ULTRA SUPERCRITICAL BOILERS

K.C.RAO
Date 05th Mar, 2013

INTRODUCTION TO L&T- MHI BOILERS

L&T-MHI Boilers (LMB)

L&T 51% + **MHI** 49% = **LMB**

Larsen & Toubro Ltd., India

Mitsubishi Heavy Industries, Japan

L&T-MHI Boilers Pvt. Ltd., India

- L&T-MHI Boilers Pvt. Ltd. Incorporated → Apr 18, 2007
- Complete Technology Transfer of Supercritical Boilers to Joint Venture
- More than 2000 Employees

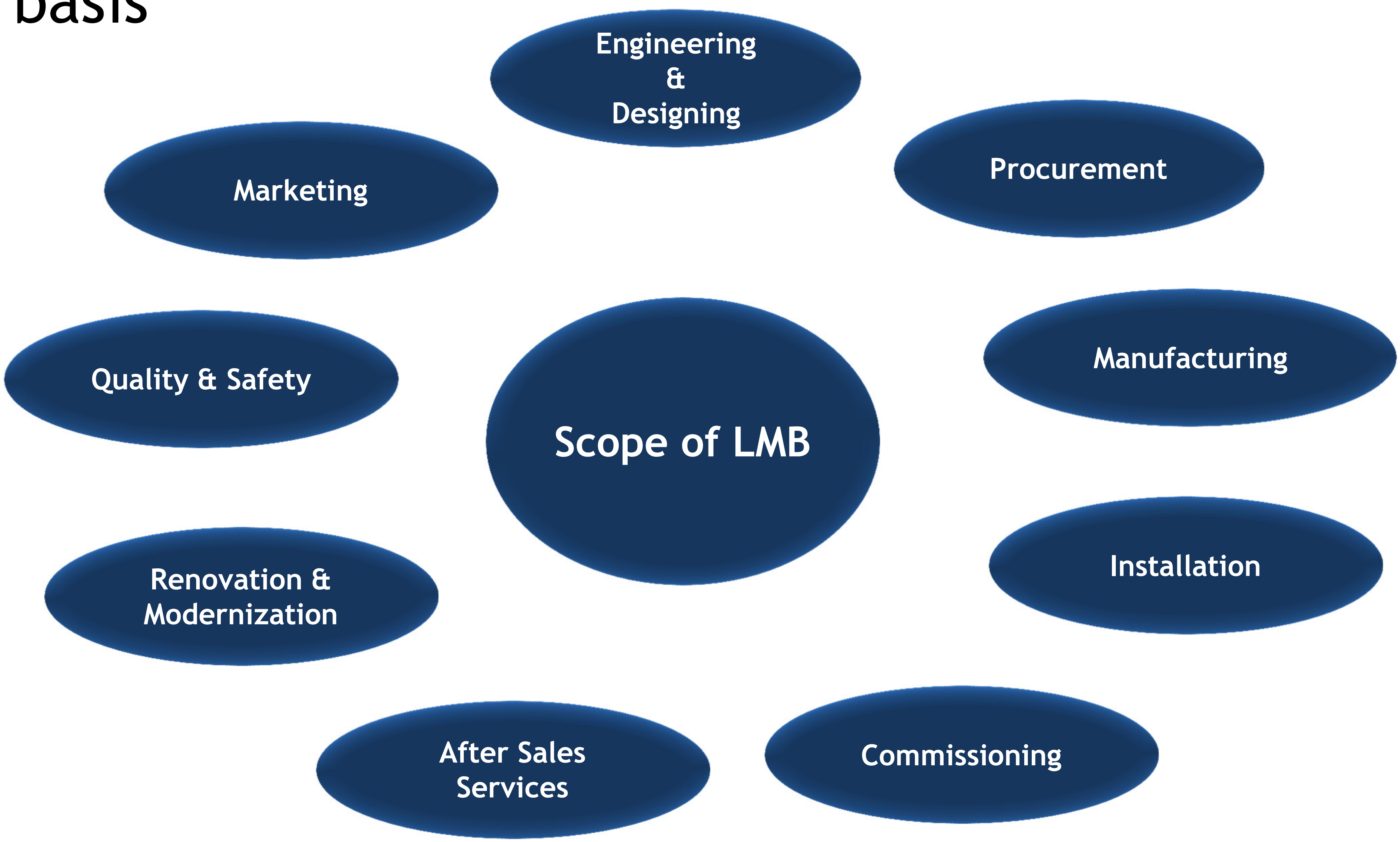
Joint Venture Highlights

Product Range	Supercritical Boilers of 500 MW & above (including Pulverizers)
License	Exclusive in India Non exclusive outside India
Term	20 years
Technology	Complete Transfer of Technology To JV

Joint Venture Highlights

Manufacturing Capacity	4000 MW Equivalent
Investment	INR 750 Crores
Training	Extensive Training in Japan

Scope of Business – EPC basis



PROJECT & OFFICE LOCATIONS

Project Sites and Office locations

ENGINEERING & MARKETING OFFICE FARIDABAD

HEAD OFFICE

VADODARA

FACTORY HAZIRA, SURAT

PULVERIZER GROUP POWAI

2 x 700 MW
NPL - RAJPURA

2 x 660 MW
JAYPEE NIGRIE

3 x 660 MW
MAHAGENCO KORADI

ENGINEERING CENTRE, CHENNAI

BOILER OUTSOURCING TRICHY

OFFICES

PROJECTS

Projects Under Execution

Jaypee Nigrie

2x660 MW

MahaGenco Koradi

3x660 MW

Nabha Power Ltd, Rajpura

2x700 MW

Boiler Overview Unit-1 – JAYPEE NIGRIE

Boiler Overview Unit-2- JAYPEE NIGRIE

CONTENTS

1. What is USC Boiler
2. Trends of USC units
3. Supply records of USC
4. Feature of USC Boiler
5. Impact on present SC design

What is USC Boiler?

Subcritical :

Pressure : 16.7 M pa

Temperature: 538/538 Deg-C or 538/560 Deg-C

Supercritical(SC) :

Pressure : 24.1 M pa

Temperature: 538/560 Deg-C to 566/593 Deg-C

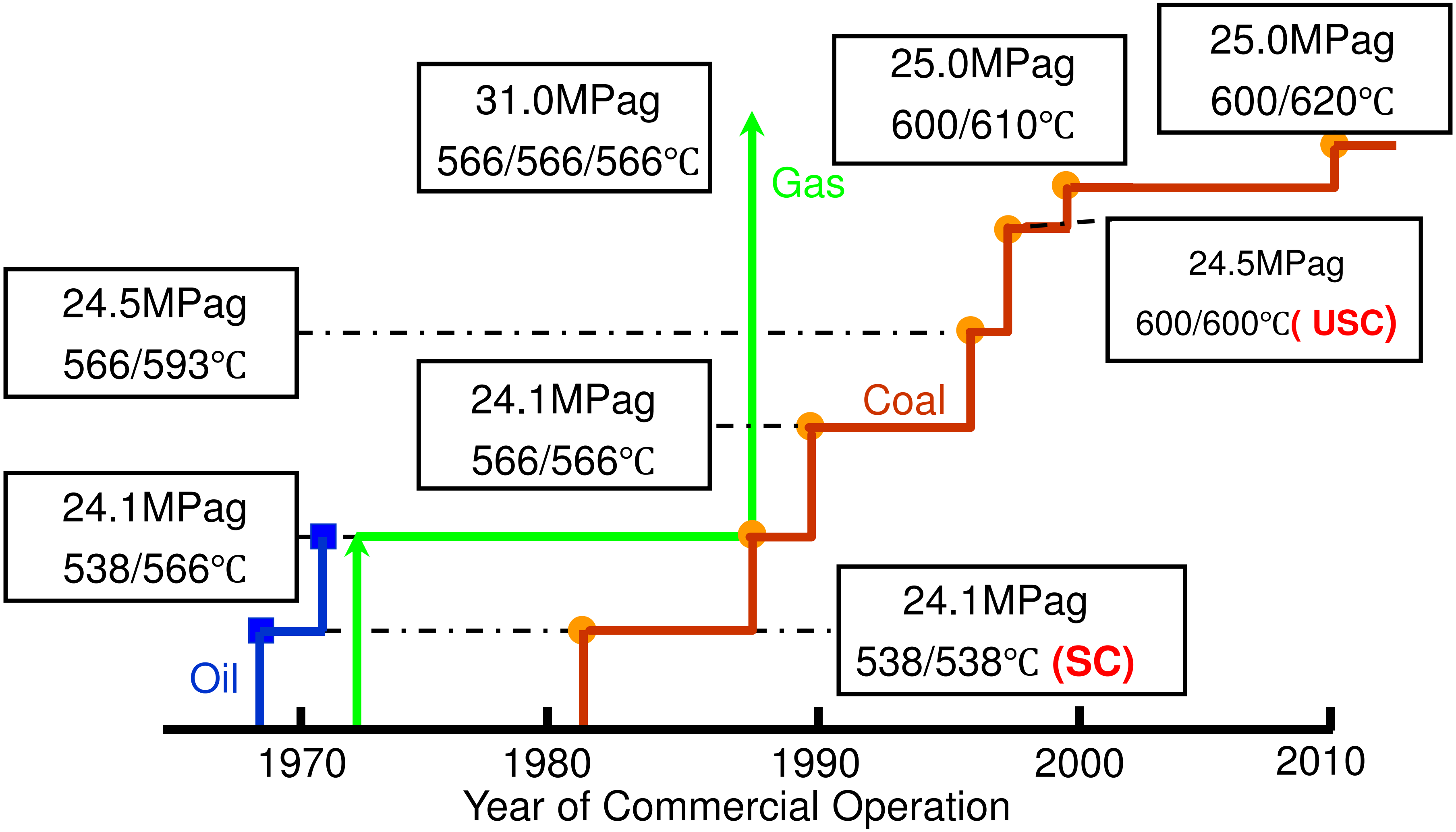
Ultra Supercritical(USC):

