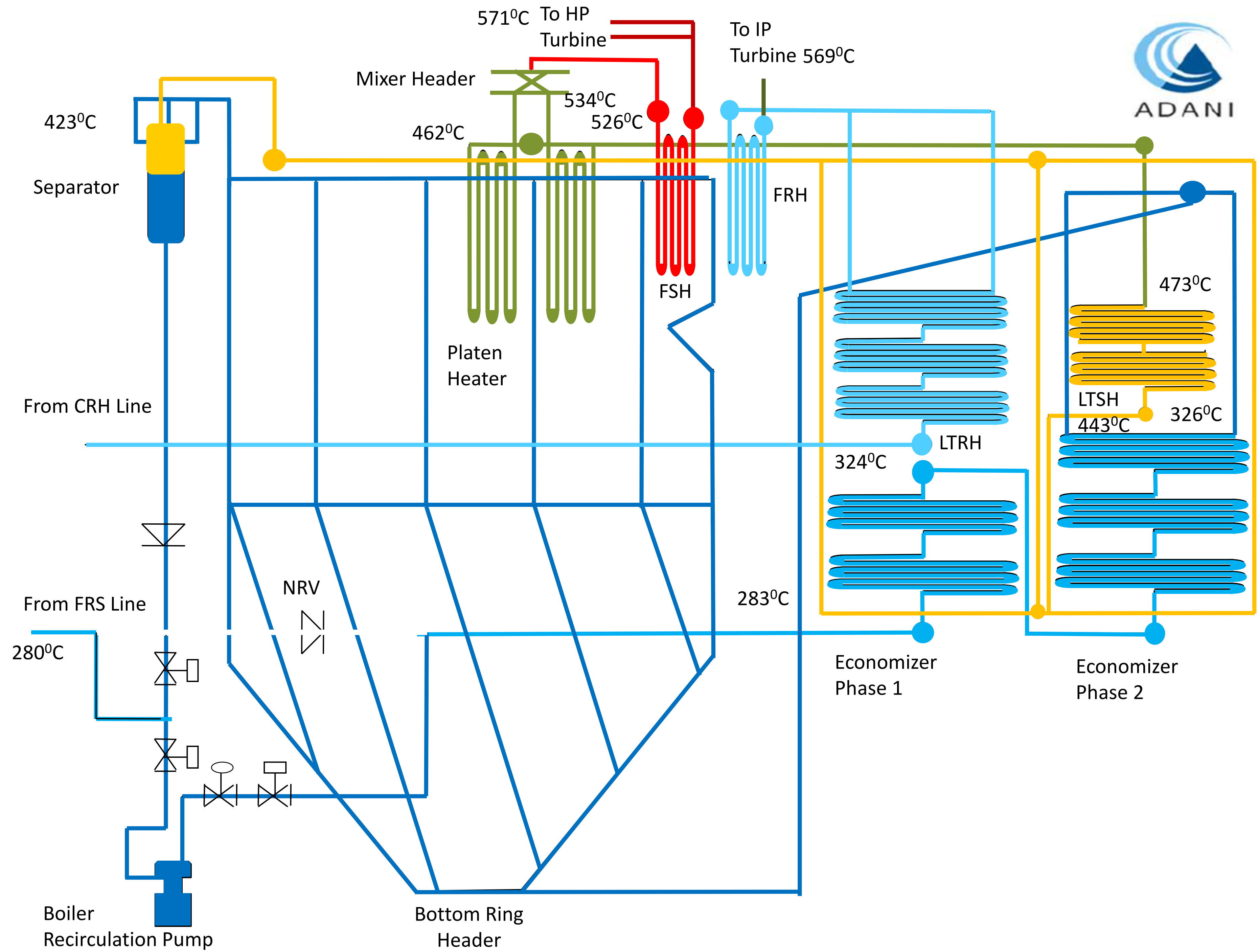


Supercritical Boiler Water Wall Rifle Tube Vs Smooth Tube



Minimum Mass Velocity : 1,500kg/m²S

Minimum Mass Velocity : 3,100kg/m²S


571⁰C
To HP Turbine
To IP Turbine 569⁰C
Mixer Header
534⁰C
526⁰C
423⁰C
462⁰C
Separator
FRH
FSH
473⁰C
Platen Heater
LTSH
326⁰C
443⁰C
From CRH Line
LTRH
324⁰C
NRV
From FRS Line
283⁰C
280⁰C
Economizer Phase 1
Economizer Phase 2
Boiler Recirculation Pump
Bottom Ring Header

Feed water control

- In Drum type Boiler Feed water flow control by Three element controller
  - 1.Drum level
  - 2.Ms flow
  - 3.Feed water flow.

- Drum less Boiler Feed water control by
  - 1.Water/Fuel ratio
  - 2.OHD(Over heat degree)

WATER WALL ARRANGEMENT

- Bottom spiral & top vertical tube furnace arrangement
- The supercritical water wall is exposed to the higher heat flux
- Spiral tube wall design (wrapped around the unit) with high mass flow & velocity of steam/water mixture through each spiral
- Higher mass flow improves heat transfer between the WW tube and the fluid at high heat flux.

