Advanced Pulverised Coal Fired Power Plants

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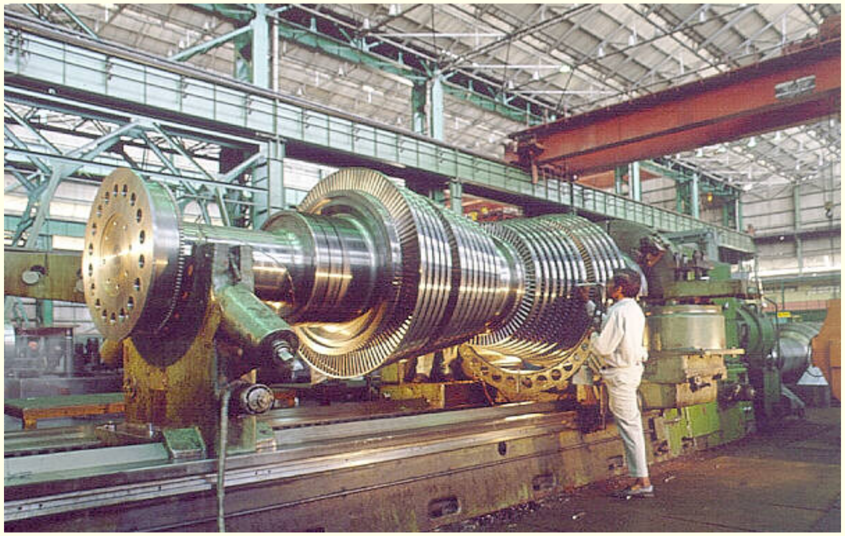

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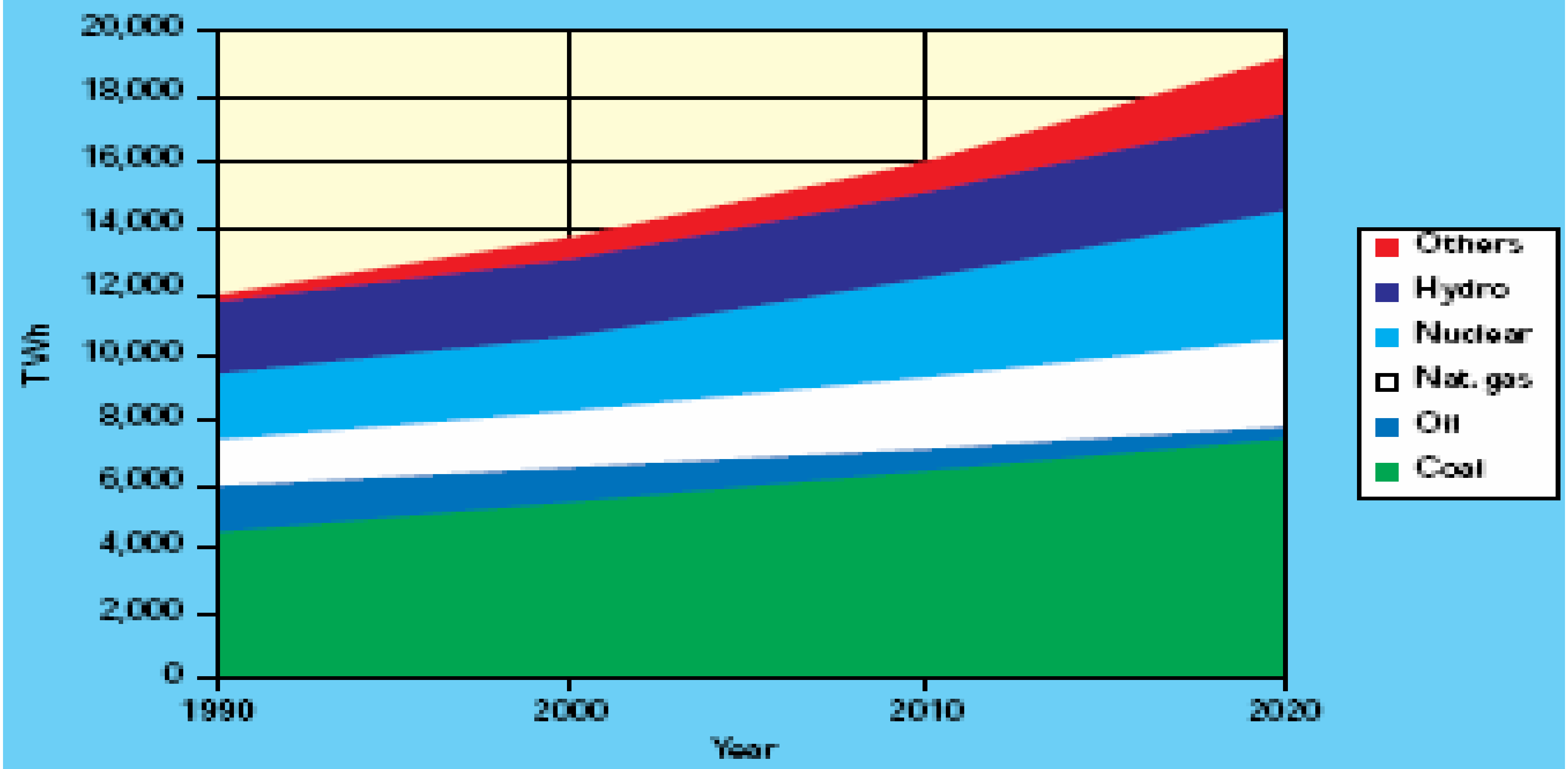
IEA. ENERGY POLICIES SCENARIO - 2050

- **A doubling of supplies can be achieved by 2050 with cleaner and more efficient technologies; the under pinning of low carbon economy.**

- **Fossil Fuels should remain a fixture in a low carbon economy. Produced more efficiently with more effective management of green house emissions.**



gure 14. Global electricity production by fuel to 2020

CEA's YEAR-WISE CAPACITY ADDITION PROGRAMME IN XI TH PLAN

MW

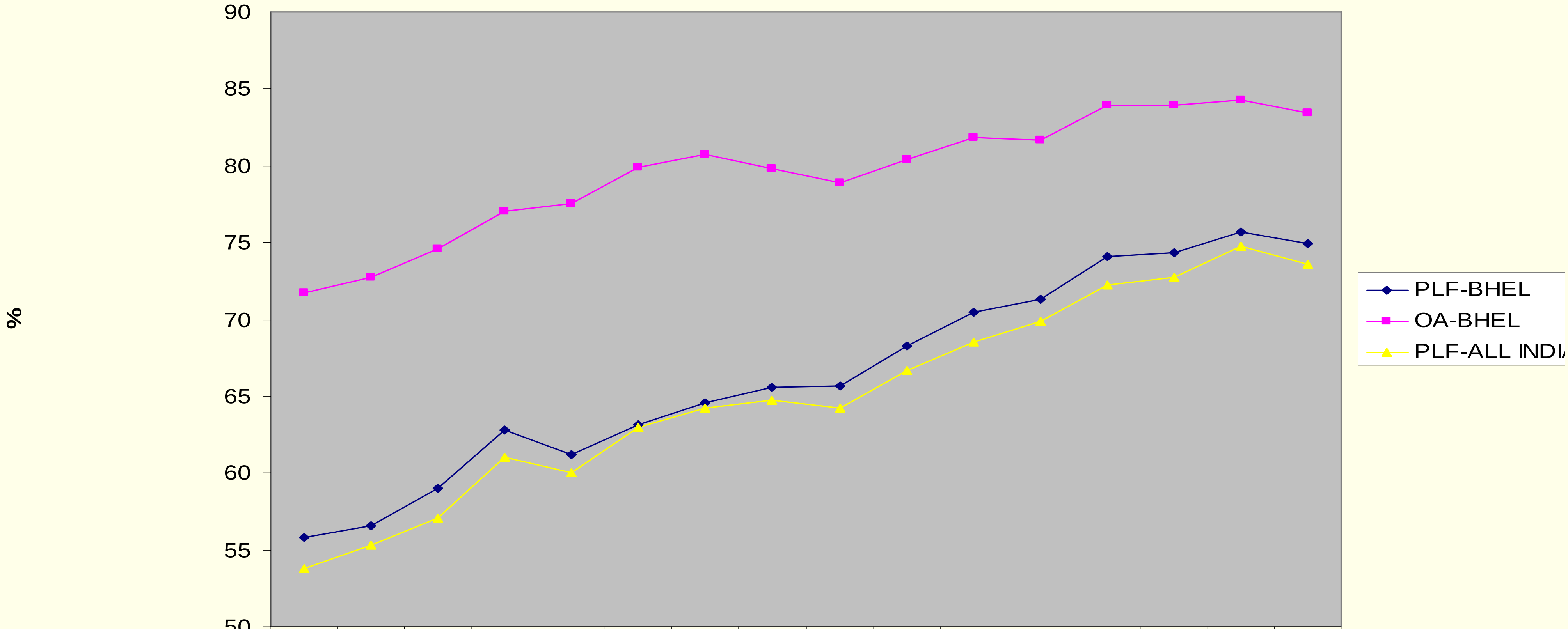
	2007-08	2008-09	2009-10	2010-11	2011-12	2007-12 (11th Plan)
Thermal	9575	4690	10000	14140	15950	54355
Gas	3129	411	773	0	0	4313
Nuclear	880	1000	1000	500	0	3380
Hydro	3201	1175	3425	2330	6422	16553
TOTAL	16785	7276	15198	16970	22372	78601

ADVANCED TECHNOLOGY – KEY DRIVERS

- **Efficiency**
- **Availability**
- **Fuel Flexibility**
- **Meeting Environmental Requirement / Legislation**

PERFORMANCE OF BHEL THERMAL SETS

Performance Trend
(Thermal sets in India)



