

SUPERCritical TECHNOLOGY AND USE OF HIGHER THERMAL UNIT RATINGS

**G.S. BINDRA
GENERAL MANAGER
(INCHARGE)
BHEL-PEM, NOIDA**

Total Installed Capacity in India (As on December 31, 2009)

Type of Plant	MW	%age
Total Thermal	99,861.48	64.6
Coal	81,605.88	53.3
Gas	17,055.85	10.5
Oil	1,199.75	0.9
Hydro	36,885.40	24.7
Nuclear	4,120.00	2.9
RES	15,225.35	7.7
Total	1,56,092.23	

Source : CEA

Mission 2012

The Ministry of Power has set a goal - Mission 2012:
Power for All.

A comprehensive Blueprint for Power Sector development with following objectives:-

- Sufficient power to achieve GDP growth rate of 8%
- Reliable of power
- Quality power
- Optimum power cost
- Commercial viability of power industry
- Power for all

Power Generation Strategy

Focus on

- Low cost generation,
- Optimization of capacity utilization
- Controlling the input cost
- Optimisation of fuel mix
- **Technology upgradation**
- Utilization of Non-Conventional energy sources

Coal Technologies

Integrated gasification combined-cycle generation technology (IGCC)

Circulating fluidized bed combustion generation technology (CFBC) and pressurized circulating fluidized bed combustion combined-cycle generation technology (PFBC-CC)

Supercritical and ultra-supercritical generation technology (SC/USC)

Capacity Addition Programme in 10th -13th Five Year National Plans

TYPE	10 th PLAN (2002-2007) (Actual)	11 th PLAN (2007-2012) (Planned)	12 th PLAN (2012-2017) (Tentative)**	13 th PLAN (2017-2022) (Tentative)**
THERMAL				
	MW	MW	MW	MW
SUB-CRITICAL (Upto 600 MW)	12114	48230	20650	NIL
SUPER CRITICAL (660 & 800 MW)	----	5940	42280	64100

❖ *THERE IS A CLEAR SHIFT IN THE PLANNED UNITS FROM SUB-CRITICAL TO SUPER-CRITICAL UNITS.*

❖ *AS PER CEA, 13th PLAN ONWARDS ALL THERMAL SETS SHALL BE SUPERCRITICAL SETS ONLY*

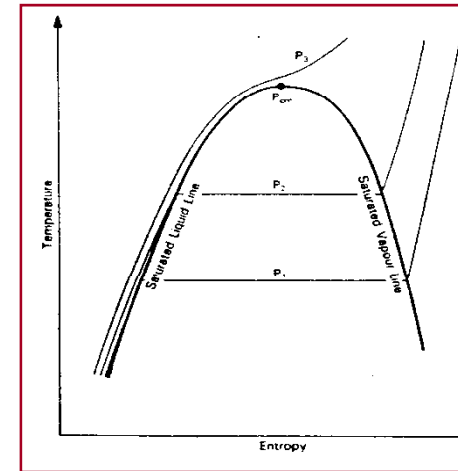
**** Based on Sites/Rating identified by Central Electricity Authority, Govt Of India. This may undergo changes keeping in view the commissioning schedule/coal linkages etc.*

What is Supercritical Parameters

AS THE FLUID PRESSURE INCREASES, LATENT HEAT (ENTHALPY OF STEAM –ENTHALPY OF WATER) REDUCES.

AT CRITICAL POINT IT BECOMES ZERO.

IN PHYSICAL TERMS AT THIS PRESSURE WATER TRANSFORMS TO STEAM SPONTANEOUSLY.



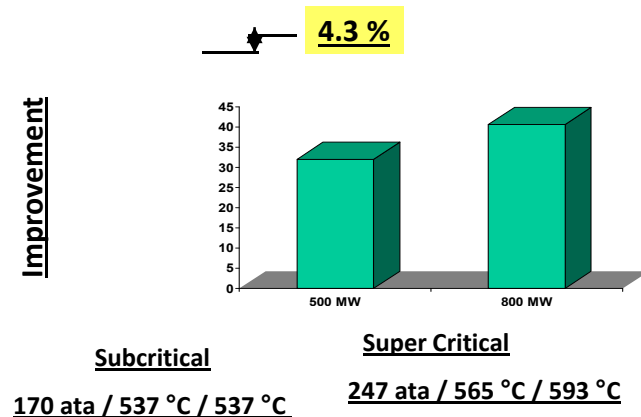
SUPER CRITICAL STEAM PARAMETERS:

PARAMETERS MORE THAN CRITICAL STATE

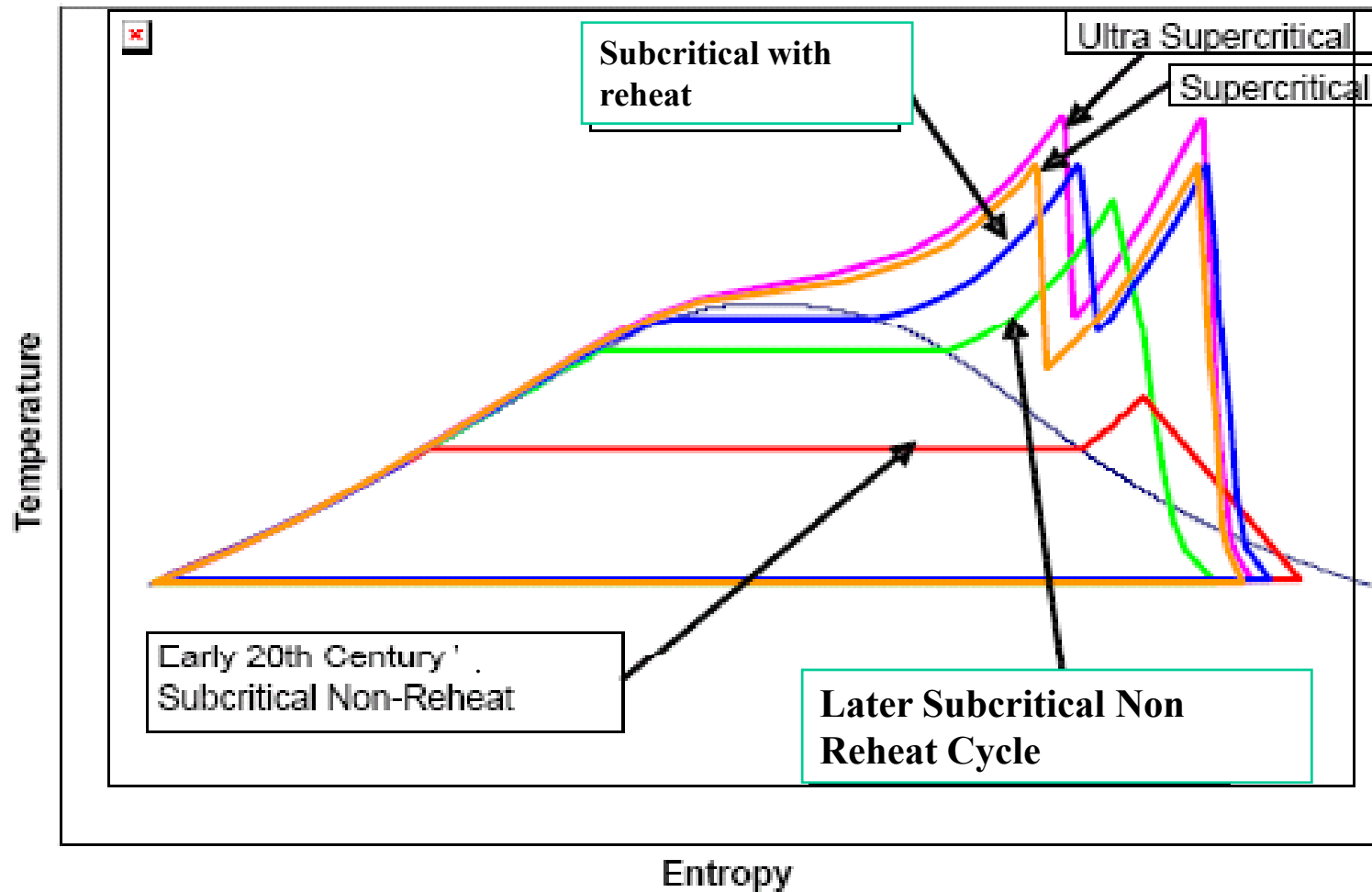
- STEAM PRESSURE > 221.2 BAR
- STEAM TEMPERATURE > 374.15 Deg C

