MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

State of Art Technologies By MHI for Air Quality Control Systems (WSD, GGH and ESP)

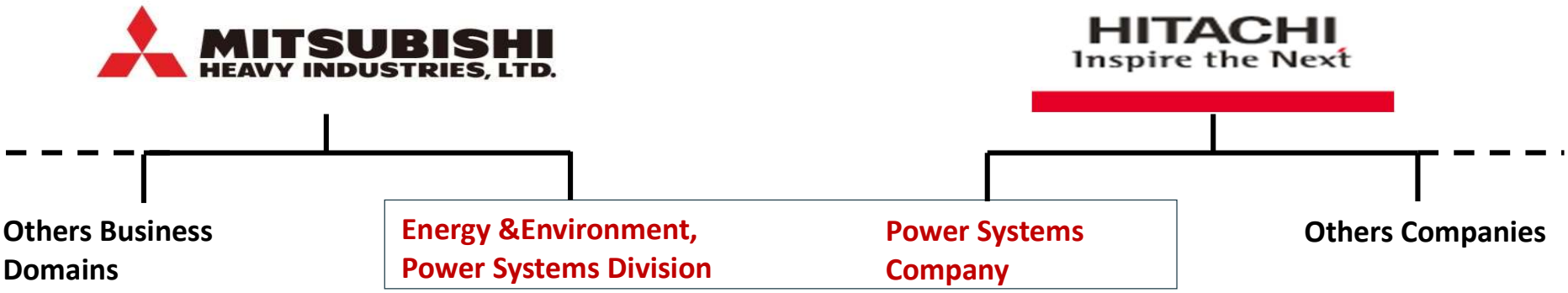
Council of Enviro Excellence (CEE)

17th August 2022

Mitsubishi Heavy Industries, Ltd.

MITSUBISHI HEAVY INDUSTRIES

Company Profile: History



Thermal Power Generation systems of "Mitsubishi Heavy Industries " and "Hitachi",

are integrated on February 1, 2014 as known of

MITSUBISHI HITACHI POWER SYSTEMS

Company Profile: History

A new brand:

“MITSUBISHI POWER”

Launched on 1st September, 2020

✓ MHPS (Mitsubishi Hitachi Power Systems) changed its name to Mitsubishi Power
✓ A new corporate logo with the three-diamonds mark adopted

MHPS → MITSUBISHI POWER

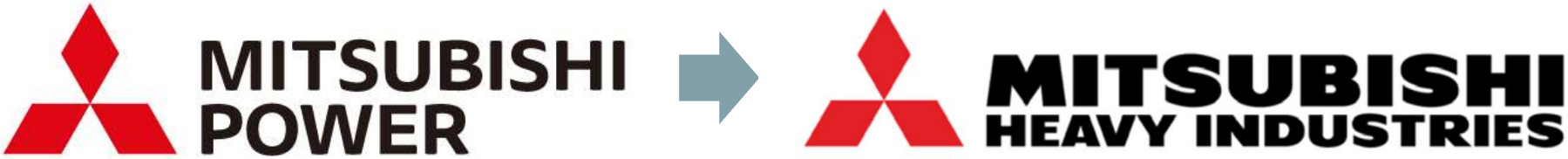
From a power equipment manufacturer
Joint Venture between MHI* and Hitachi

To an Energy Solution Company
100% MHI* owned subsidiary

MHI* : Mitsubishi Heavy Industries, Ltd

Mitsubishi Power to be Integrated into MHI

Integration of business operations to MHI effective October 1, to vigorously advance "Energy Transition" solutions



Even after integration with MHI, the "Mitsubishi Power" brand name, widely recognized around the globe, will continue to be used for overseas markets. Mitsubishi Power, Ltd. will continue to exist as a corporation within Japan, functioning as the presiding company and contract agent for the core Asian and Middle Eastern markets, etc.

For Japan	For Global Markets
三菱重工 (Corporate Logo)	MITSUBISHI POWER (Business Brand Logo)

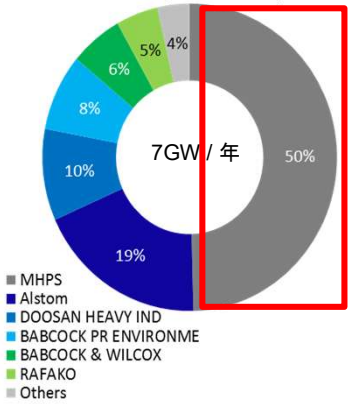
MHI AQCS: Product Portfolio

MHI covers wide ranged AQCS products to offer systems which match the needs of customers.

Flue Gas Denitrification (SCR)

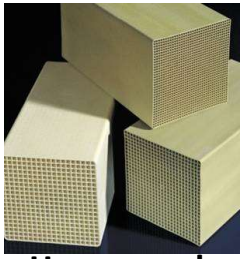
Flue Gas Desulfurization(FGD)

Market Share in Wet Coal Method
(2012-2014) [excl. China]
（Source：McCoy Power Report）

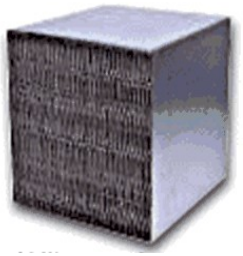


Electrostatic Precipitators (ESP)

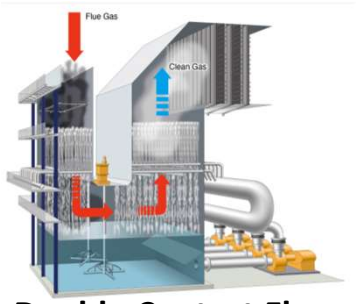
Plate Catalyst



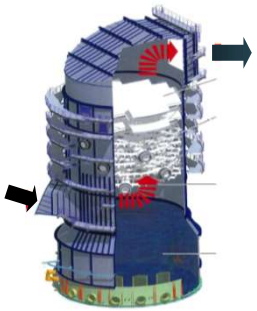
Honeycomb Catalyst



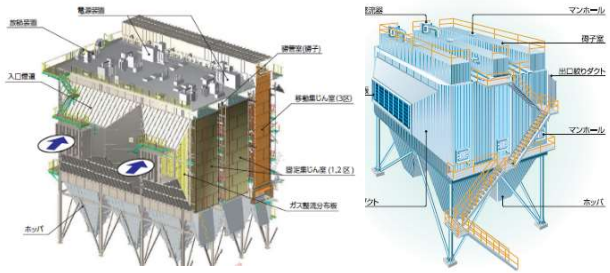
Spray Tower



Double Contact Flow Scrubber (DCFS) Tower



Conventional



Moving Electrode

New Environmental Regulation issued on 7th Dec 2015

	TPP installed before 31 December 2003		TPP installed after January 2004 up to 31st December 2016		New install from 1st January 2017
Capacity	Smaller than 500 MW	500 MW & Above 500 MW	Smaller than 500 MW	500 MW & Above 500 MW	Any Size
Particulate	100 mg/Nm^3		50mg/Nm^3		30 mg/Nm^3
SO2	600 mg/Nm^3	200 mg/Nm^3	600 mg/Nm^3	200 mg/Nm^3	100 mg/Nm^3
NOx	600 mg/Nm^3		450 mg/Nm^3 **		100 mg/Nm^3
Mercury	-	0.03 mg/Nm^3	0.03 mg/Nm^3		0.03 mg/Nm^3

** Revised in October 2020

- The new regulation may require application of state of art technologies
- MHI has enough experience to comply with stringent requirements in Japan and MHI can supply reliable technologies to meet Indian regulation.

Present Scenario and Challenges Ahead

New emission norms call for of DeSOx and NOx control technologies besides augmentation of ESPs.

ESP

- In ESP R&M, space availability and layout are the major constraints.
- To meet the 30-50mg/Nm3 seriously, the different proven technology to be applied.

FGD

- Selection of FGD Technologies - Wet Limestone, Sea Water and Dry.
- Units < 500 MW capacity do not have space to install FGD.
- Units > 500 MW have space provisions, but involve arrangement for supply and transport of limestone.
- Quality of limestone and its availability in India and logistics are to be addressed. MOP may think of using Limestone powder instead of limestone.
- Disposal / utilization of Gypsum and tie-up with Cement plant would be required.

Present Scenario and Challenges Ahead

DeNOx

- Proposed standards of 600 mg/Nm3 can be met using Low NOx burners.
- To meet 300 and 100 mg/Nm^3, either SNCR or SCR technology is required. Now with revision from 300 to 450 mg/Nm3, we can achieve using low Nox burners.
- SCR for High ash Indian coal - Only a few suppliers like MHI have the experience of high ash application.
- Pilot studies conducted by NTPC to establish the technology and the type of catalysts.
- Selection of catalyst Honeycomb/Plate type, Ammonia availability, transportation, handling, storage are to be addressed.
- Catalyst Management.

Present Scenario and Challenges Ahead

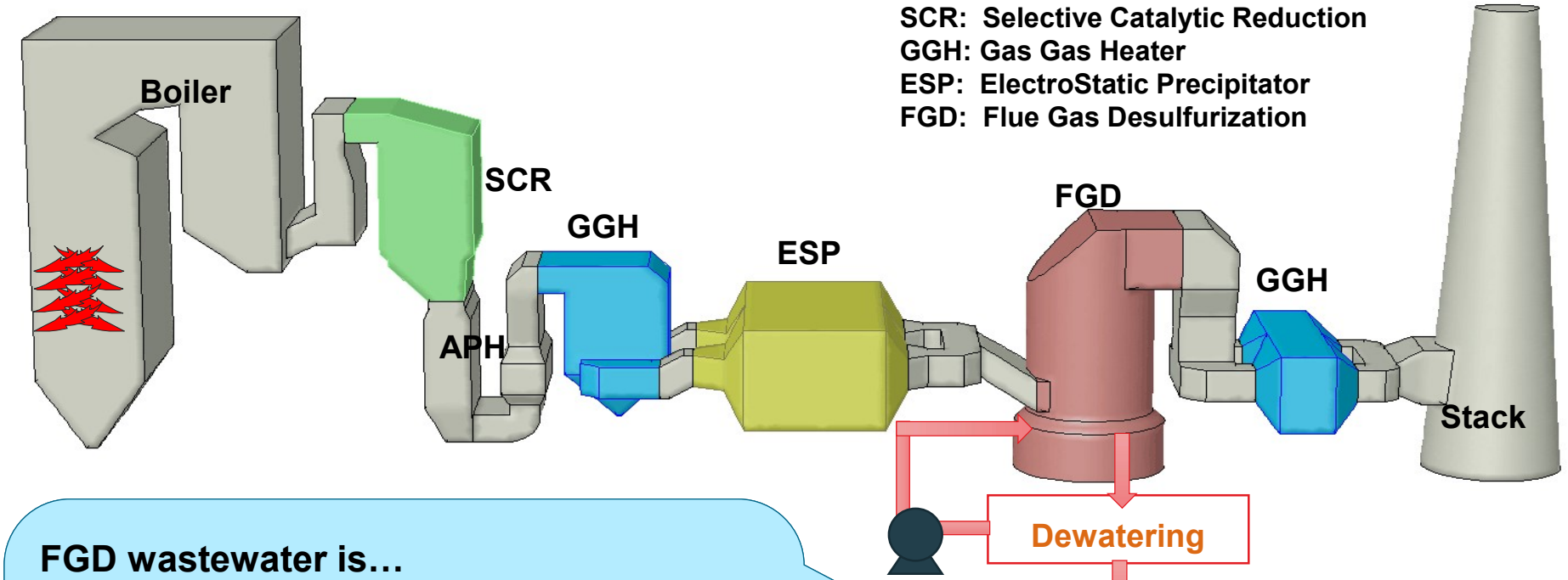
General

- Selection of state of Art Technologies - Power plants, Customers and Consultants discuss with various suppliers for the proven state of art technologies.
- For R&M, space availability and layout are the major constraints.
- Making Feasibility study to understand cost and time required for implementation
- Preparation of technical specification and availability of vendors in India or to be imported
- Local vendors for critical equipments like RC Pups, Wet Ball Mill, Gypsum Dewatering system, Agitators and Lining.
- Financial assistance for implementation of the project.
- Delay in executing the projects due to Post Covid situation.