Pressure : 24.1 to 31.0 M pa

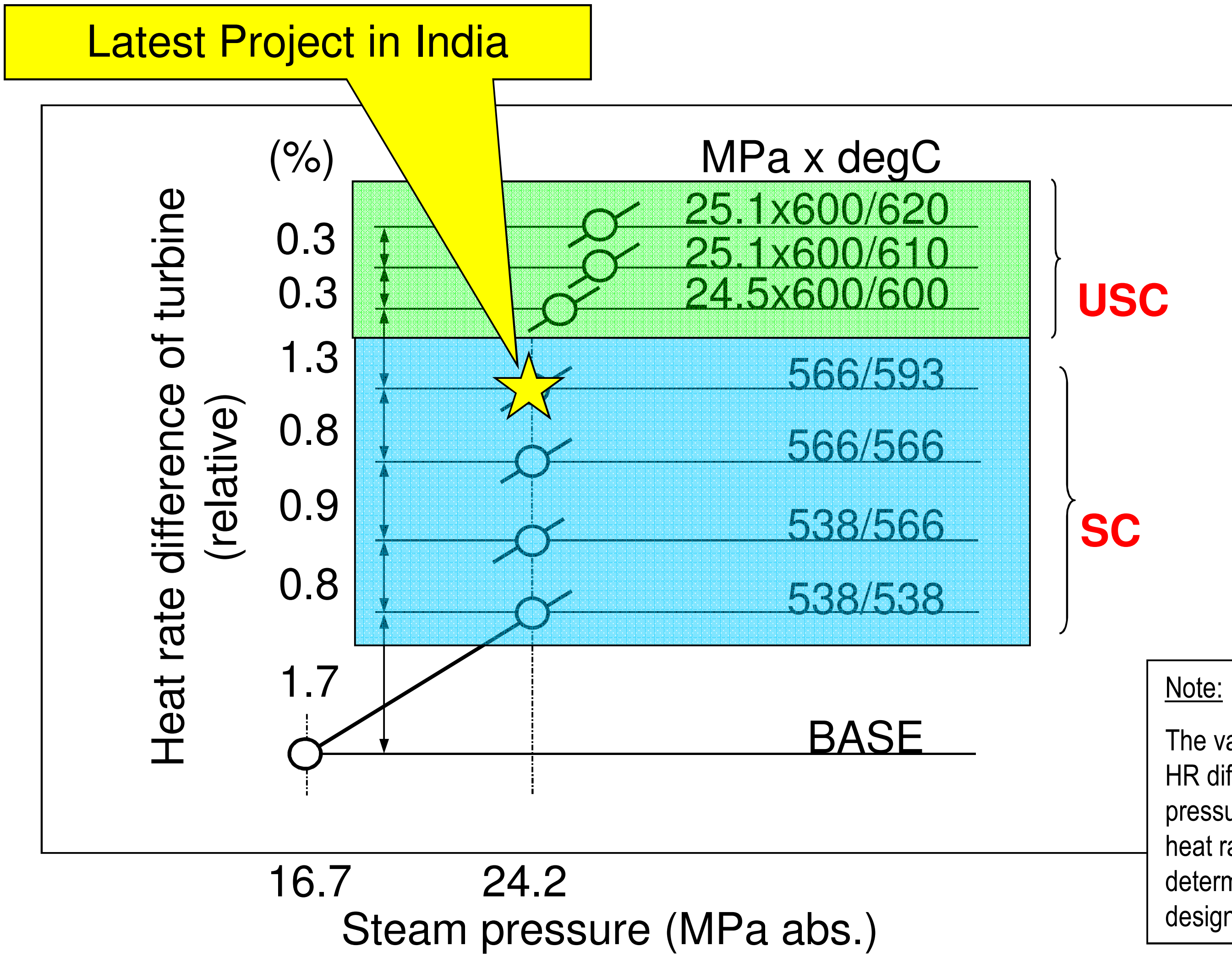
Temperature: 593/593 Deg-C to 600/620 deg.c

1. What is USC Boiler
2. Trends of USC units
3. Supply records of USC
4. Feature of USC Boiler
5. Impact on present SC design

Evolution of Steam Pressure & Temperature of Thermal Power Plant in Japan



Thermal Efficiency improved by Steam Conditions



Note:

The values in diagram are typical HR differences respect to steam pressure and temperature. Actual heat rate may differ and shall be determined based on a given design condition.

Technoeconomic comparison – **Subcritical Vs Supercritical Vs Ultra Supercritical Boilers**

Capacity : 700 MW
Fuel : Indian coal with 42 % ash
Fuel GCV : 3300 kCal/kg

Description	Unit	Subcritical 16.7 M pa 538/538 deg.c	Supercritical 24.1 M pa 566/593 deg.c	Ultra Supercritical 24.1 M pa 600/600 deg.c	Reduction Sub Vs SC	Reduction Sub Vs USC
Turbine Heat rate	kCal / kWh	1918	1838	1814	80(4.2%)	104(5.5%)
Boiler efficiency	%	87 %	87%	87%	0	0
Plant heat rate	kCal / kWh	2207	2113	2085	94(4.2%)	121(5.5%)
Coal consumption	MM T/Annum	3.676	3.524	3.477	0.152(4.2%)	0.199 (5.5%)
Ash Generation	MM T/Annum	1.544	1.48	1.46	0.064(4.2%)	0.084 (5.5%)
CO_2	MM T/Annum	7.278	6.981	6.888	0.297(4.2%)	0.39 (5.5%)
SOx	MM T/Annum	0.0230	0.0221	0.0218	0.0009(4.2%)	0.0012 (5.5%)

* Calculation with 90% PLF

Technoeconomic comparison – Subcritical Vs Supercritical

Fuel : Indian coal with 42 % ash and GCV of 3300kCal/kg

DSCRIPTION	700 MW SUBCRITICAL VS SUPERCRITICAL IN CRORES	700 MW SUBCRITICAL VS SUPERCRITICAL IN CRORES	700 MW SUBCRITICAL VS SUPERCRITICAL IN CRORES
COAL COST	1500 RS/TON	2000 RS/TON	2500 RS/TON
Reduction in Coal cost per annum	22.8	30.4	38
Carbon credit benefit per annum @10Euro/MT (1Euro= Rs.60)	17.8	17.8	17.8
Total cost Benefit per annum	40.6	48.2	55.8
NPV considering plant life of 30 years with 5 % escalation in coal cost (Sub Vs SC) COAL COST	301	402	502
NPV considering plant life of 30 years with 5 % escalation in coal cost (Sub Vs SC) COAL COST & CDM BENEFIT	537	637	737

-

Technoeconomic comparison – Subcritical Vs Ultra Supercritical

Fuel : Indian coal with 42 % ash and GCV of 3300kCal/kg

DSCRIPTION	700 MW SUBCRITICAL VS ULTRA SUPERCRITICAL IN CRORES	700 MW SUBCRITICAL VS ULTRA SUPERCRITICAL IN CRORES	700 MW SUBCRITICAL VS ULTRA SUPERCRITICAL IN CRORES
COAL COST	1500 RS/TON	2000 RS/TON	2500 RS/TON
Reduction in Coal cost per annum	29.8	39.8	49.8
Carbon credit benefit per annum @10Euro/MT (1Euro= Rs.60)	23.4	23.4	23.4
Total cost Benefit per annum	53.2	63.2	73.2
NPV considering plant life of 30 years with 5 % escalation in coal cost (Sub Vs USC) COAL COST	394	526	658
NPV considering plant life of 30 years with 5 % escalation in coal cost (Sub Vs USC) COAL COST & CDM BENEFIT	703	835	967

Technoeconomic comparison – Supercritical Vs Ultra Supercritical

Fuel : Indian coal with 42 % ash and GCV of 3300kCal/kg

DSCRIPTION	700 MW SUPERCRITICAL VS ULTRA SUPERCRITICAL IN CRORES	700 MW SUUPERCRITICAL VS ULTRA SUPERCRITICAL IN CRORES	700 MW SUUPERCRITICAL VS ULTRA SUPERCRITICAL IN CRORES
COAL COST	1500 RS/TON	2000 RS/TON	2500 RS/TON
Reduction in Coal cost per annum	7.05	9.4	11.75
Carbon credit benefit per annum @10Euro/MT (1Euro= Rs.60)	5.5	5.5	5.5
Total cost Benefit per annum	12.55	14.9	17.25
NPV considering plant life of 30 years with 5 % escalation in coal cost (Sub Vs USC) COAL COST	93	124	155
NPV considering plant life of 30 years with 5 % escalation in coal cost (Sub Vs USC) COAL COST & CDM BENEFIT	166	197	228

1. What is USC Boiler
2. Trends of USC units
3. Supply records of USC
4. Feature of USC Boiler
5. Impact on present SC design

MHI Reference List of USC Boilers

➢ MHI/LMB has adequate experience for over 600/600 boiler.