	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	04-05	05-06
PLF-BHEL	55.8	56.6	59	62.8	61.2	63.1	64.6	65.6	65.7	68.3	70.5	71.3	74.1	74.3	75.7	74.9
OA-BHEL	71.7	72.7	74.6	77	77.5	79.9	80.7	79.8	78.9	80.4	81.8	81.7	83.9	83.9	84.3	83.4
PLF-ALL INDIA	53.8	55.3	57.1	61	60	63	64.2	64.7	64.2	66.7	68.5	69.9	72.2	72.7	74.8	73.6

year

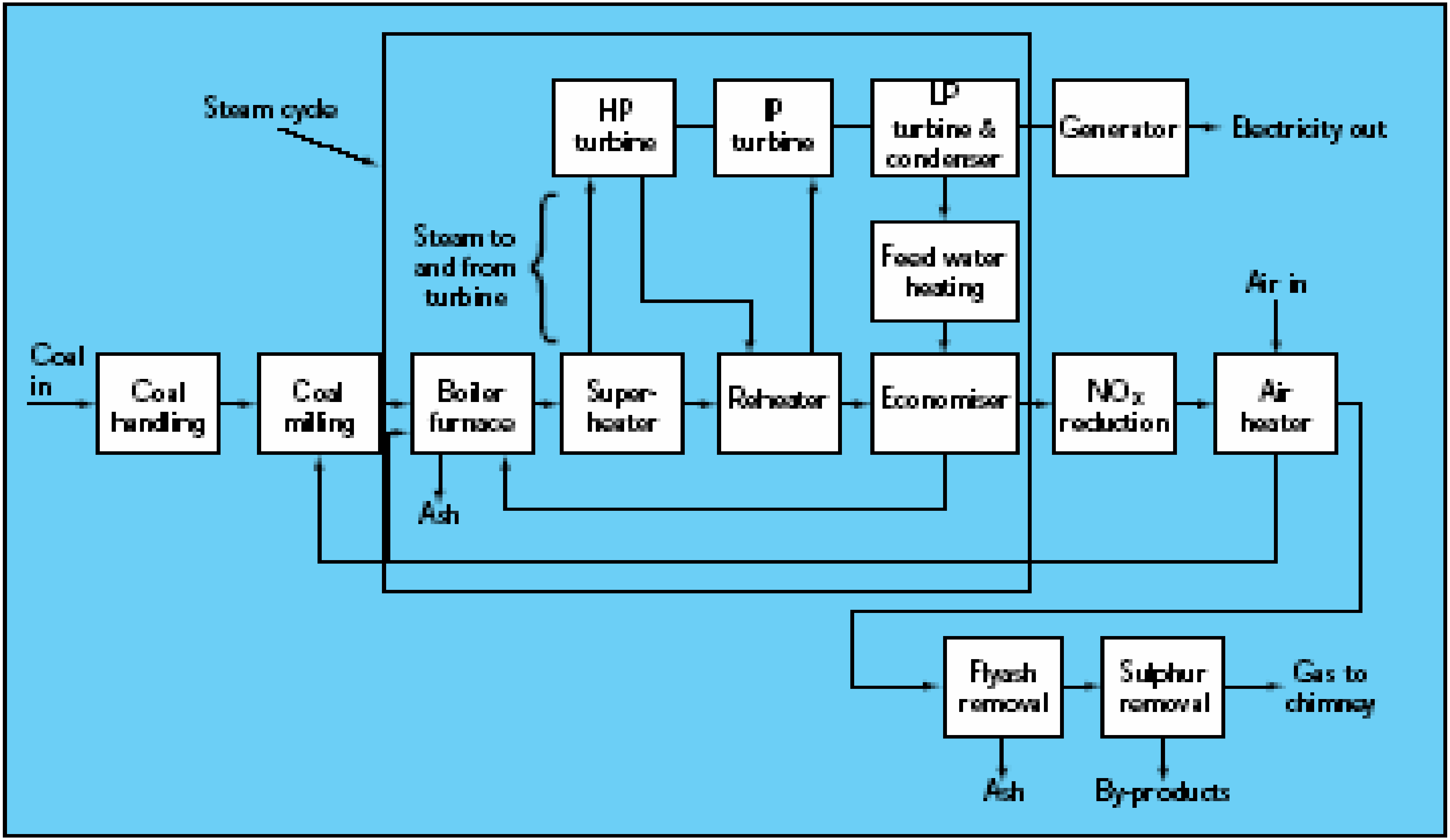


Figure 1. Typical pf plant-process diagram

IMPROVEMENTS IN STEAM CYCLE

- **Steam Cycle Performance**

- Increase in main, reheat temperatures and pressures.

- Cycle configuration – Reheat stages, number of feed heaters.

- **Cycle boundary condition – Flow and temperature of flue gas leaving boiler, condenser pressure.**

IMPROVEMENTS IN STEAM CYCLE

contd/

- **Reduced Auxiliary Power Consumption**

  -Improved performance of individual plant components like condenser, pumps and fans.

Current Trends in Steam Parameters

- 1980s : Pressure increased from 175-180 bar to 225 bar; temp mostly around 540 Deg.C
- 1990s : Pressures raised to 285 bar; Temp raised to 565 Deg.C
- 300 bar & 620 Deg.C not unusual today
- 255 bar 568/568 Deg C commonly used presently

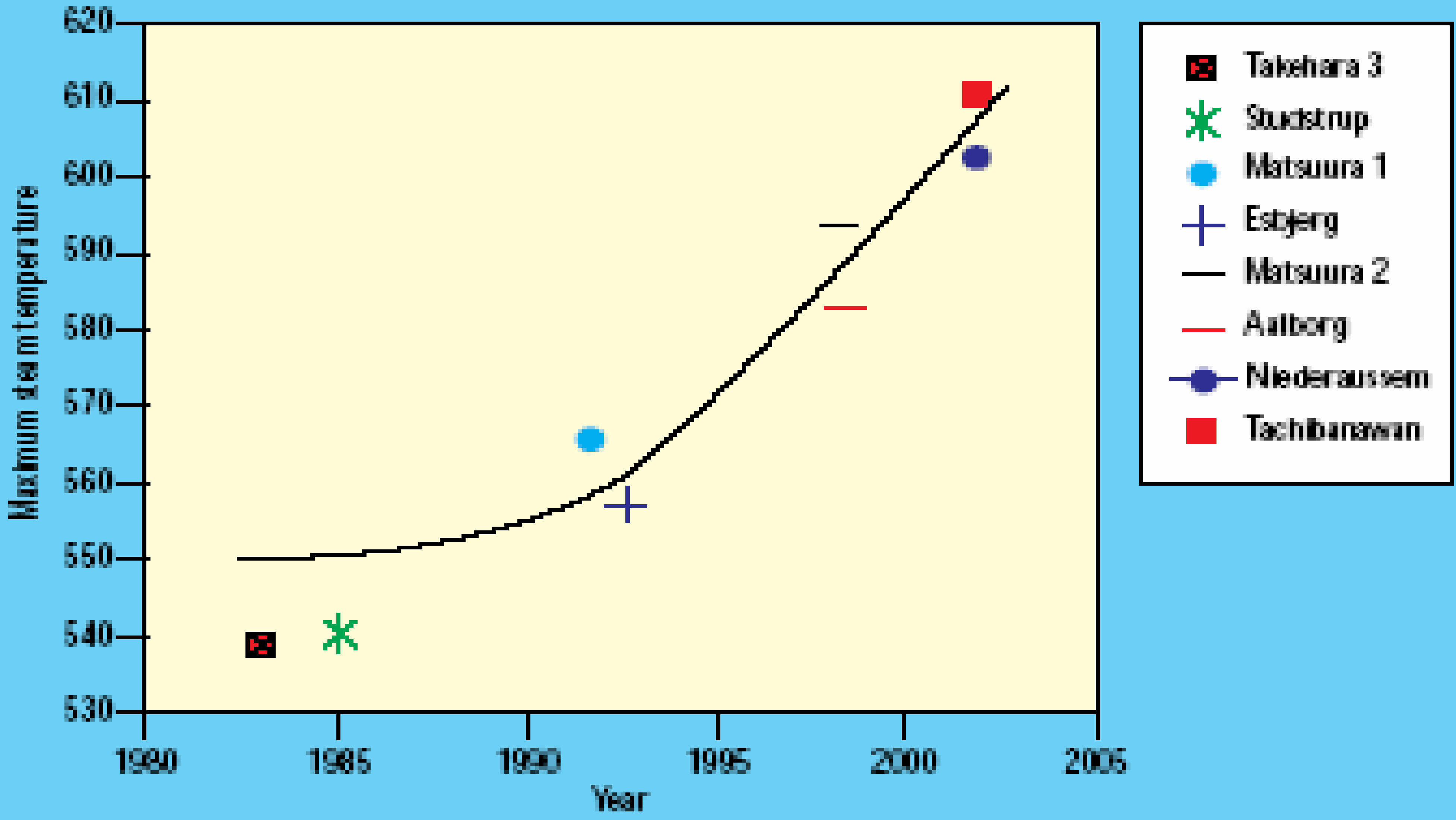
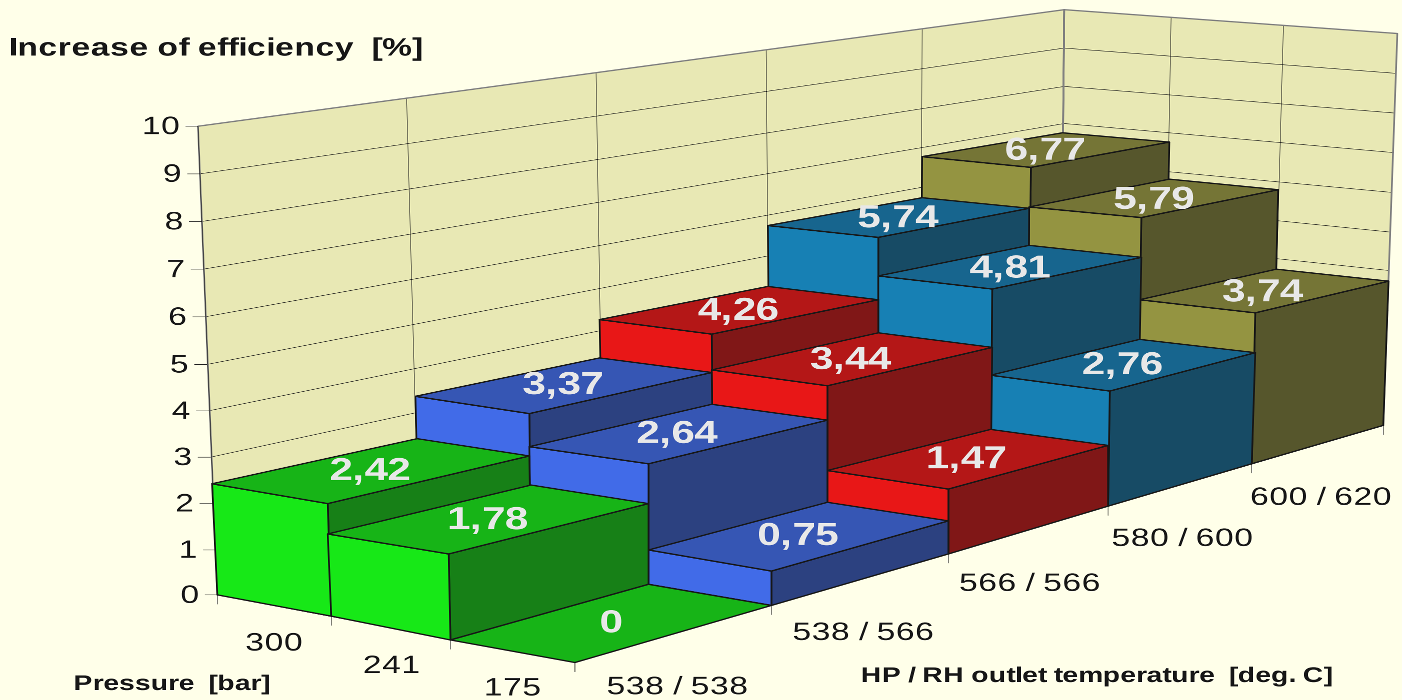


Figure 11. Maximum steam temperatures of leading supercritical units

Cycle Efficiency benefits of supercritical units are derived from higher pressures and temperatures of steam