ZLD
(Zero Liquid Discharge)

Mitsubishi Heavy Industries, Ltd.

FGD Waste water from Thermal Power plant



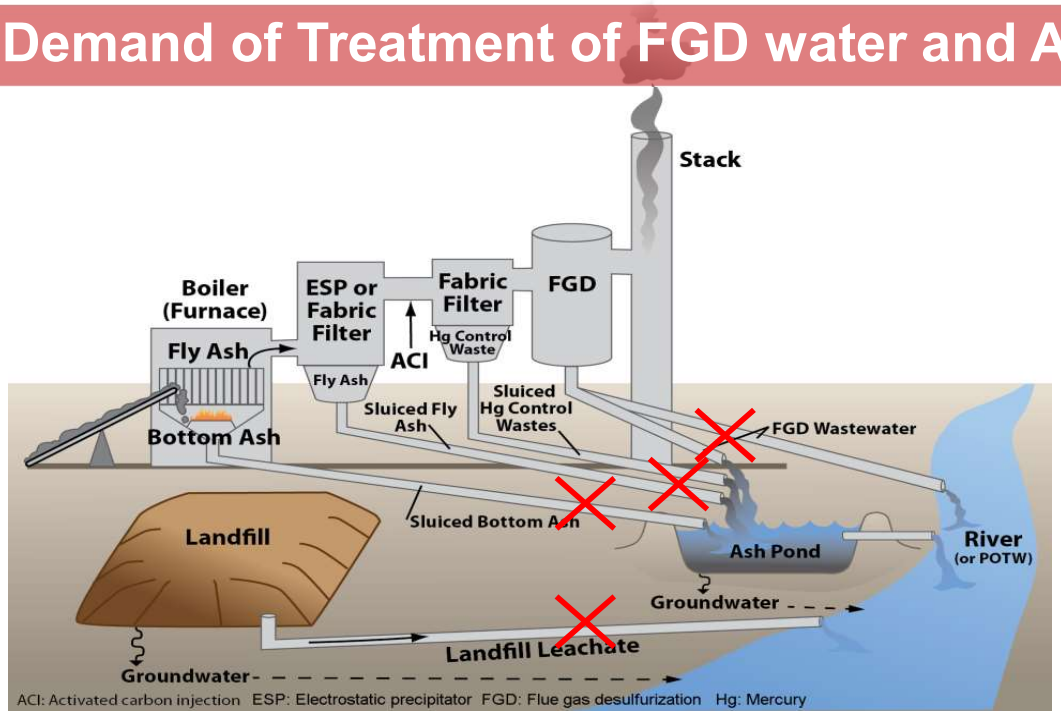
FGD wastewater is…

- Harmful heavy metals are included
- Restricted release into river and/or sea
- Easy clogging in filter or membrane by saturated Calcium.
- Corrosive with high density of Chlorine.

Typical wastewater Condition	
Hg, Se	Included
Ca^{2+}	Saturated
Cl^-	10,000 ~ 20,000 ppm

Demand for FGD Wastewater ZLD

Demand of Treatment of FGD water and Ash pond



Waste water sources from Coal fired plant

Photo of the overflow of pond water to river in USA

- In USA, the coal ash from 161,000m2 pond water flows in to the river after a retention wall collapsed in Dec. 2008.
- From this disaster, USA government started to consider the stringent rule for ash pond water e.g. EPA published the following rules and ZLD level is required.
  - Effluent limitation Guideline(ELG)
  - Coal Combustion Redials

MHI has developed ZLD technologies to maintain the environment

Mitsubishi ZLD Technology : WSD (Wastewater Spray Dryer)

WSD (Waste Water Spray Dryer) was developed to achieve Zero Liquid Discharge from FGD.

Pros

- Patented Technology
- Simple solution to eliminate FGD Waste Water
- Fully isolatable for easy maintenance
- Doesn't generate a new solid waste stream
- Low capital & operating cost
- No chemical or biological treatment required
- Water saving due to less evaporation at FGD
- Handles wide range of dissolved solids content
- Save Water Consumption in FGD

Cons

- Require regular clean up and maintenance
- Slight increase of Chlorides in fly ash (~ 2%) *1)
- Slight impact to heat rate (~ 1%)

*1) depends on coal Chloride level

Wastewater Spray Dryer (WSD)

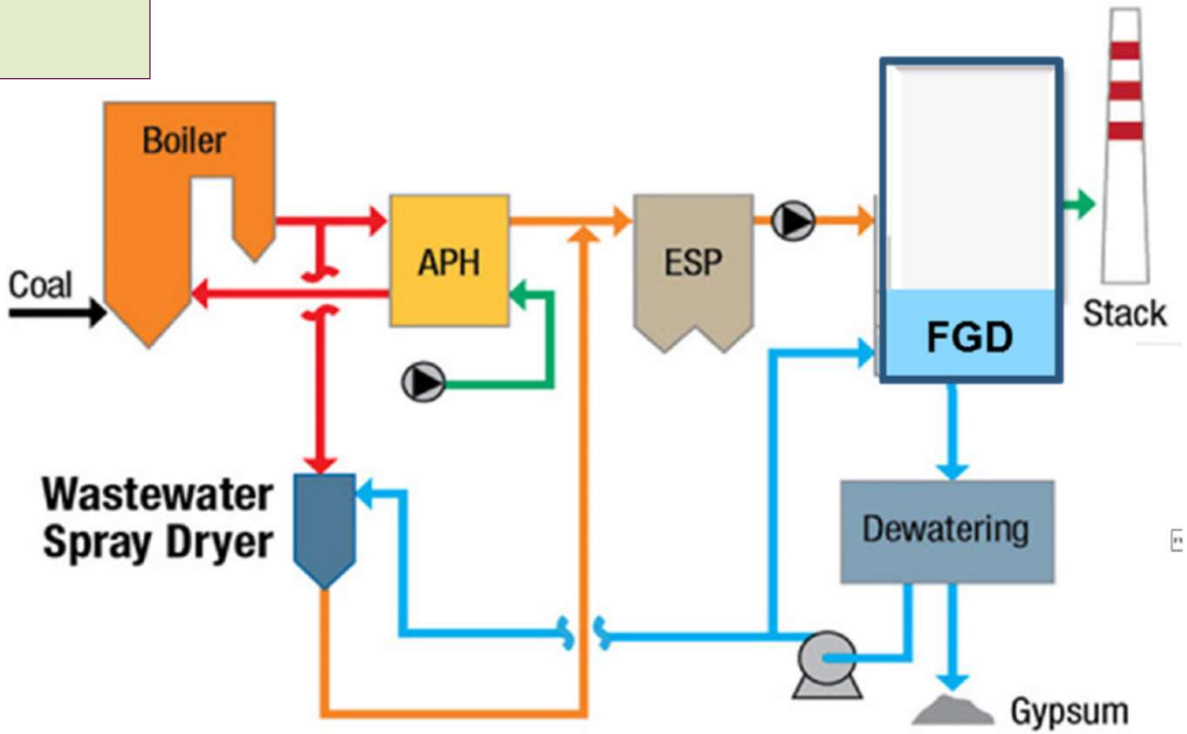
Multiple US Patents

8,388,917; 8,475,750; 8,715,402; 8,883,107; 8,986,428, 9,409,117; 9,555,341; 9,468,861; 9,468,862 9,511,305; 9,700,839; 9,669,356; 9,943,804; 9,895,658 Etc.


United States of America
United States Patent and Trademark Office

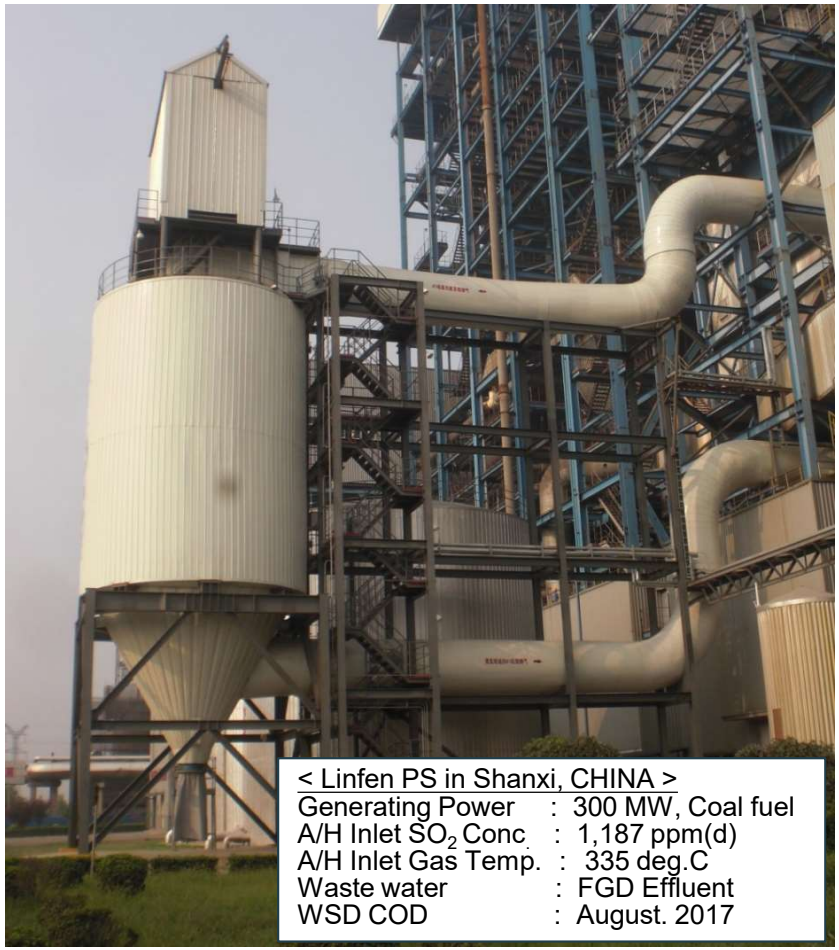
WSD

Reg. No. 5,435,878
Registered Apr. 03, 2018
Int. Cl.: 11
Trademark
Principal Register