SPIRAL VS VERTICAL WALL

VERTICAL WALL

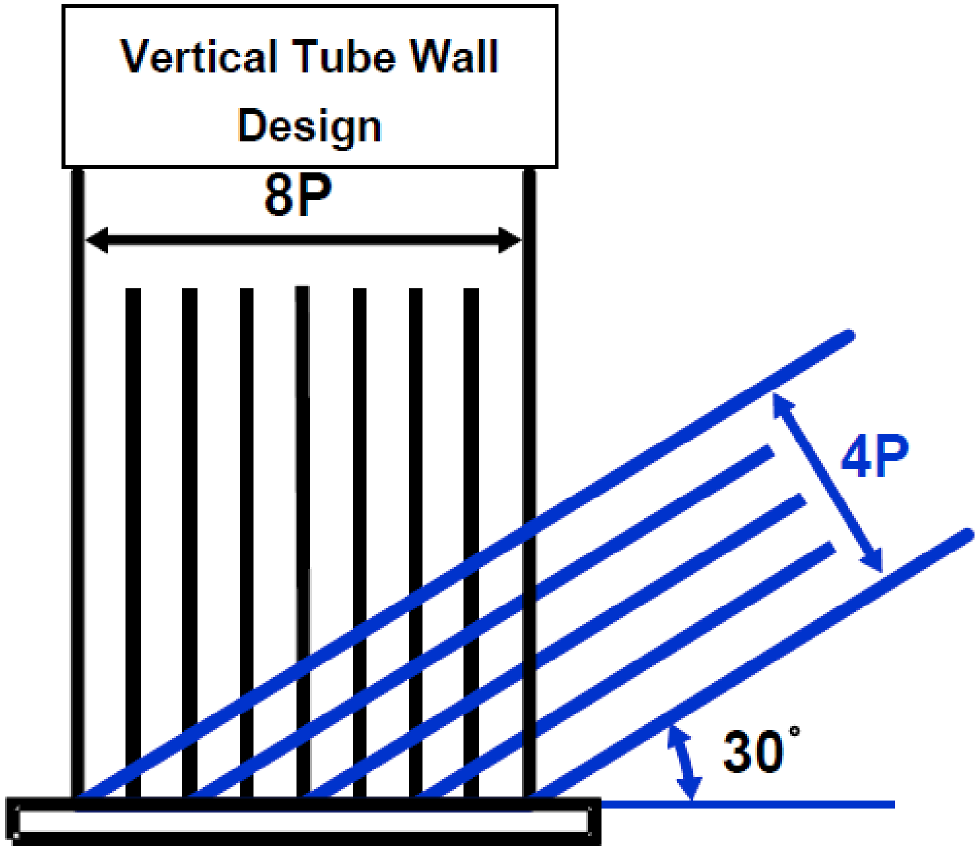
- Less ash deposition on wall
- Less mass flow
- More number of tubes
- More boiler height for same capacity
- No uniform heating of tubes and heat transfer in all tubes of WW

SPIRAL WALL

- More ash deposition
- More fluid mass flow
- Less number of tubes
- Less boiler height
- Uniform heat transfer and uniform heating of WW tubes

Supercritical Boiler Water Wall Design

Comparison of Vertical Wall and Spiral Wall



Difference of Subcritical(500MW) and Supercritical(660MW)

COMPARISION OF SUPER CRITICAL & SUB CRITICAL

DESCRIPTION	SUPERCRITICAL (660~800MW)	SUB-CRITICAL (500~600MW)
Circulation Ratio	1	Once-thru=1 Assisted Circulation=3-4 Natural circulation= 7-8
Feed Water Flow Control	-Water to Fuel Ratio -OHD(22-35 ^{O}C)	Three Element Control -Feed Water Flow -MS Flow -Drum Level
Latent Heat Addition	Nil	Heat addition more
Sp. Enthalpy	Less	More
Sp. Coal consumption	Low(~0.6 kg/kwh)	High(~0.68kg/kwh)
Air flow, Dry flu gas loss	Low	High

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DESCRIPTION	SUPERCRITICAL (660~800MW)	SUB-CRITICAL (500~600MW)
Coal & Ash handling Capacity	Low	High
Pollution	Low	High
Aux. Power Consumption	Low	High
Overall Efficiency	High (40-42%)	Low (36-37%)
Total heating surface area Reqd	Low (~128 m^2/MW)	High (~143 m^2/MW)
Tube diameter (ID)	Low	High

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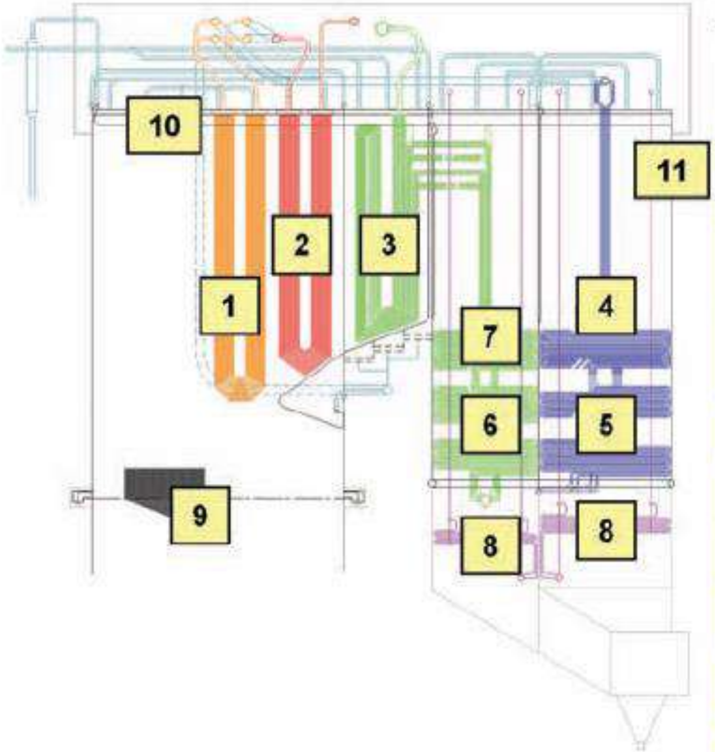
DESCRIPTION	SUPERCRITICAL (660~800MW)	SUB-CRITICAL (500~600MW)
Blow down loss	Nil	More
Water Consumption	Less	More
Type(drum)	Drum Less	Drum Type