Customer Station	MW	Steam Condition (⁰C)	Fuel	C/O
Soma Joint EPCO Shinchi #2	1,000	538/566	Coal	1995
Tohoku EPCO Haramachi #1	1,000	566/593	Coal	1997
Chugoku EPCO Misumi #1	1,000	600/600	Coal	1998
Hokuriku EPCO Tsuruga #2	700	593/593	Coal	2000
Kyusyu EPCO Reihoku #2	700	593/593	Coal	2003
Kansai EPCO Maizuru #1	900	595/595	Coal	2004
Tokyo EPCO Hirono #5	600	600/600	Coal	2004
China Yuhuan (4 units) Licenser	1,000	600/600	Coal	2006
China Taizhou (2 units) Licenser	1,000	600/600	Coal	2007
PJ in China (15 units) Licenser	600, 660	600/600	Coal	2007~
China Jinling (1 units) Licenser	1,000	600/600	Coal	2009
China Chaozhou (2 units) Licenser	1,000	600/600	Coal	2010
P.T. Paiton Energy Paiton III	866	538/566	Coal	(2012)
Projects in India (11 units)	660, 700	565/593	Coal	(2013～)

MHI Reference List of USC Turbines

- MHI/LMTG has plenty of experience for over 600/600 steam turbines.

Customer Station	MW	Steam Condition (^0C)	Fuel	C/O
Chubu EPCO Hekinan #3	700	538/593	Coal	1993
Hokuriku EPCO Nanao-Ota #1	500	566/593	Coal	1995
EPDC Matsuura #2	1,000	593/593	Coal	1997
Chugoku EPCO Misumi #1	1,000	600/600	Coal	1998
EPDC Tachibanawan #2	1,050	600/610	Coal	2000
Kansai EPCO Maizuru #1	900	595/595	Coal	2004
Tokyo EPCO Hirono #5	600	600/600	Coal	2004
China Yingkou (2 units) Licenser	600	600/600	Coal	2007
China Kanshan (2 units) Licenser	600	600/600	Coal	2008
China Heyuan (2 units) Licenser	600	600/600	Coal	2009
ENEL Torrevaldaliga Nord (3 units)	678	600/610	Coal	2009
XCEL Comanche #3	830	566/593	Coal	2010
Tokyo EPCO Hirono #6	600	600/600	Coal	(2013)
Korea EWP Danjin (2 units)	1000	600/600	Coal	(2015/6)

Chubu EPCO Misumi #1

Turn Key 1000MW Coal-Fired Supercritical Plant including Major BOPs
Customer: Chugoku Electric Power Company

MAJOR SPECIFICATIONS

- **CUSTOMER :Chugoku EPCO.**
- **COMMERCIAL OPERATION : 1998.06.30**
- **CAPACITY : 1000MW**
- **STEAM CONDITION: 24.5MPa x 600/600degC**
- **STEAM TURBINE : Cross Compound**
- **BOILER MCR : 2,900t/h**
- **FUEL : Coal**
- **BOP : FGD, SCR, EP**

-SCOPE OF MHI
BOILER, TURBINE-GENERATOR, DCS, EP, FGD, SCR, COAL HANDLING SYS., ERECTION, COMMISSIONING

Kansai EPCO Maizuru #1

Kansai EPCO Maizuru #1

Turn Key 900MW Coal-Fired Supercritical Plant
Customer: Kansai Electric Power Company

MAJOR SPECIFICATIONS

- **CUSTOMER : Kansai EPCO.**
- **COMMERCIAL OPERATION : 2004.08.12**
- **CAPACITY : 900MW**
- **STEAM CONDITION : 24.5MPa x 595/595degC**
- **BOILER MCR : 2,570 t/h**
- **FUEL : Coal**
- **STEAM TURBINE : Cross Compound, 4 Exhaust Flows**

-SCOPE OF MHI
BOILER, TURBINE-GENERATOR, DCS, SCR, ERECTION, COMMISSIONING

Tokyo EPCO Hirono #5

Turn Key 600MW Coal-Fired Supercritical Plant
Customer: Tokyo Electric Power Company

MAJOR SPECIFICATIONS

- **CUSTOMER : Tokyo EPCO.**
- **COMMERCIAL OPERATION : 2004.07.12**
- **CAPACITY : 600MW**
- **STEAM CONDITION : 24.5MPa x 600/600degC**
- **BOILER MCR : 1,770 t/h**
- **FUEL : Coal**
- **STEAM TURBINE : Tandem Compound, 2 Exhaust Flows**

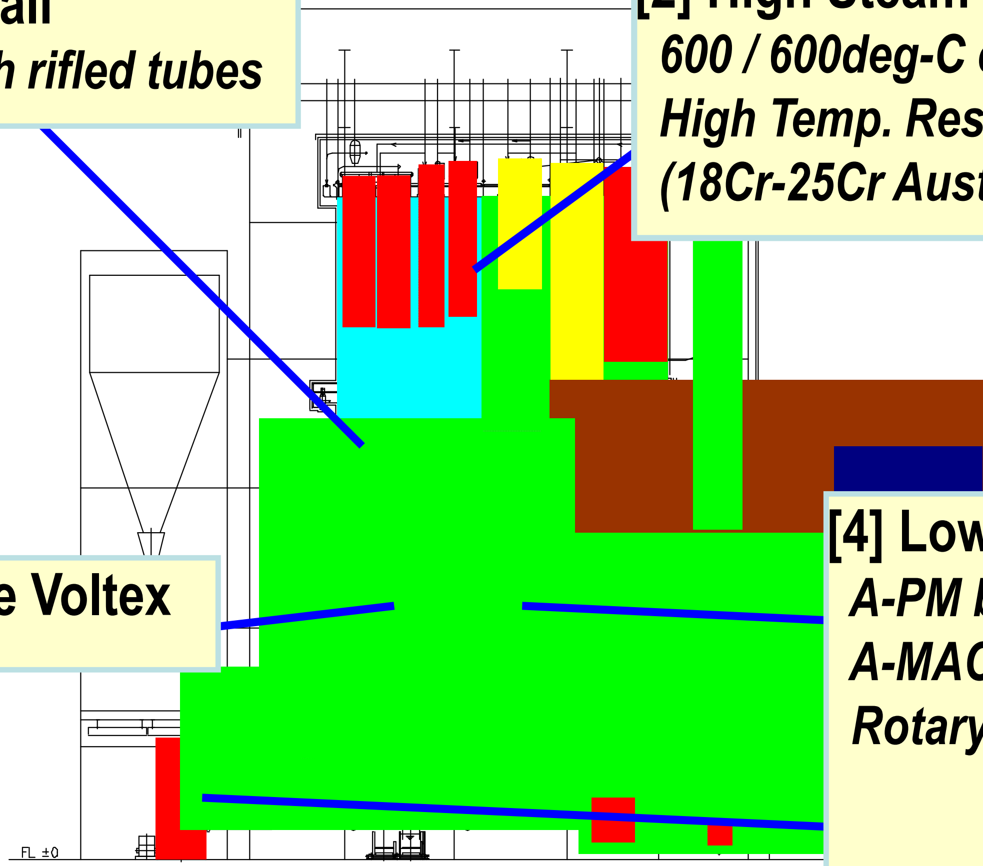
-SCOPE OF MHI
BOILER, TURBINE-GENERATOR, DCS, EP, FGD, SCR, ERECTION, COMMISSIONING

1. What is USC Boiler
2. Trends of USC units
3. Supply records of USC
4. Feature of USC Boiler
5. Impact on present SC design