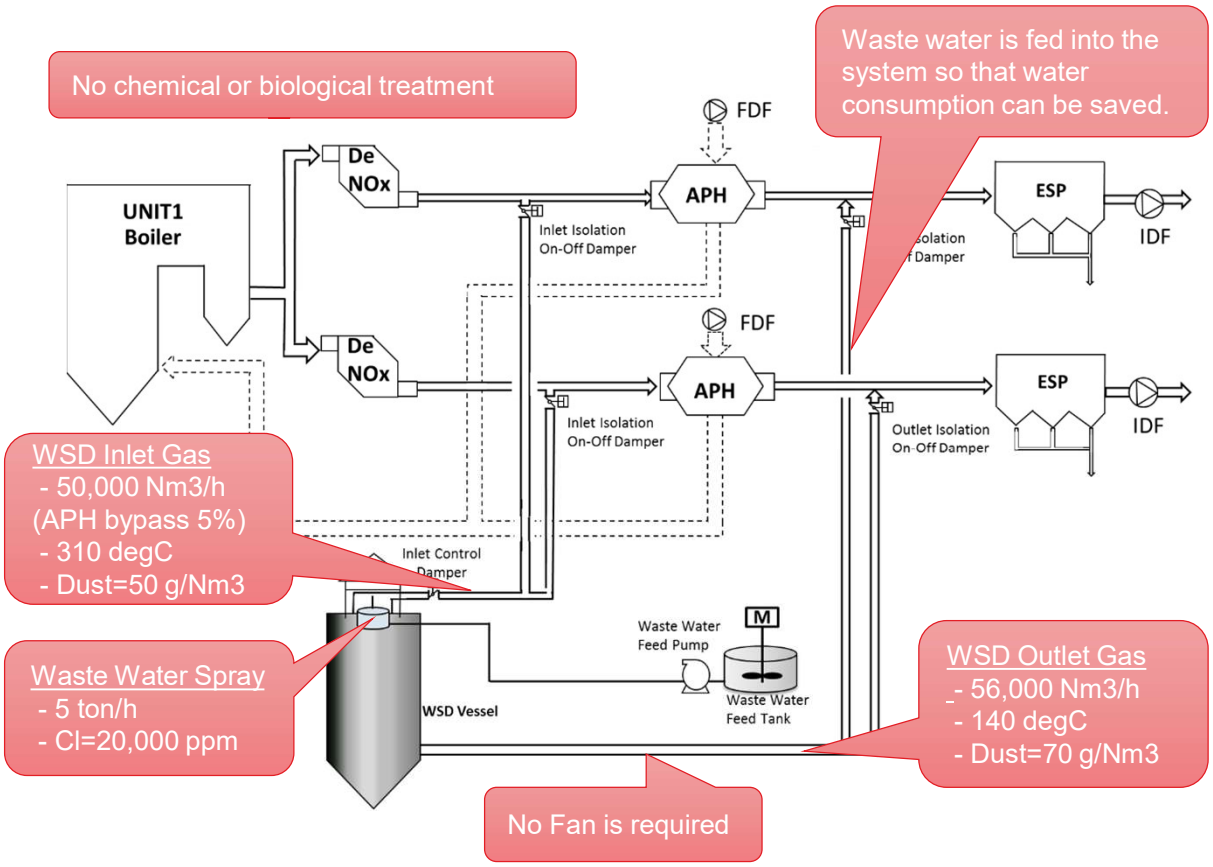


Mitsubishi ZLD Technology : WSD (Wastewater Spray Dryer)

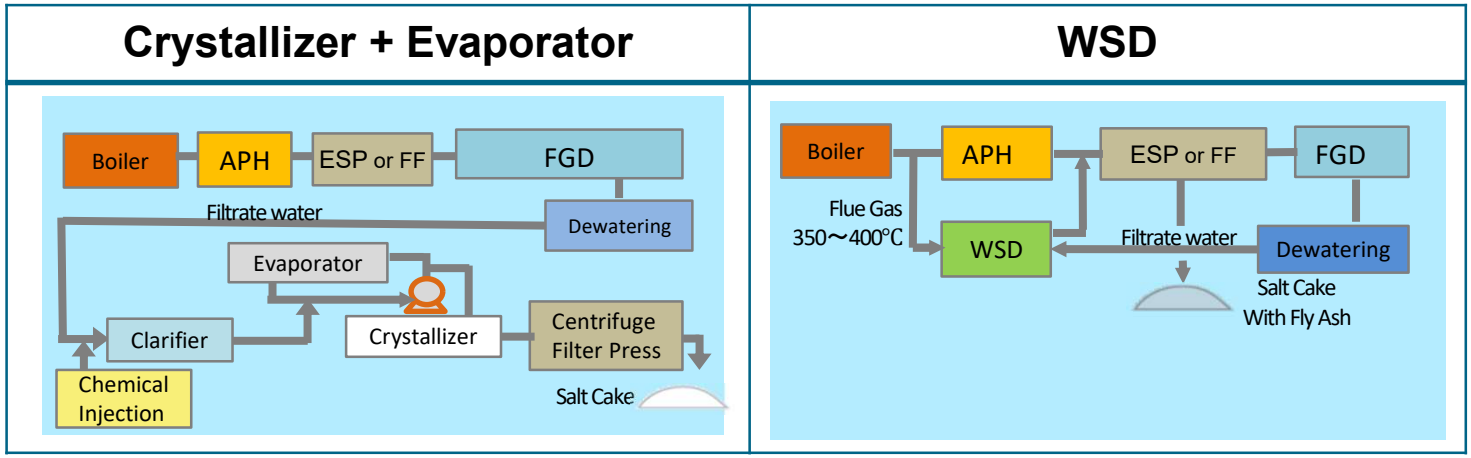
WSD full scale demonstration test has been complemented in Linfen Power Station, China.
It has been continuously operated since 2017.

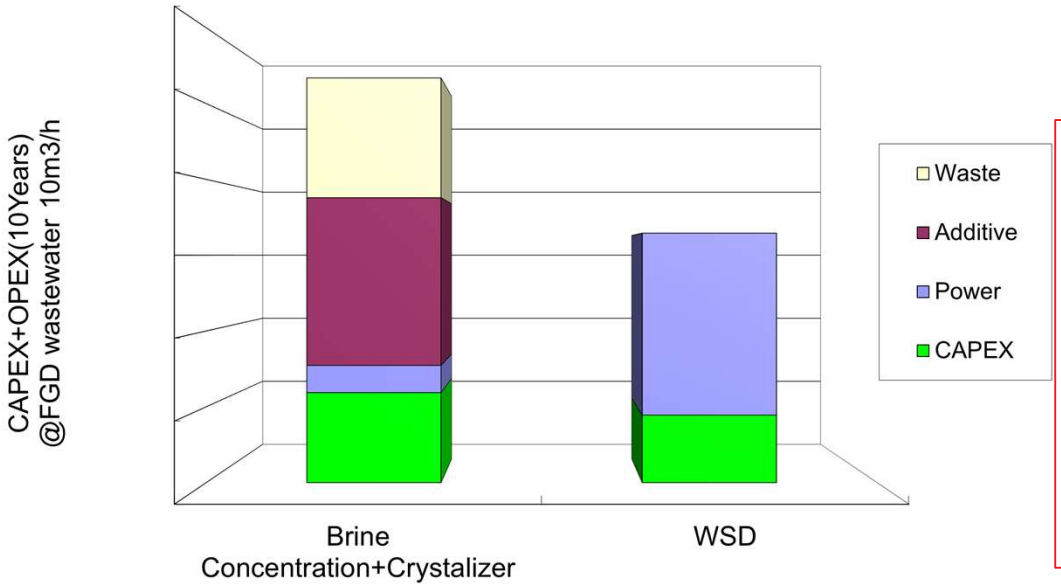


< Linfen PS in Shanxi, CHINA >
Generating Power : 300 MW, Coal fuel
A/H Inlet SO_2 Conc : 1,187 ppm(d)
A/H Inlet Gas Temp. : 335 deg.C
Waste water : FGD Effluent
WSD COD : August. 2017



WSD Advantage





WSD is able to achieve ZLD by low cost impact.
→ Minimum Cost impact to plant operation

WSD has advantage for operation cost economically compared with Crystallizer + Evaporator
→ Lowest operation cost in ZLD technology

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Heat Recovery System

Mitsubishi Heavy Industries, Ltd.

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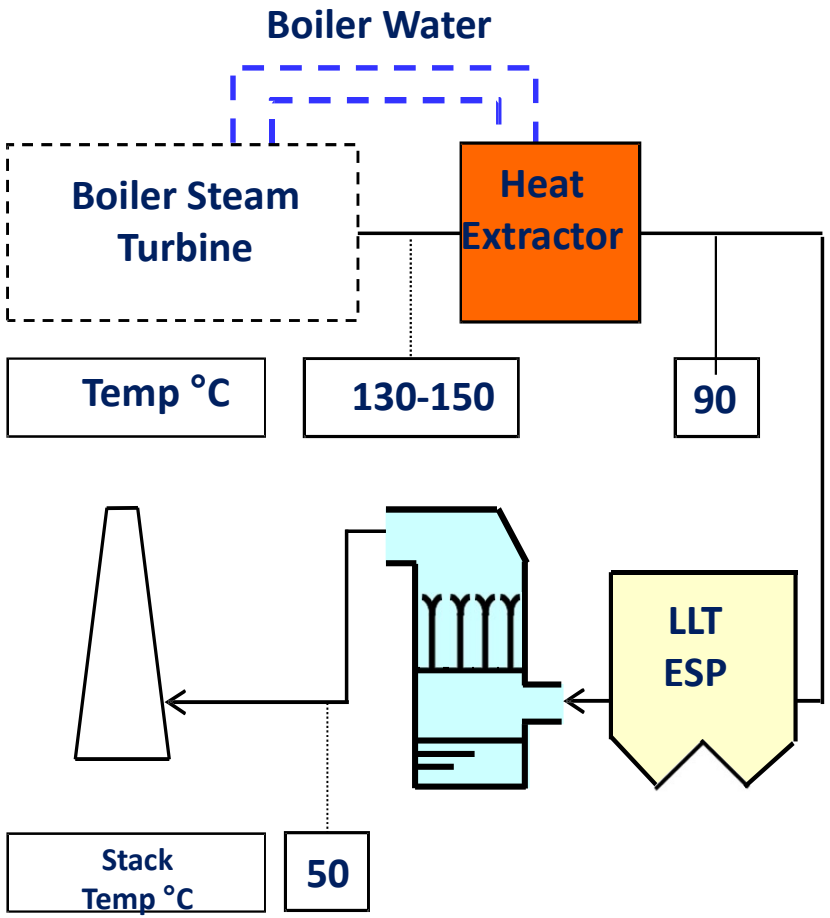
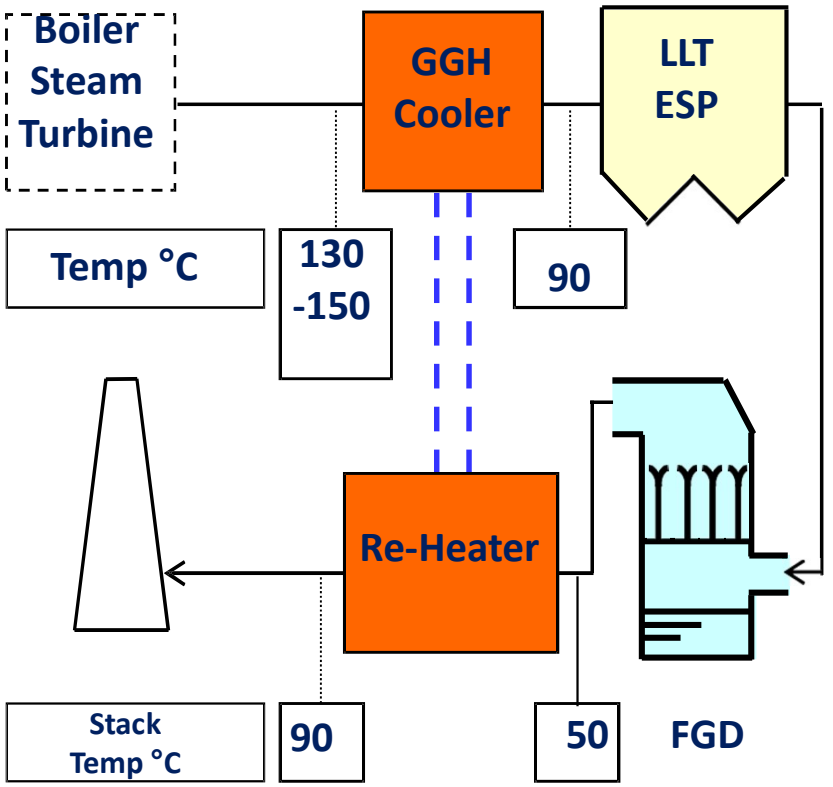
Use of Gas-Gas Heater (GGH)

