MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Mitsubishi Power
Air Quality Control System Technologies

Mitsubishi Power, Ltd.

MITSUBISHI POWER

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   (AQCS=Air quality control system)

2. SCR System (NOx Removal)
   (SCR=Selective Catalytic Reaction)

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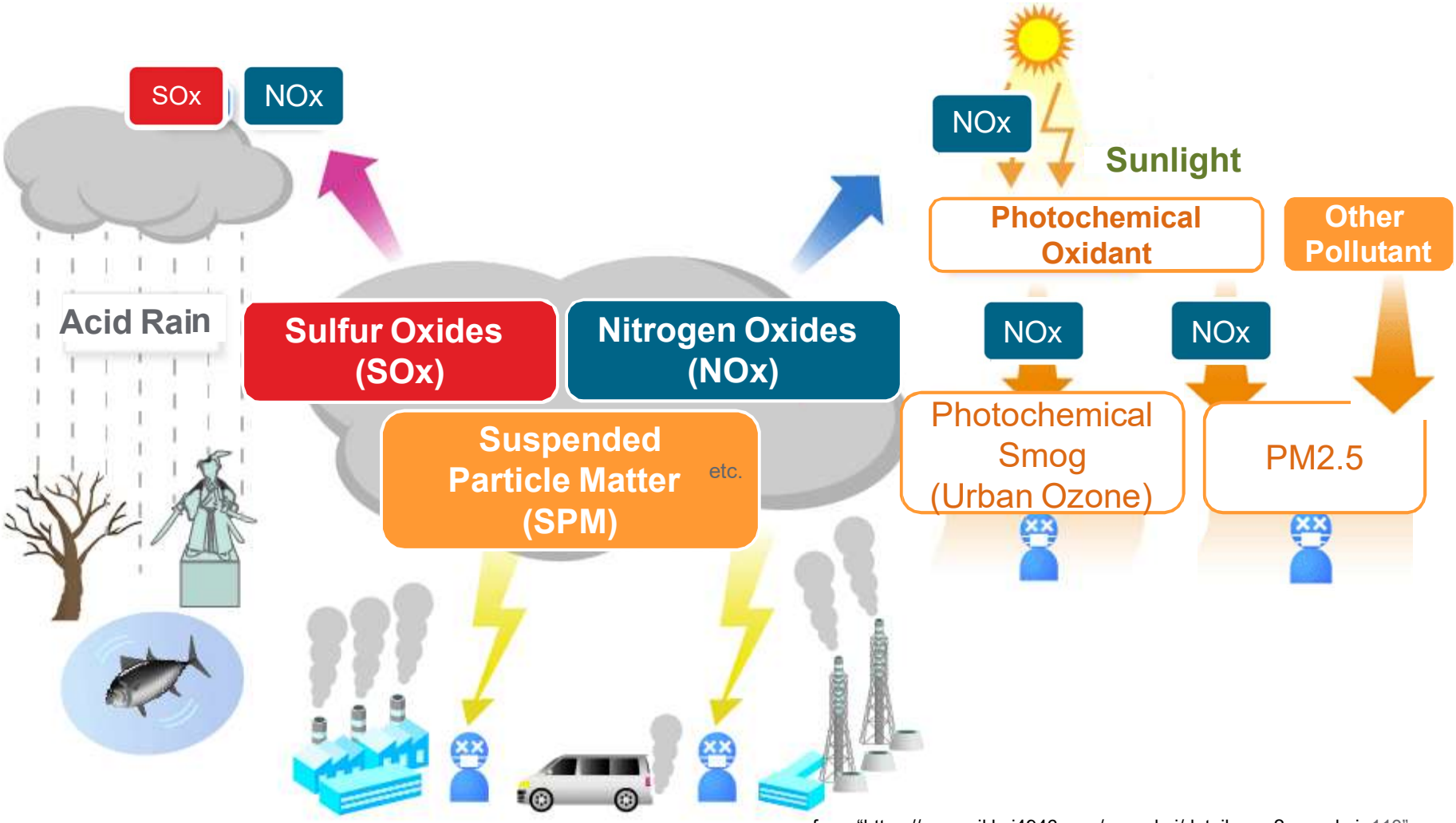
   (ESP=Electrostatic precipitator)

4. FGD System (SO2 Removal)
   (FGD= Flue Gas Desulfurization)

1. Mitsubishi Power AQCS System

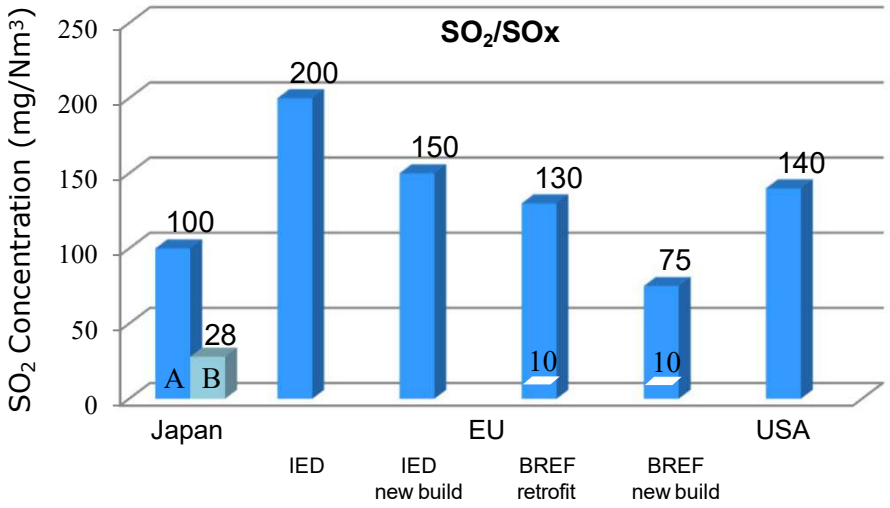
1.1 Mechanism of air pollution

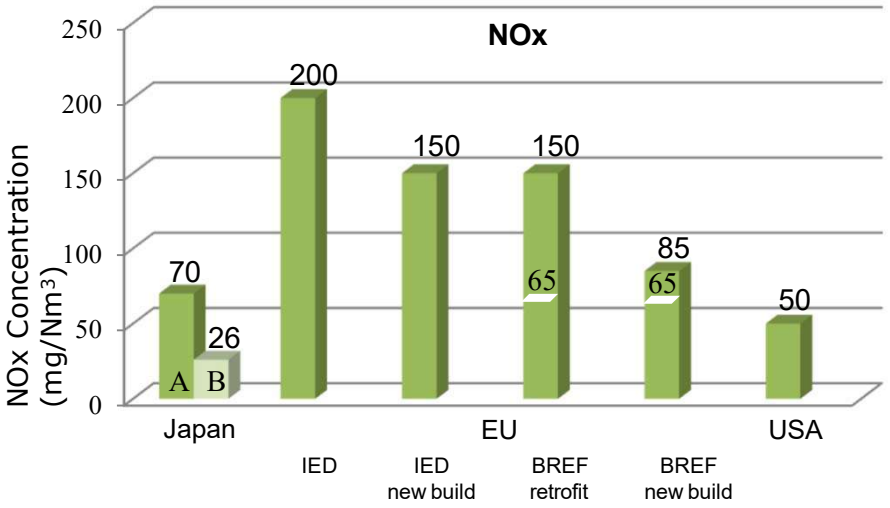


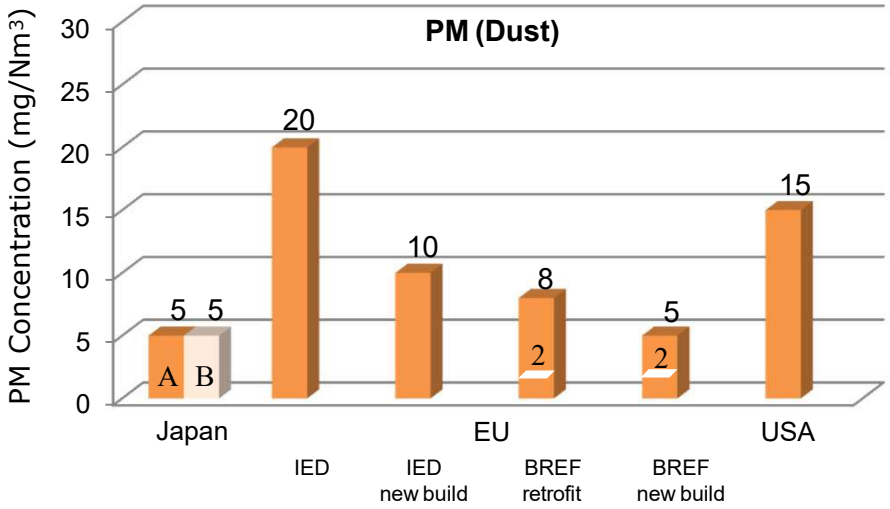
from "https://www.nikkei4946.com/zenzukai/detail.aspx?zenzukai=110"

Air pollutants such as SOx, NOx, PM, included in exhaust flue gas, **affect to air environment , nature, and human health**.