INCREASE IN PRESSURE & MAIN AND REHEAT TEMP. > 537 Deg C

RESULTS IN SIGNIFICANT IMPROVEMENT IN HEATRATE



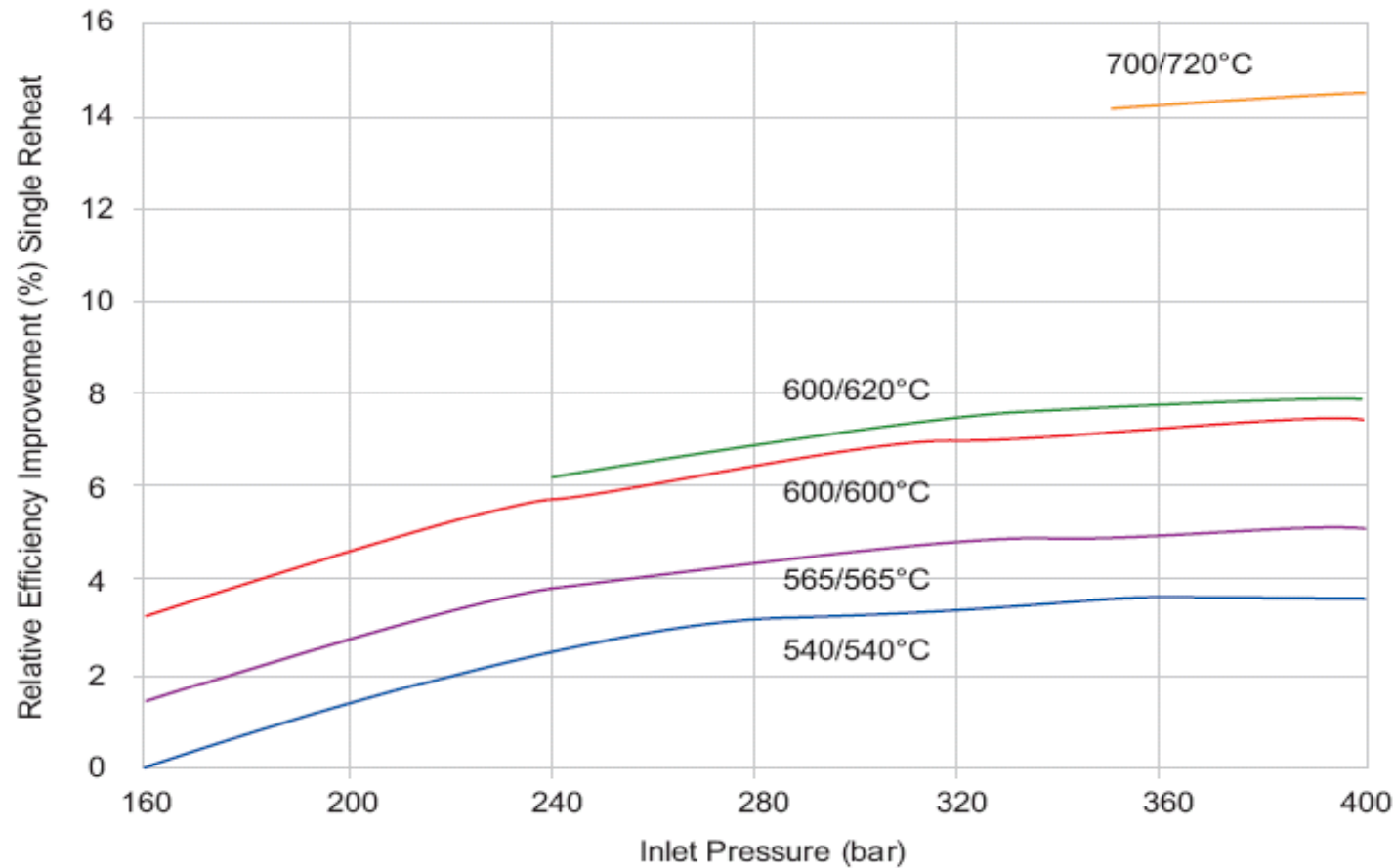
Evolution of Steam Cycle Parameters



Efficiency of Existing 500MW and above ratings

	500 MW Old BHEL	500 MW New BHEL	660 MW (under construction) Non BHEL	660/800 MW (Under Development) BHEL
Technology	Sub-Critical	Sub-Critical	Super-Critical	Super-Critical
HPT Inlet Pr (kg/cm ²)	170	170	247	247
HPT Inlet Temp (C)	537	537	537	565
IPT Inlet Temp (C)	537	565	565	593
Design Turbine Cycle Heat Rate (Kcal/kW-hr)	1945	1932	1900	1850
Gross Efficiency	37.6	37.8	38.5	39.4

Relative Efficiency Improvement With Parameters



Effect of Steam Parameters on Turbine Heat Rate

- For every 1 Bar improvement of main steam pressure:
turbine heat rate could be reduced $\sim 0.015\%$
- For every 10 °C improvement of main steam temperature:
turbine heat rate could be reduced by $0.25\% \sim 0.30\%$
- For every 10 °C improvement of reheat steam temperature:
turbine heat rate could be reduced by $0.15\% \sim 0.20\%$

The Basic Heat Cycle

Sub-critical units: Main steam pressure < 221.1 bar

Super-critical units: Main steam pressure > 221.1 bar

Ultra-supercritical units:

Higher steam pressure and temperature than supercritical units

Japan: Main steam pressure > 242 Bar, or Steam temperature > 593 °C

Denmark: Main steam pressure > 275 Bar

China: Main steam pressure > 270 Bar

USA (EPRI) : Main steam temperature > 593 °C

Supercritical Technology – Indian scenario

- Supercritical technology being adopted to enhance efficiency, reduce coal consumption and GHG emission
- 660/ 800 MW units planned in big way.
- Parameters adopted 247kg/ cm²/ 565/ 593 deg C
- Eight units of 660 MW under execution at Sipat and Barh by NTPC
- Two units of 800MW under execution at Krishnapattnam by APGENCO
- For 2x800 MW Yermarus, 1x800 MW Edlapur TPS and 2X800 MW Udangudi TPS - JV for Super Critical Projects with KPCL and TNEB
- 9 Ultra Mega Projects, 4000 MW each, envisaged with supercritical units.
- 4 projects already awarded to IPPs through tariff based competitive bidding.

Identified Ultra Mega Projects

State	Project	Location	Status
Chattisgarh	Akaltara	Pithead	-
Gujarat	Mundra	coastal	Awarded to Tata
Karnataka	Tadri	coastal	-
Madhya Pradesh	Sasan	Pithead	Awarded to Reliance
Maharashtra	Giriye	coastal	-
Andhra Pradesh	Krishnapatnam	coastal	Awarded to Reliance
Orissa	Bhedabahal (Sundergarh district)	Pithead	-
Tamil Nadu	Cheyur	coastal	-
Jharkhand	Tilaiyya	Pithead	LOI issued to Reliance

Drivers For Higher Rating Supercritical Power Plants

- Demand for power is growing with growth in economy
- Large capacity addition needed to meet the projected growth in demand
- With tariff based bidding gaining ground, utilities have to bring down their cost of generation to remain competitive
- Emphasis on Environment and Clean Technologies
- **Fuel, Land & Water availability becoming more and more difficult.**

Use Of Super Critical Technology

- Supercritical Technology is widely established and accepted with more than 500 units in operation.
- Widely prevalent cycle parameters (At turbine end):
 - Pressure: 246 -270 kg/cm²
 - Temperature: 537/566 deg C (In 660MW Sipat & Barh TPS)

565/593 deg C (In 660 MW Barh-II and
2 X 800MW Krishnapattnam)

593/593 or 600/600 deg C
(Ultra Supercritical parameters-Yet to be adopted in
our country)
- Parameters adopted by BHEL for 660 and 800MW are 247kg/cm² /565/593 deg C.