Case 1- Recovered heat to Boiler Water



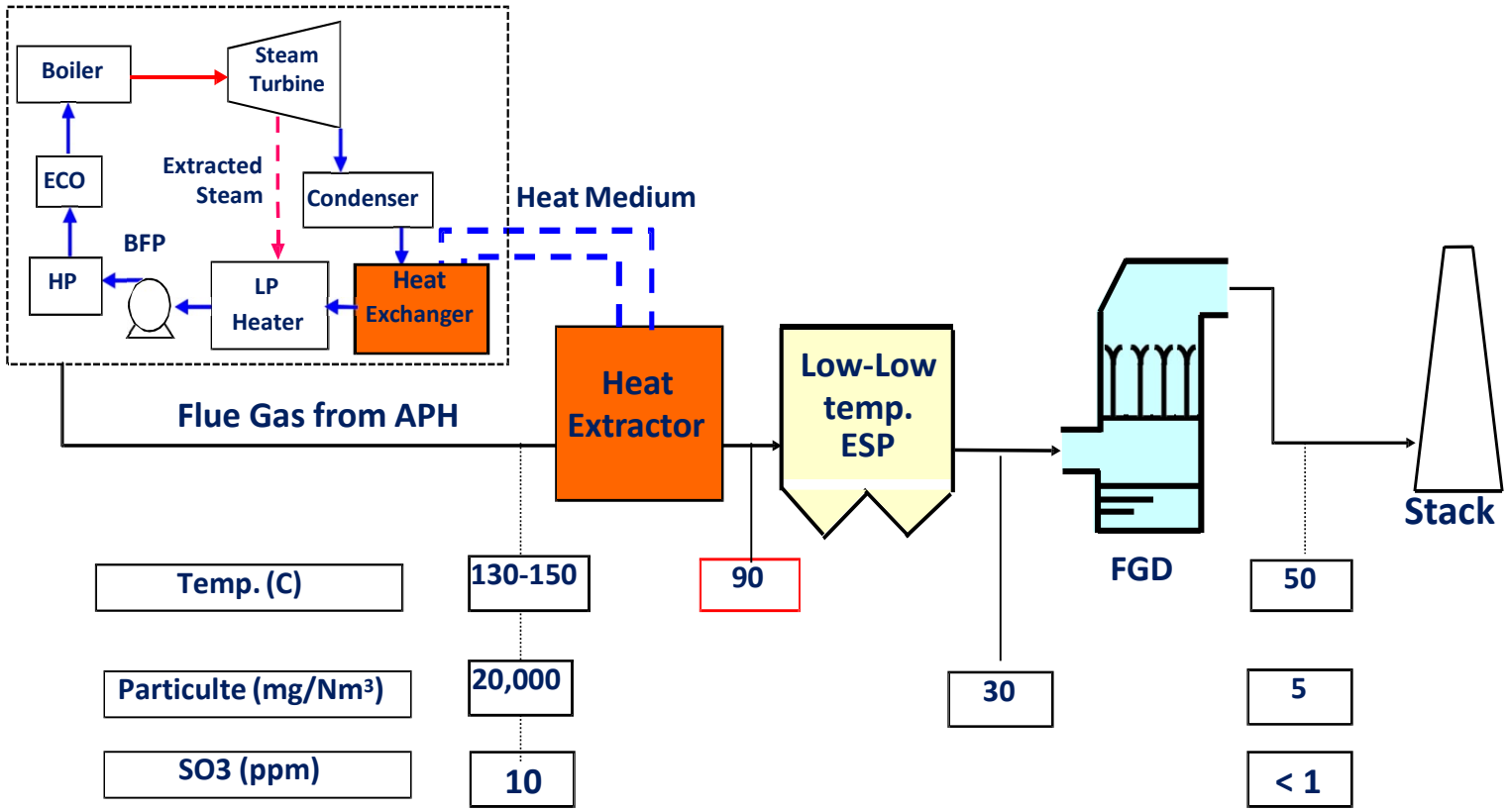
Improvement of Thermal Efficiency

Case 2
Recovered heat to Flue Gas Outlet



- ✓Dry stack can be used
- ✓Better SO2 dispersion to the atmosphere

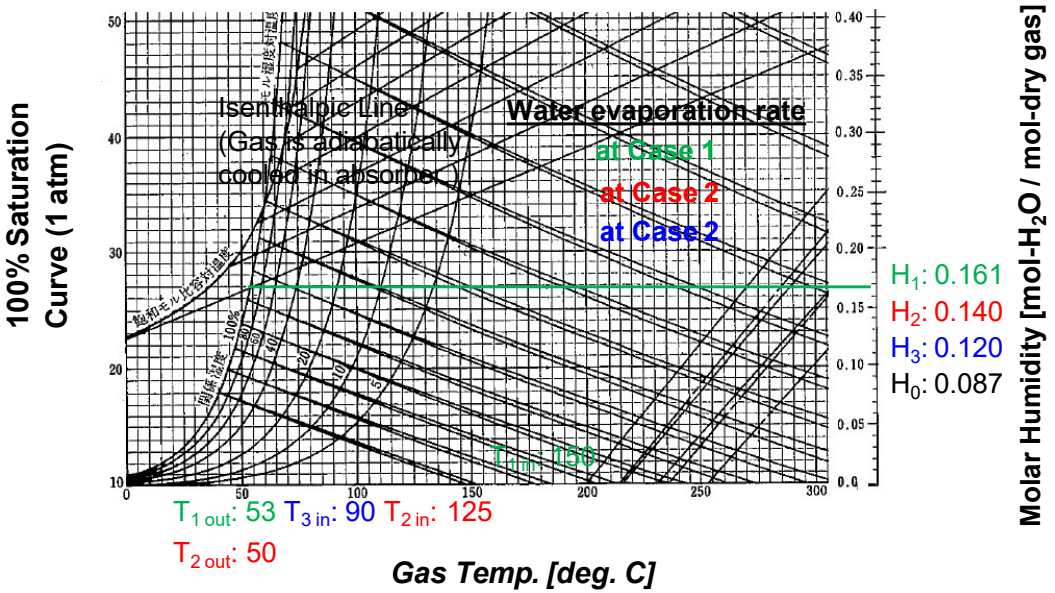
Case 1 - Recovered heat to Boiler Water



- ✓ Improvement of Plant Thermal Efficiency (Increased by 0.3 – 0.5%)
- ✓ Low Particulate Matter/SO3 emission
- ✓ MHI has got a patent of this system (Patent application number 4959156)

Case 1 - Recovered heat to Boiler Water

Theoretical Water Evaporation Amount from Psychrometric Chart



H_0:Absorber inlet gas humidity
mol-H_2O / mol-dry gas
$H_1/H_2/H_3$: *Absorber outlet gas humidity [mol-H_2O / mol-dry gas]*

Evaporated water amount
Dry flue gas flow rate x (H –H) [m3N/h

Calculated in 600 MW class coal fired power plant @FGD inlet condition

- **Gas flow rate: 1,950,000 Nm³/h wet**
- **Gas moisture content : 8 vol.%**
- **SO2 conc.: 2,165 / 82 mg/Nm³ dry**

Approximately 50% Saving of Water consumption in FGD by reducing Gas temperature to 90 Deg C			
▪ Gas Temp. at APH Outlet	150 Deg C	150 Deg C	150 Deg C
• FGD Inlet	150 Deg C	125 Deg C	90 Deg C
• Water consumption in whole process	123 tph (Base)	93 tph (75 %)	64 tph (52%)

Reference Plant

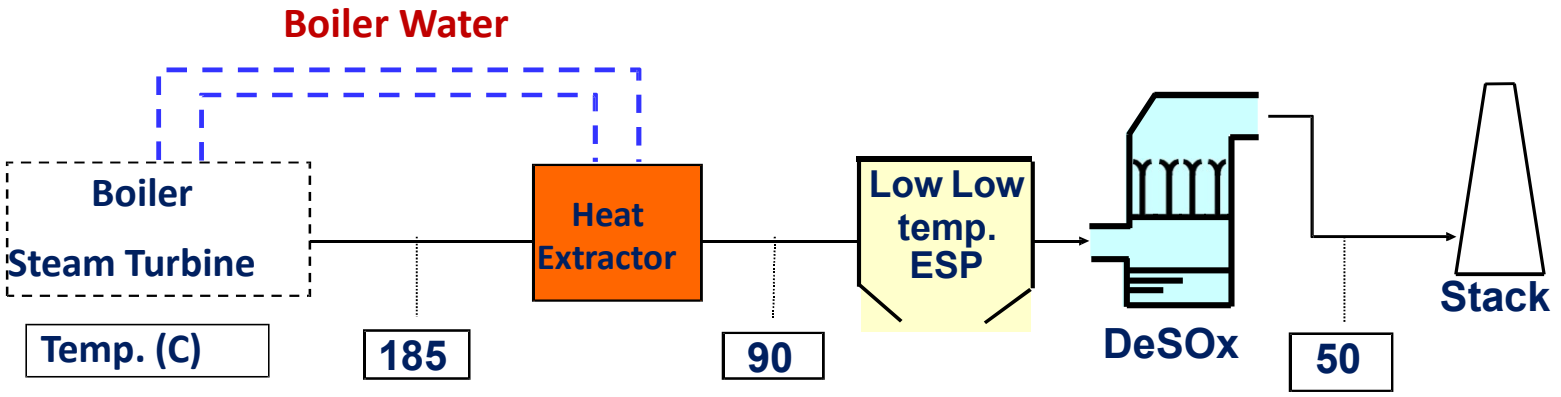
(Plant Specification)

- Plant Name : Kashima South Joint Power
- Capacity : 140MW
- Fuel : Heavy Oil
- Flue gas : 432,000m^{3}N/h

(Fruitful results)

✓ Approx.3% saving of fuel consumption by improving plant thermal efficiency

✓ Approx. 3.5 M USD saving a year



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ESP
(Electrostatic Precipitators)

Mitsubishi Heavy Industries, Ltd.