Super Critical Boiler Materials

Advanced Supercritical Tube Materials (300 bar/600^{0}c/620^{0}c)



Ref	Heating surface	Material	Design temp (°C)
1	Platen SH	SA 213 TP347H/ TP310HCbN/ T92*	640
2	Final SH	SA 213 TP347H/ TP310HCbN / T92*	650
3	Final RH	T22/ T91/ TP347H/ TP310HCbN/ T92*	680
4	Prim SH	SA 213 T91	550
5	Prim SH inlet	SA 213 T23	530
6	RH inlet	SA 210C	470
7	RH	SA 213 T12	540
8	Econ	SA 210C	375
9	Water wall	SA 213 T12/ T23	515
10	Furnace roof	SA 213 T23	510
11	Rear cage	SA 213 T23	510

* SA213 T92 used for outlet tube stub connections

Advanced supercritical (ASC) boiler tube materials

Material Comparison

Description	660 MW	500 MW
Water wall	SA213 T-12/22	Carbon Steel
SH Coil	T23, T91, TP347H/ TP347HFG	T11, T22, T91,347H
RH Coil	T91/TP347H/ TP347HFG/ T12/T23	T22, T91, T11,347H
LTSH	T12/T23	T11
Economizer	SA210-C	Carbon Steel
Welding Joints (Pressure Parts)	50,204 Nos	24,000 Nos

Steam Water Cycle Chemistry Controls

S. No.	Parameter	Sub Critical	Super Critical
1	Type of Boiler water treatment	➢ LP and HP dosing. Or ➢ All Volatile Treatment (Hydrazine + Ammonia)	➢ No HP dosing ➢ Combined water treatment (CWT).
2	Silica	< 20 ppb in feed water and steam, < 250 ppb in boiler drum	Standard value <15 ppb in the cycle Expected value <10 ppb in the cycle
3	pH	9.0 - 9.5 for feed, steam & condensate, 9.0 – 10.0 for Boiler drum	9.0 – 9.6 for AVT(All volatile treatment) 8.0 – 9.0 for CWT(Combine water treatment)
4	Dissolved Oxygen (DO)	< 7 ppb for feed.	< 7 ppb for feed in case of AVT 30 – 150 ppb for feed in case of CWT
5	Cation (H^+) Conductivity	<0.20 µS/cm in the feed & steam cycle	Standard value <0.15 µS /cm in the cycle Expected value- <0.10 µS /cm in the cycle
6	(CPU)	CPU is optional	CPU is essential for 100% flow.
7	Silica and TDS control	By maintaining feed water quality and By operating CBD	Blow down possible till separators are functioning (upto 30% load).

Advantages of SC Technology

I) Higher cycle efficiency means
Primarily

– less fuel consumption
– Per MW infrastructure investments is less
– less emission
– less auxiliary power consumption
– less water consumption

II) Operational flexibility

– Better temp. control and load change flexibility
– More suitable for widely variable pressure operation

ECONOMY

Higher Efficiency (η%)