1.2 Typical Emission Regulation in the World







Mercury (Hg) Regulation/Standard	
Japan	8μg/Nm³ 10μg/Nm³ (existing)
BREF (EU)	4μg/Nm³ 7μg/Nm³ (existing)
MATS (USA)	0.013lb/GWh (existing) (5.9μg/kWh)

Japan: A = Plant emission level
B = Latest Case

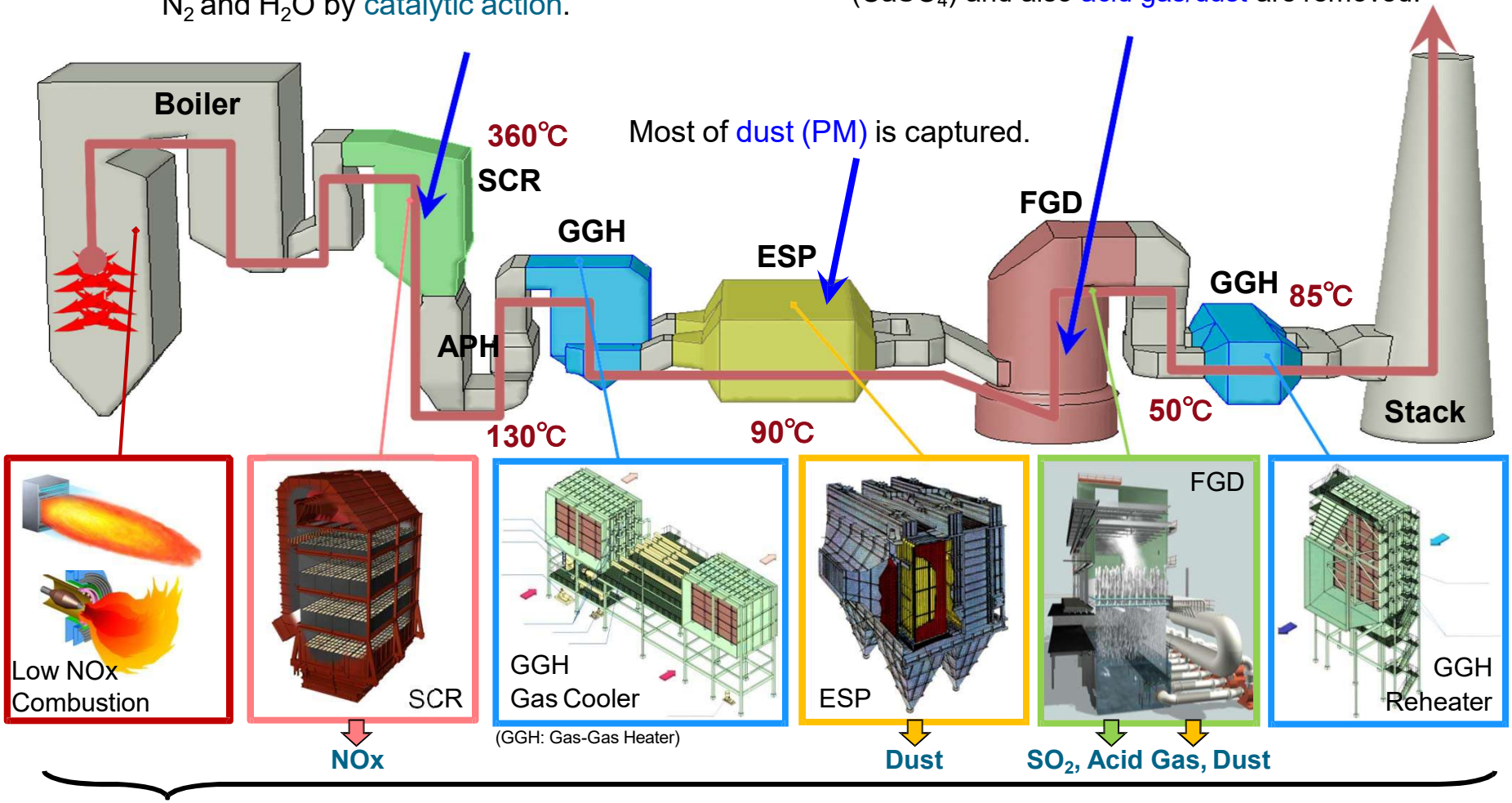
BREF = Best Available Reference Document (values: min. and max.)

IED = Industrial Emission Directive 2010/75/EU

1.3 Air Quality Control System (AQCS) for Thermal Power Plant

Harmful NOx is decomposed into harmless N_2 and H_2O by catalytic action.

Harmful SO_2 is recovered as harmless gypsum ($CaSO_4$) and also acid gas/dust are removed.

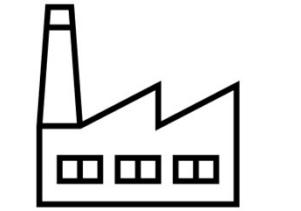


One-stop AQCS solution by Mitsubishi Power

World lowest level emission (SOx, NOx, dust) can be achieved by applying the integrated AQCS system.

High Efficiency AQCS is also vital for amin type Carbon Capture

CO2 capturing process flow



Coal fired plant

Flue gas (NOx, SOx, Dust, CO2)

Step 1: Pre-treatment of flue gas (by AQCS)

SCR → Dry ESP → FGD → WET ESP

NOx removal | Dust removal | SO2 removal | SO3 removal

Pre-treated flue gas（containing CO2）

The installation of AQCS is **IMPORTANT for future installation of CO2 Capturing.**