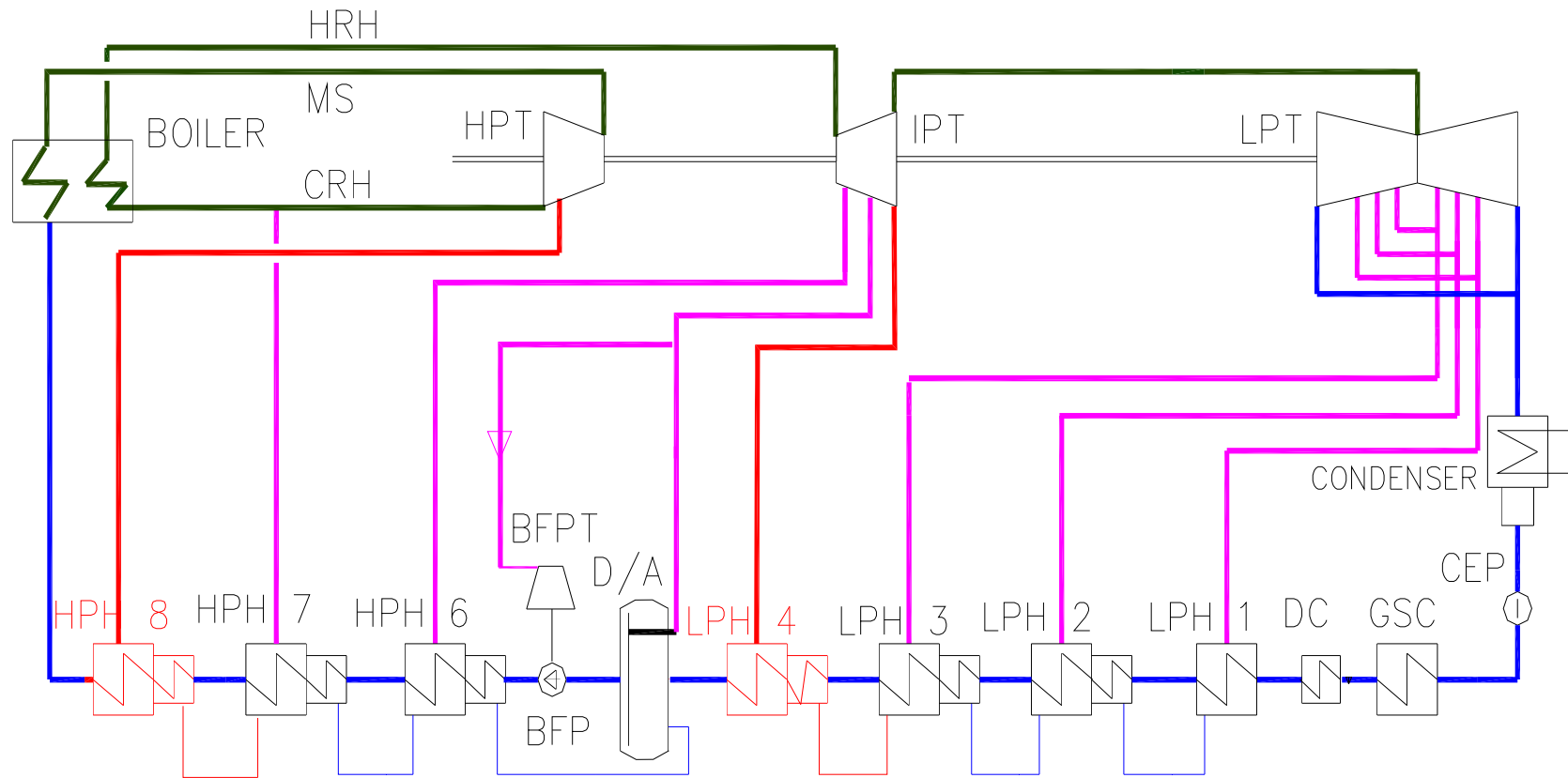
Comparison of Parameters

Parameter	Unit	250MW	500MW	660MW	800MW
Main Steam Pressure	ATA	150	170	247	247
Main Steam Temp.	°C	537	537	565	565
Main Steam Flow	T/Hr	740	1515	1960	2340
Reheat Pressure	ATA	36.0	40.5	50.4	56.6
Reheat Temperature	°C	537	537	593	593
Reheat Flow	T/Hr	665	1335	1625	1940
CRH Pressure	ATA	40	45	56.0	61.5
Cold Reheat Temp.	°C	344	336	336	348
Final FW Temp.	°C°C	245.4	253	290	290
BMCR Flow	T/hr	810	1625	2120	2600