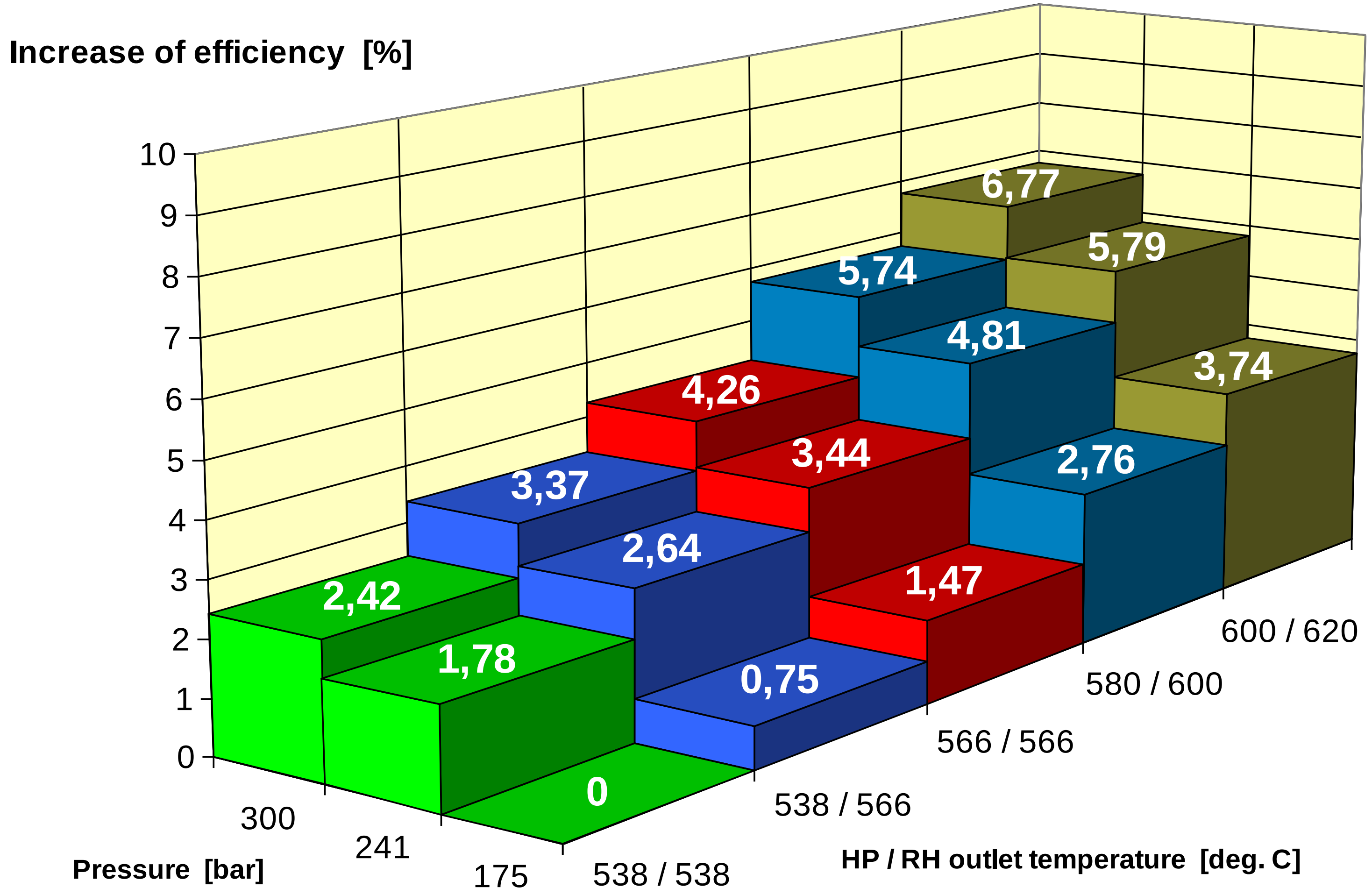
- Less fuel input.
- Low capacity fuel handling system.
- Low capacity ash handling system.
- Less Emissions.

Approximate improvement in Cycle Efficiency

Pressure increase : 0.005 % efficiency per bar

Temp increase : 0.011 % efficiency per deg C

Increase of Cycle Efficiency due to Steam Parameters



Sub. vs. Supercritical Cycle

Impact on Emissions

	Subcritical	Supercritical
Plant Efficiency, %*	34 - 37	37 - 41

Plant Efficiency, %	34%	37%	41%
Fuel Consumption/Total Emissions including CO_2	Base	Base-8%	Base-17%

* HHV Basis

Challenges of supercritical technology

- Water chemistry is more stringent in super critical once through boiler.
- Metallurgical Challenges
- More complex in erection due to spiral water wall.
- Maintenance of tube leakage is difficult due to complex design of water wall.
- Ash sticking tendency is more in spiral water wall in comparison of vertical wall.

STEAM BLOWING

CHEMICAL CLEANING PROCESS

- **BOILER FRONT SYSTEM ALKALINE FLUSHING**
  - Mass Flushing
  - Hot water Rinsing
  - Alkaline Flushing 0.05 % Non Ionic Detergent (SNID PGN)
    0.2 to 0.5% of TSP ($Na_3PO_412H_2O$)
    0.1 to 0.2% of DSP ($Na_2HPO_412H_2O$)
  - Hot DM water Rinsing

- **MAIN BOILER SYSTEM ACID CLEANIG**
  - Super Heater Filling
  - Mass Flushing
  - Alkaline Flushing
  - Hot DM water Rinsing
  - Acid Cleaning =3-3.5% Citric acid ($C_6H_8O_7H_2O$)
  - Passivation- GAMMA FERRIC OXIDE [1-2 % sodium Nitrite($NaNO_2$) with TSP &DSP].

PURPOSE :

Steam blowing of MS lines, CRH,HRH,SH,RH,HP & LP bypass pipe lines of turbine is carried out in order to remove welding slag, loose foreign materials, iron pieces, rust etc. from the system, generated during manufacturing, transportation & erection.

EFFECT OF BLOWING DEPENDS ON :