Step 2: CO2 Capturing process

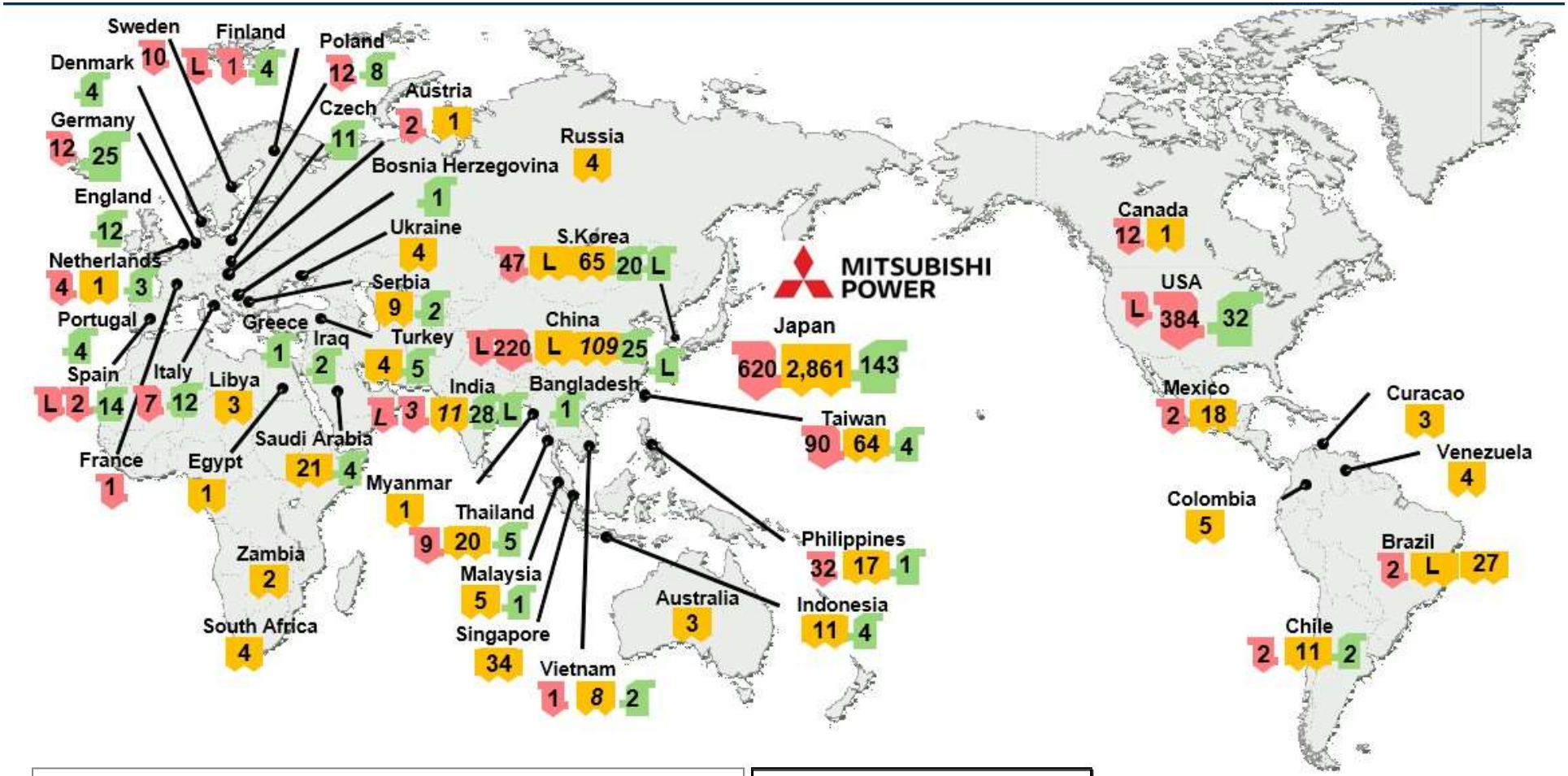
- Amine will be easily deteriorated with NOx, SOx, Dust.
- Important to clean flue gas in pre-treatment process,

Captured CO2

Step 3: CO2 storage/utilization

1.5 Mitsubishi Power AQCS Worldwide Experiences

Mitsubishi Power has delivered AQCS units all over the world



: SCR/Catalyst 1,475 Units (22 Countries)
: ESP 3,334 Units (31 Countries)
: FGD 380 Units (29 Countries)

Number : References
L : License

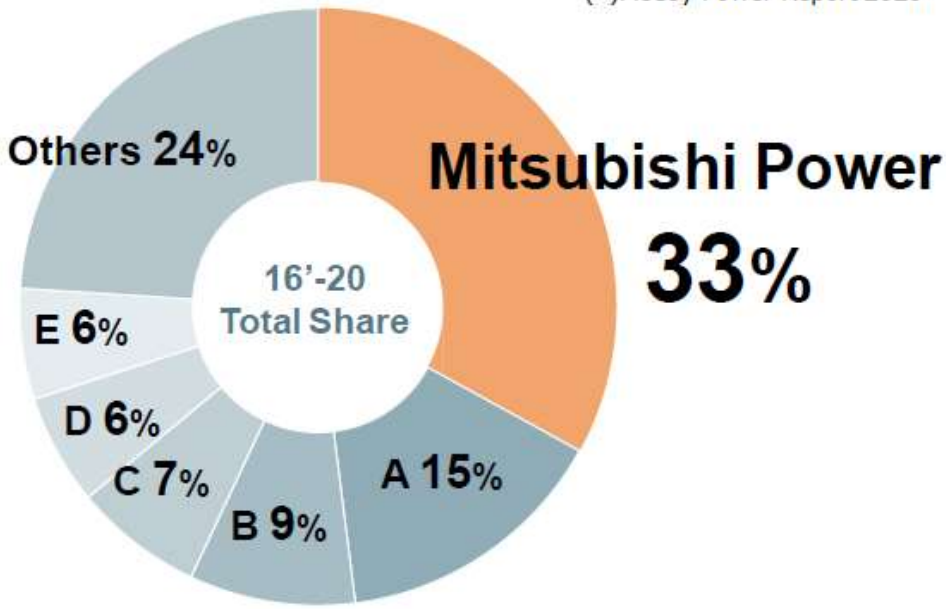
As of June 2020
Including under construction

No. 1 Global Market Share in Environmental Impact Mitigation Technology

Our world-leading technologies in Air pollutant reduction helps keeping the planet clean

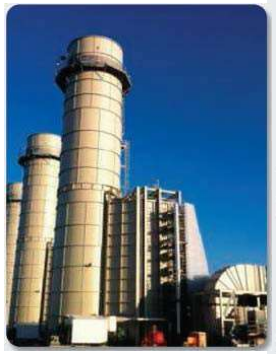
- 5 years cumulative data between 2016 to 2020
  Top share **33%**(*)
- Cumulative total plant output 47GW

(*)McCoy Power Report 2020

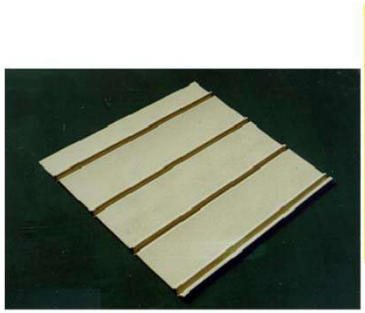


2. SCR System (NOx Removal)

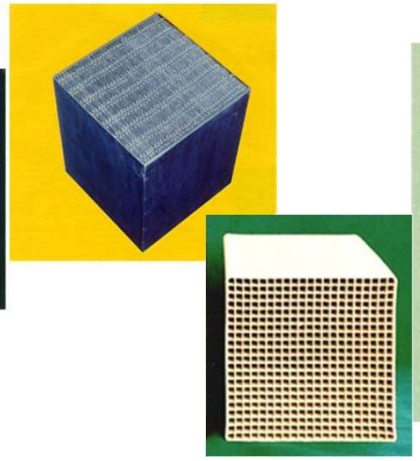
2.1 Selective Catalytic Reaction (SCR) System Application



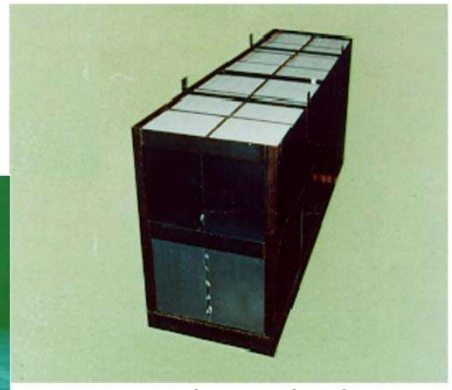
2.2 Mitsubishi Power SCR Features (DeNOx System)



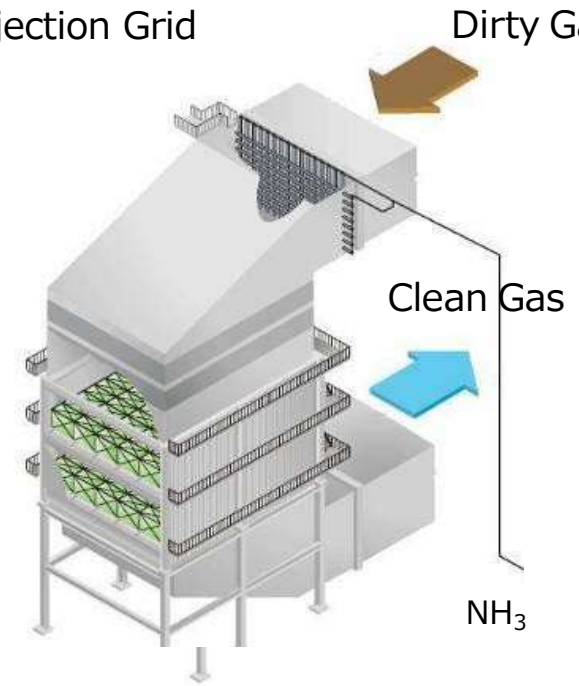
Catalyst Element (Plate Type)