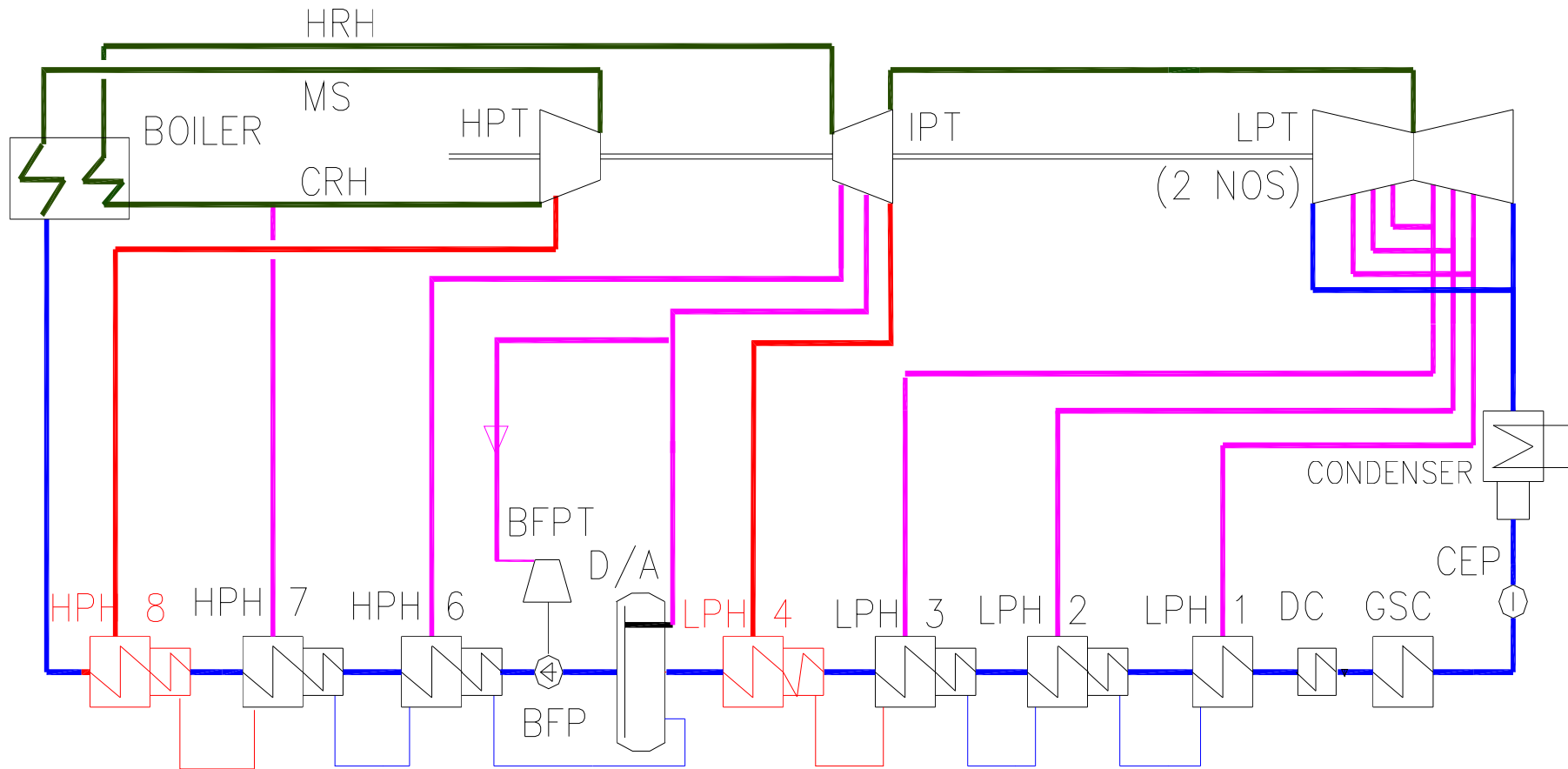
Power Cycle Equipment

EQUIPMENT	250MW SUB CRITICAL	500 MW SUB CRITICAL	660 MW SUPER CRITICAL	800 MW SUPER CRITICAL
BOILER	Drum Type	Drum Type	Once Through Type	Once Through Type
TURBINE	1HP + 1IP + 1LP	1HP + 1IP + 1LP	1HP + 1IP+ 1LP	1HP + 1IP+ 2LP
CONDENSER	One	One	One	Two
TYPE OF GOVERNING	THROTTLE	THROTTLE	THROTTLE	THROTTLE
GENERATOR	294 MVA	588 MVA	780 MVA	950 MVA
LP HEATERS	3 Nos	3 Nos	4 Nos	4 Nos
HP HEATERS	TWO	TWO (2X50% EACH)	THREE (2X50% EACH)	THREE (2X50% EACH)
DEAERATOR	ONE	ONE	ONE	ONE
CONDENSATE EXTN. PUMPS	2x 100%	3 x 50%	3 x 50%	3 x 50%
BOILER FEED PUMPS	3 x 50% (MD)	2 x 50%(TD) / 1 x 50% (MD)	2 x 50 % (TD) / 1 x 50 %MD	2 x 50 % (TD) / 1 x 35/50 %MD
CONDENSATE POLISHING UNIT	2 x 50%	2 x 50%	4x 33%	3 x 50%

Typical 660 Mw Cycle



Typical 800 MW Cycle



Indian scenario of USC Technology

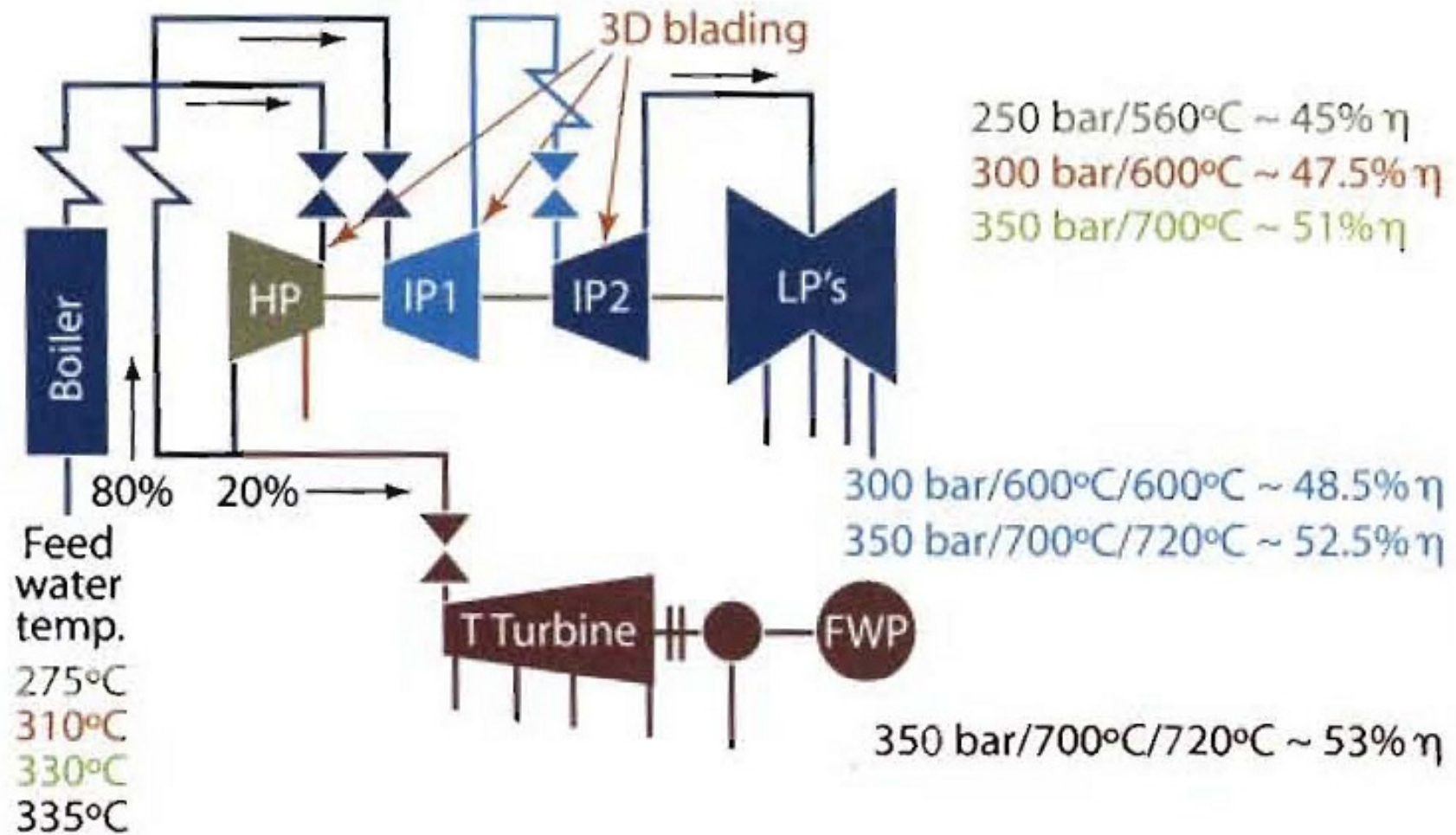
1. Parameters of about 280 bars and 600 deg C may be adopted (Source: CEA).
2. BHEL's collaborators have experience to meet the above requirement.
3. Ultra supercritical plant are more efficient but will require higher capital cost.
4. Supercritical plants technology is still under gestation in our country.

Future Of USC Plants – Programme AD700

Objectives of AD700

- Development, design & demonstration of pulverised coal fired power plant with advance steam parameters 700/720 deg c, 375 bar
- Efficiency of 52-55%, with CO₂ emission reductions of upto 15% compared to today's best available technology which is 600 deg c, 300 bar, 47%
- Qualification of advance nickel based boiler & turbine materials and improved austenitic and ferrite steels