Features of MHI USC Coal-Fired Boiler

[1] Water Wall
Vertical with rifled tubes

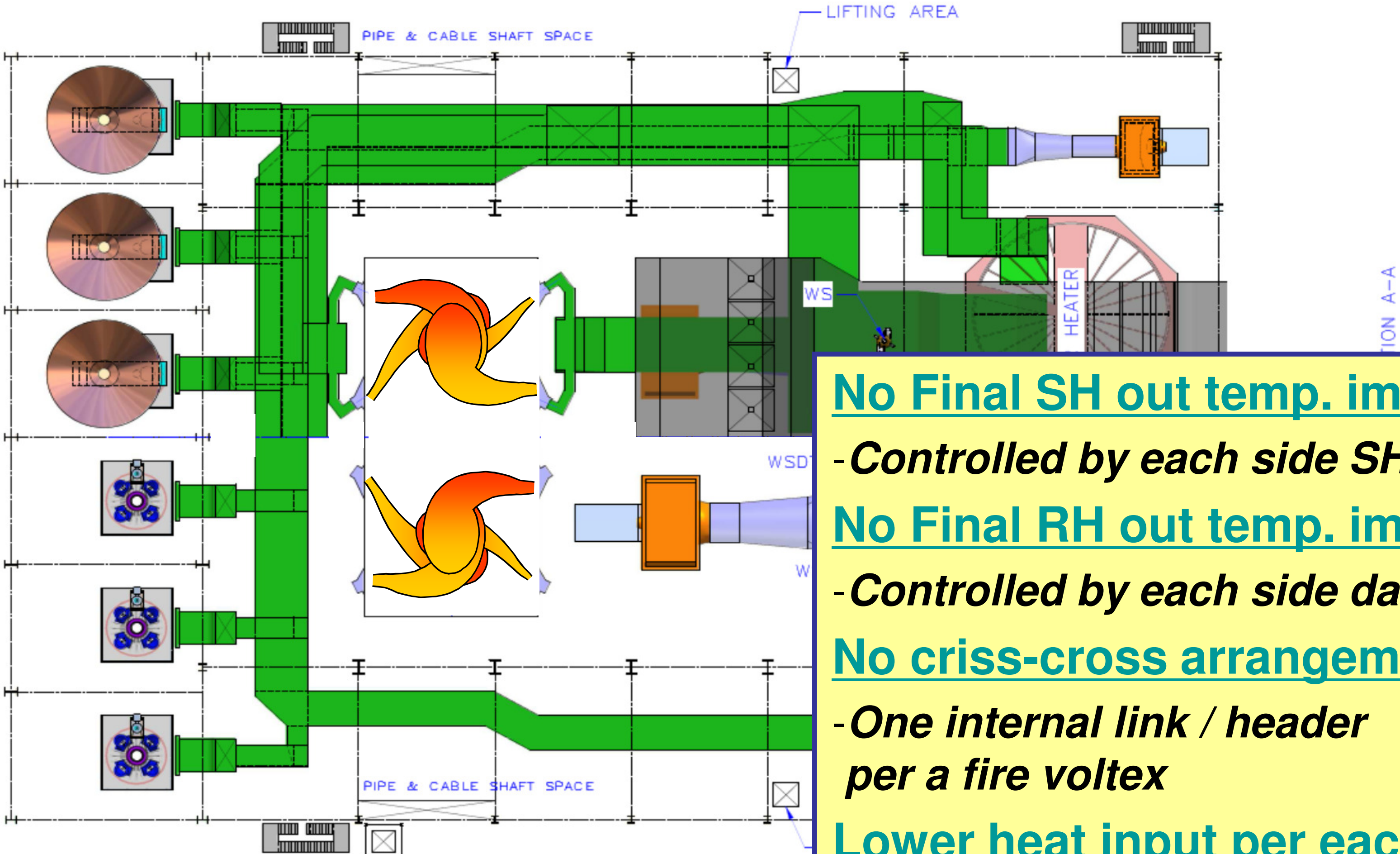
[2] High Steam Temperature
600 / 600deg-C class
High Temp. Resistant Material
(18Cr-25Cr Austenitic Steel)



[3] Twin Fire Voltex

[4] Low NOx system
A-PM burner
A-MACT
Rotary Separator Pulverizer

Design Feature of Mitsubishi Twin fire-vortexes design



No Final SH out temp. imbalance

-Controlled by each side SH spray

No Final RH out temp. imbalance

-Controlled by each side damper

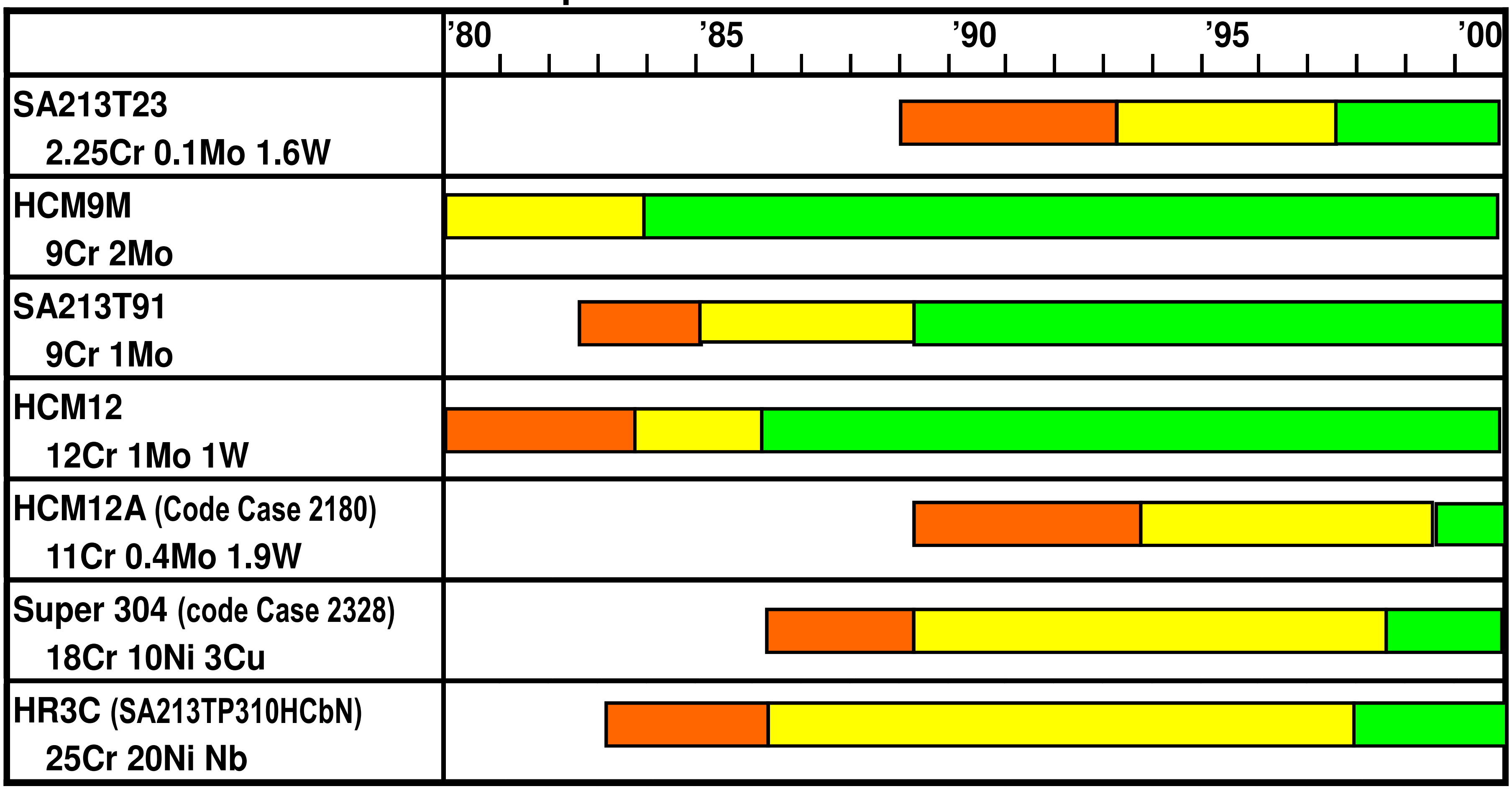
No criss-cross arrangement

-One internal link / header per a fire voltex

Lower heat input per each burner

-Heat input is half of single fire-voltex

History of Tube Material MHI Field Test for Supercritical Boilers



※ [orange] : Factory Test , [yellow] : Actual Boiler Test , [green] : Practical Use

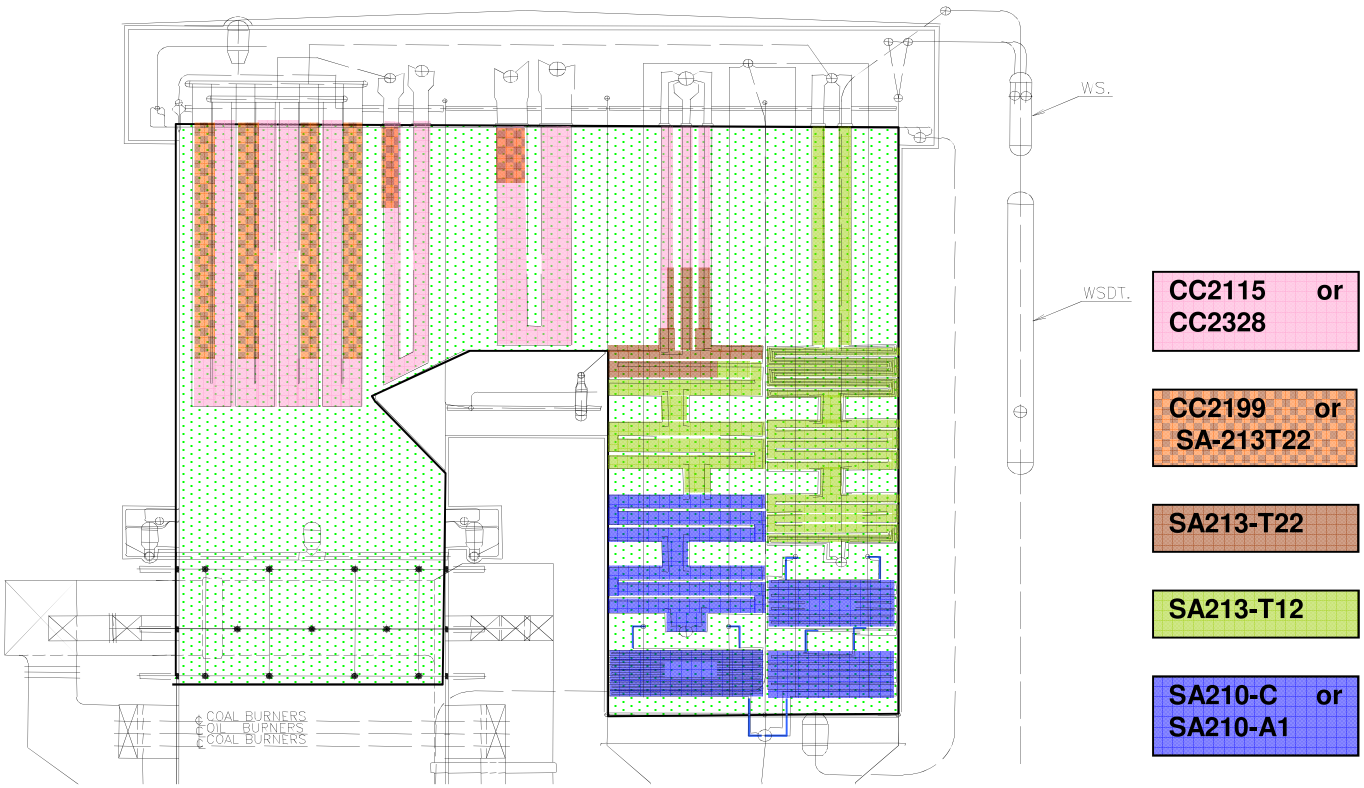
Ultra Supercritical Sliding Pressure Boiler High Temperature Resistant Material