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Particulate Removal Technologies

- Electrostatic Precipitator
- Fabric Filters
- Combination of ESP + Fabric Filters

Retrofit options

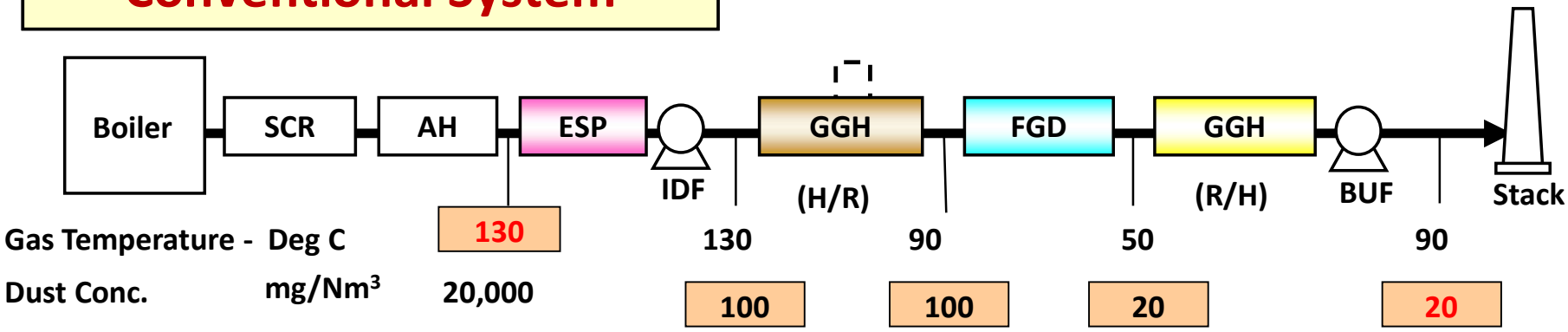
- Adding fields in series or in parallel
- Rebuilding existing precipitator with taller CE system
- Installing fabric filters
- Flue gas conditioning (Ammonia injection, SO3 conditioning and water fogging)

State of Art Technology by MHI

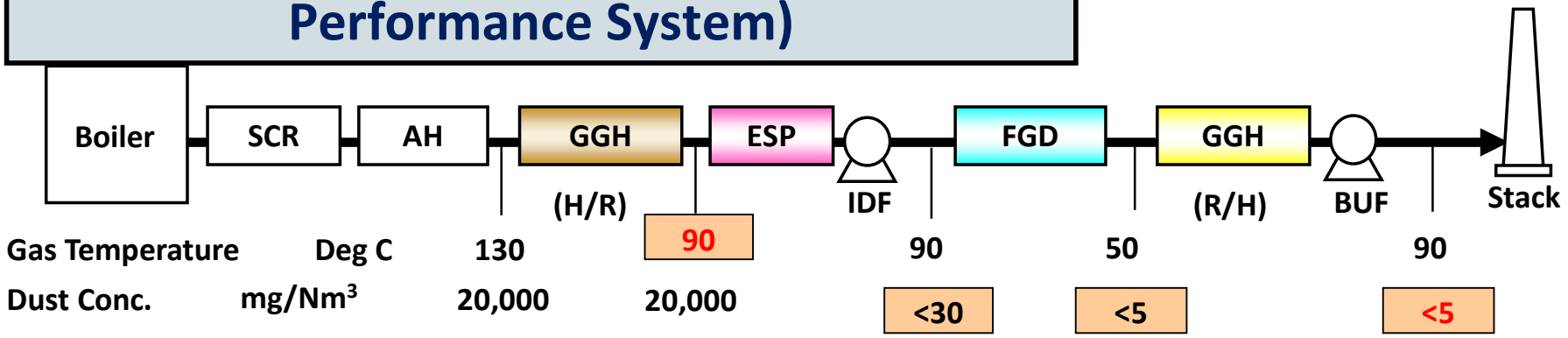
- Low-Low Temperature High Performance ESP system
- Moving Electrode Electrostatic Precipitator (MEEP)

Low-Low Temperature High Performance ESP

Conventional System



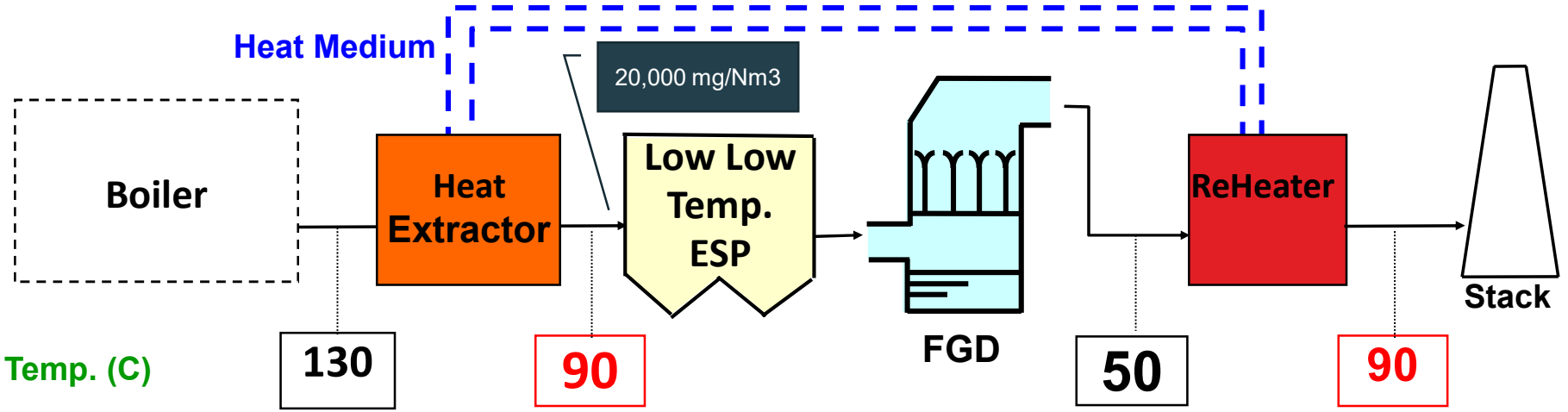
Low-Low Temp. ESP System (High-Performance System)



SCR : Selective Catalytic Reduction A/H: Air Heater GGH: Gas-Gas Heat Exchanger
DESP: Dry Electrostatic Precipitator FGD: Flue Gas Desulfurization

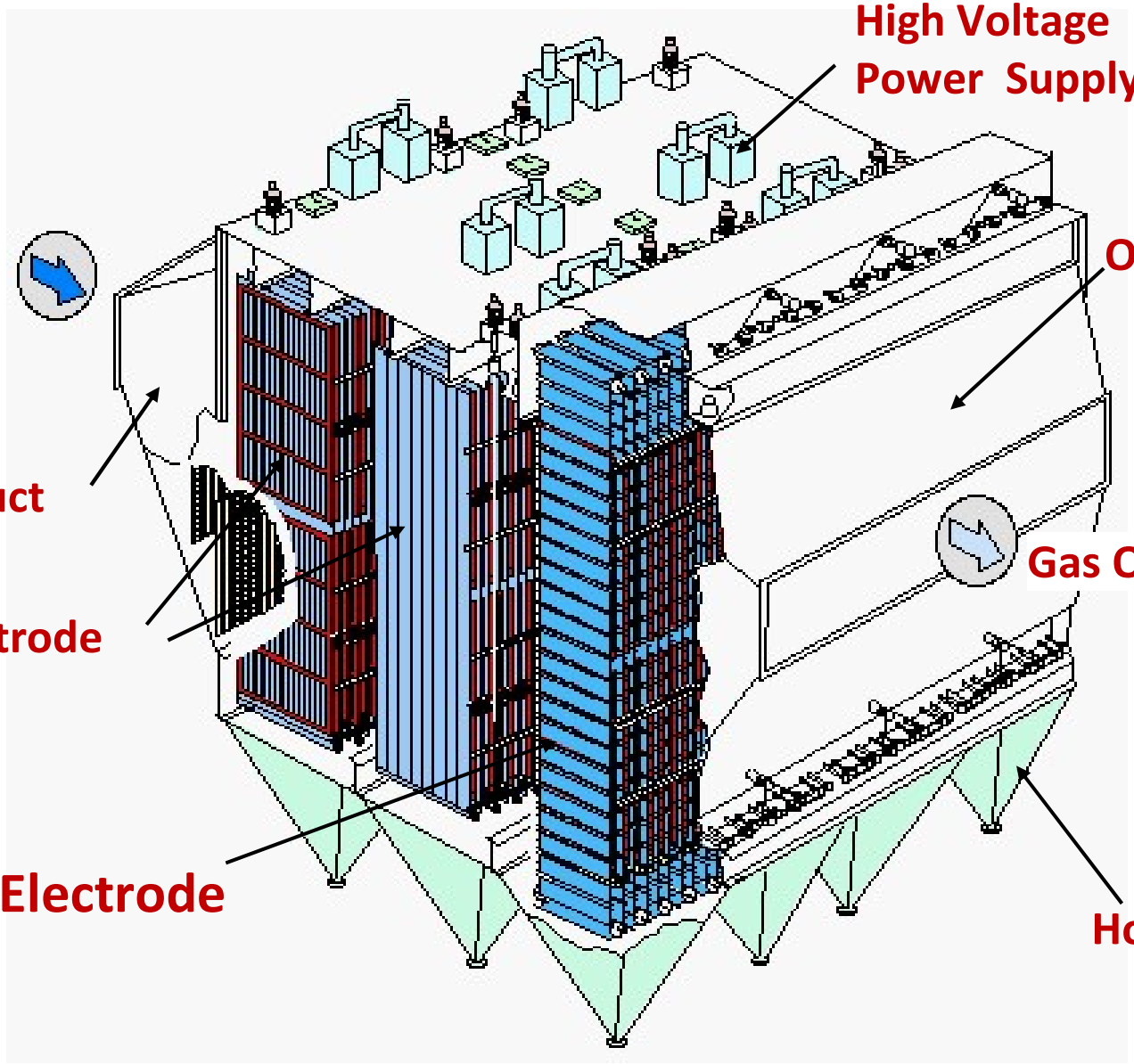
Advantage of Low-Low Temperature ESP

Gaseous SO3	10 PPM	< 10 ppm
Particulate Matter	20,0000 mg/Nm3	≤ 5 mg/Nm3

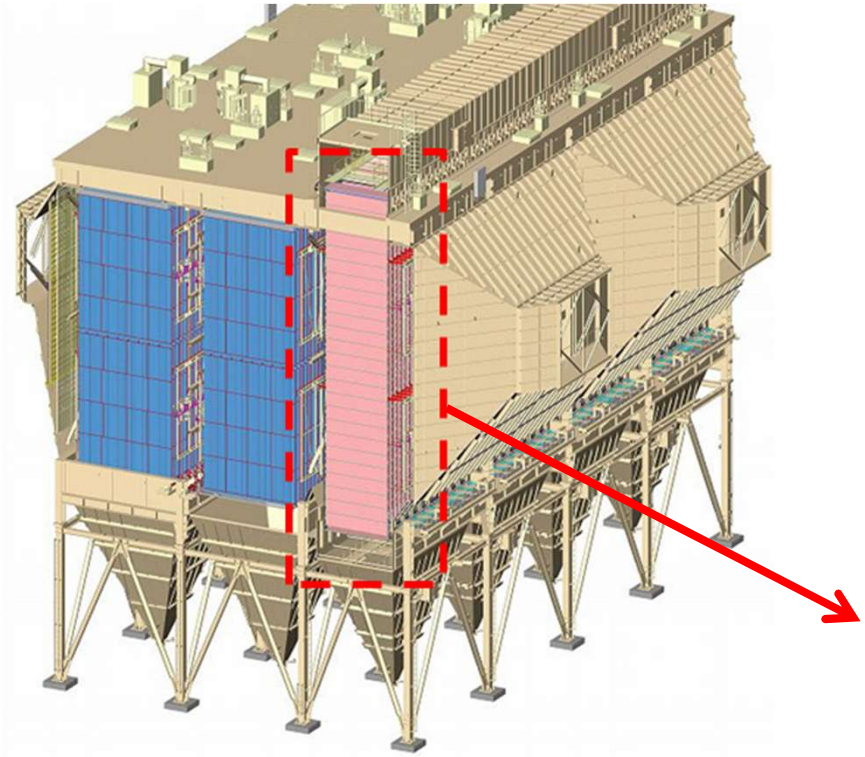


- SO_3 removal : SO_3 gas is condensed on fly ash
- Lower gas flow on account of reduced gas temperature and high performance
- Ash resistivity reduced approximately 100 times
- Lesser foot print (20 – 30%)
- Opacity reduction : No plume caused by SO_3 mist at stack
- Reduced stack height
- With integration of ESP+FGD, emission less than 5 mg/Nm3 can be achieved