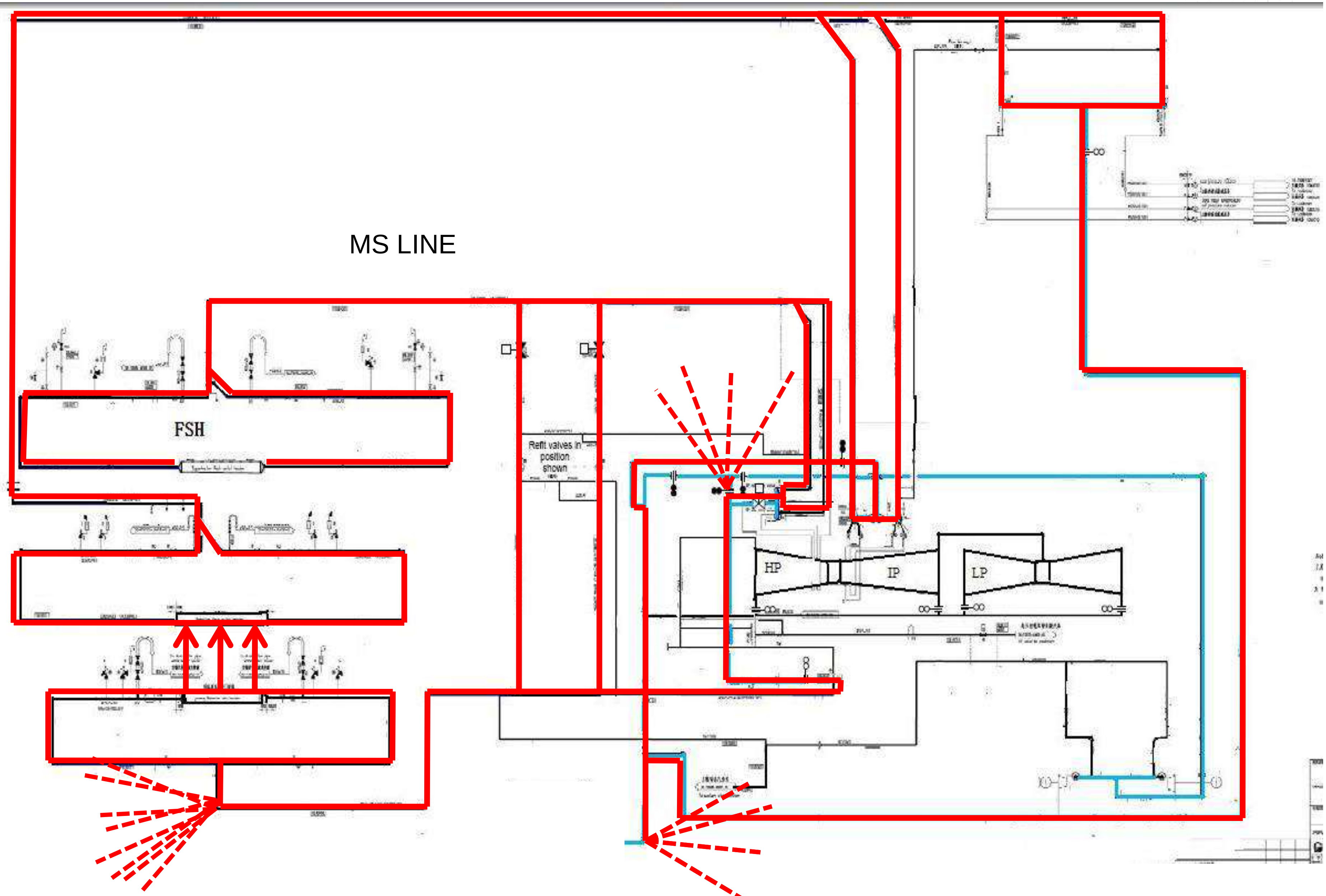
1) Thermal shock
2) Dragging / Pulling force of steam

BASIC TECHNIQUE USED

1) PUFFING METHOD

2) PURGING METHOD / CONTINUOUS BLOW METHOD

PUFFING METHOD



CONTINUOUS BLOWING METHOD

- The initial procedure is same as puffing method except:
- Continuous firing till the completion of steam blowing. No need to shut of the firing during blowing.
- Maintain constant pressure during the blow
- **Recommended blowing parameters**

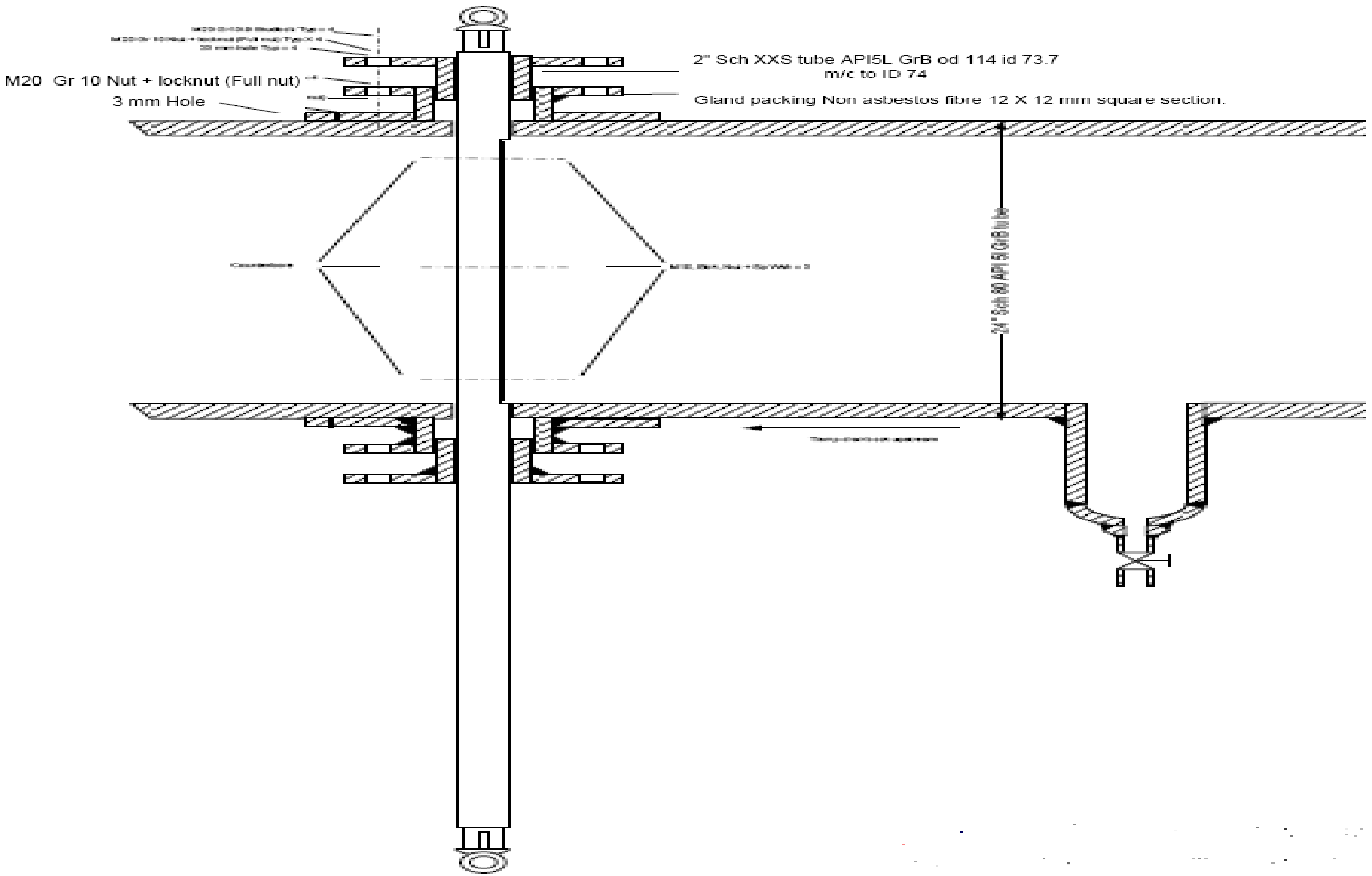
- Dynamic steam pressure = 55-60 kg/cm^2
- MS temp = 390-420 ^{O}C
- HRH temp = 480(not to exceed)
- Steam flow = 845 TPH
- Furnace load ≈ 40%
- Cleaning Force Required(CFR)/ Distribution Factor(K) > 1.25