- MHI has, in association with the tubes and pipes manufacturers, strived to continuously develop new grades of materials for use in high temperature applications.
- Improved creep and fatigue resistance suitable for cyclic operations.
- High strength in high temperature zone
- Use of advanced materials such as
  - Code Case 2115 — 25Cr Austenitic
  - Code case 2328 — 18Cr Austenitic
  - SA-213T92 and SA-335P92 — 9Cr Ferrite
  - Code Case 2199 (SA-213T23) — 2 1/4Cr Ferrite

Ultra Supercritical Sliding Pressure Boiler High Temperature Resistant Material

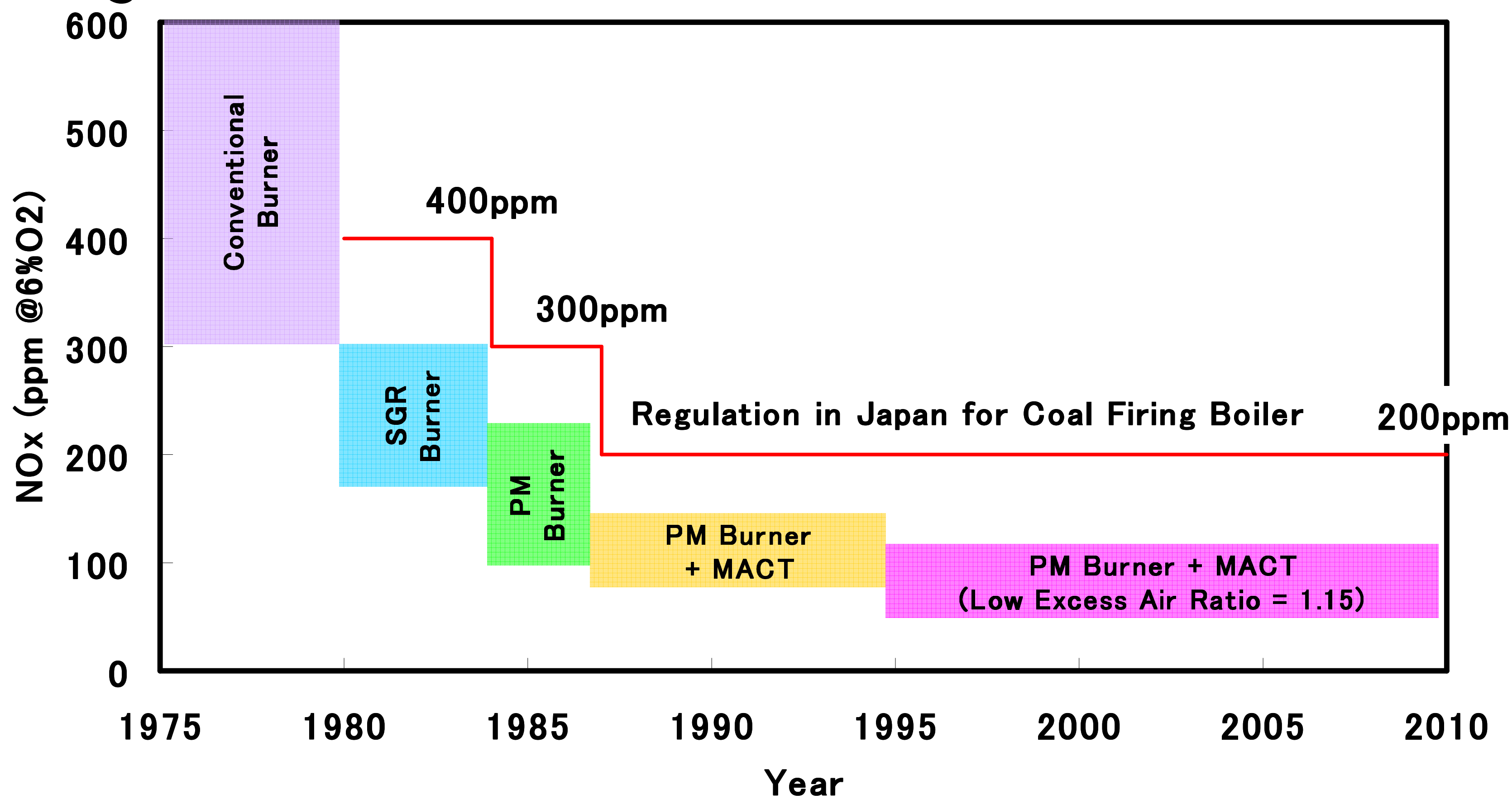
		Superheater			Reheater		Eco.	WW
		3rd SH	2nd SH	1ry SH	2nd RH	1ry RH		
25Cr 18Cr	Code Case 2115 Code Case 2328 SA213TP347H	V	V		V	V		
9Cr	SA213T91(unheated zone)	V	V		V	V		
2.25Cr	SA213T22		V		V	V		
1Cr	SA213T12		V	V	V	V		V
Carbon Steel	SA192 SA210					V	V	

Ultra Supercritical Sliding Pressure Boiler
High Temperature Resistant Material

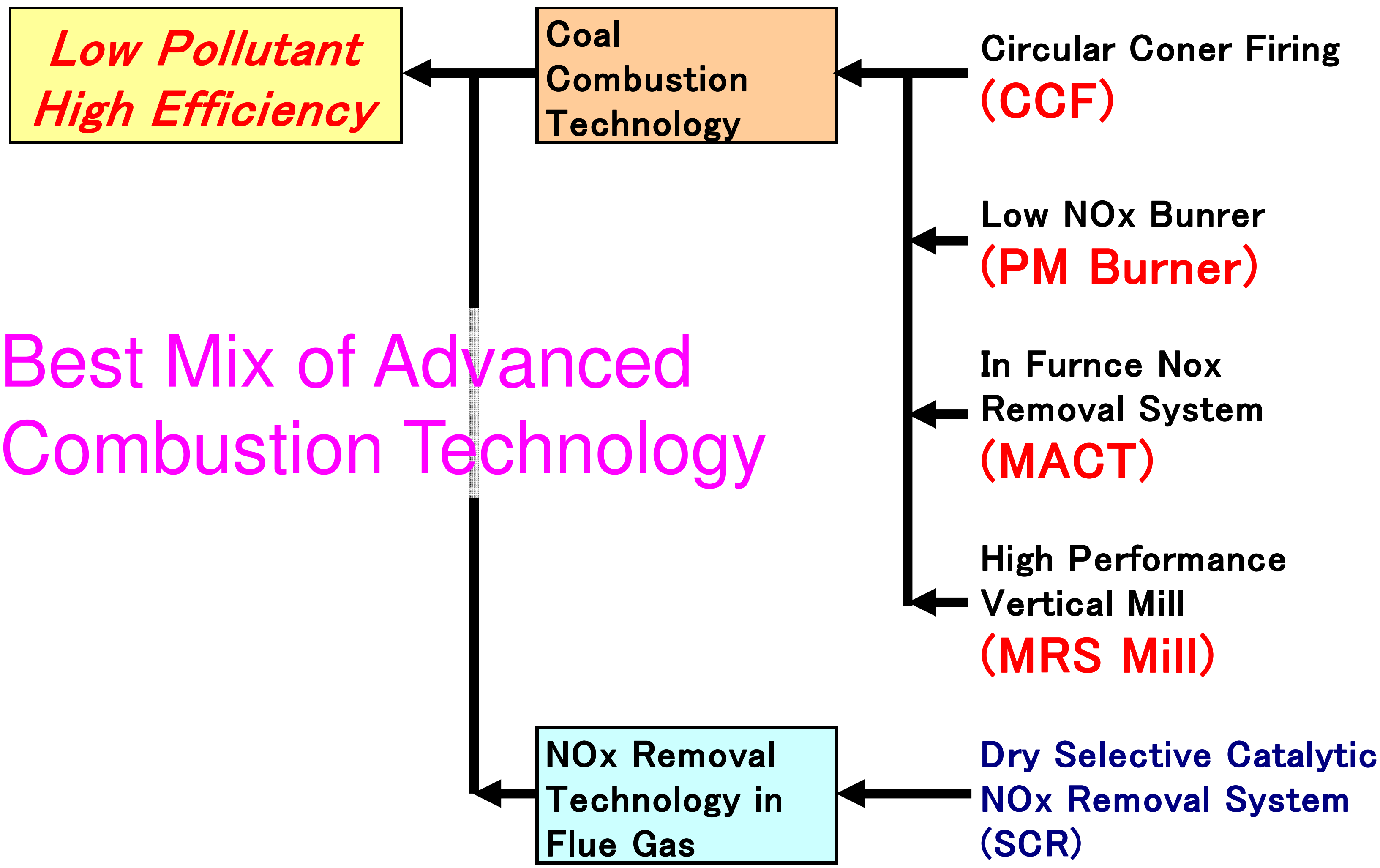


History of Mitsubishi Low NOx Combustion Technology

- Continuous Improvement following Japanese Regulation.