Schematic For AD700



Future Of USC Plants – Parameters

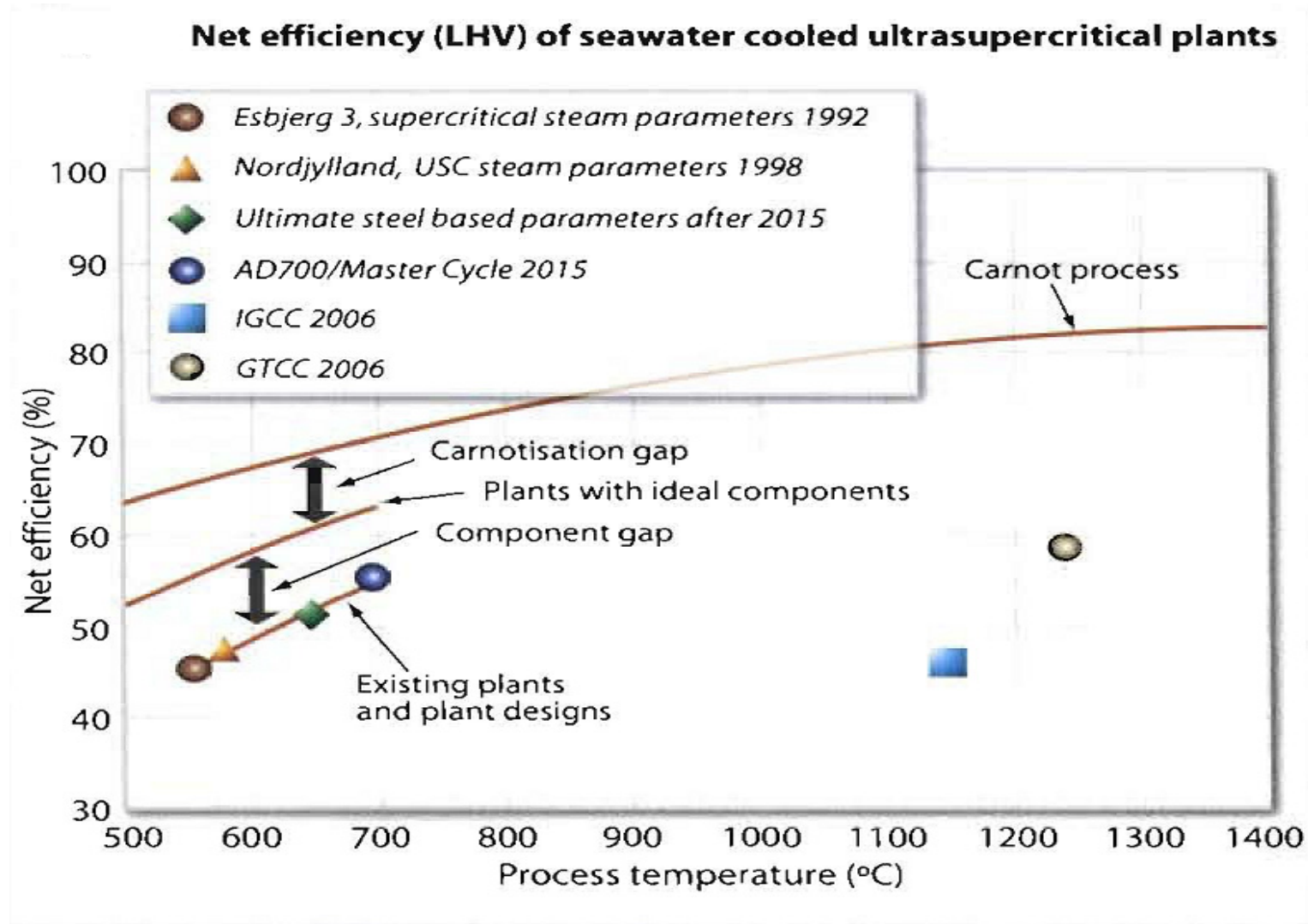
- DEMONSTRATION PLANT – BY 2014
- EXPECTED STEAM PARAMETERS OF AD700 TECHNOLOGY

	Main Steam Pressure (bar)	Main Steam Temperature (Deg C)	Reheat Pressure (bar)	Final Feed Water Temperature (Deg C)	Reheat Temperature (Deg C)	Condenser Pressure (mbar)
Single Reheat	350	700	75	720	330	40
Double Reheat	375	700	130/30	720/720	350	40

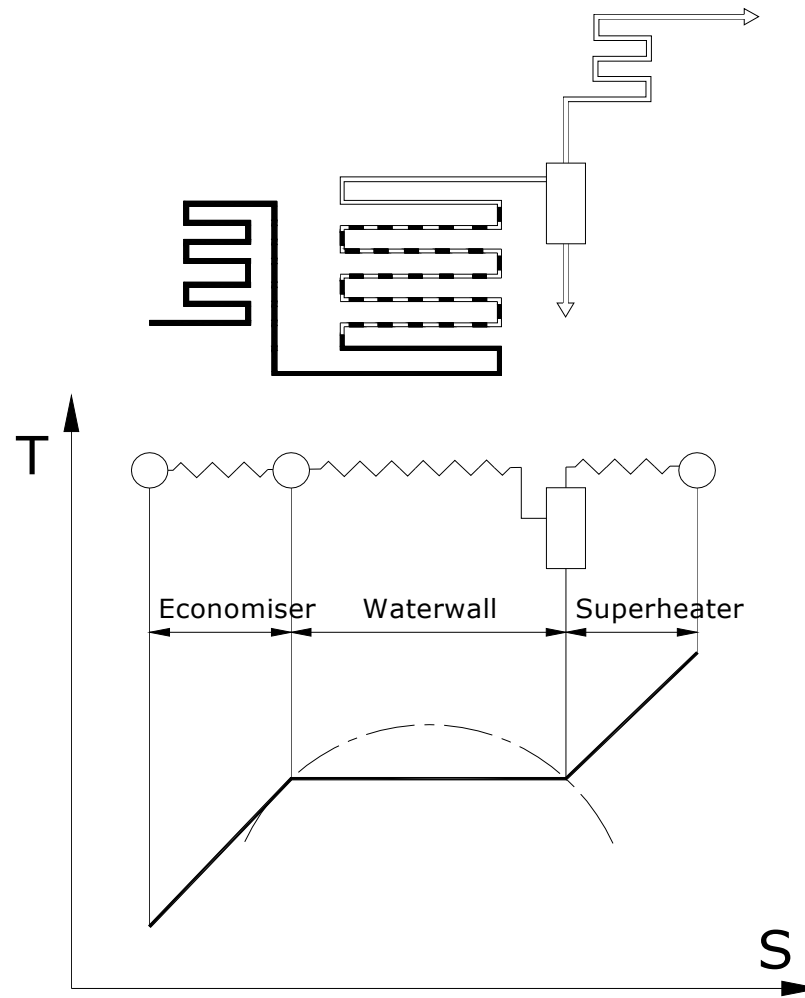
- NET EFFICIENCY TARGETS

	400 MW PLANT		930 MW PLANT	
	Single Reheat	Double Reheat	Single Reheat	Double Reheat
Inland site	49.3	50.4	49.5	50.8
Coastal Site	50.7	52	50.9	52.4

Temperature Vs Efficiency



Concept of Once through Steam Generator



Supercritical Boilers

- Supercritical pressure boiler has no drum and heat absorbing surface being, in effect, one continuous tube, in which the water & steam generated in the furnace water walls passes through only once hence called ‘Once through Supercritical pressure boilers’
- The water in boiler is pressurized by Boiler Feed Pump, sensible heat is added in feed heaters, economizer and furnace tubes, until water attains saturation temperature and flashes instantaneously to dry saturated steam and super heating commences.