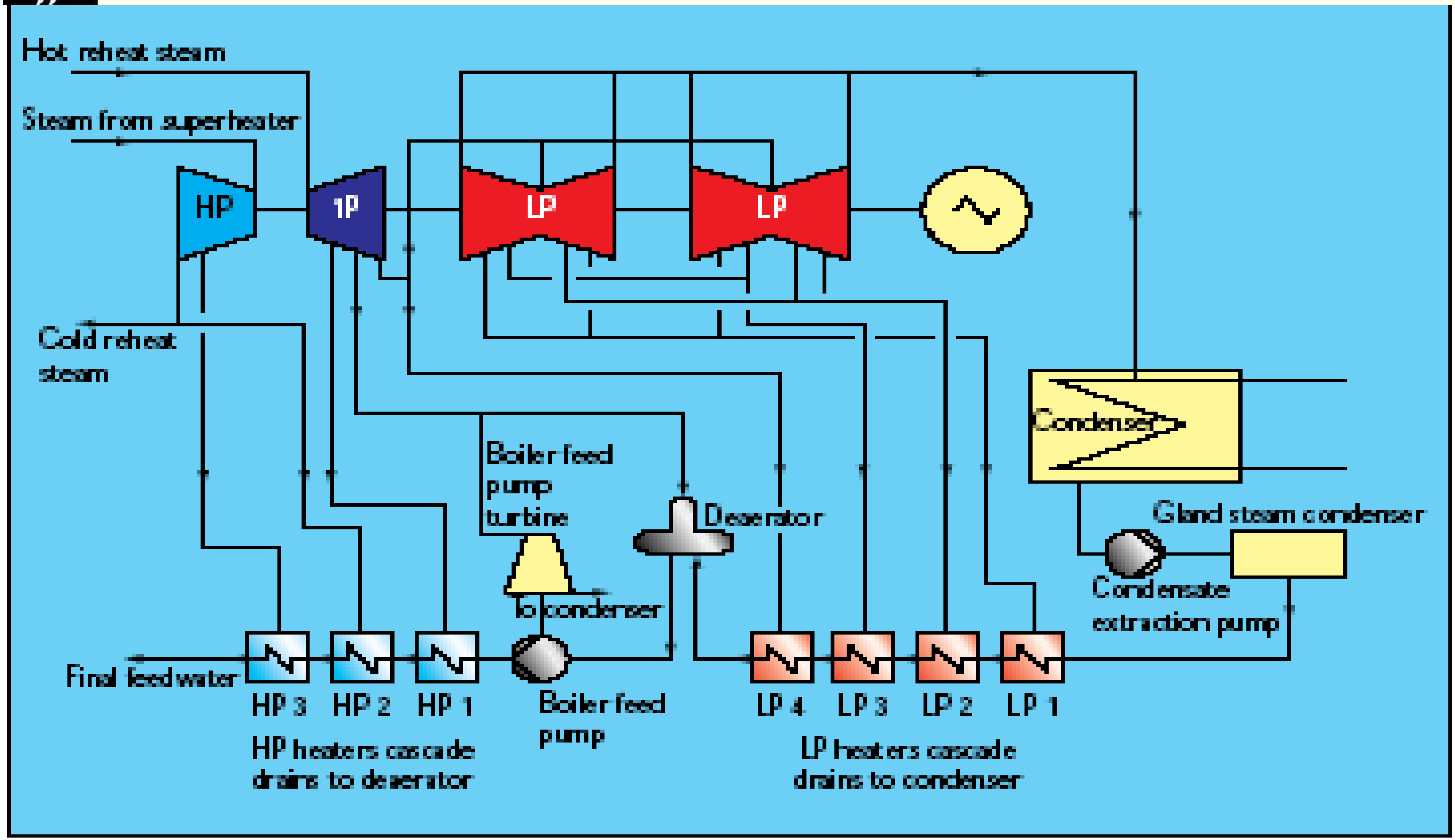


Figure 5. Steam turbine cycle

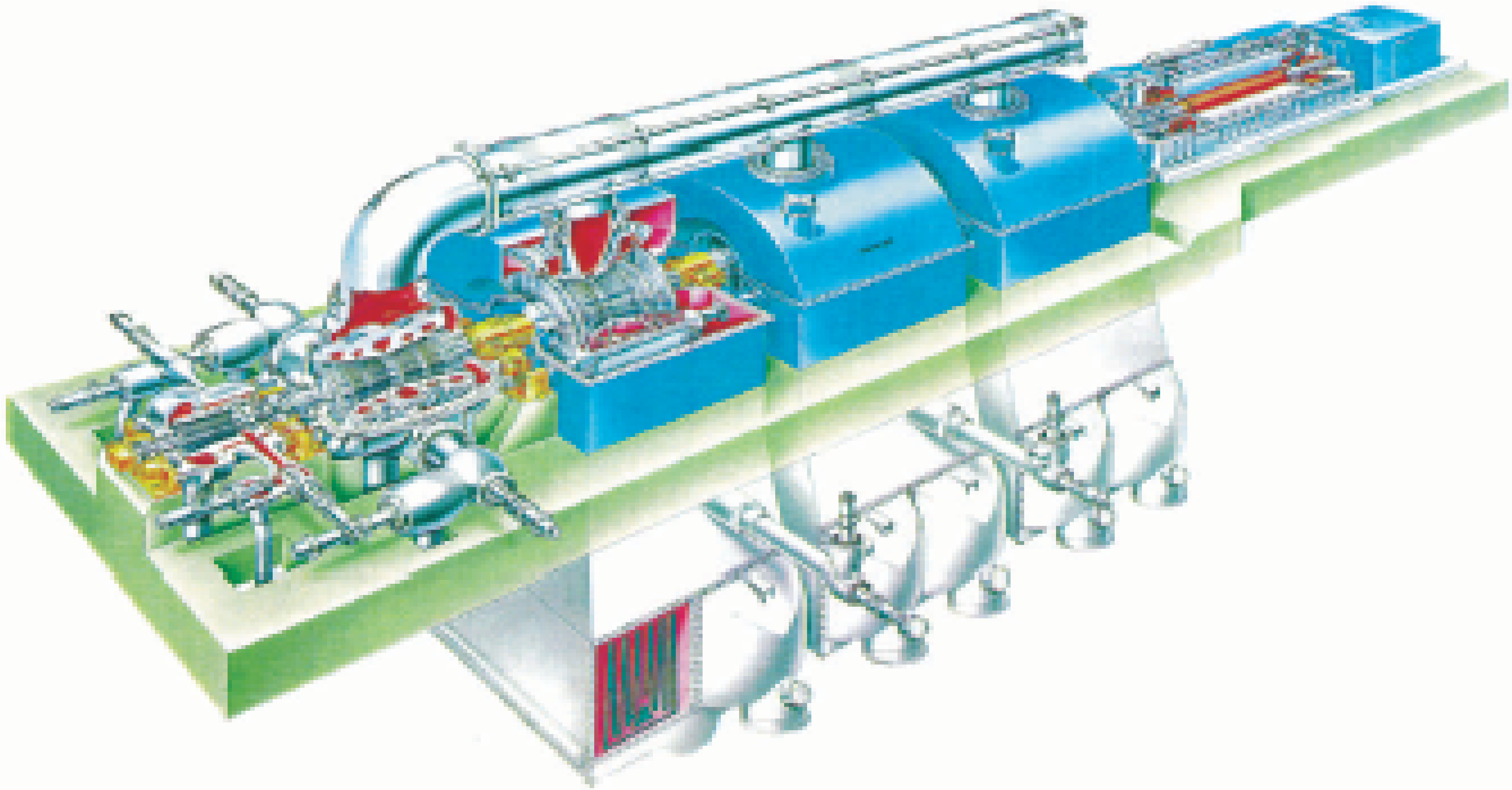


Figure 7. Typical turbine arrangement (courtesy of Siemens)

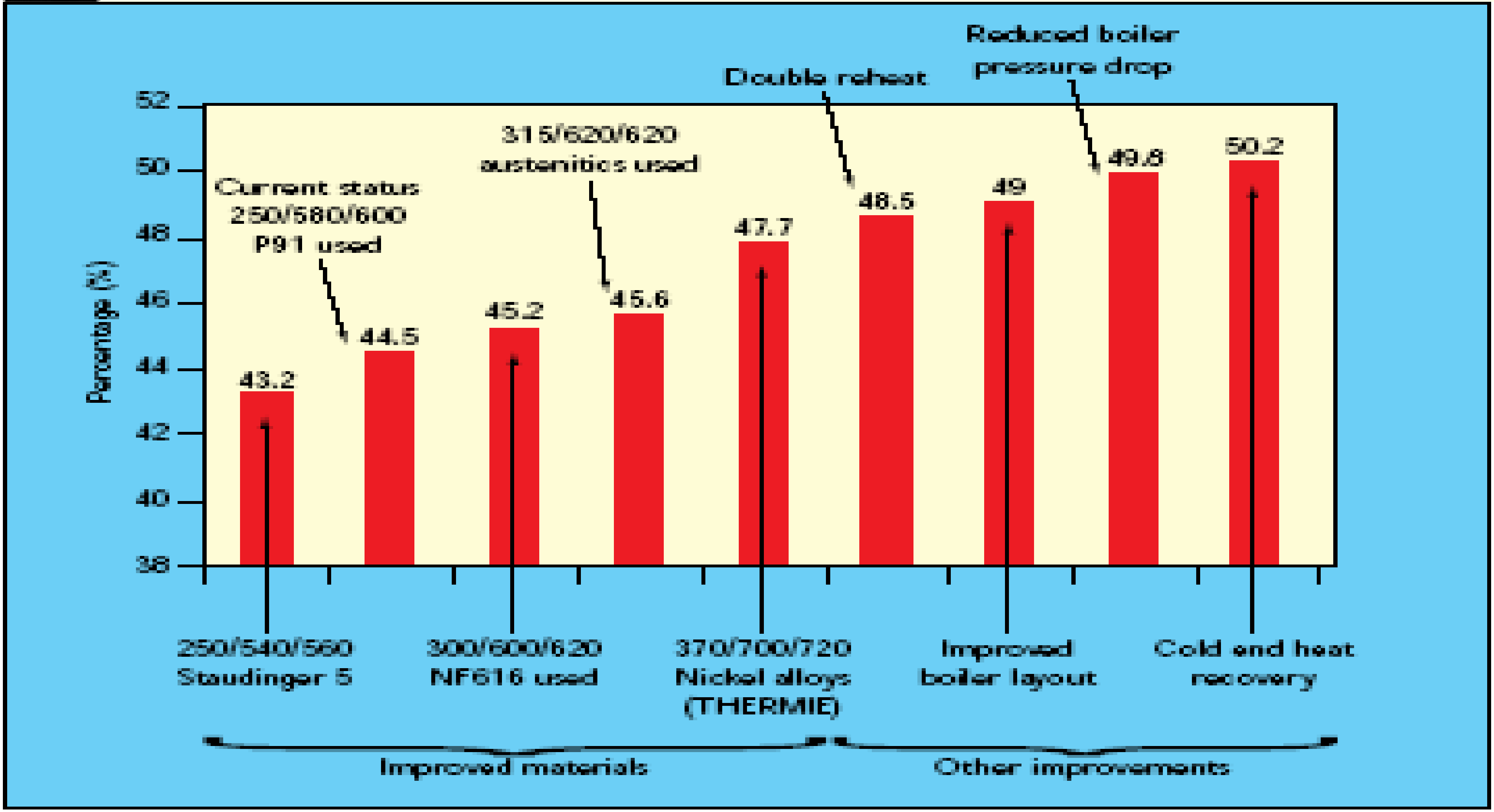


Figure 12. Potential efficiency improvements (based on a 700MW bituminous coal-fired plant, with a 40mbar condenser pressure)

BENEFITS OF TECHNOLOGY

- **Reduced fuel cost due to improved thermal efficiency.**
- **Reduced CO_2 emissions per unit of electricity.**
- **Proven Technology**
- **Very good part load efficiencies.**
- **Comparable plant costs to sub-critical technology.**

BENEFITS OF TECHNOLOGY

-Contd.