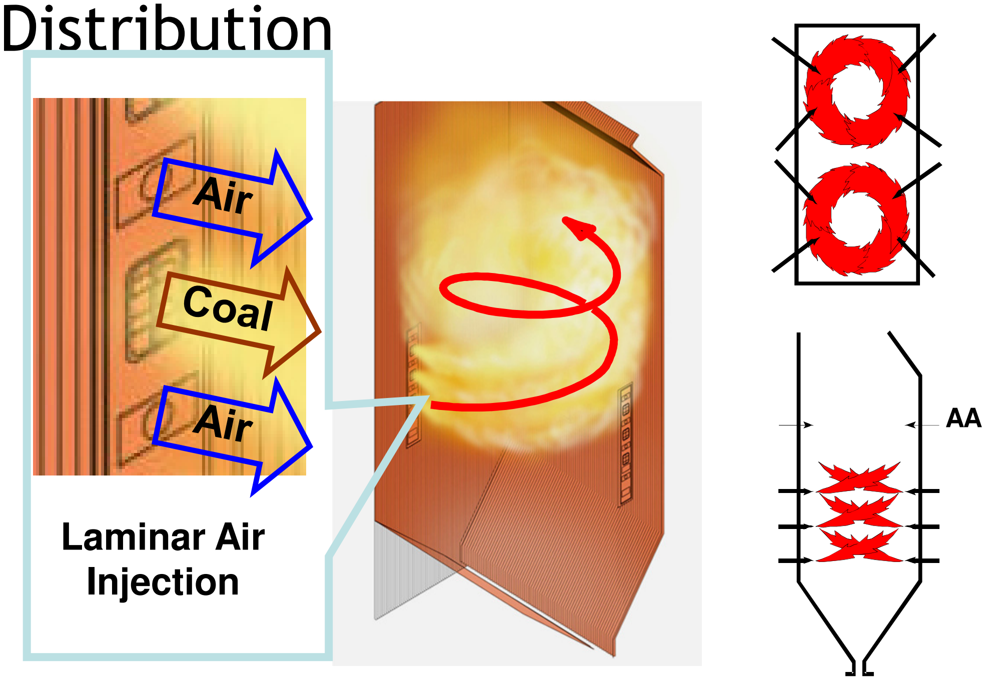


LMB Coal Combustion Technology



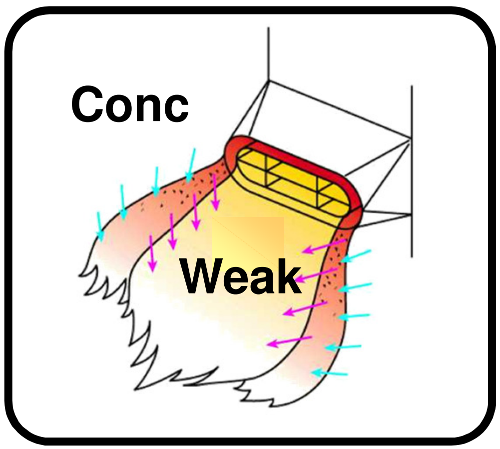
CCF : Circular Corner Firing

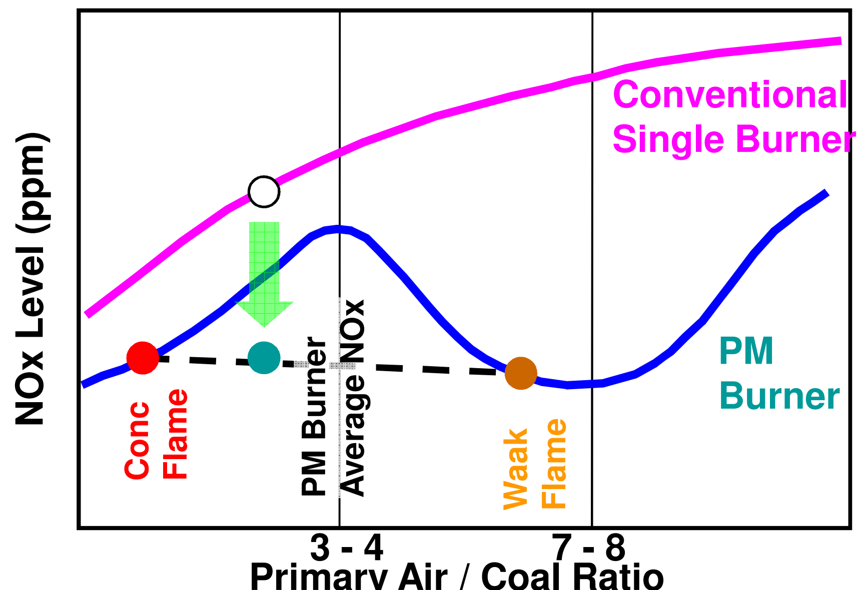
- Features of CCF
  - High Ignitability and Combustibility
  - High Occupation rate of Fire Vortex in Furnace
  - Uniform Heat Flux Distribution
- Means...
  - Low NOx & Unburnt Carbon
  - High Efficiency
  - Good Operability
  - Low Slagging Tendency



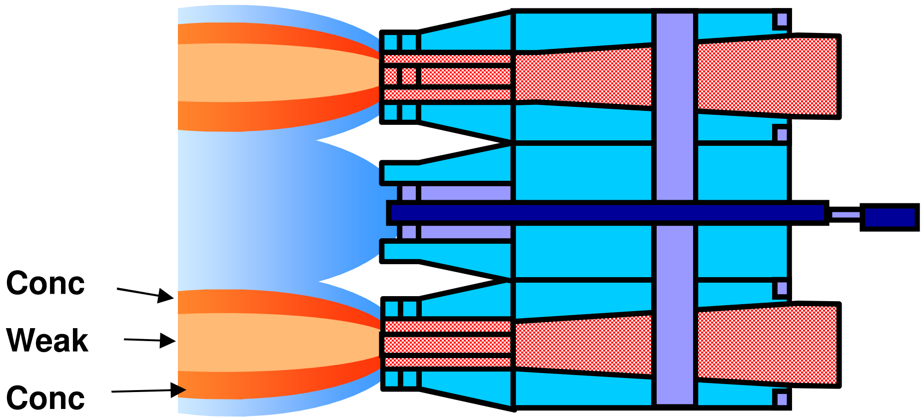
Low NOx PM Burner : Pollutant Minimum

- Coal flame composed by
  Conc : Fuel Rich ⇒ Good Ignition
  Weak : Fuel Lean⇒ Moderate Combustion
- Divided flame achieves simultaneously;
  - Stable Ignition and Combustion
  - Low NOx Combustion





LMB Firing system
Low NOx Burners (PM burners)



- **High ignitiability even under low-O2 condition**
- **Application for all solid fuel (incl. low combustive fuel)**