Moving Electrode Electro Static Precipitator (MEEP)



Moving Electrode Electrostatic Precipitator (MEEP)



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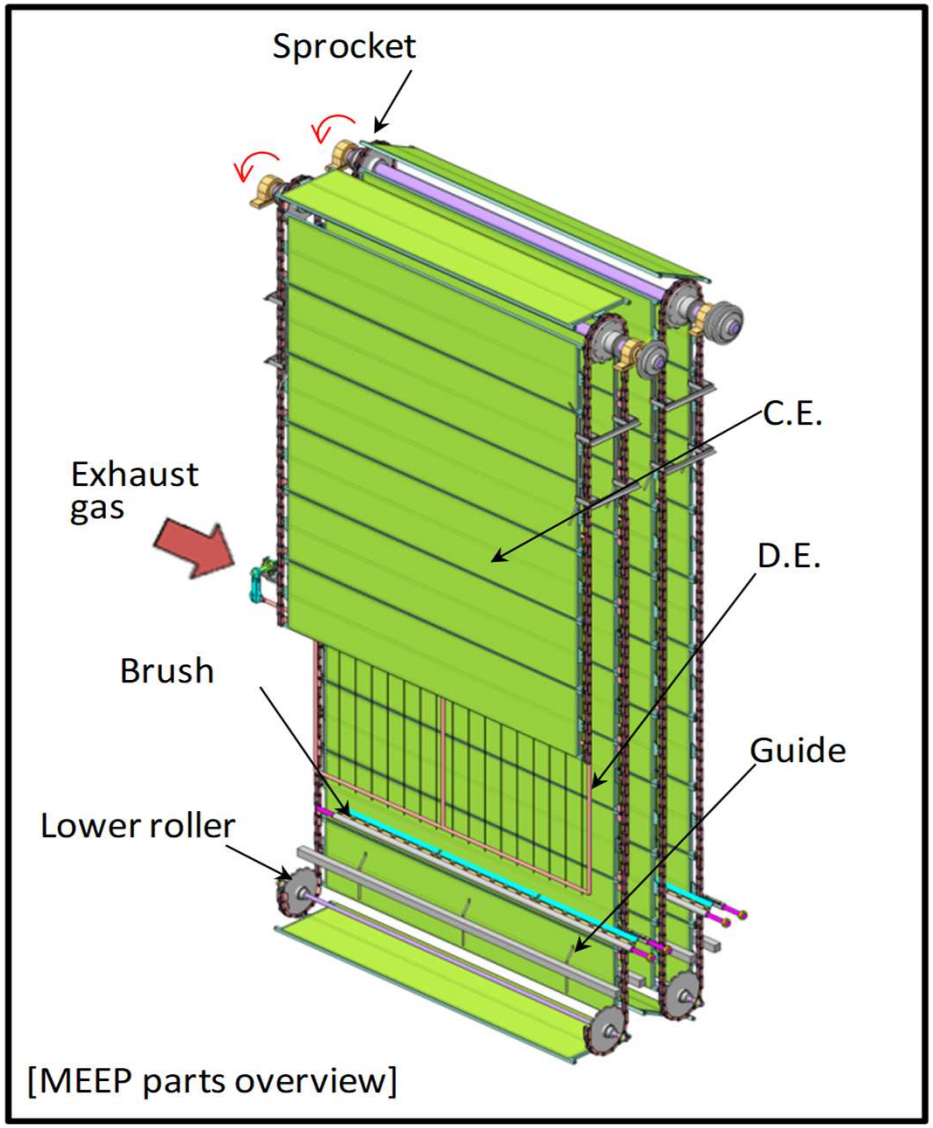
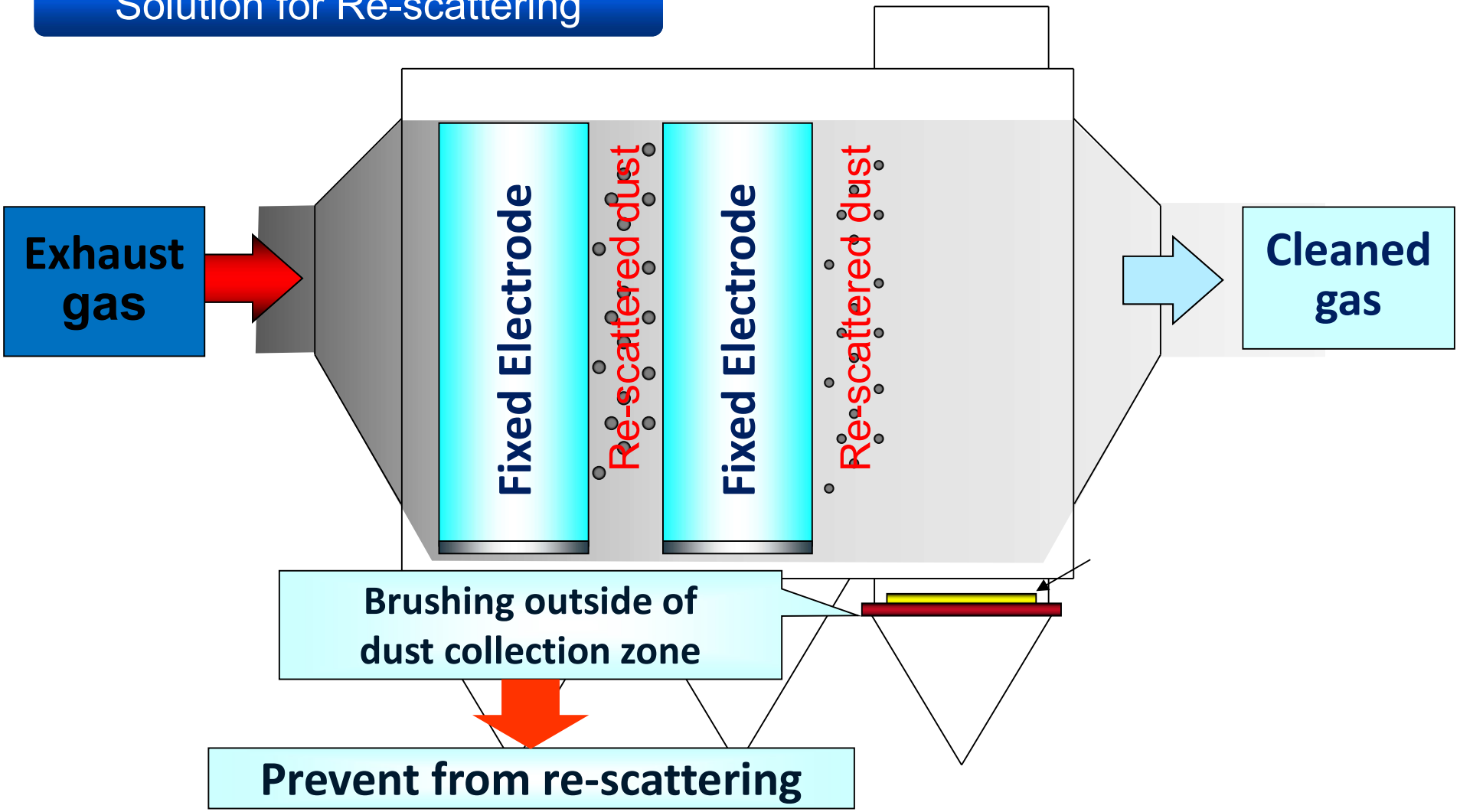


[MEEP parts overview]