- Less than other clean coal technologies

- Low emissions of Nox, Sox and particulates achievable with modern flue gas clean-up equipment

ENVIRNOMENTAL ASPECTS – ROAD MAP

Area of focus - NOx control in pulverized coal fired boilers

NOx emission scenario of Indian plants while firing different fuels:

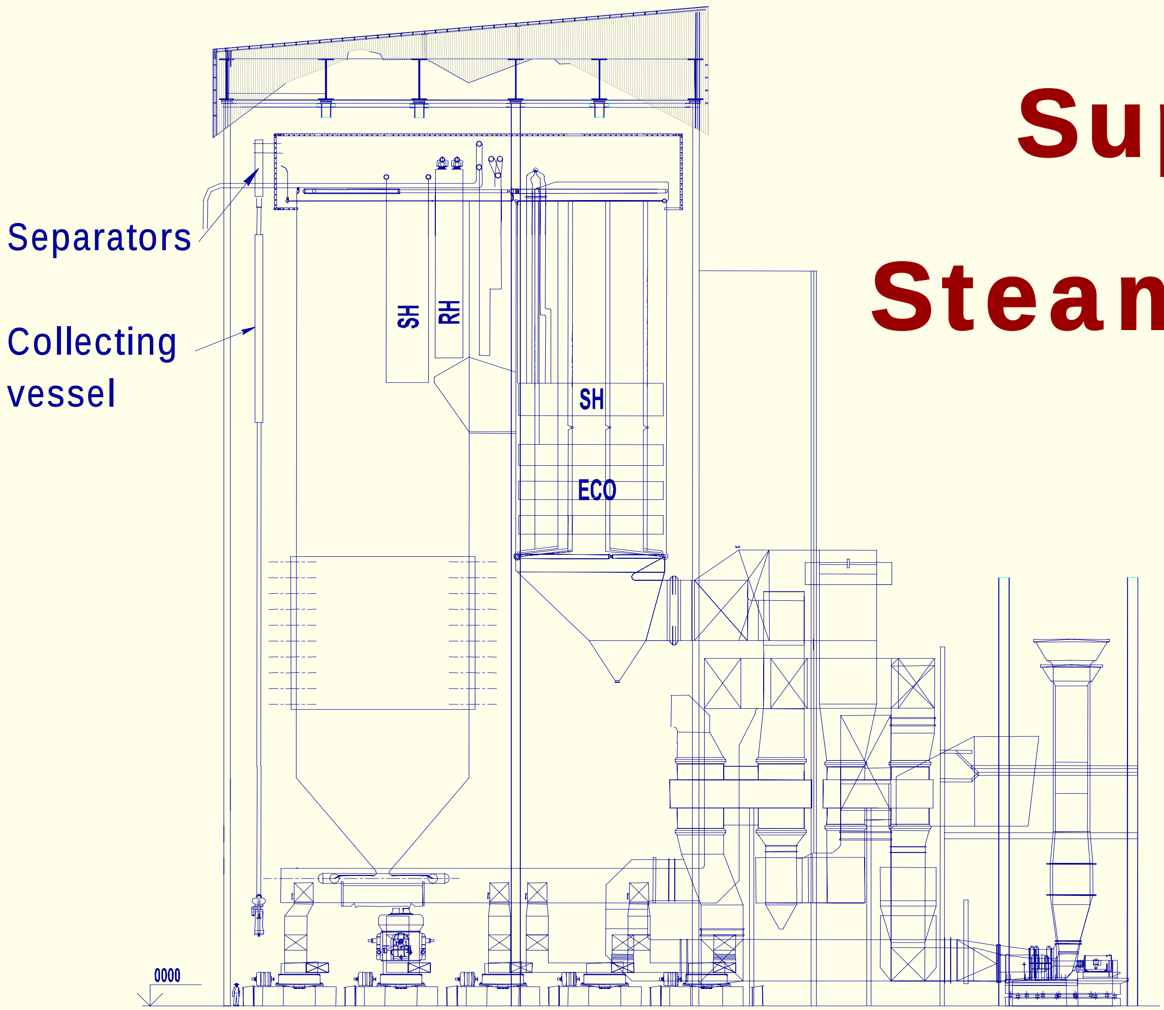
Unit capacity, MW	fuel	NOx emission, ppm at 3.0 % O_2
500	gas	73
500	oil	129 to165
500	coal	271 to 434
250	coal	266 to 322
210	coal	247 to 478
210	lignite	242 to 280
120	coal	389

Development of low NOx wall fired coal burner - 2006
Establishment of SCR demo plant - 2007
Commercialisation of wall burner - 2008
Commercialisation of SCR system - 2010

Plant	Siting	Coal	MWe net	Boiler geometry	Main suppliers: boiler; turbine	Ultra-super-, Super- or sub-crit	Steam conditions MPa/°C/°C(/°C)	Why selected
Europe – Denmark: Nordjyllandsværket 3	coastal	international	384	tower	FLS miljo/BWE, Aalborg Industries, Volund Energy Systems; GEC Alsthom (now Alstom)	USC	29/582/580/ 580	Most efficient coal plant; double-reheat; very low emissions
Europe – Germany: Niederaussem K	inland	lignite	965	tower	EVT (today Alstom), Babcock and Steinmüller (today HPE); Siemens	USC	27/580/600	Lignite; top efficiency lignite plant; lignite drier demonstration
North America – Canada: Genesee 3	inland	sub-bituminous	450	2-pass	Babcock-Hitachi	S/C	25/570/570	Sub-bituminous coal; first sliding pressure S/C North America
Asia – Japan: Isogo New Unit 1	coastal	international	568	tower	IHI; Fuji Electric (Siemens)	USC	25/600/610	Very high steam parameters; very low emissions; activated coke regenerable FGD
Asia – Korea: Younghung	coastal	international	2x774	tower	Doosan Heavy Industries & Construction Co.	S/C	25/566/566	Most recent and largest coal-fired units in Korea
Asia – China: Wangqu 1, 2	inland	Chinese lean	2x600	2-pass	Doosan Babcock; Hitachi	S/C	24/566/566	Location; wall-firing of low-volatile coal with low NOx
Asia – India: Suratgarh 1-5	inland	~30% ash	5x227	2-pass	BHEL	Drum sub-crit	15/540/540	Location; high ash coal; drum boiler
Africa – South Africa: Majuba 1-6	inland	~30% ash	3x612 (dry) 3x669 (wet)	tower	Steinmüller; Alstom	once-through sub-crit	17/540/540	Location; dry versus wet cooling; high ash coal, once-through sub-critical boiler

USC: ultra-supercritical (steam temperatures of 580°C and above)
S/C: supercritical

Supercritical Steam Generators



Growth of unit sizes in India

Rating	Year of Introduction
60/70 MW	1965
110/120 MW	1966
200/210 MW	1972
250 MW	1991
500 MW	1979
660 MW	2004

Next higher unit size identified is 800 MW

Increase in unit sizes to match increase in Cycle parameters

Unit Size	Steam Flow (t/h.)	SHO Pressure (Kg/cm^2)	SHO/RHO Temperature (Deg. C)
30MW	150	63	490
60/70MW	260	96	540
110/120MW	375	139	540/540
200/210MW	690	137/156	540/540
250MW	805	156	540/540
500MW	1670	179	540/540
660MW	2245	256	540/568
800MW	2600	256	568/595

Heat rate Improvement

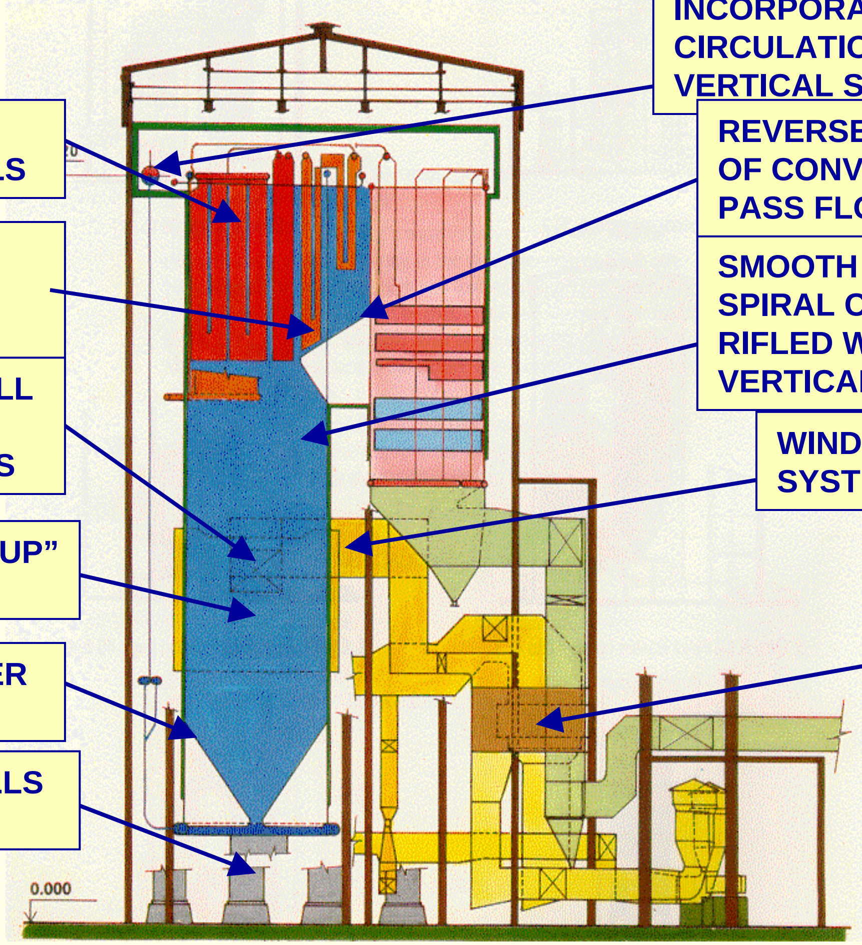
Parameters at Turbine Inlet (bar/^{o}C / ^{o}C)	% Improvement In Station Heat Rate
170 / 538 / 538	Base
170 / 538 / 565	0.5%
170 / 565 / 565	1.3%
246 / 538 / 538	1.6%
246 / 538 / 565	2.1%
246 / 565 / 565	3.0%
246 / 565 / 598	3.6%
306 / 598 / 598	5.0%

Reduction in coal consumption and CO_2 emissions

	Unit	500 MW	660 MW	800 MW
Cycle parameters	Bar / ^{0}C / ^{0}C	170 / 538 / 538	246 / 538 / 565	246 / 565 / 598
Heat rate improvement	%	Base	2.1	3.6
Savings in annual coal consumption	tons	Base	56000	96000
Reduction in annual CO_2 emissions	tons	Base	61600	105600