REQUIREMENT FOR CONTINUOUS STEAM BLOWING

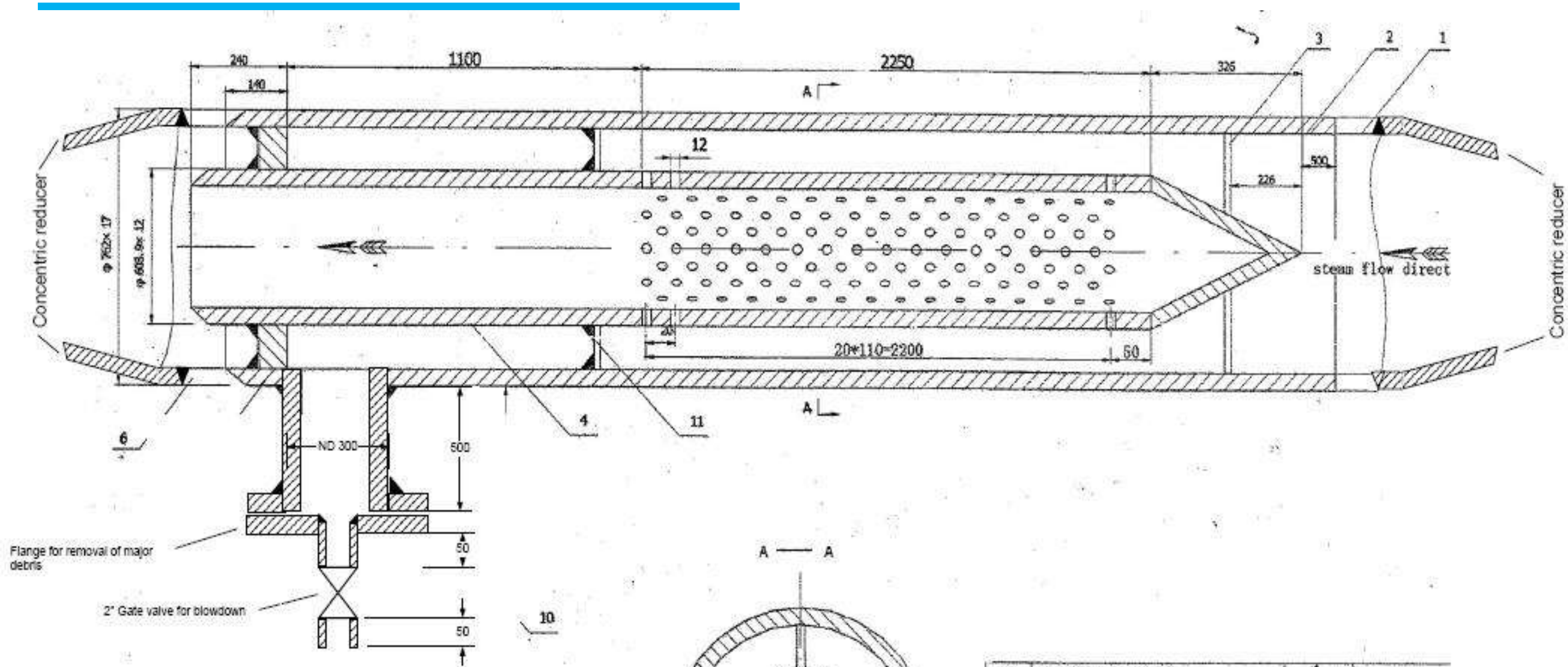
- Additional requirement along with the pre-condition checks of puffing method

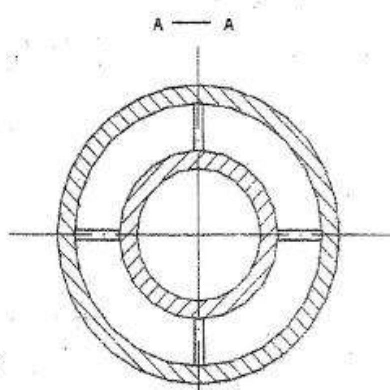
1) ***Silencer*** must be connected at temporary pipe exit
2) ***Debris filter*** at CRH inlet (horizontal line)
3) Middle & low level ***Coal Mill system*** to furnace should be ready (A,B,C)
4) ***CHP*** readiness
5) Economizer hopper and bottom ash hopper and ***ash evacuation system***
6) ***On-line target plate change over*** arrangement.