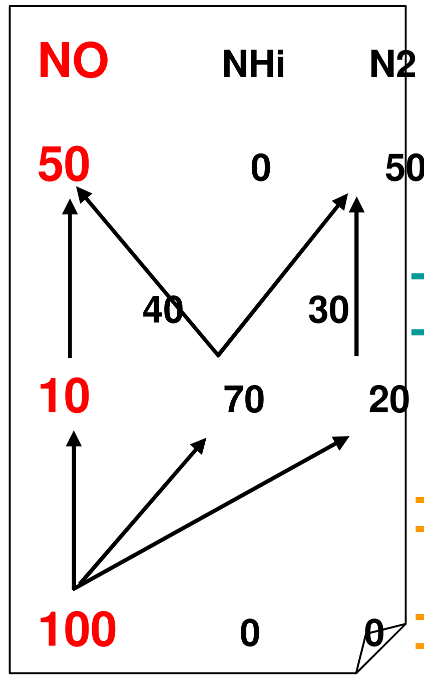
PM : Pollution Minimum

PM burner with vertical waterwall

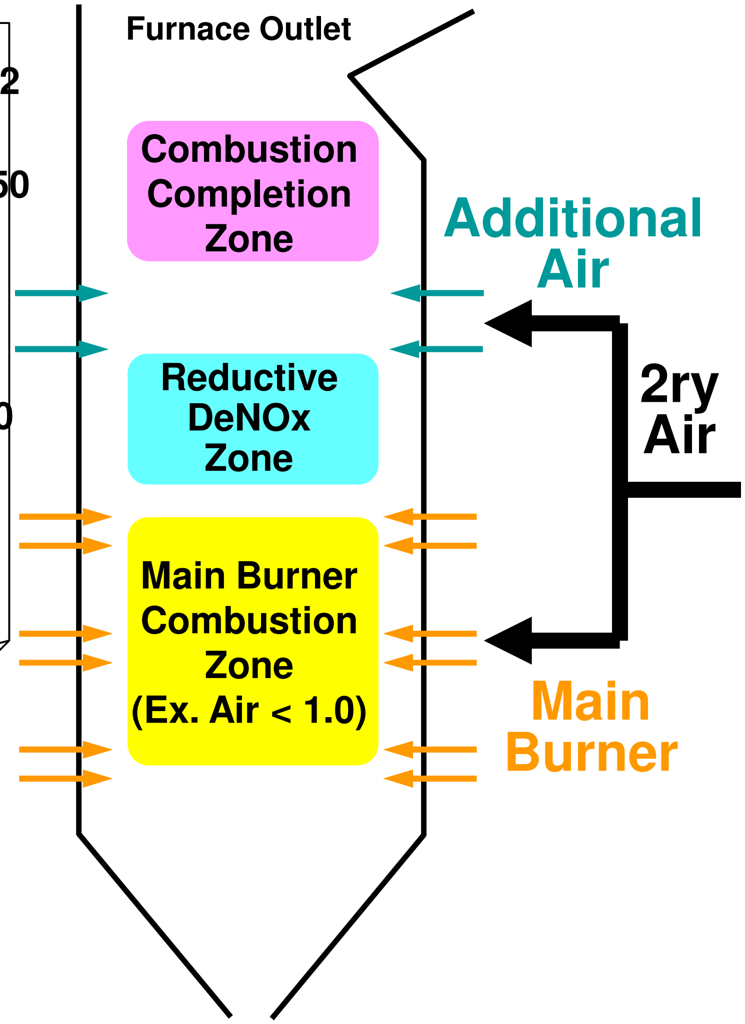
MACT : Mitsubishi Advanced Combustion Technology
(In-furnace NOx Removal System)

[Advantages of MACT]

- No additional cost of Ammonia Injection or Catalyst.
- No emission of Substance Matter
- No change of Boiler Efficiency and Flue Gas Flow
- Stable and Reliable Combustion in Furnace
- Applicable to all fossil fuels, Gas, Oil, Coal, etc.



Concept of NOx Reduction



LMB Firing system
MACT system -in-furnace DeNOx-

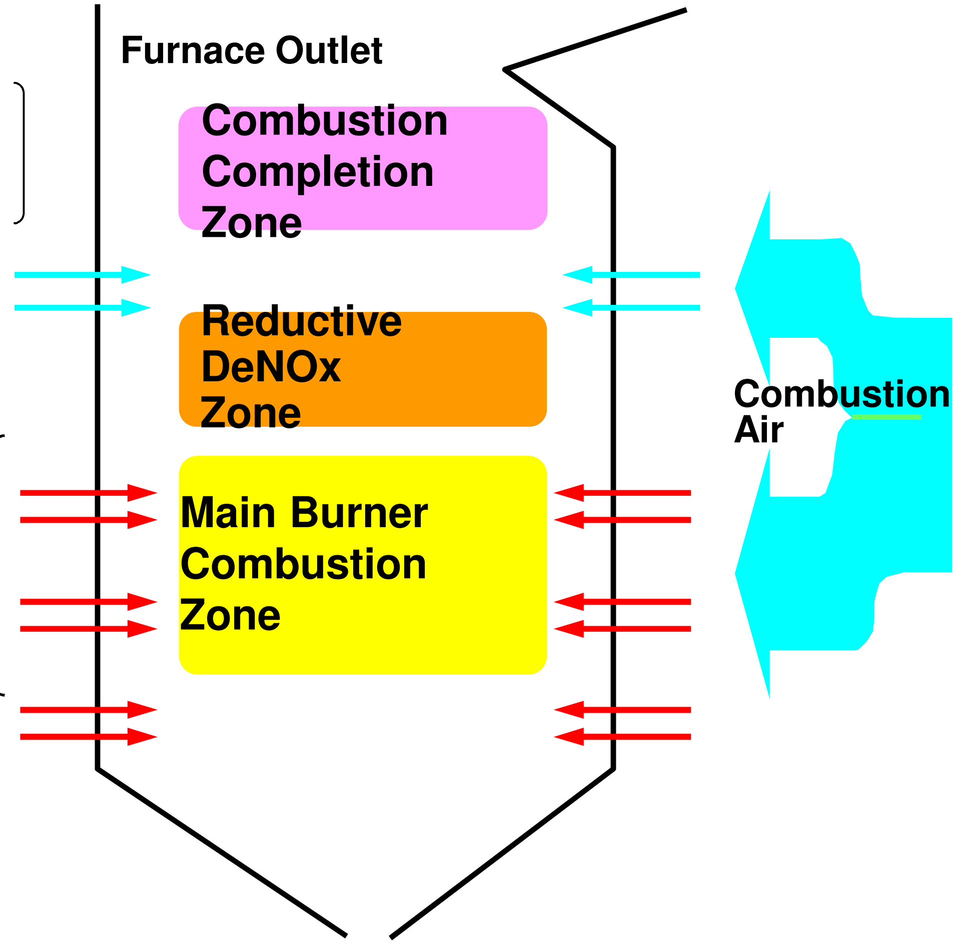
$Cn''Hm''+O_2 \rightarrow CO_2+H_2O$
$Cn'Hm'+O_2 \rightarrow CO_2+H_2O$
$CO+H_2+O_2 \rightarrow CO_2+H_2O$
$NHi+O_2 \rightarrow NO+N_2$

Additional Air

$CnHm+O_2 \rightarrow H_2+CO_2+Cn'Hm'$
$Cn'Hm'+NO \rightarrow NHi+N_2+Cn''Hm''$

Main Burner

$CnHm+O_2 \rightarrow CO_2+H_2O$
$N+O_2 \rightarrow NO$



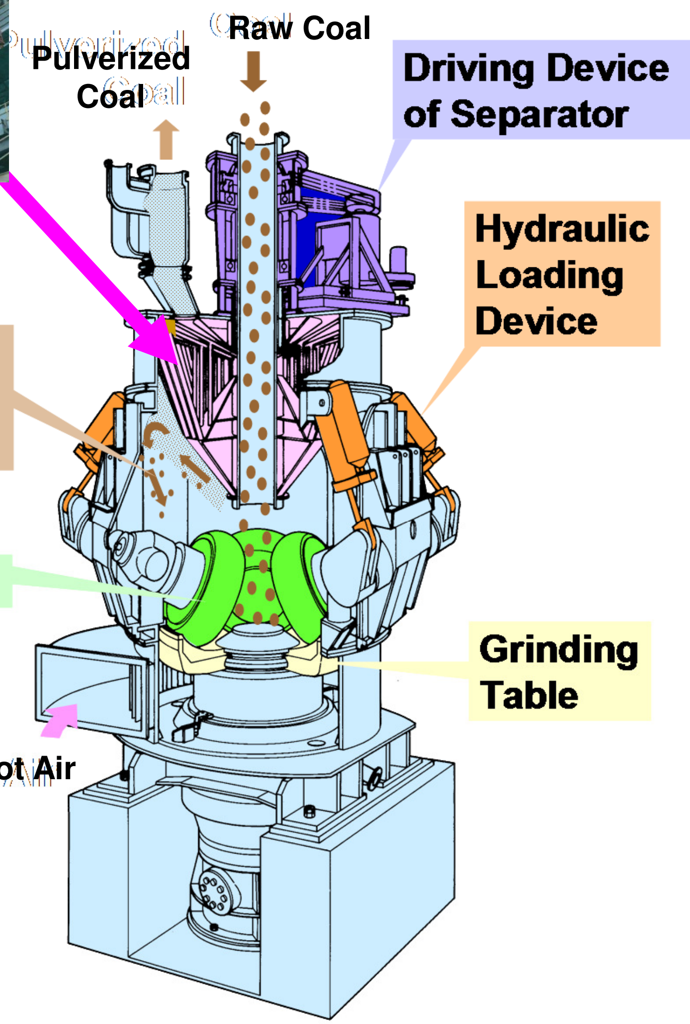
MRS Mill : Mitsubishi Rotary Separator (High Performance Vertical Mill)

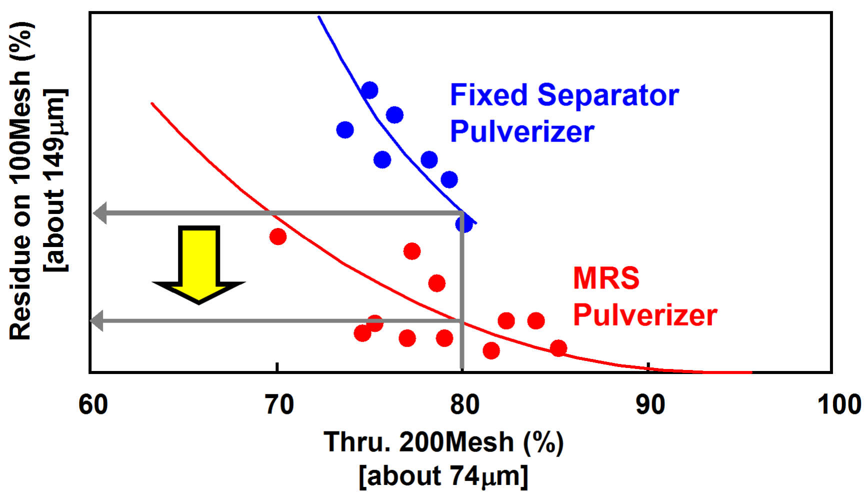
- Effective Classification of Coarse Particles