The Concept

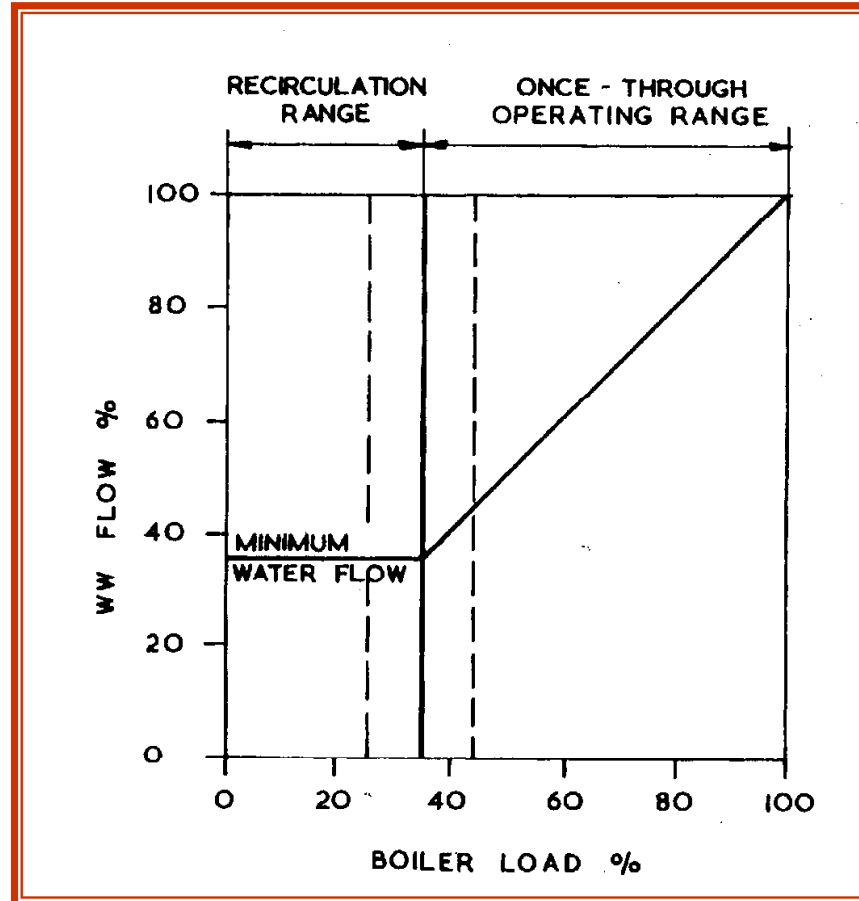
The mass flow rate thru' all heat transfer circuits from Economiser inlet to Superheater outlet is kept same except at low loads wherein recirculation is resorted to protect the water wall system

Once through Supercritical Boilers

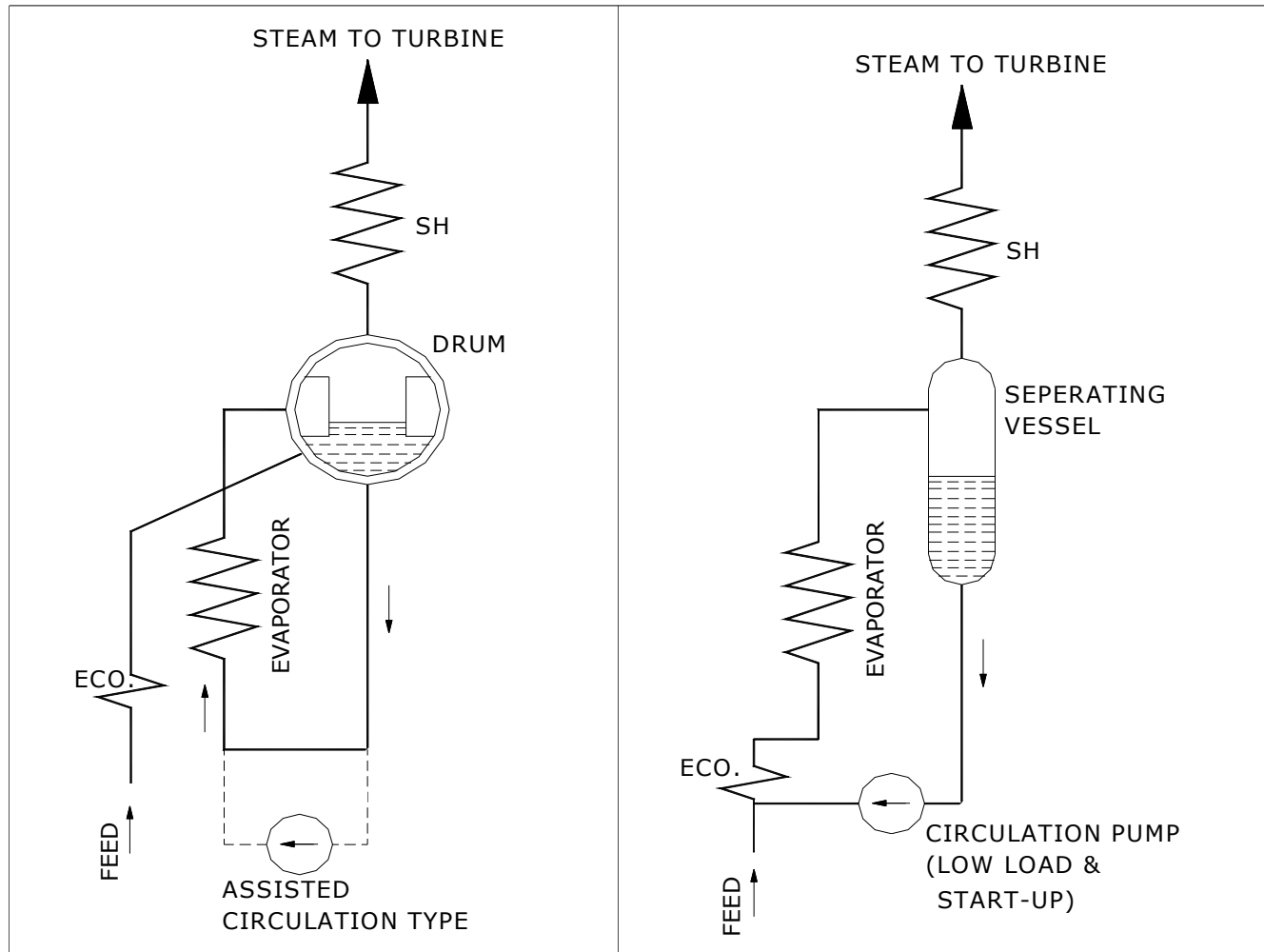
Major differences from Drum type boiler :