Boiler Equipment Upgrades

500 MW DRUM TYPE ⟶ 800 MW Once Thru Supercritical



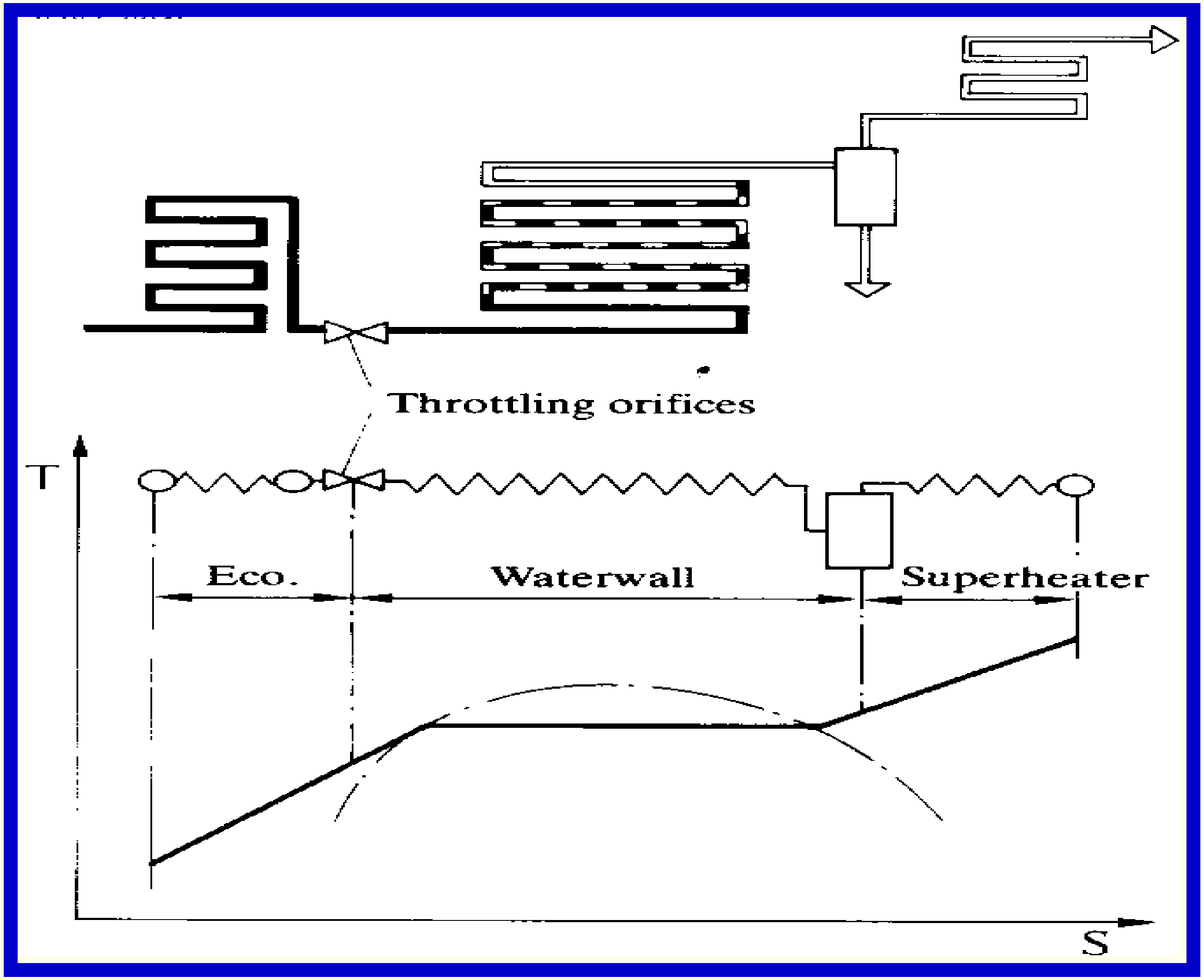
Features of Boiler

- Pulverised coal fired
- Once through, evaporator suitable for variable pressure operation
- Single reheat
- Tilting Tangential firing System
- Dry Bottom
- Balanced draft furnace
- Side mill layout

Types of boilers

- Drum Type
- Once-through type

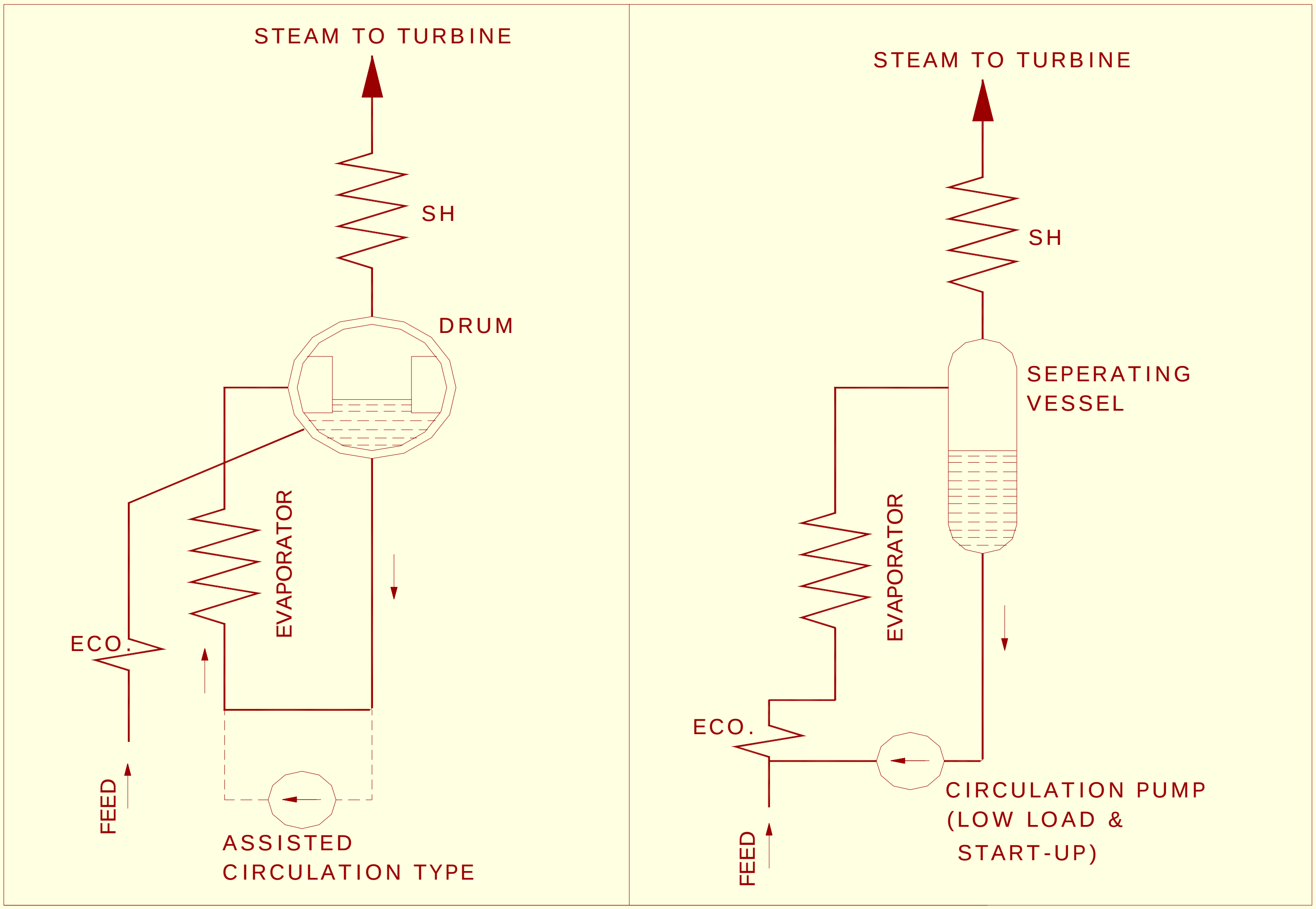
Concept of Once through Steam Generator



Drum type boiler

- Natural Circulation Boiler
  - Circulation thru water walls by thermo-siphon effect
- Controlled Circulation Boiler
  - At high operating pressures just below critical pressure levels, thermo-siphon effect supplemented by pumps

Circulation Systems



Drum Type **Once-through**

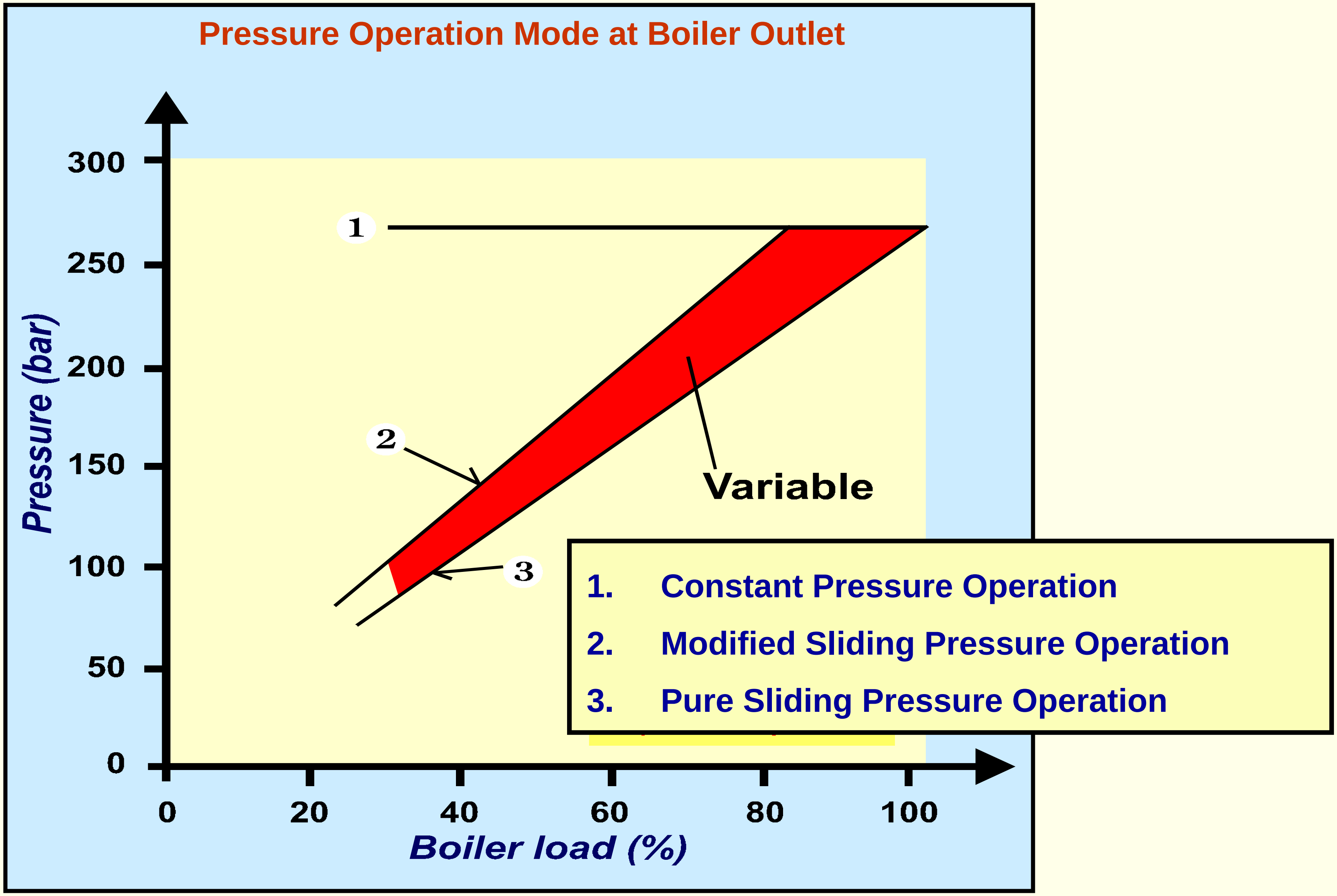
Major differences from drum type boilers

- Evaporator System Design
- Start-up and low load system
- New materials to meet High pressure and temperature

Features of Once Through Steam Generator

- To ensure adequate mass flow rates through water wall, spirally wound water wall tubes are used.
- Start-up and low load system up to 30-40%BMCR required.
- Feed water quality requirements are very stringent.
- Can be designed for both sub-critical and super-critical pressures.
- Ideally suited for sliding pressure operation due to the absence of thick walled components.