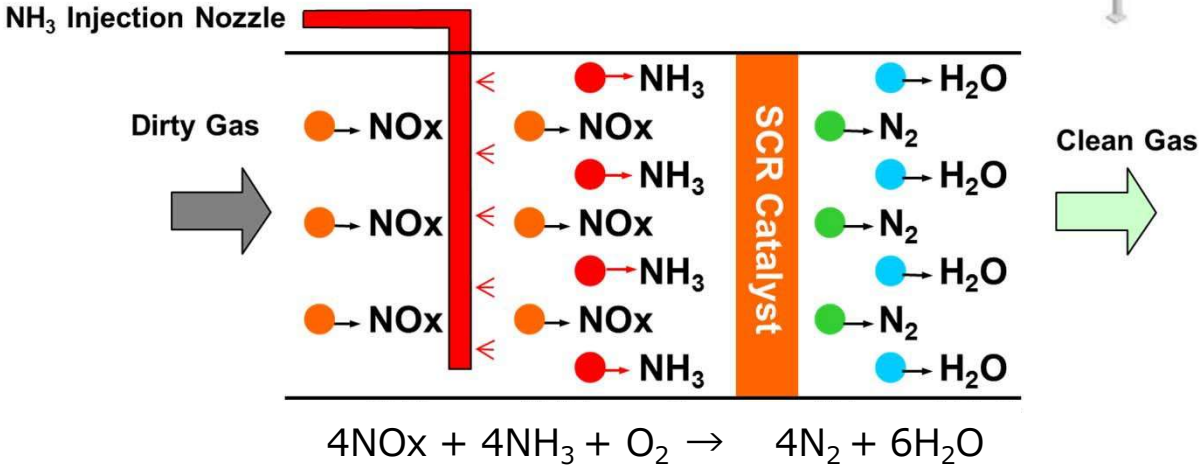


Catalyst Unit



Catalyst Block

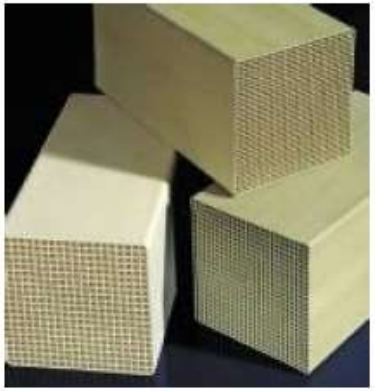




$4NOx + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

Optimum SCR system design with high performance & economical operation

2.3 Catalyst Comparison

	Honeycomb	Plate Catalyst
		
Coal	Low Dust	High Dust
Gas	High DeNOx	Low DeNOx
Oil	High DeNOx, Less SO_2 Oxidation	Low DeNOx

The ONLY SCR supplier who manufactures its own Catalyst
MPW Plate Type is the best suited for high ash content Coal

2.4 Design for High Ash Coal

No.	Country	Capacity	Dust conc. g/m3N	Operation
1	China	200MW x 4	46.6	2008
2	China	660MW x 2	41.0	2011
3	China	350MW x 2	43.6	2011
4	China	1000MWx2 +300MWx2	41.2	2012
5	China	600MW x 2	53.7	2012
6	China	300MW x 5	68.9	2012/2013
7	China	600MW x 2	55.0	2013
8	China	250MWx2 +200MWx3	57.5	2013
9	China	350MW x 2	64.3	2013
10	China	350MW x 1	48.2	2013
11	China	300MW x 2	46.7	2013
12	China	600MW x 4	50.0	2013/2014
13	China	220 t/h x4	43.5	2013-2014
14	China	300MW x 2	40.0	2013
15	China	300MW x 1	50.6	2013
16	China	360MW x 4	53.8	2013
17	China	300MW x 1	40.0	2013
18	China	630MW x 1	41.0	2013
19	China	300MW x 1	48.2	2013
20	China	130MW x 1	41.4	2013

No.	Country	Capacity	Dust conc. g/m3N	Operation
21	China	630MW x 2	51.7	2013-14
22	China	220t/h x1	43.1	2013
23	China	260 t/h x2	40.0	2013
24	China	300MW x 1	58.7	2013
25	China	600MW x 1	57.3	2013
26	China	300MW x 2	60.0	2013-14
27	China	600MW x 1	41.4	2014
28	China	660MW x 1	50.9	2014
29	China	360MW x 2	53.3	2014
30	China	300MW x 2	47.9	2014
31	China	12.5MW x 2	53.5	2014
32	China	1000MW x 1	48.5	2014
33	China	300MW x 2	70.8	2014
34	China	220MW x 2	56.5	2014
35	China	300MW x 1	48.2	2014
36	China	300MW x 1	58.7	2014
37	China	300MW x 1	52.6	2014
38	China	13.5MW x 2	52.9	2014、2015
39	China	13.5MW x 2	53.6	2014、2015

> 50g/m3N: 20 Projects

> 60g/m3N: 4 Projects

2.5 SCR Supply Reference (retrofit for existing plant)

Location: Europe

Fuel: Coal

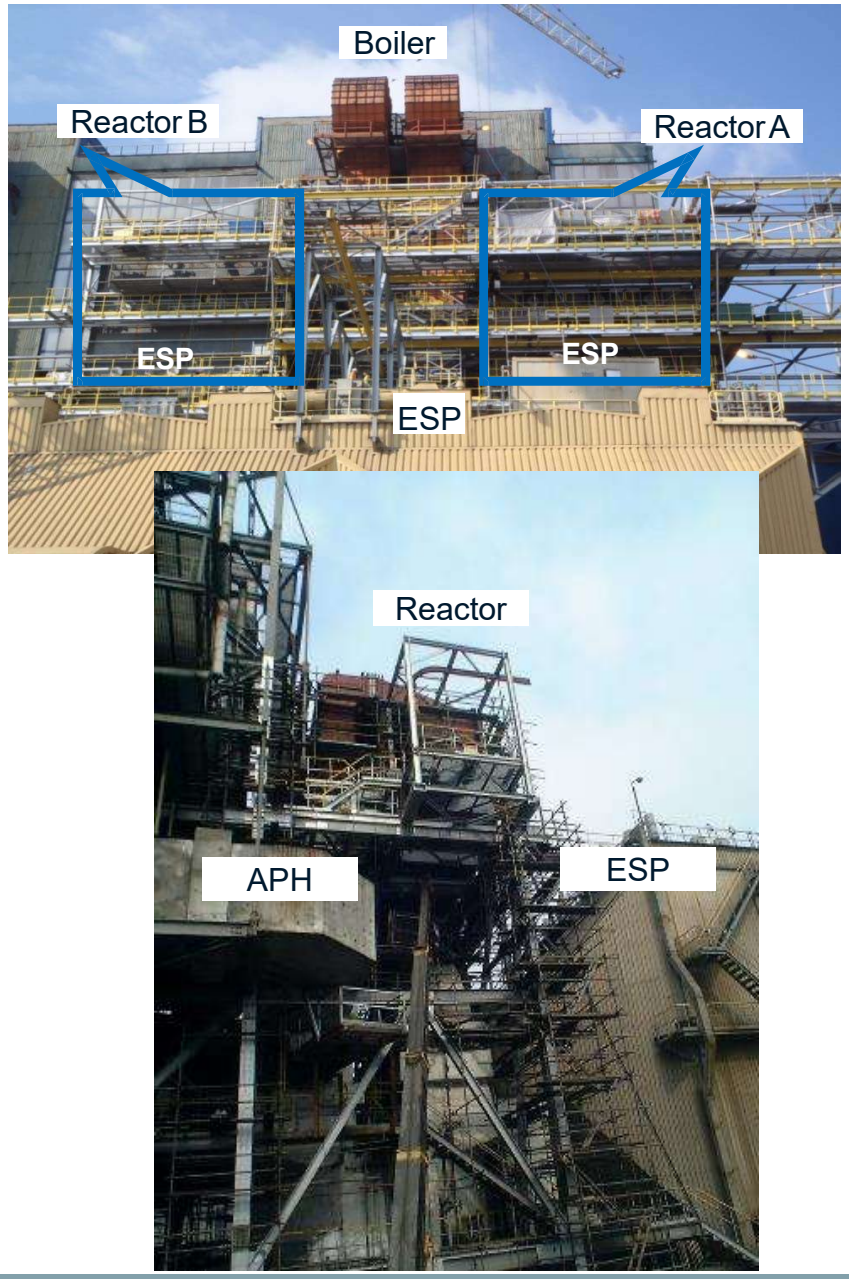
Capacity: 100MW x 4 (approx.)