- Evaporator system
- Low load Recirculation system
- Separator

Once-through Operating Range



Circulation Systems



Drum Type

Once-through

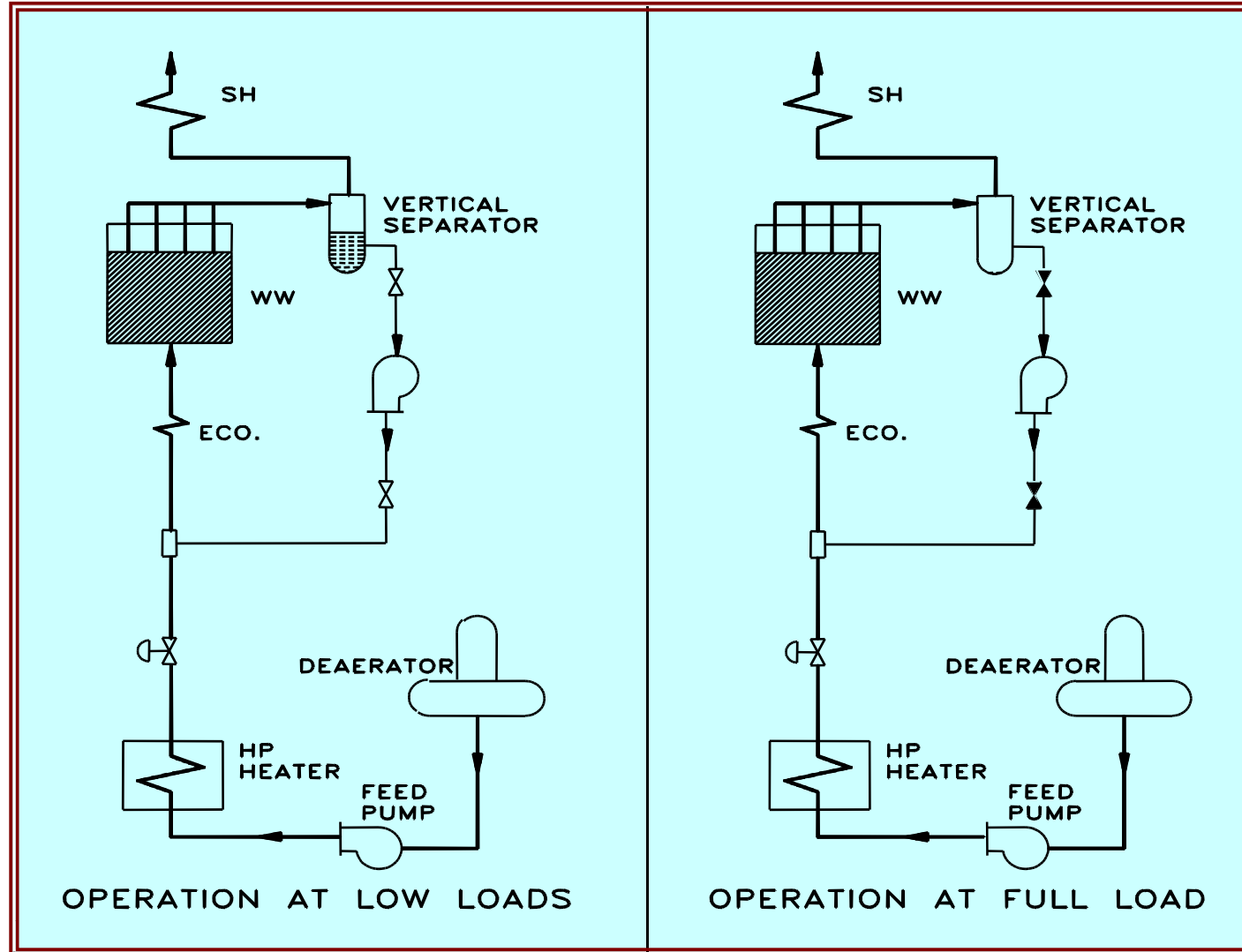
Once - thru' Boiler

Low load circulation system :

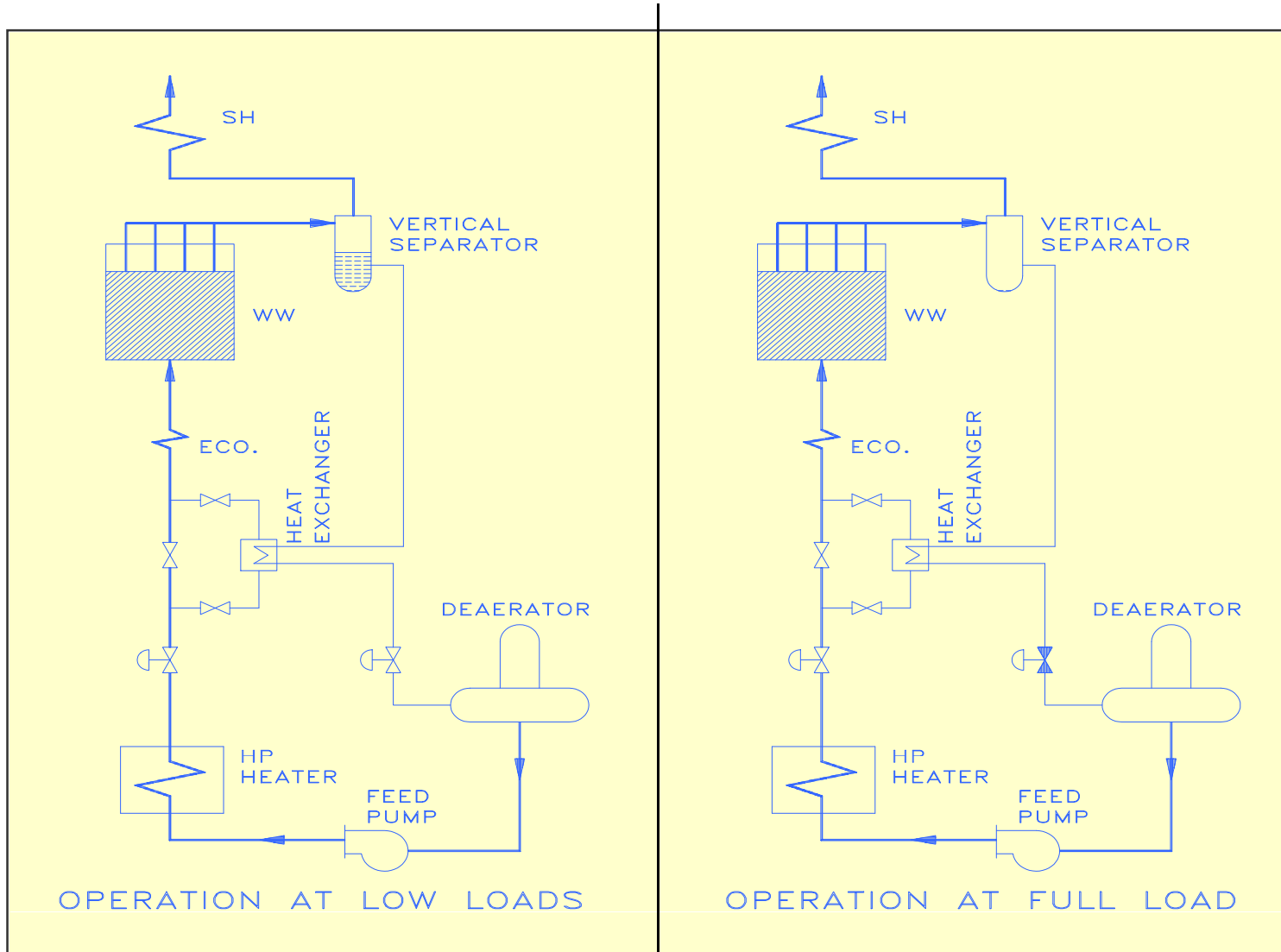
The excess flow over the once-thru flow separated in separator and

- Returned to the condenser thru' a heat exchanger
or
- Recirculated back to the boiler directly by the dedicated circulating pump

Low Load System with Circulating Pump



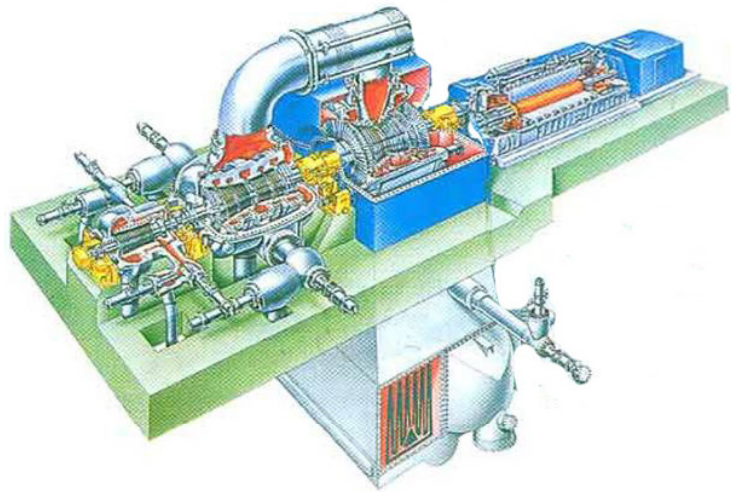
Low Load System With Heat Exchanger



Steam Turbine Module Configuration

MODULE	500 MW	660 MW	800 MW
HP TURBINE	H30-100	H30-100	H30-100
IP TURBINE	M30-63	M30-100	M30-100
LP TURBINE	N30-2 x 10	N30-2 x 12.5	N30-4 x 8
HP VALVES	2 x FV320	2 x FV250A	2 x FV250A
IP VALVES	2xAV560	2xAV560A	2xAV560A