Sliding Pressure Supercritical Operation



Boiler Pressure Part Materials
Tubing Oxidation Temperature Limits

MATERIAL	ASME ALLOY	OXIDATION LIMIT
Carbon Steel	SA-178C/ D	454°C (850°F)
	SA-210 A-1/ C	
Carbon-1/2 Mo	SA-209 T-1A	482°C (900°F)
1 Cr-1/2 Mo	SA-213 T-12	552°C (1025°F)
2-1/4 Cr-1 Mo	SA-213 T-22	593°C (1100°F)
2-1/4 Cr-1.6W-V-Cb	SA-213 T-23	593°C (1100°F)
9 Cr-1 Mo-V	SA-213 T91	649°C (1200°F)
9 Cr-2W	SA-213 T92	649°C (1200°F)
18 Cr-8 Ni	SA-213 TP304H	760°C (1400°F)
18 Cr-10 Ni-Cb	SA-213 TP347H	760°C (1400°F)
18 Cr-9 Ni-3Cu-Cb-N	SA-213 Super304H	760°C (1400°F)
25 Cr-20 Ni-Cb-N	SA-213 HR3C	760°C (1400°F)

Materials used in various pressure parts of conventional boilers

Area of application	Material	ASME specification	
		Tubes	Pipes
Drum	Carbon steel / Low alloy steel	-	SA 299
Water walls, Economizer	Carbon Steel	SA192 SA210 Gr.A1 SA210 Gr.C	SA106 Gr.B SA106 Gr.C
SH and RH	1 ¼ Cr ½ Mo	SA213 T11	SA335 P11
	2¼ Cr 1 Mo	SA213 T22	SA335 P22
	9 Cr 1 Mo ¼V	SA213 T91	SA335 P91
	18 Cr 8 Ni	SA213 TP304 H	-
	18 Cr 10 Ni Cb	SA213 TP347 H	-

New materials for high temperature

A. Evaporators

- T12
- T23 and T24 : For 600ºC (SHO) / 620ºC (RHO)

B. Superheaters and Reheaters

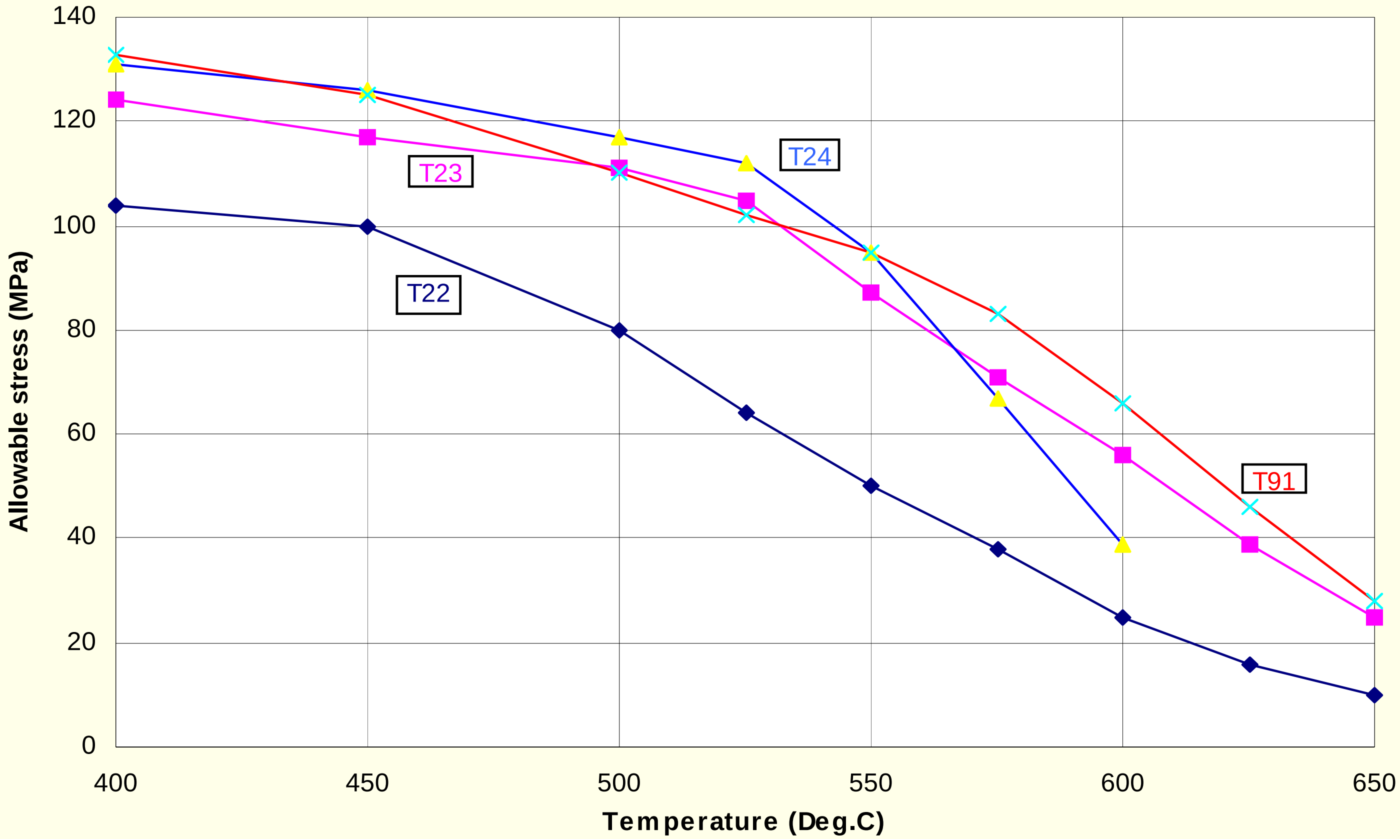
- T91 : for 550oC (SHO) / 570ºC (RHO).
- P91 : Upto 270 bar and 580ºC (SHO)
- P92 : Upto 290 bar and 600ºC (SHO)
- Austenitic steels Super 304H / TP347HFG : For temperature 600ºC (SHO) / 620ºC (RHO)

Effects of alloying elements in ferritic and martenistic steels

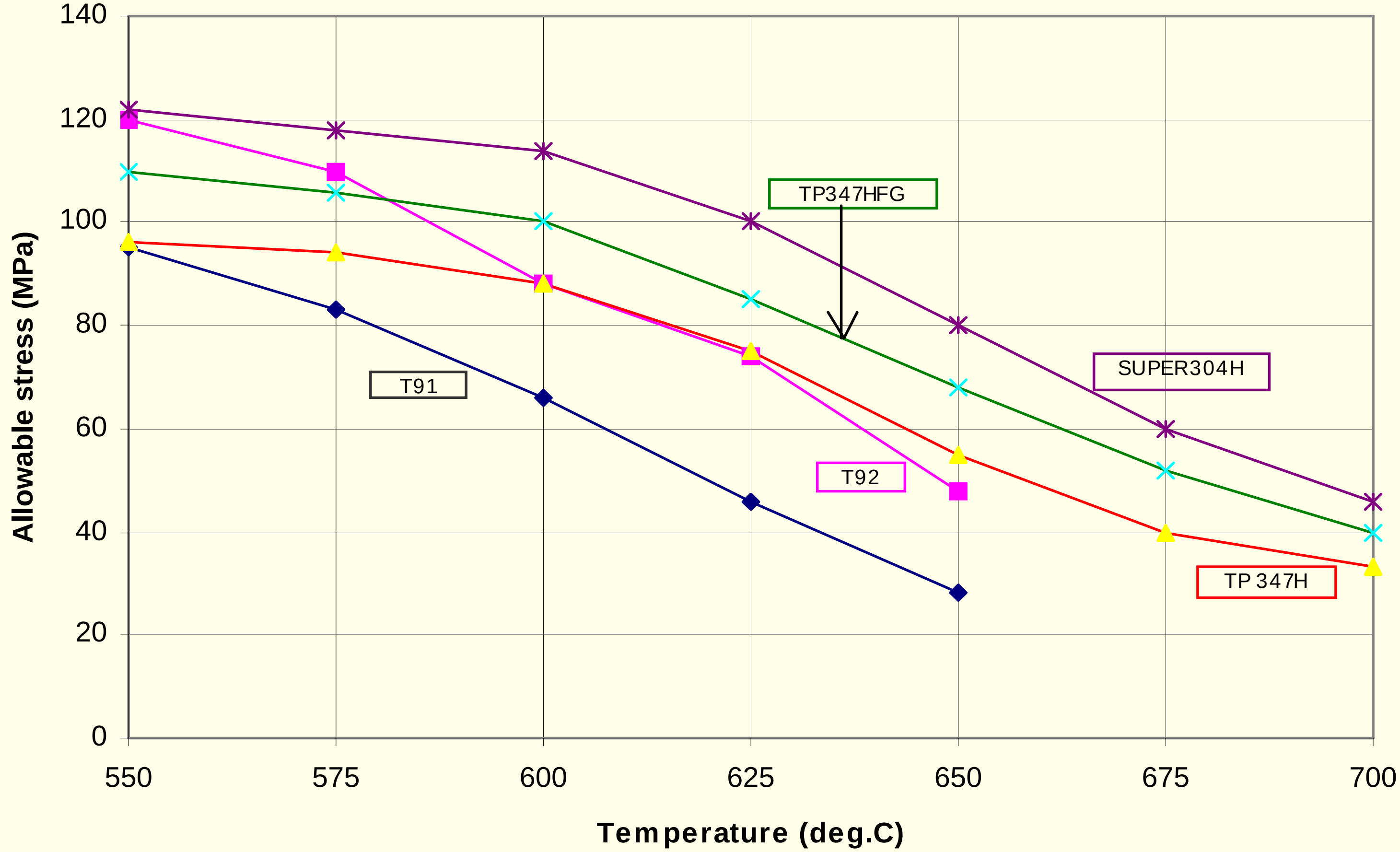
T23/T24

- Developed based on T22
- Alloyed with tungsten together with reduction of Mo
- Micro-alloyed with Vanadium, Columbium Nitrogen and Boron
- Increase in creep properties come close to T/P91
- Initially developed for WW panel in supercritical boilers
- Can be used in SH/RH in conventional boilers.