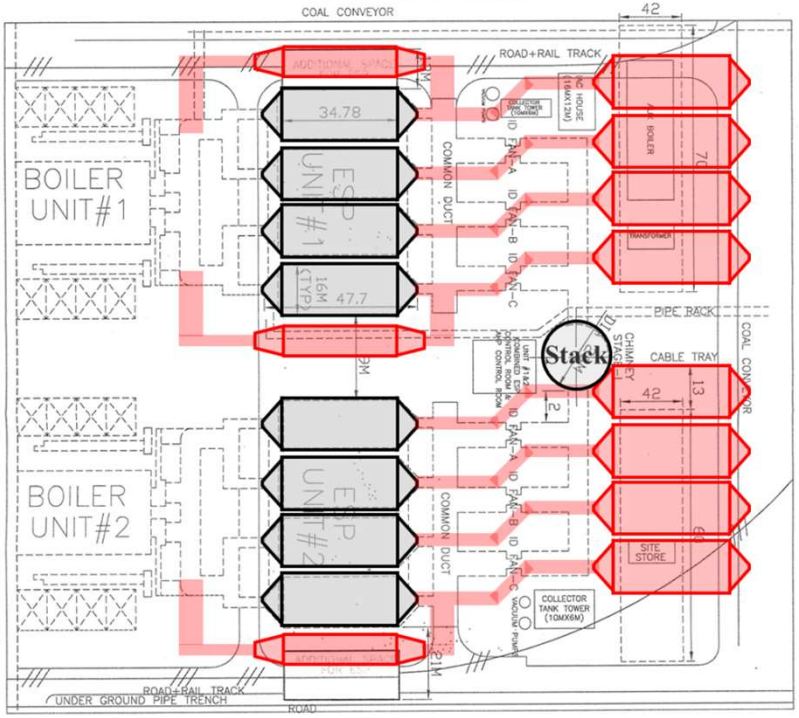
Application of MEEP Technology

Solution for Re-scattering



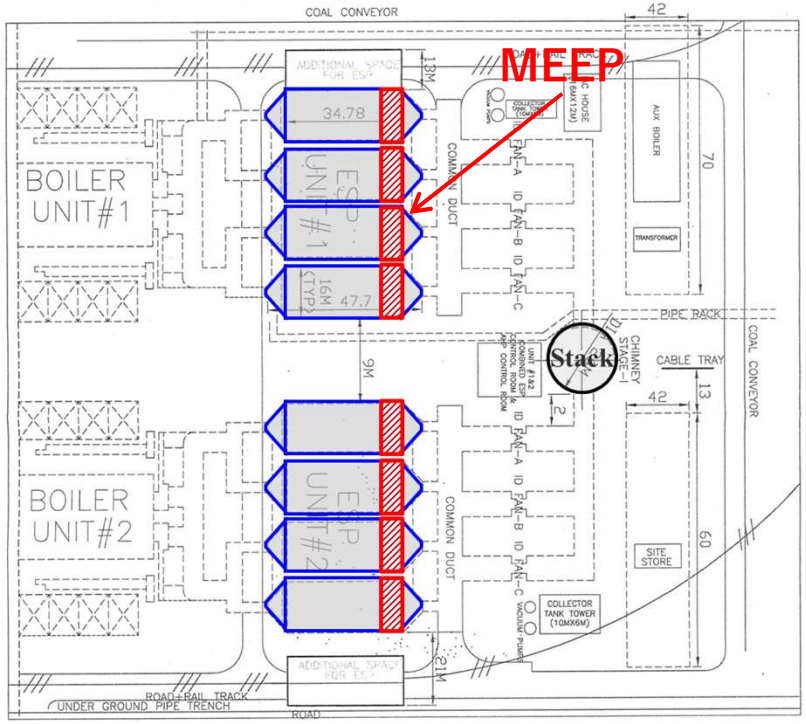
MHI AQCS: Product Portfolio

Conventional Technology demands more space to improve dust removal efficiency……



MEEP requires no additional space –

can be installed in the original ESP itself

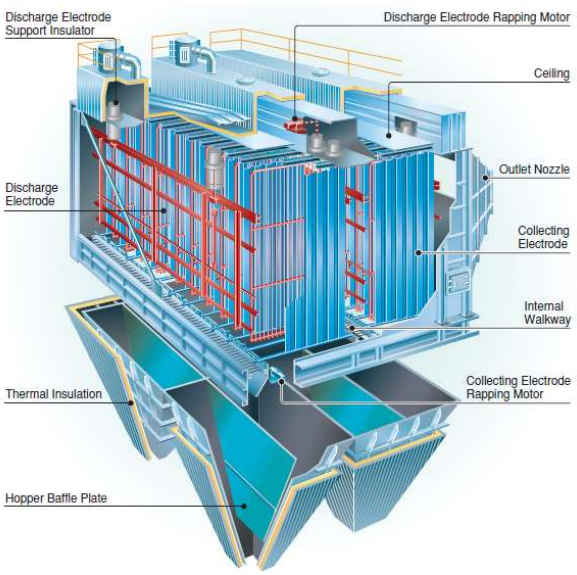


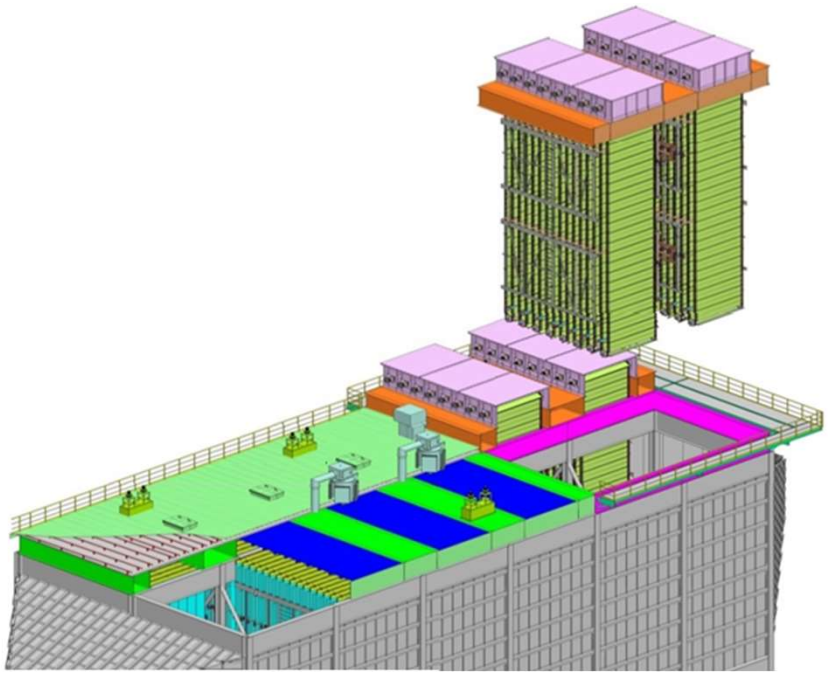
MHI AQCS: Product Portfolio

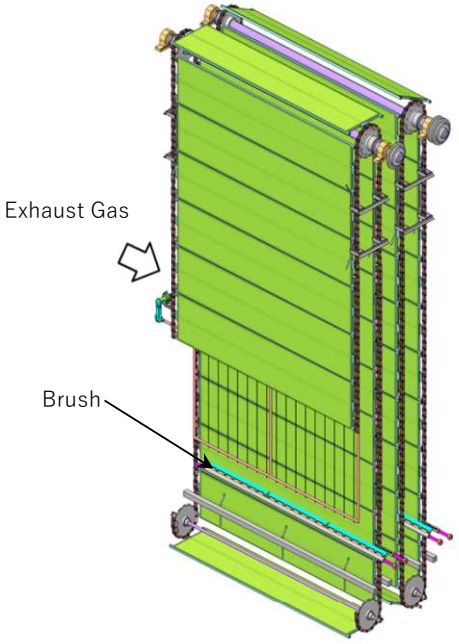
- **ESP performance upgrade will be achieved by replacing MEEP parts only.**
- **No replacement of fixed electrodes will be needed. It will be benefit for customers.**
- **While, the deep inspection before the work will be indispensable. The conditions of existing fixed electrodes and structure of existing ESP should be inspected.**

MEEP Supply Records

Application	Number
Coal Fired boiler	88
Sinter	10
Others	13
Total	111







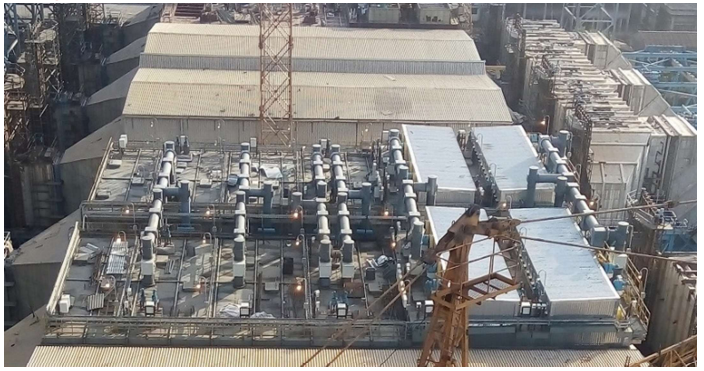
MEEP Advantage in maintaining Layout

Applied for Indian high ash coal

NTPC Rihand 2x500 MW – ESP R&M

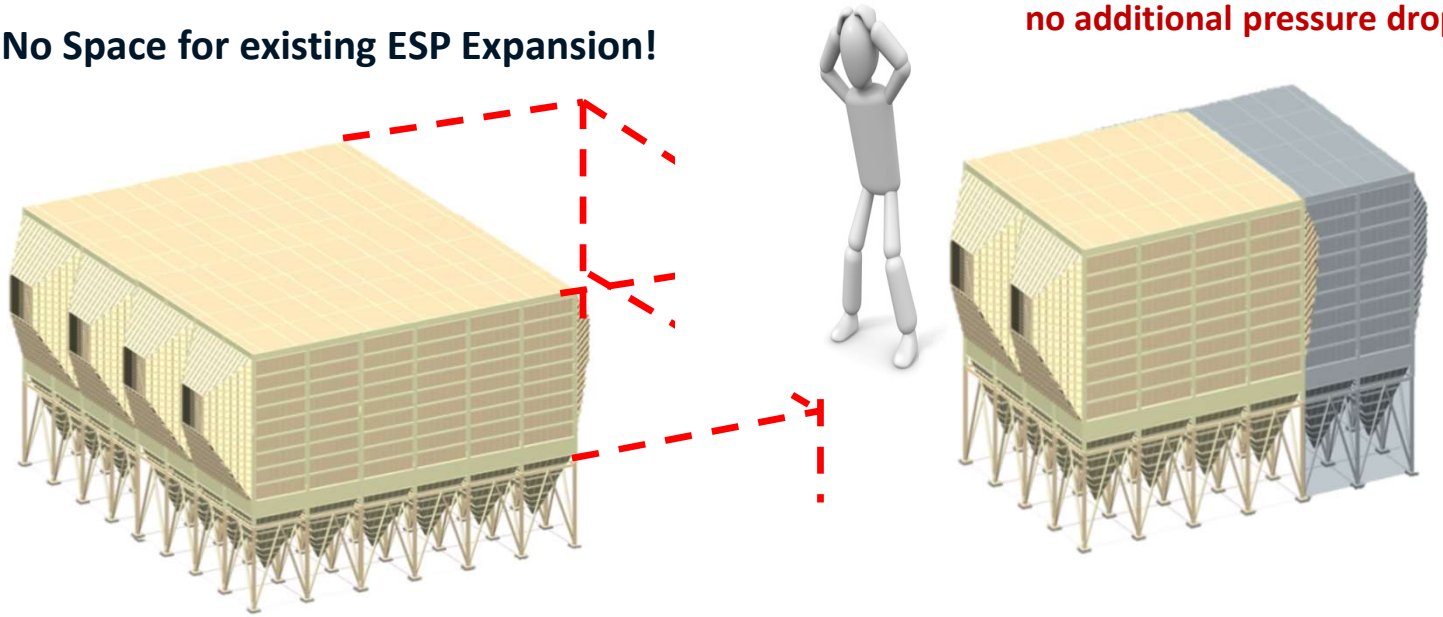
- **Upgrading by Moving Electrode (MEEP)**
- **Project commissioned in 2016, and under operation.**
- **Reducing dust emission from 500 to 50 mg/Nm^3**

Newly Installed MEEP at Rihand Power Station

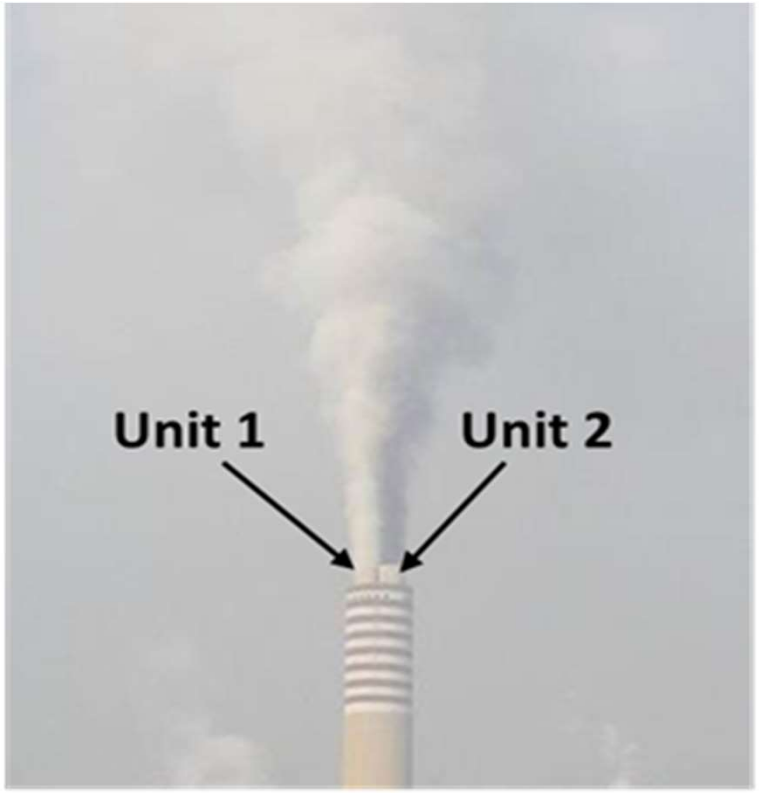


- **By MHI MEEP technology the collection efficiency increased within the original space!**
- **No Civil works, additional AHS, Control room space and no additional pressure drop**