660MW Steam turbine: With Supercritical parameters



Module Combination

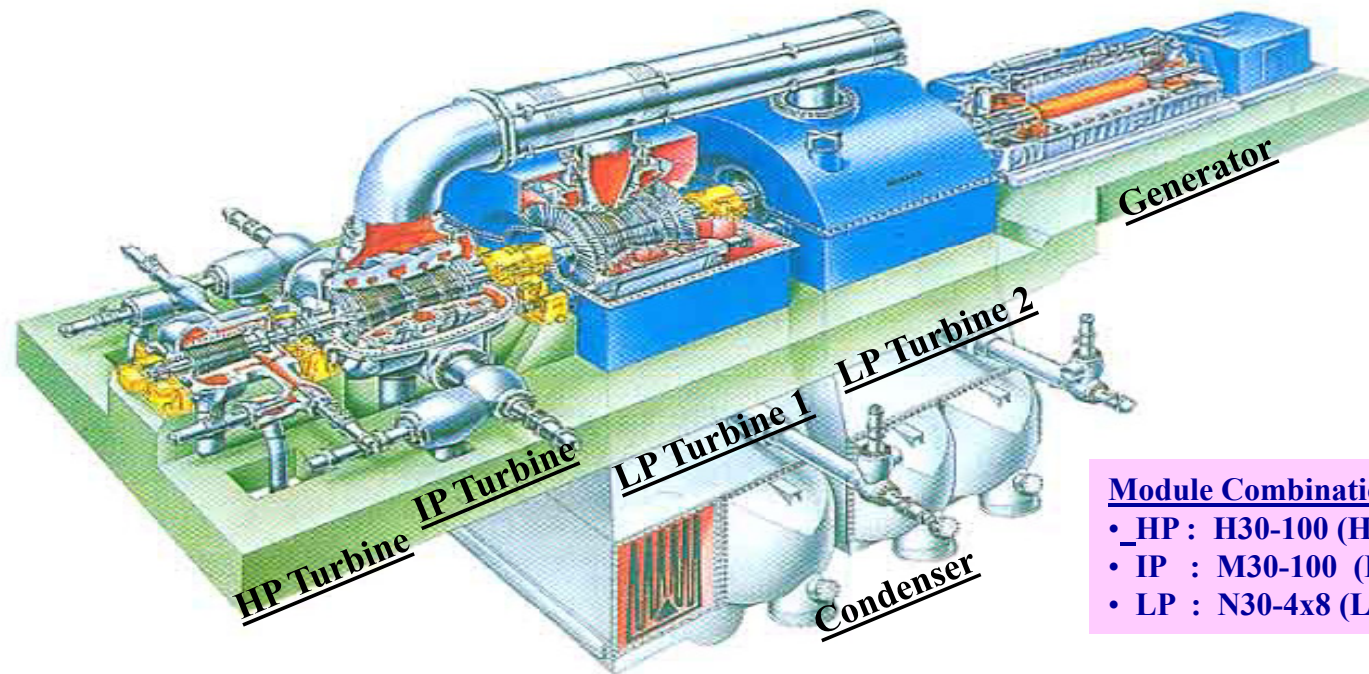
- HP : H30-100 (H70-V4)
- IP : M30-100 (I60-V2)
- LP : N30-2x12.5

Salient Feature:

New series of HP & IP modules for supercritical parameters
Higher size LP module

247 ata Main Steam Pressure
565 °C Main Steam Temperature
593 °C Hot reheat Temperature

800MW Steam turbine: With Supercritical parameters



Module Combination

- HP : H30-100 (H70-V4)
- IP : M30-100 (I60-V2)
- LP : N30-4x8 (L4x8)

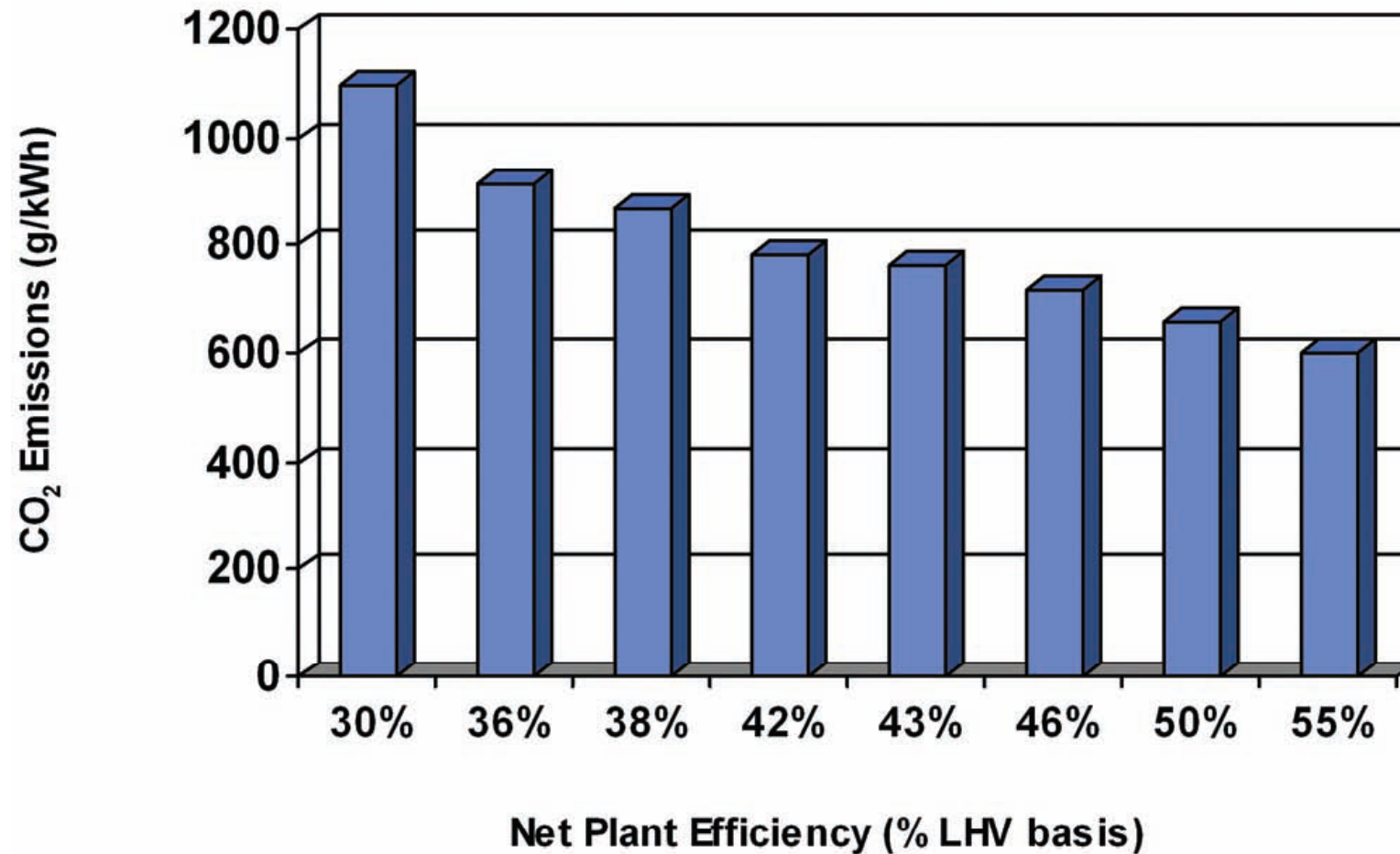
Salient features:

New series of HP, IP modules for super critical parameters

4 cylinder turbine (2 LP's)

247 ata Main Steam Pressure
565 0C Main Steam Temperature
593 0C Hot reheat Temperature

Efficiency Vs. Emissions



CO₂ Emission Comparison

Performance	Subcritical	Supercritical	USC
Net Heat Rate kcal/kW-h	2380	2233	1986
Net Efficiency (HHV)	36.1%	38.5%	43.3%
Coal use (10 ⁶ t/y)	1.469	1.378	1.221
CO ₂ emitted (10 ⁶ t/y)	3.30	3.09	2.74
CO ₂ emitted (g/kW-h)	894	830	738

Assumptions:

500 MW net plant output ; 85% Capacity Factor

Pulverized Coal Combustion Technologies without CCS .

Conclusion

- Higher parameters leads to Better Efficiencies
- Better Efficiencies result in Less Emissions and Less Carbon Dioxide
- Metallurgy Currently Available for Temperatures adopted in Supercritical/ Ultra-supercritical Power Plants.
- Higher units ratings of 660MW & 800MW envisaged.
- BHEL under its present collaboration agreement can supply SC/USC plants

THANK YOU