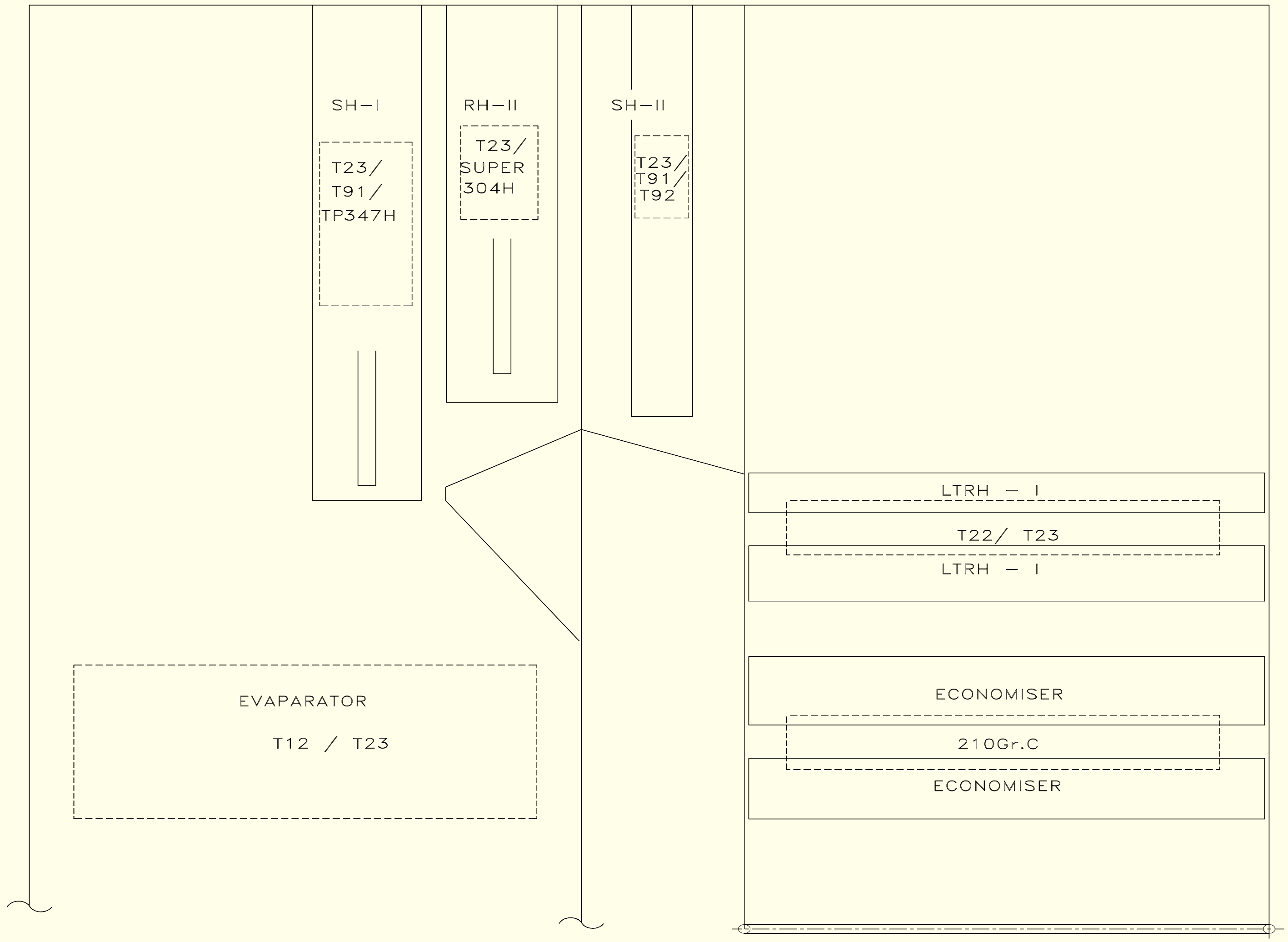
Comparison of allowable stress T22/T23/T24/T91



Comparison of allowable stress (T91/T92/TP347H/TP 347HFG/Super 304H)



Materials in typical 800MW



R&D efforts on New generation steels

- Research Program on “Manufacturing studies of new generation materials” launched
- Materials identified include
  - 9Cr1Mo steel bearing tungsten for pipes and tubes
  - Super austenitic SS for tubes
  - WB36 for feedwater system


THANKYOU
2 3 2007

IGCC POWER GENERATION - DEVELOPMENT IN BHEL

- 6.2 MW IGCC Pilot Plant at its Trichy Complex.
- Technical feasibility of upgrading the 6.2 MW Combined Cycle Demonstration Project of BHEL to ~100 MW had been established
- Preliminary assessment made for 400 MW IGCC Plant
- Plan to set up 125 MW IGCC Demonstration plant

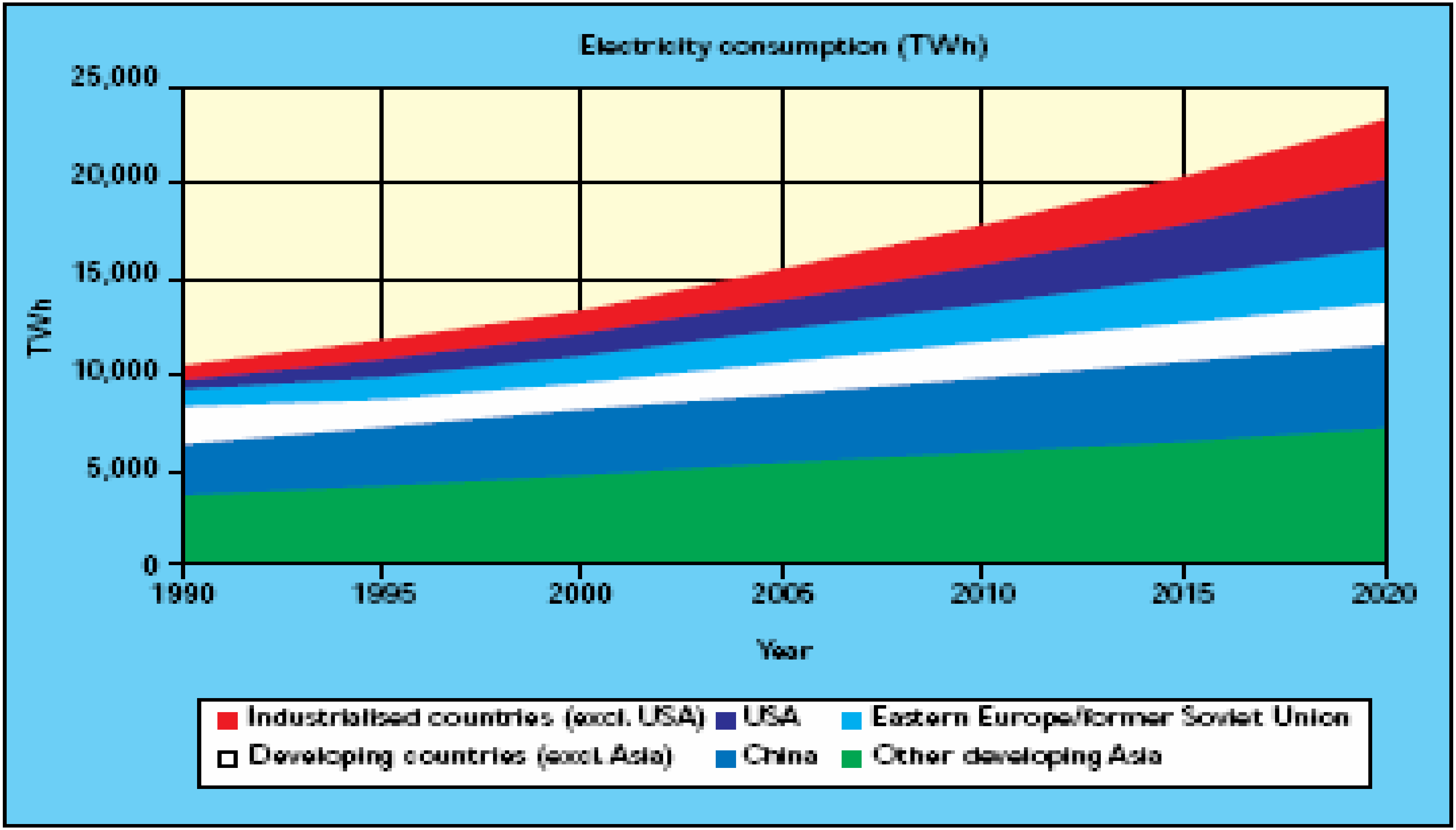
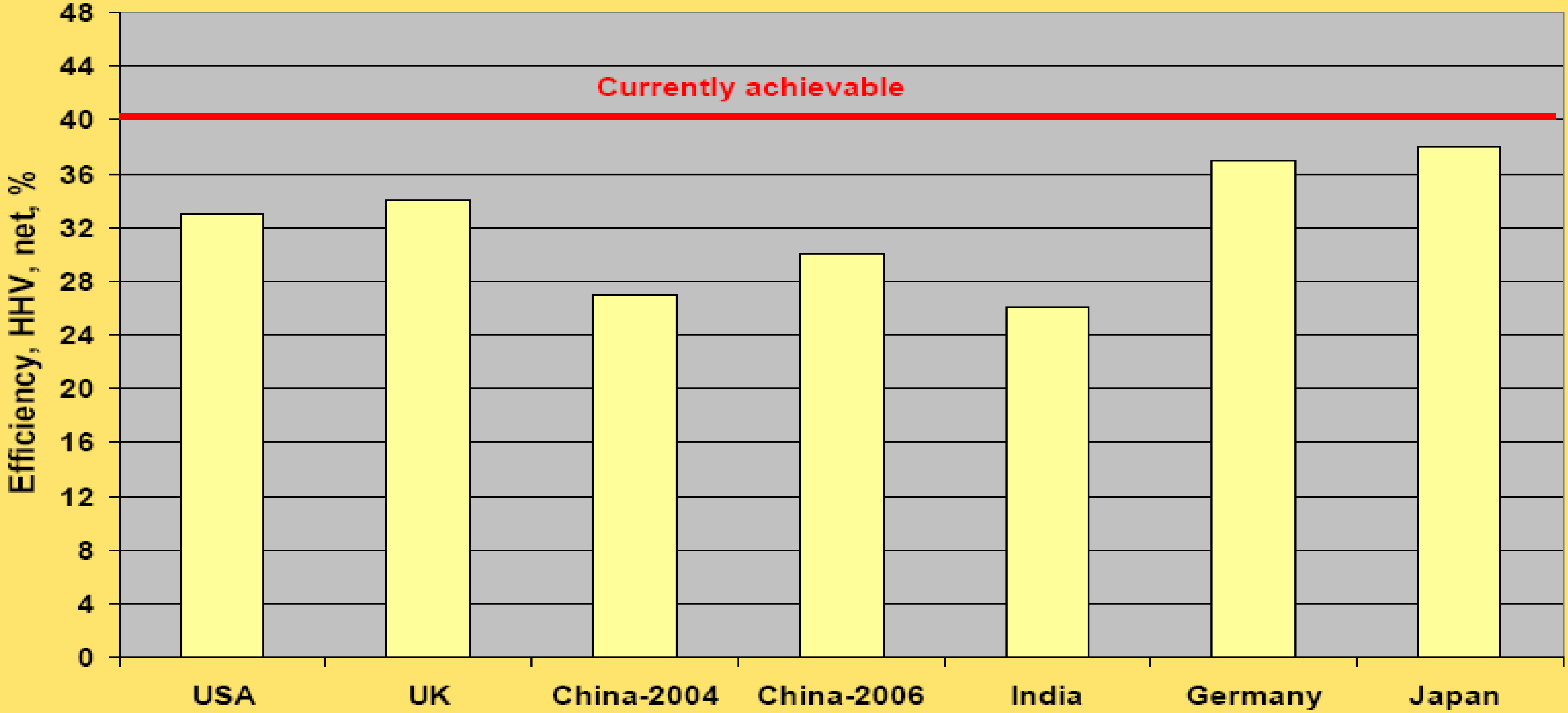


Figure 13. Electricity consumption projection to 2020 by region (EIA 1998)

Prospects to upgrade and replace coal-fired power plants



The average efficiency of the coal-fired fleet in major coal using countries range between 26-38%. Over 1.5 GT CO_2 could be saved each year by raising this to 40%, a significant reduction in coal consumption would also be achieved.