ONLINE TARGET PLATE CHANGE ARRANGEMENT



DEBRIS FILTER





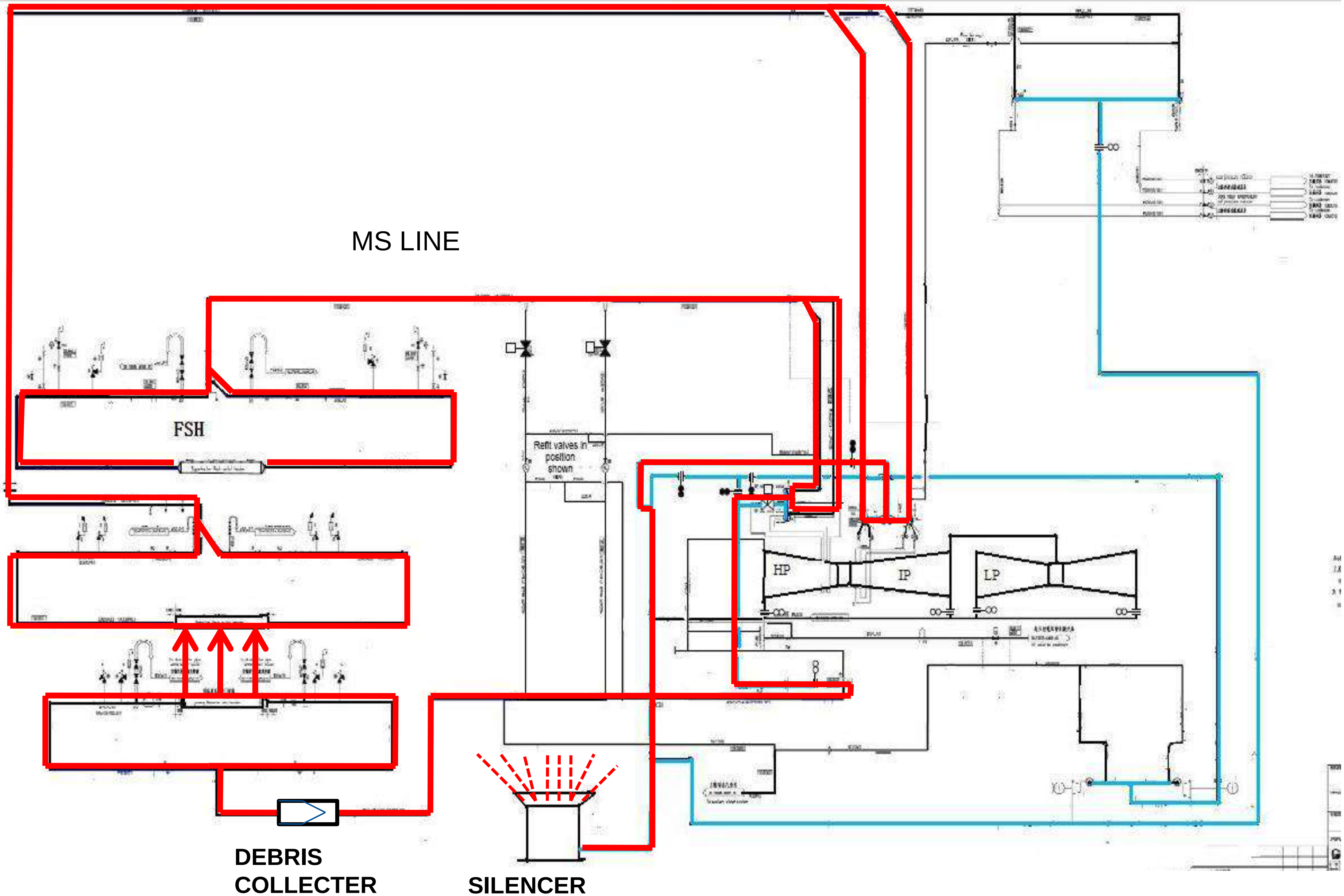
note:

1.the diameter of hole in the multihole pipe is 12 mm. the space of each hole in the perimeter is 23mm, the axial distance of holes is 20mm.the total number of holes in the multihole pipe are 9020 number .the holes should be arranged alternately .