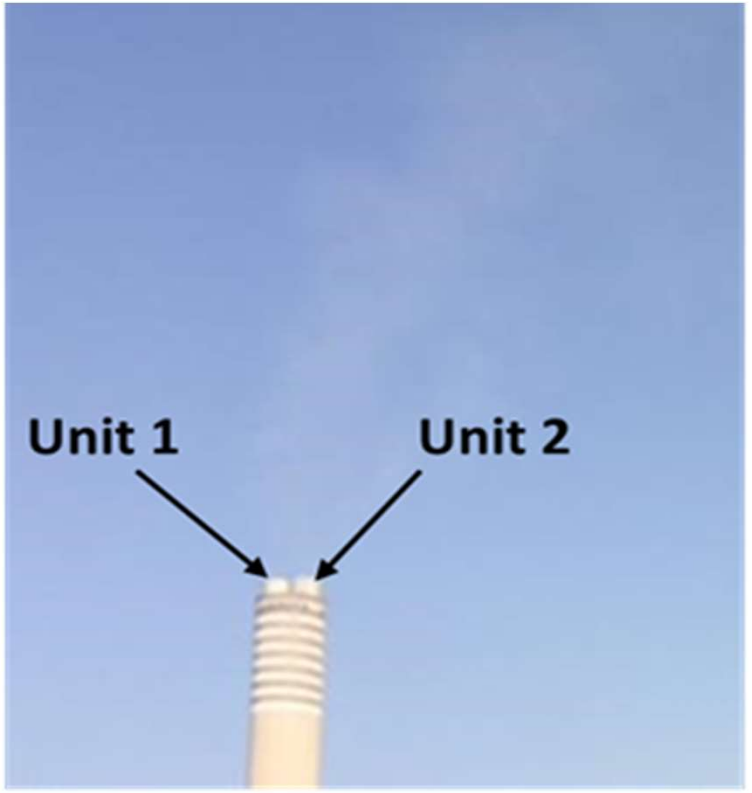
No Space for existing ESP Expansion!



Typical ESP Performance after MEEP installation



Before modification
(500-600mg/m^{3}N)

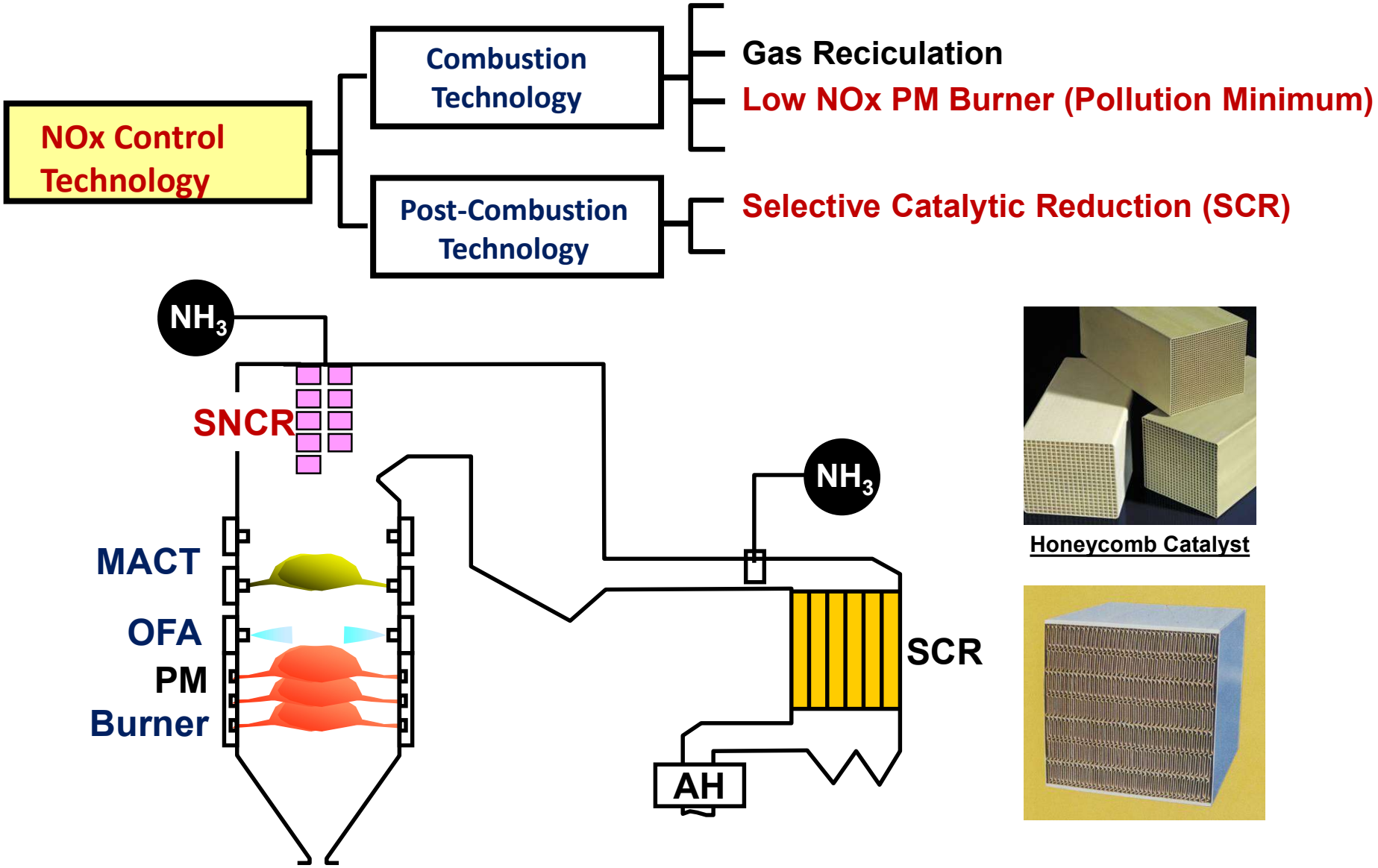


After modification
(≦50mg/m^{3}N)

Selective Catalytic Reactor (SCR)

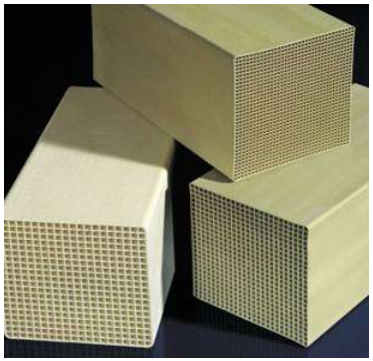
Mitsubishi Heavy Industries, Ltd.

NOx Control Technologies

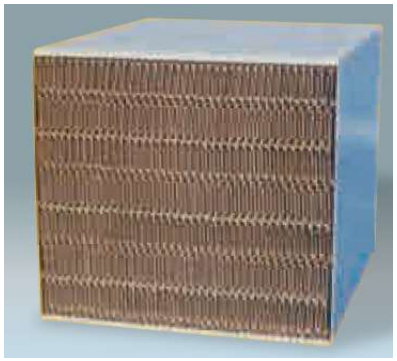


Honeycomb Catalyst

Types of SCR Catalysts



Honeycomb / Plate cover all applications.

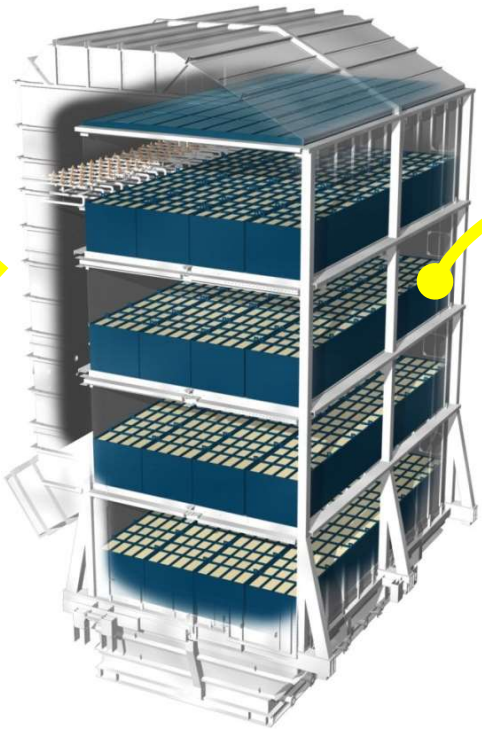


Honeycomb Catalyst | **Plate Catalyst**

Coal	Low Dust	High Dust
Gas	High DeNOx	Low DeNOx
Oil	High DeNOx, Less SO_2 Oxidation	Low DeNOx

Best Selection of Catalyst provides benefit on Plant Operation and Maintenance Costs.

SCR System - What MHI Offers



SCR System

or

Plate Catalyst

SCR Performance

NOx removal efficiency > 90% can be achieved.

MHI AQCS: Product Portfolio

Shijingshan Power Plant #1-4
Beijing Jingneng Thermal Power Co., Ltd.

Location	Beijing, China
Boiler Output	200MW x 4
Fuel	Coal
Gas flow rate	773,395 m^3(Normal)/h
Flue gas temperature	335-390 ℃
Removal Eff.	83.3 %
Dust Leading	50 g/m^3(Normal)
COD	2007～2008
Note	High dust experience

MHI AQCS: Product Portfolio

Project Outline

Plant : Poland

Fuel : Coal

Plant Power : 2 x 220 MW

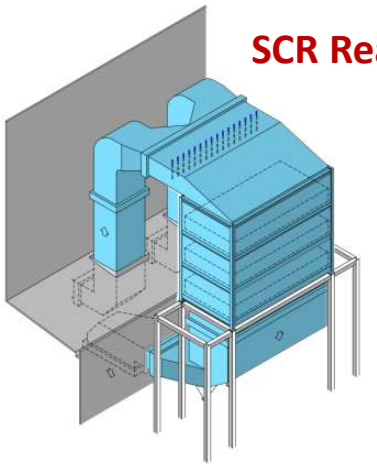
DeNOx Efficiency: 80 %

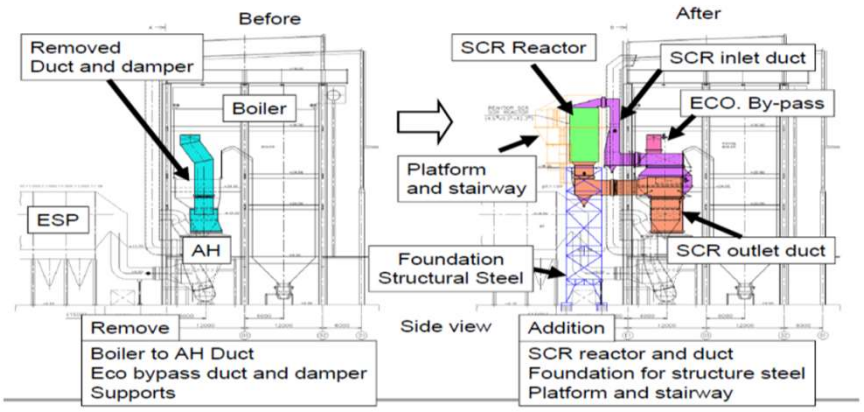
Slip NH_3: 2 ppm

Start up: U2 Oct. 2015
U1 Mar. 2016

After Installation

SCR Reactor





MHI AQCS: Product Portfolio

- **Total solution covering for environmental equipment**
- **Developed novel AQCS technologies to meet stringent emission levels demanded by any standards.**
- **Extensive experience for retrofitting AQCS to the existing plants within limited space and limited period.**
- **Experiences of various type of coal to design optimum catalyst to suit Indian high ash application.**
- **Understanding the importance of cost competitiveness, Mitsubishi Power would consider local supply chains for further cost reduction.**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