Gas Flow Rate: 477,189 $Nm^3/h(w)$

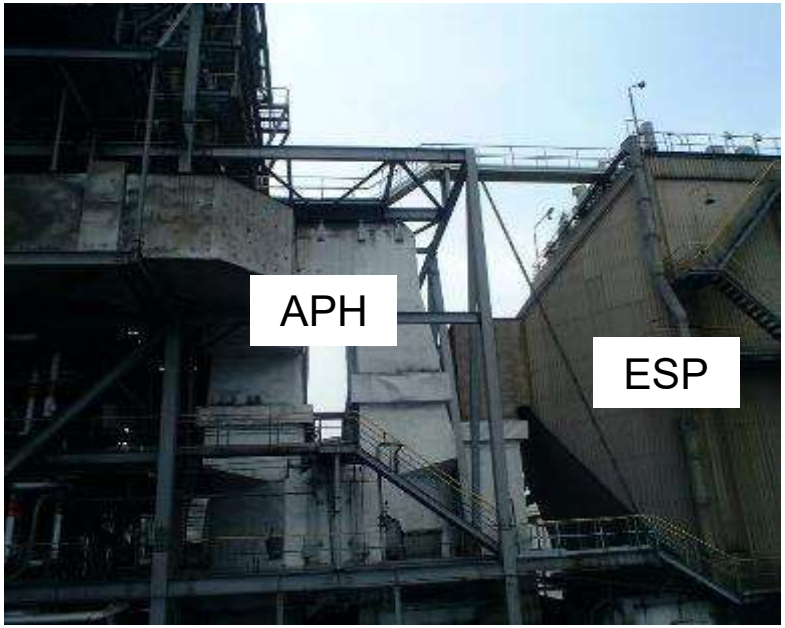
Inlet NOx Conc: 550 mg/Nm^3

DeNOx Efficiency: 67.3%

After Installation



Before Installation

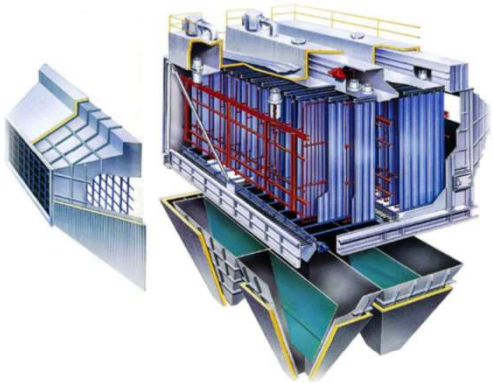


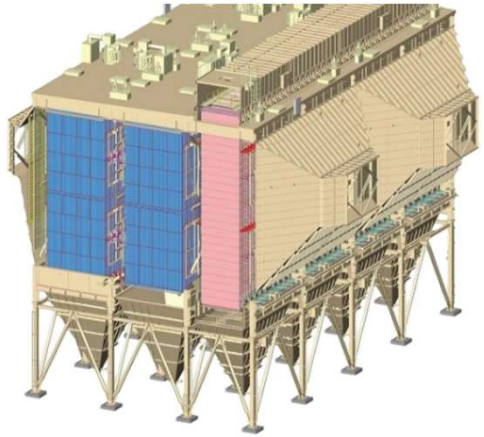
3. ESP System (PM Removal)

Dust Collecting System (DCS)

Electrostatic Precipitator (ESP)

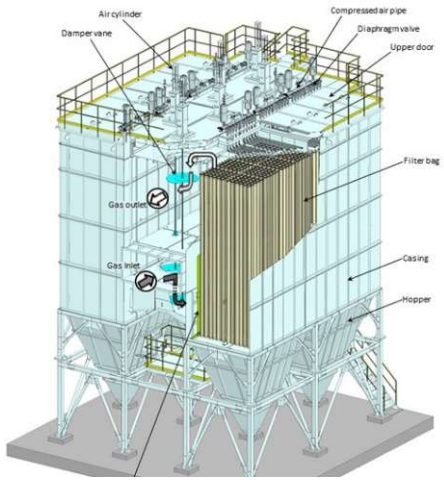
- Dry Type ESP
  - Fixed type ESP (Conventional Type)
  - ★MHI's UNIQUE TECHNLOGY
  - Moving Electrode Electrostatic Precipitator (MEEP)
- Wet Type ESP





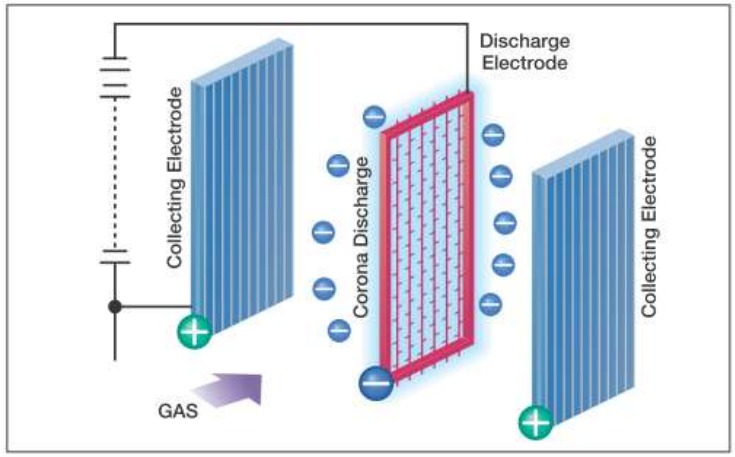
Fabric Filter (FF)

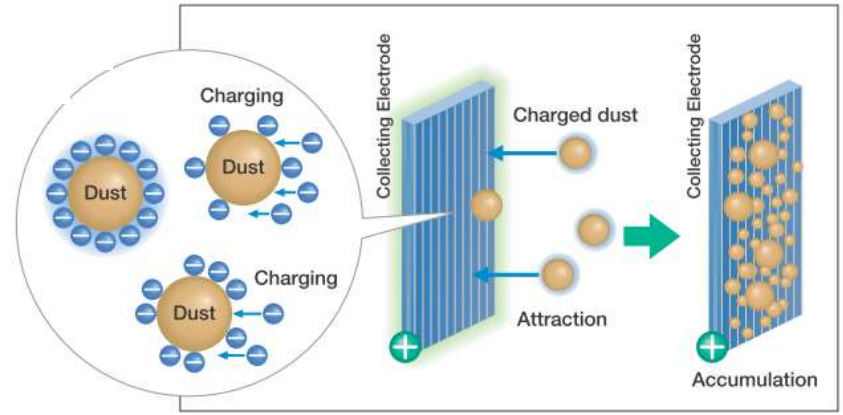
- Pulse Jet Type
- Reverse Type

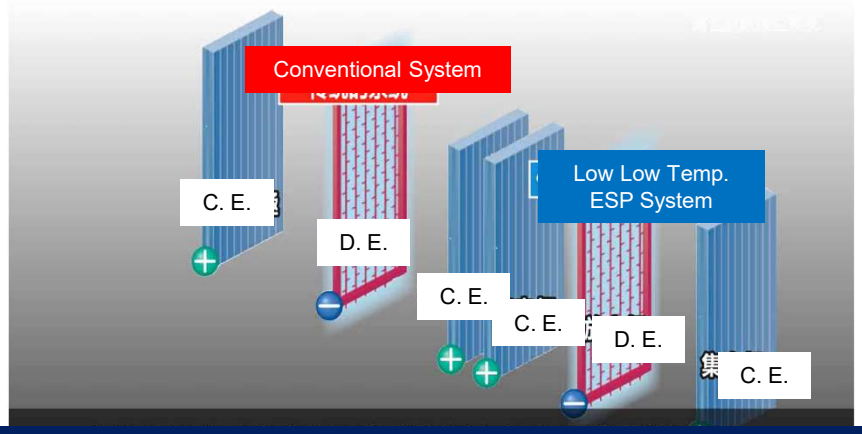


3.2 ESP Technology Principle

- Supplying high voltage between Collecting Electrode and Discharge Electrode generates a Corona Discharge that produces minus ion. The electrically charged dusts are attracted towards the Collecting Electrode by an electrical force.
- The accumulated dusts are discharged by rapping hammer/brushing (Dry ESP) or by flushing water (Wet ESP).