↓

Good Ignition & Combustion


Rotary Separator

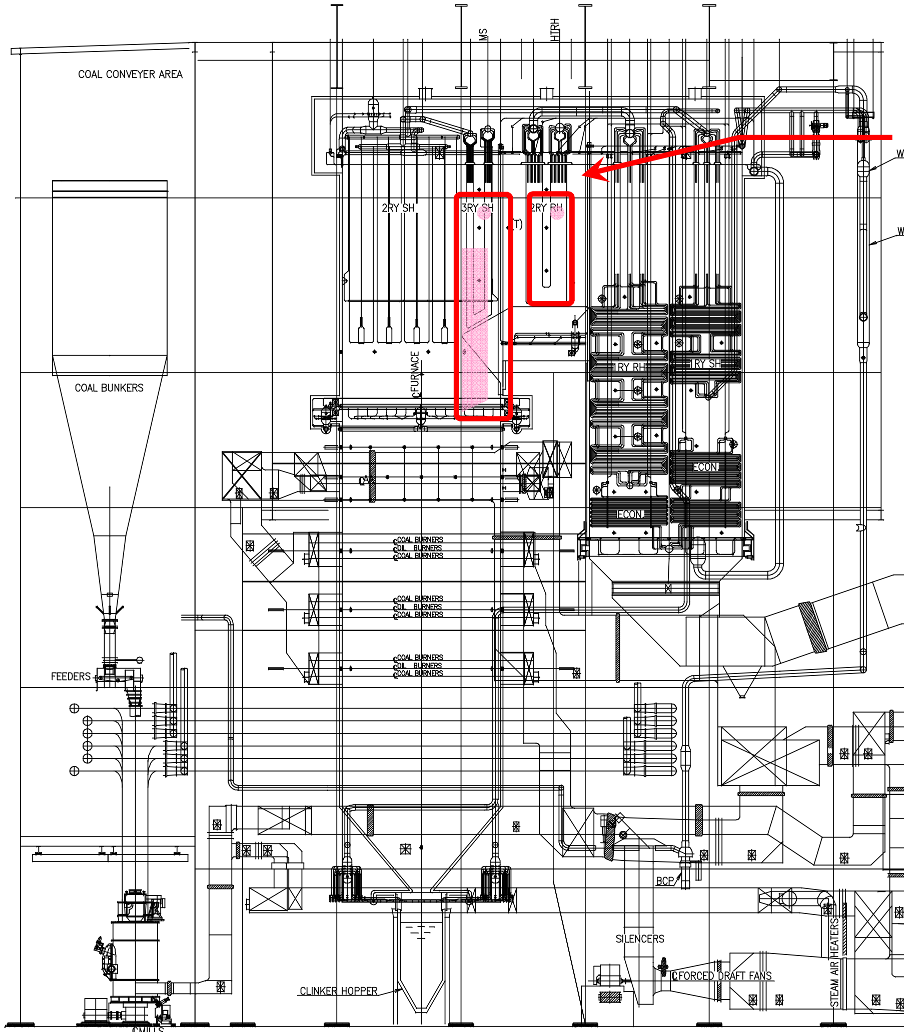




1. What is USC Boiler
2. Trends of USC units
3. Supply records of USC
4. Feature of USC Boiler
5. Impact on present SC design

Boiler Design for USC 600/600

➢ To meet with the elevated steam condition from present 566/593 to 600/600, following design change is required. It can be modified based on our existing design.



Modified Point of 600/600 Case

3SH <Tube>

- Increase the No. of tubes
- Tube material is same

3SH <Outlet HDR>

- Increase diameter
- Header material is same

2RH <Tube>

- Increase the No. of tubes
- Tube material is same

2RH <Outlet HDR>

- Increase thickness
- Header diameter is same
- Header material is same

What next to Ultra Super Critical

What Next to Super Critical

Efficiency improvement

ADVANCED ULTRA SUPERCRITICAL TECHNOLOGY

- With pressures up to 30 MPa & Temperatures 700 / 700 Deg.C
- Cycle efficiency up to 50% on LHV basis

INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)

- Using super high temperature GTs (1700 deg. c class)
- Cycle efficiency up to 55% on LHV basis

What Next to Super Critical

Emission improvement

ADVANCED ULTRA SUPERCRITICAL TECHNOLOGY

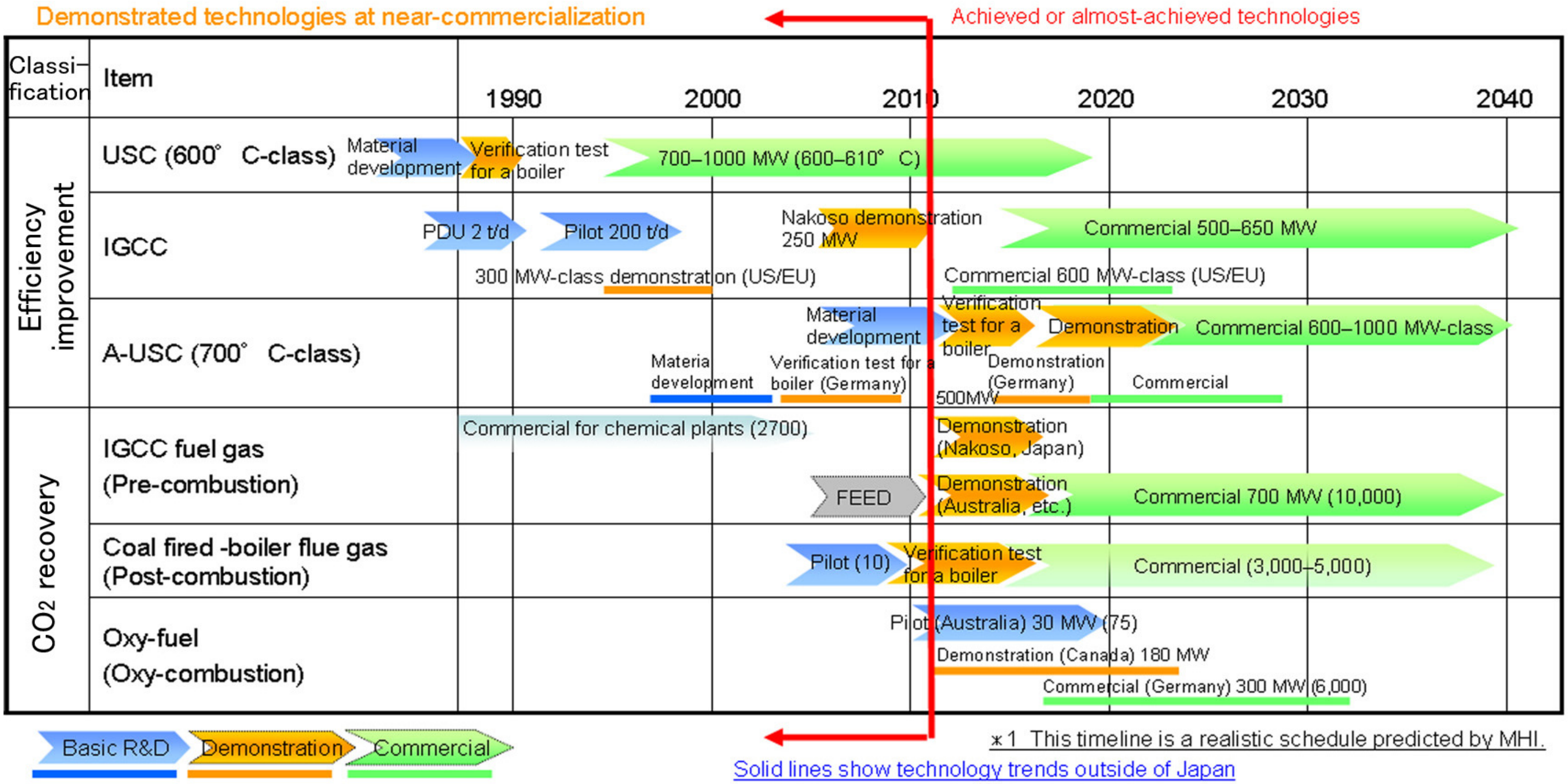
- Cumulative CO_2 emissions reduction by 20-25 %
- By using OXY fuel combustion CO_2 emissions reduction by 90%
- Reduction of Sox, Nox & SPM levels proportional to Eff. Improvement

INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)

- Cumulative CO_2 emissions reduction by 25-30%
- By using Pre combustion recovery method CO_2 emissions reduction by 90%
- Reduction of Sox, Nox & SPM levels to 4-5 PPM

What Next to Super Critical

CO2 Reduction Roadmap for Coal-fired Power Generation



*1 This timeline is a realistic schedule predicted by MHI.

Solid lines show technology trends outside of Japan

Recovered and stored CO_2 volumes (t-CO2/d) are in parentheses.

IGCC could be widely and practically used by 2020.

FEED: Front End Engineering Design

Source : From MHI Technical review

Advantages of A-Ultra Super Critical Technology

Increase in plant Efficiency:

Type	Parameter	Efficiency LHV BASIS
Sub Critical	16.6MPa /538 / 538°C	38-40%
Super Critical	24 MPa / 566 /593°C	40-42%
Ultra Super Critical	25~30 MPa /600 /620°C	43-46%
A-Ultra Super critical	25~30 MPa /700 /700°C	46-50%

Lesser emissions:

These increases in plant efficiency can reduce CO2 emissions by a ratio of 2 to 1 (i.e. a one percentage point increase in efficiency reduces emissions by around two percent). Improved efficiencies also reduce the level of other pollutants and overall fuel use.

L&T MHI Boilers