Table S2 • Costs, emissions and efficiencies of the case study plants and comments

Plant	Capital cost, USD/kWso	Achieved emissions at 6% O_2, dry	MWe net	Steam conditions MPa/°C/°C (/°C)	Design efficiency, net %, LHV and HHV bases	Annual operating efficiency, net %, LHV and HHV bases	Factors affecting efficiency and other comments
Europe – Denmark: Nordjyllandsværket 3	1500 (2006) for new 800 MWe excluding owners costs or IDC	NOx 146 mg/m³ SO_2 13 mg/m³ Dust 18 mg/m³	384	29/582/580/580	47 LHV (no heat load) 44.9 HHV (no heat load)	47 LHV (not annual) 44.9 HHV (not annual)	High steam parameters Cold sea water cooling Double reheat Low auxiliary power Extremely low emissions No solid waste for disposal
Europe – Germany: Niederaussem K	1175 (2002) Total project cost	NOx 130 mg/m³ SO_2 <200 mg/m³ Dust <50 mg/m³	965	27/580/600	43.2 LHV 37 HHV	43.2 LHV (base load) 37 HHV (base load)	Lignite fuel, 50-60% moisture content High steam parameters Large cooling tower for low condenser pressure Innovative heat recovery systems Low auxiliary power
North America – Canada: Genesee 3	1100 (2005) Overnight cost	NOx 170 mg/m³ SO_2 295 mg/m³ Dust 19 mg/m³	450	25/570/570	41.4 LHV 40 HHV	41 LHV (base load) 39.6 HHV (base load)	Moderately high steam parameters Low auxiliary power First N American sliding pressure supercrit. Sub-bituminous coal
Asia – Japan: Isogo New Unit 1	1800 (2006) Total project cost incl New Unit 2 under construction	NOx 20 mg/m³ SO_2 6 mg/m³ Dust 1 mg/m³	568	25/600/610	42 LHV 40.6 HHV	42 LHV (base load) 40.6 HHV (base load)	High steam parameters Moderately warm sea water cooling Low auxiliary power Low power demand FGD Extremely low emissions No solid waste for disposal

Table S2 • *Costs, emissions and efficiencies of the case study plants and comments (continued)*

Plant	Capital cost, USD/kWso	Achieved emissions at 6% O_2, dry	MWe net	Steam conditions MPa/°C/°C (/°C)	Design efficiency, net %, LHV and HHV bases	Annual operating efficiency, net %, LHV and HHV bases	Factors affecting efficiency and other comments
Asia – Korea: Younghung	993 (2003) Basis uncertain	NOx 83 mg/m³ SO_2 80 mg/m³ Dust 10 mg/m³	2x774	25/566/566	43.3 LHV 41.9 HHV	41 LHV (capacity factor not known) 39.7 HHV (capacity factor not known)	Moderately high steam parameters Very low emissions Low auxiliary power
Asia – China: Wangqu 1, 2	580 (2006) Overnight cost	NOx 650 mg/m³ SO_2 70 mg/m³(des) Dust 50 mg/m³	2x600	24/566/566	41.4 LHV 40 HHV	New plant - no operating history	Moderately high steam parameters Low auxiliary power Advanced low-NOx lean coal combustion system
Asia – India: Suratgarh 1-5	822 (2002) Basis uncertain	SO_2 unabated Dust 50 mg/m³ (unit 5)	5x227	15/540/540	37.1 LHV 35.1 HHV	33.9 LHV (base load) 32.1 HHV (base load)	Subcritical cycle High ash coal
Africa – South Africa: Majuba 1-6	410 (2001) Total project cost	SO_2 unabated Dust 50 mg/m³	3x612 (dry); 3x669 (wet)	17/540/540	35-37 LHV 33.8-35.7 HHV	34 LHV (two-shifting) 32.8 HHV (two-shifting)	Subcritical cycle High ash coal Dry cooling from water supply constraints
Europe – United Kingdom: Natural gas plant: Enfield	950 (1999) Total project cost	NOx 128 mg/m³ SO_2 negligible Dust zero	373	Advanced GTCC	58 LHV 52 HHV	52 LHV (40% capacity factor) 47 HHV (40% capacity factor)	Combined cycle with reheat gas turbine Low auxiliary power Zero solid waste
IGCC general review	PCC+20%	NOx 50-75 mg/m³ SO_2 ~20 mg/m³ Dust <1 mg/m³	300/ module	IGCC	40-43 LHV 38-41 HHV		Combined cycle Syngas-fired gas turbine Inert solid waste

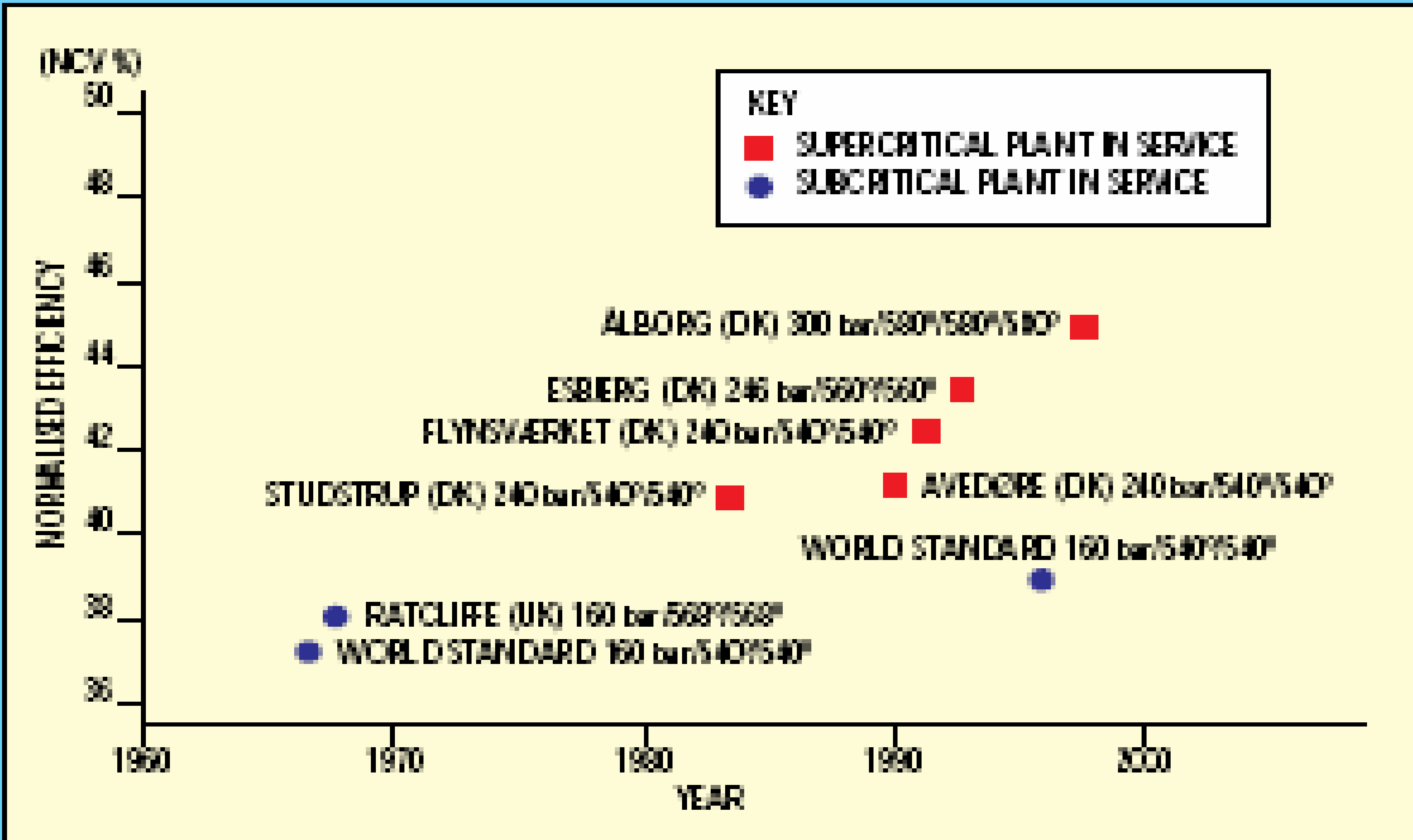


Figure 2. Efficiency (normalised) of Danish pf-fired plant

Emission (mg Nm^{-3} @ 6% oxygen, dry volume basis)	Current EU limit	Best achievable*	Technology
Particulates	50	25 15 <10	ESPs bag filters with FGD downstream
SO_x	400	100	Limestone gypsum FGD
NO_x	650	100	Low-NO_x burners and SCR

*Exact figure depends on coal quality

ESPs: electrostatic precipitators

SCR: selective catalytic reduction

Table 1. Gaseous emissions using best available established technology on coal-fired plant

BHEL

Super critical once through Boilers-Technology status

Technology holder	Type of Unit	No of units > 500 MW	Max capacity, MW	Highest Parameters Bar/deg C/deg C
Babcock Hitachi KK, Japan	Spiral wall Wall fired Two pass	10	1050	272 / 542 / 567 264 / 605 /613
Babcock Hitachi, Europe	Spiral wall Wall fired Two pass/Tower	3	550	267 / 580 / 600
IHI, Japan	Spiral wall Wall fired Two pass/Tower	12	1050	280 / 605 / 613
MHI, Japan	Spiral/ Vertical wall, TT firing Two pass	21	1050	245 / 600 / 610 258 / 538 / 566
Alstom	Spiral wall TT firing Two pass, Tower	2 2	600 900	257 / 537 / 566 278 / 541 / 569
MBEL,UK	Spiral wall Wall fired Two pass	2	650	259 / 571 / 569 256 / 599 / 568

Thank U All