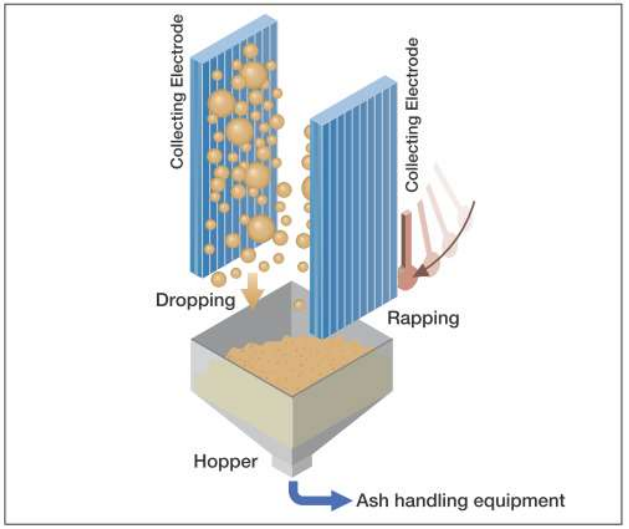




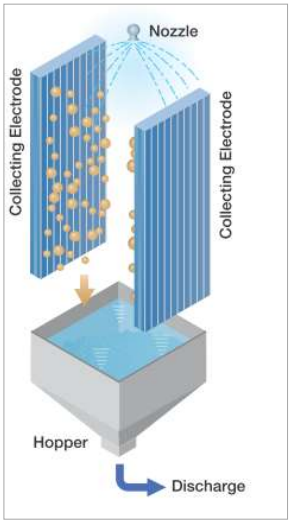


In case of LLT ESP system, gas temperature is reduced and dust resistivity is also reduced. As a result, ESP performance is much improved and become stable for almost all kinds of coals.

Dry ESP

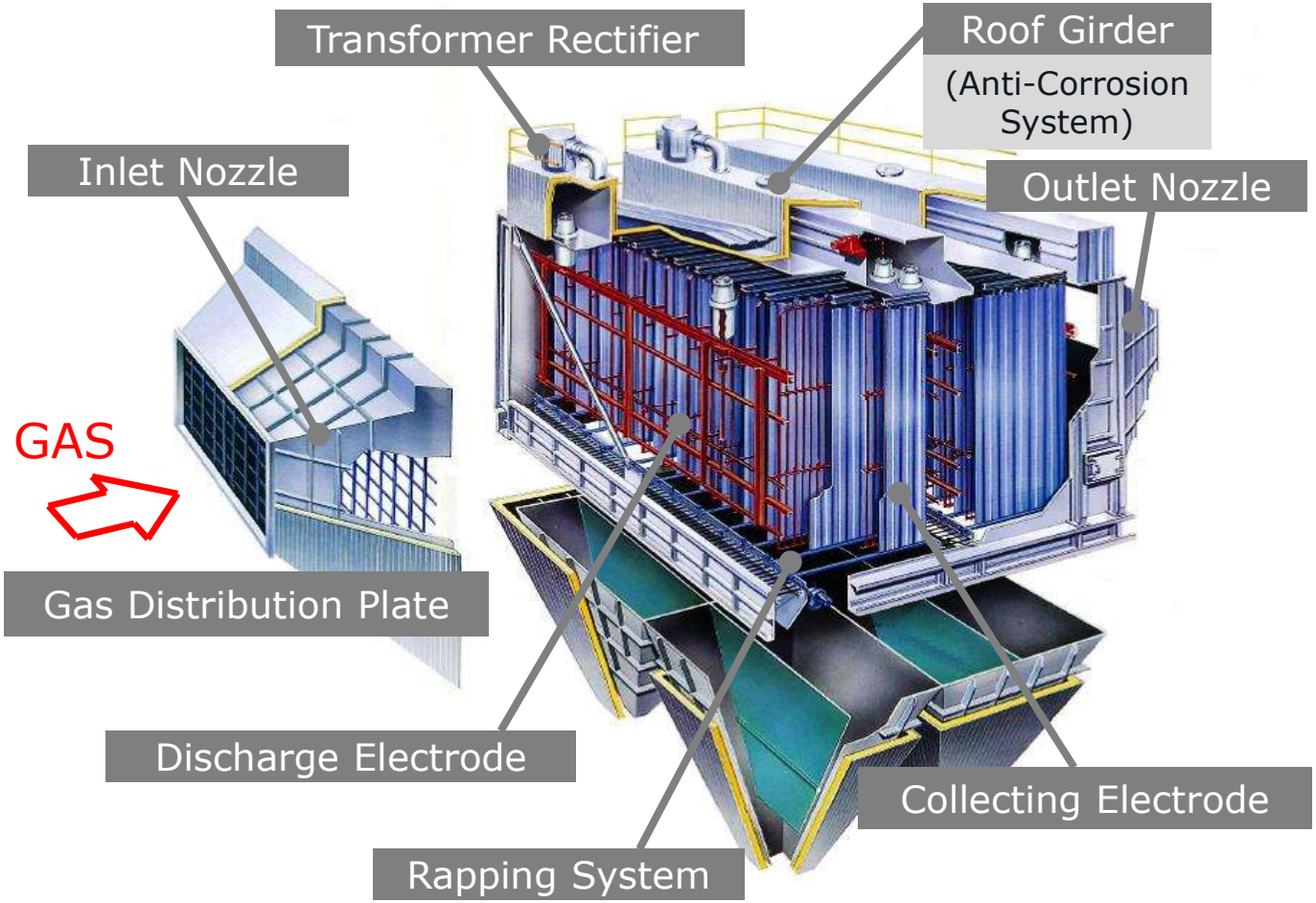


Wet ESP



3.3 Fixed type ESP (Conventional Type)

- Very limited moving parts (at least no high-speed moving parts) inside, then corrosion and erosion of inner part and casing are less
- Less consumable parts, less maintenance frequency, then easy to maintain

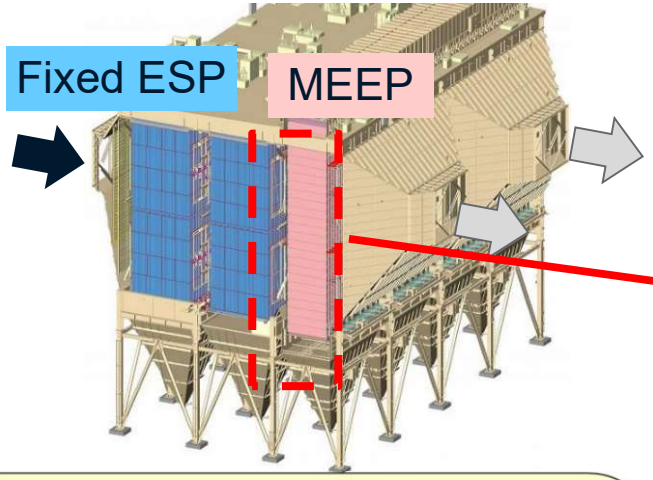


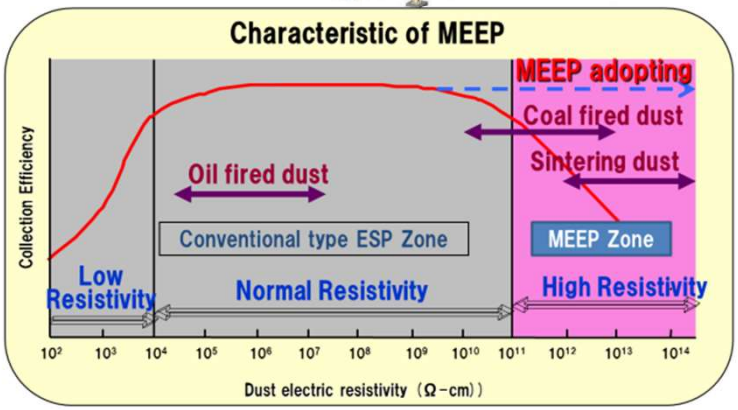
Structure

- Composed of parallel Collecting Electrode (CE) plates.
- Discharge Electrode are arranged between each CEs
- Transformer Rectifier is installed at the top of ESP.
- Special energizing system is applied