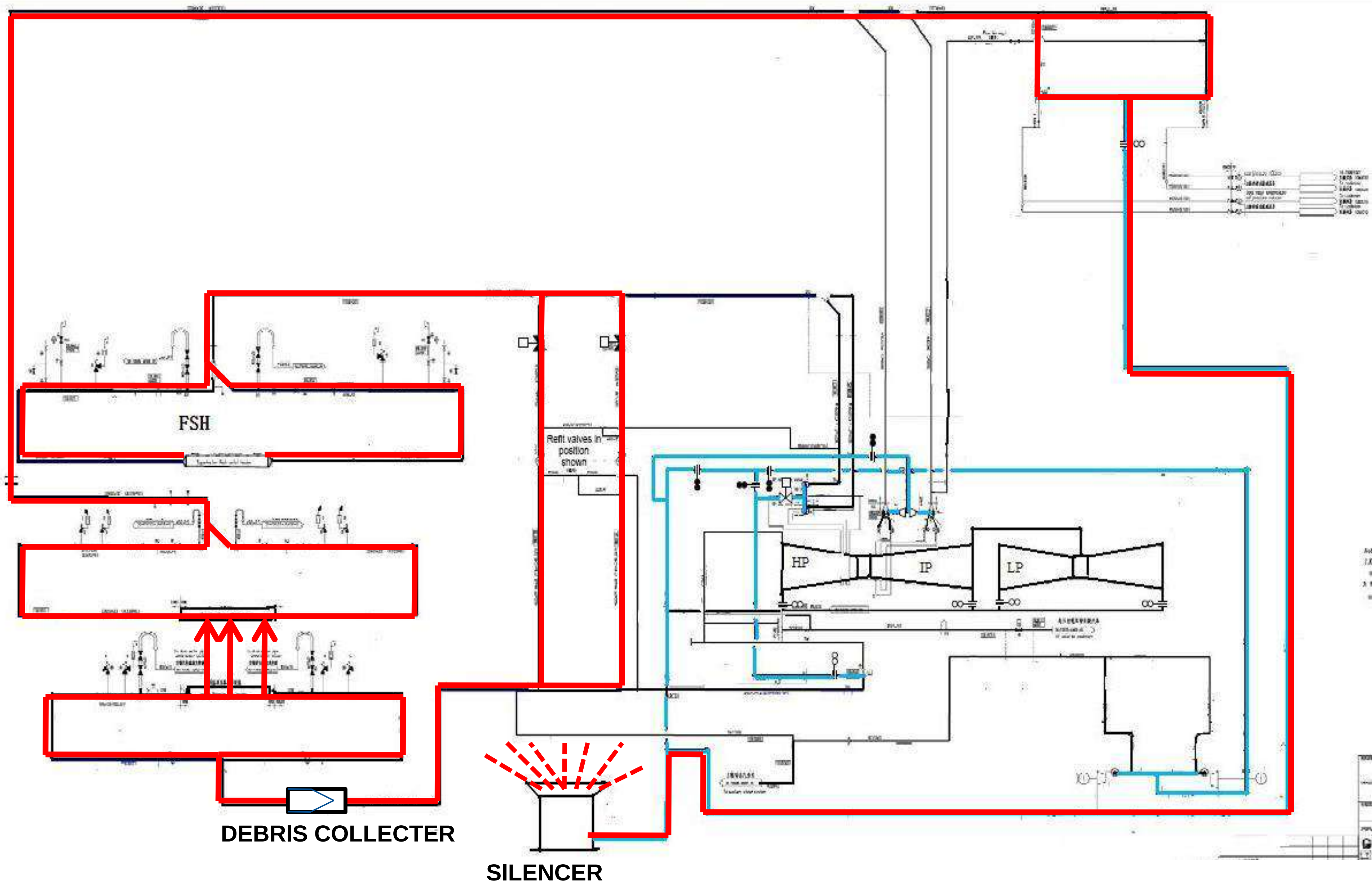
2.No.2 and No.4's material must be same as cold reheat pipe(No.1 item) .

NO.	title	quantity	specificati
11	reinforcing rib	4	
10	flange of root tube	1	
9	blind plate	1	
8	draining valve	1	PN25,DN76
7	particle collection box	1	
6	cold reheat pipe near RH	1	
5	blind plate	1	δ ≥ 35mm
4	tube with multihole	1	
3	reinforcing guide plate	4	δ =8~10mm
2	outside barrel of PC	1	
1	cold reheat pipe	1	

FSH,MS LINE,CRH,RH,HRH



HP BYPASS AND LP BYPASS



ADVANTAGES

- Required less time for completion of the total process
- Less time required to normalize the system for final light-up to synchronization due to availability of coal mill system, ash handling system, less piping erection and welding work.
- This reduces the reactionary forces on the temporary pipes
- Stresses on the boiler system are lower

COMPARISION BETWEEN PUFFING & CONTINUOUS METHOD

PUFFING METHOD	CONTINEOUS METHOD
• More time required for complete steam blowing due to stage wise blowing(15-20 days) • More time required for stage wise temporary pipe erection and shifting of blowing device	• Less time required for completion (3-4 days) • Less time required as only valves to be opened for different systems
• No mill required	• Minimum 02 nos. of mill required
• CHP readiness, Economizer hopper and bottom ash hopper and its evacuation system not required	• CHP readiness, Economizer hopper and bottom ash hopper and its evacuation system

Comparison …

PUFFING METHOD

- Thermal shock is the driving force of cleaning
- More thermal stress on tube material and sudden loading on supports
- Repeated light-up and shutdown
- There is a time gap between the blows to make-up DM water
- System normalization time after steam blowing is more
- Silencer use is optional

CONTINEOUS METHOD

- Steam velocity or Removal force is the driving force
- Less thermal stress on tube material
- Light-up only once in the beginning of the steam blowing
- DM water make-up to the system during steam blowing is a challenge
- System normalization time after steam blowing is less.
- Silencer use is compulsory.

ADANI

THANK YOU