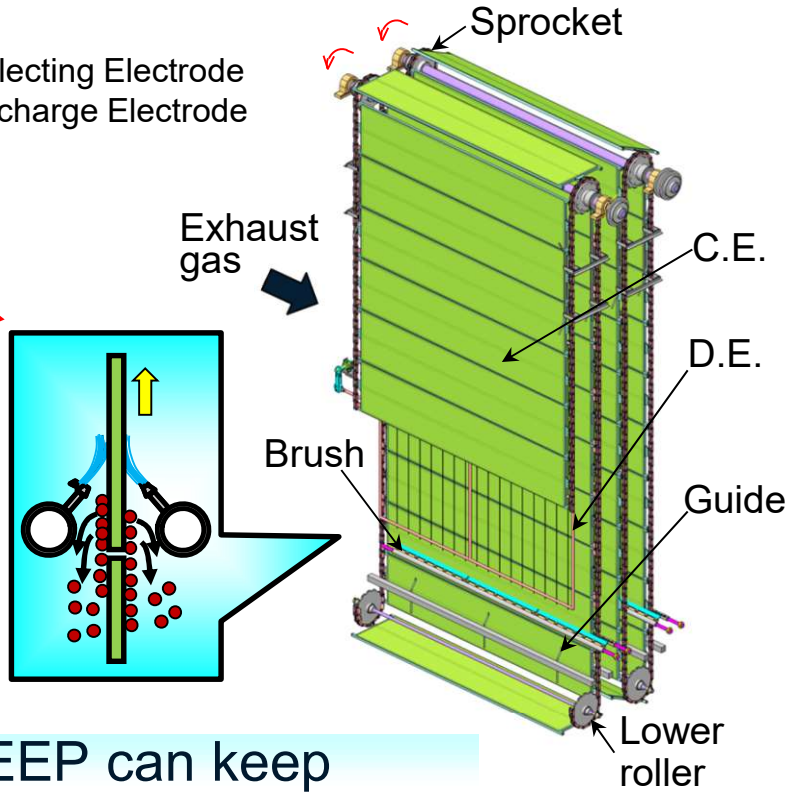
3.4 Moving Electrode Electrostatic Precipitator (MEEP)

- MEEP moves the Collecting Electrode and scrapes off the dust on the C.E. surface. Therefore, it can prevent back corona.
- Scraping brush is installed at the bottom where is out of the gas flow. Therefore, it can prevent dust re-entrainment.
- MEEP can efficiently collect high electrical resistivity dust which is difficult to collect with a conventional fixed type ESP. Therefore, space-saving can be achieved.





C.E. :Collecting Electrode
D.E. :Discharge Electrode



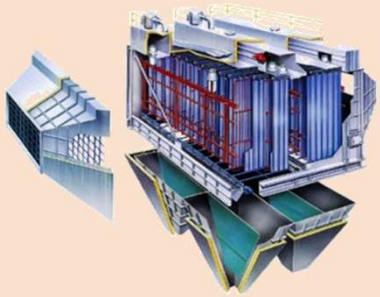
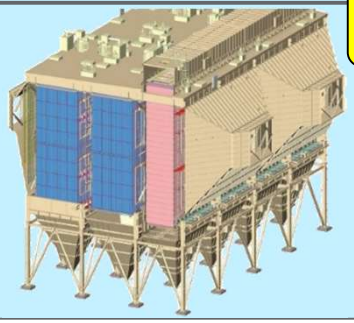
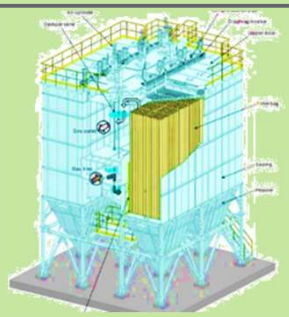
MEEP can keep clean surface by brushing

3.5 MEEP Supply Records

As of May 2022

Application	Number of ESP	Year
Coal Fired Boiler	88	1981～
Steel Plant (Sinter Machine)	10	1991～
Non-Steel Plant	2	1991～
Glass melting Furnace	2	1982～
Cement Kiln	2	1989～
Sewage Sludge Treatment	5	1982～
Oil (FCC)	2	1979～
Total	**111**	

3.6 Selection of Dust Collector Technology

	Fixed type ESP	MEEP type ESP	Fabric Filter (FF)
Contents		 BAT※	
Collecting performance	More than 99 % Outlet dust ≦ **30** mg/m3N	More than 99 % Outlet dust ≦ **10** mg/m3N	More than 99 % Outlet dust ≦ **10** mg/m3N
Pressure Drop	**Low** (approx. 0.2 kPa)	**Low** (approx. 0.2 kPa)	**High** (approx. 2.0 kPa)
Maintenance	Can be **operated for a long term** with only **simple maintenance** works. (ex. general maintenance span：1 time for 2 years)	Can be **operated for a long term** with only **simple maintenance** works. (ex. general maintenance span：1 time for 2 years)	Must be Renewed filter clothes every 2～3 years. And filter clothes are renewed, a **large-scale replacement** and **waste treatment work** are required
Technical Features	・ESP **performance changes** according to the **coal** and **ash properties**(ex. **Dust electrical resistivity** etc.)	・ESP performance can **keep high** ・By combining with MEEP, high electrical resistivity dust **can be collected** with **high efficiency**.	・Collecting performance gets **worse** when **filter clothes tear** ・There is a risk of **clogging** or **breakage** of filter clothes due to sulfuric acid mist when oil-based or high sulfur fuel is used
Remarks	・**Low** OPEX (Low pressure drop) ・IDF Capacity : **Small** ・ESP Footprint : **Large**	・**Low** OPEX (Low pressure drop) ・IDF Capacity : **Small** ・ESP Footprint : **Small**	・**High** OPEX (High pressure drop, renew filter clothes.) ・IDF Capacity : **Large** ・FF Footprint : **Large**

※Best Available Technology

4. FGD System (SO2 Removal)

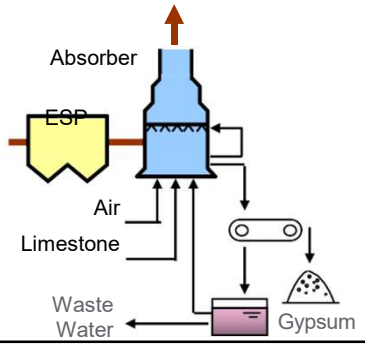
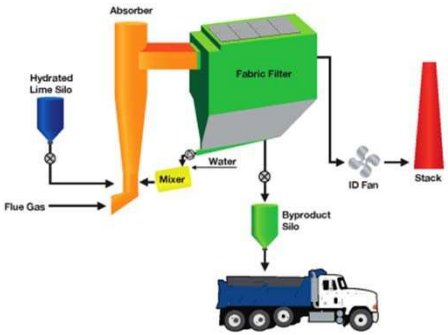
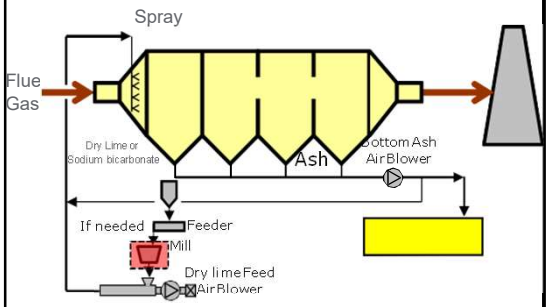
4.1 Selection of Flue Gas Desulfurization (FGD) Technology

- : Mitsubishi Power Technology

FGD

- **Wet Process**
  - **Limestone-Gypsum Process**
  - **Seawater Process**
  - Magnesium Process
  - Soda Process
- Dry Process
  - Dry Solvent Injection Process
  - Electron Beam Process
  - Activated Carbon Process
- Semi-Dry Process
  - Spray Dry Process
    - Enhanced All-dry Scrubber(EAD)

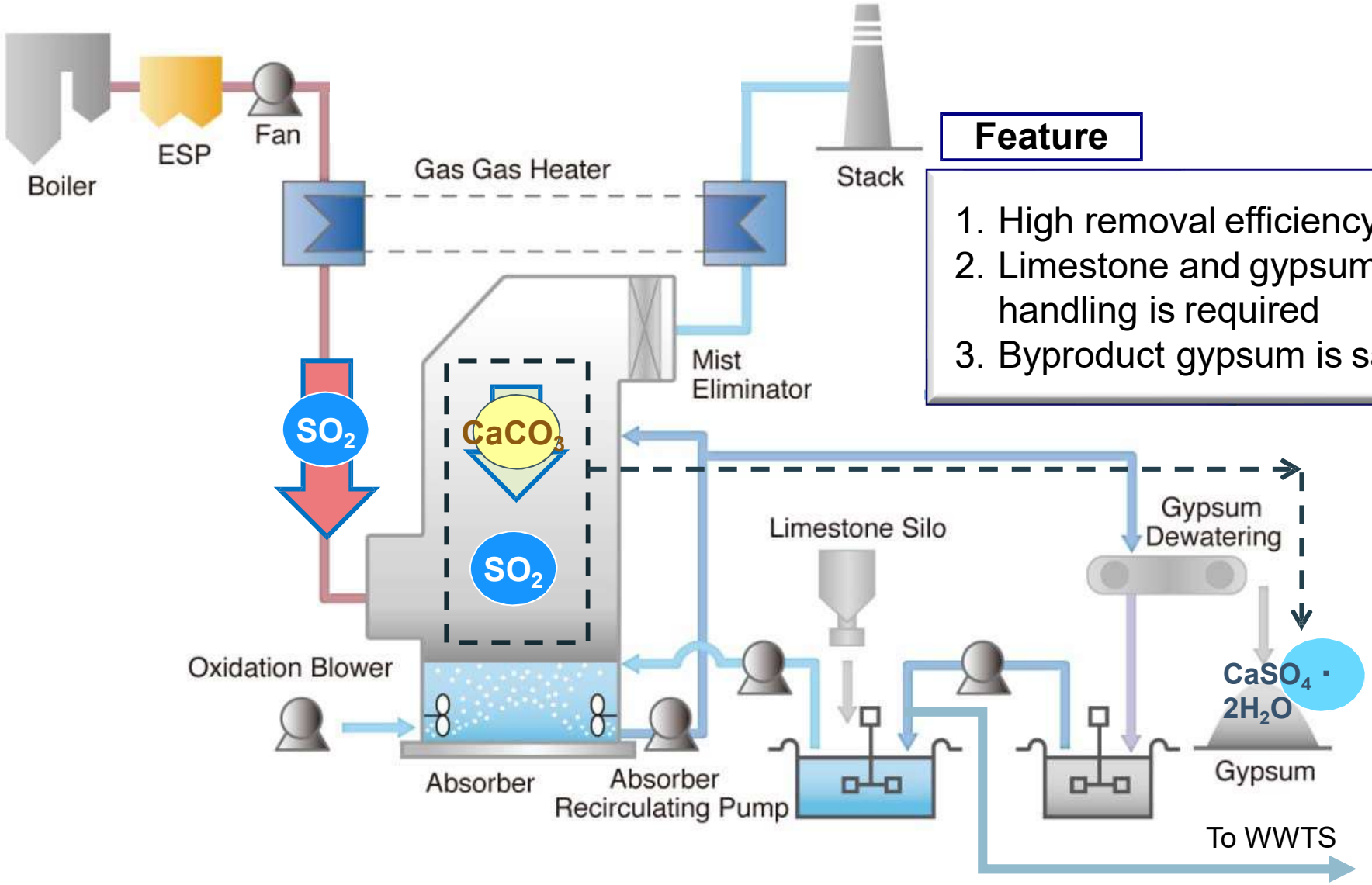
4.2 Selection of Flue Gas Desulfurization (FGD) Technology

	Limestone Gypsum	Semi-Dry (EAD)	Dry Solvent Injection
Process			
Absorbent (delivery form)	Limestone：$CaCO_3$	Lime：CaO (Lime or Lime powder)	Dry Lime or Sodium bicarbonate
S in Coal	Unlimited (< 30,000 ppmdv SO2 in flue gas)	Suitable for < 2%	Suitable for < 0.5%
Efficiency	90 – 99 %	80 ~ 95 %	~ 70 %
Absorber Module	up to 1,000MW equivalent (single absorber for multiple boiler)	75～90 MW equivalent (multiple module required)	80 MW equivalent
Byproduct	Gypsum Salable byproduct	Calcium Sulfite Hazardous Waste (?)	Calcium Sulfite Hazardous Waste (?)
Technical Risks	Scaling due to slurry	Multi-modules are required	Multi-modules are required Limitation of inlet condition
Remarks	Capable to high removal efficiency and large capacity plant	Suitable to small capacity plant No byproduct reuse	Suitable to small capacity plant No byproduct reuse

4.3 Limestone-Gypsum Process

◆ Remove SO_2 as Gypsum by using Limestone

($CaSO_4 \cdot 2H_2O$) ($CaCO_3$)



Feature

1. High removal efficiency
2. Limestone and gypsum handling is required
3. Byproduct gypsum is salable

4.4 Reference Plant

Location: Poland

Fuel: Coal

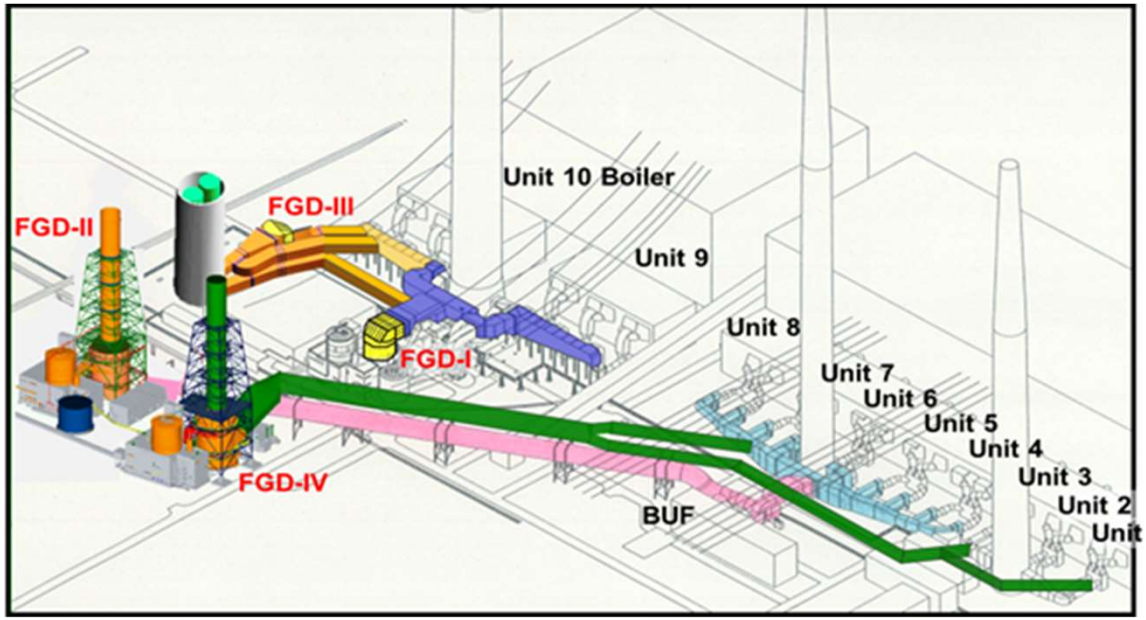
Capacity: 200MW x 4

Gas Flow Rate: 3,480,000Nm^3/h(w)

Inlet SO2 Conc: 3,200 mg/Nm^3

DeSOx Efficiency: 93.75% (200 mg/Nm^3)

Start Up: 93.47%

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