MITSUBISHI POWER

AQCS

Air Quality Control Systems

Mitsubishi Heavy Industries, Ltd.
Energy Systems

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METP-01AQ01E1-A-0, (1.0)21-09, ZEG

Mitsubishi Power is a power solutions brand
of Mitsubishi Heavy Industries.

MOVE THE WORLD FORW>RD MITSUBISHI HEAVY INDUSTRIES GROUP

HOW TO POWER THE WORLD

OUR PLANET IS CALLING FOR AFFORDABLE, SUSTAINABLE, HIGHLY RELIABLE AND CLEAN POWER. TOGETHER WE CAN ACHIEVE IT.

Power grows when we all work together.

There is a strong demand for energy decarbonization in the world today. One in ten people is forced to live without reliable access to electricity, while global demand for power continues to grow. Mitsubishi Power addresses such needs by providing stable, highly reliable, and clean energy solutions.

Mitsubishi Power, a power solutions brand of Mitsubishi Heavy Industries based on a long history of product development and supply for more than a century, has been dedicated to designing, manufacturing, verifying, engineering, installing and providing services for a wide range of proprietary power generation systems.

One of our products is gas turbine combined cycle (GTCC) power plants, which provides incredibly efficient electric power while reducing CO_2 emissions.
We also provide next-generation power systems, such as integrated coal gasification combined cycle (IGCC) power plants, steam power plants, geothermal power plants, air quality control systems (AQCS) and intelligent solutions TOMONI™.

Mitsubishi Power combines cutting-edge technology with deep experience to deliver innovative, integrated solutions that help to realize a carbon neutral world, improve the quality of life and ensure a safer world.

AQCS

Mitsubishi Power's advanced AQCS solutions are build on 100 years of experience to meet the emission standards of the future.

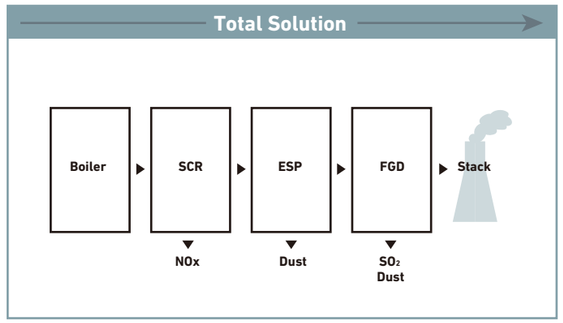
What is AQCS?

Air quality control systems (AQCS) enable power generation and industrial plants to meet the increasingly stringent air quality and emission standards being enforced worldwide, providing environmentally effective and economically efficient solutions that enable even fossil fuel power plants to meet today's environmental regulations.

Mitsubishi Power advanced technologies help protect the environment

Mitsubishi Power is a world leader in air quality control systems (AQCS) including selective catalytic reduction (SCR), flue gas desulfurization (FGD), electrostatic precipitator (ESP) and more, offering a range of solutions for reducing emissions.

Mitsubishi Power's advanced technologies provide vital industries with reliable air quality control, even as we continue to research better ways of meeting our customers' evolving needs.



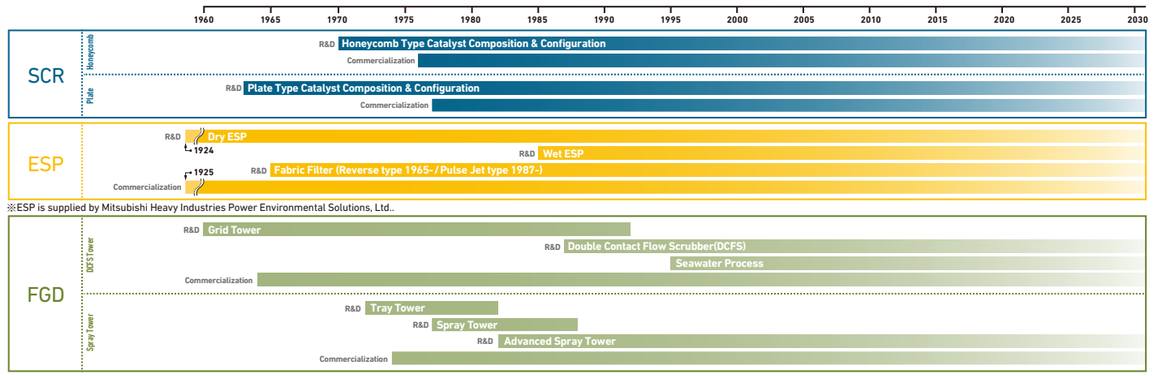
AQCS Research & Development

Since the early 1960s, Mitsubishi Power has been engaged in research and development of AQCS, exploring not only NOx, SO_2, and particulate control technologies, but also SO_3, mercury and other pollutant control technologies for various fuel sources, to meet the stringent emission standards established around the world. We remain committed to R&D endeavors for all our products and technologies and in bringing about continuous improvements for our clients.

Major R&D Advances

- FGD technologies including desulfurization efficiency improvements, fuel diversification, desulfurization agents and reduced auxiliary power and utilities
- SCR and catalyst technologies including NOx removal efficiency improvements, fuel diversification, low SO_2/SO_3 oxidation, mercury oxidation and reduced auxiliary power and utilities
- ESP technologies including dust removal efficiency improvements, fuel diversification, moving electrodes, current control and reduced auxiliary power and utilities
- Multi-pollutant control technologies including mercury and SO_3 control

A Brief History of R&D and Commercialization



Retrofitting lignite coal-fired power plants to meet stringent air quality standards

Ugljevik Power Plant

Specifications

Country	Bosnia Herzegovina
Plant Capacity	300 MW
Fuel	Lignite
Type of FGD	Limestone-Gypsum
FGD performance	99% (<200mg/Nm³)
Mitsubishi Power Scope	Supply & Management
COD	July 2019

Nikola Tesla A Power Plant

Specifications

Country	Serbia
Plant Capacity	1,300 MW
Fuel	Lignite
Type of FGD	Limestone-Gypsum
FGD performance	97% (< 200mg/Nm³)
Mitsubishi Power Scope	Supply & Management
COD	Scheduled December 2022

In Bosnia and Herzegovina, Serbia and Republika Srpska in the Western Balkans, lignite coal-fired power plants are the primary power sources. However, for many years some power plants in both countries have emitted high levels of SO_2 and dust, impacting the health of local people and adversely impacting the environment. With their application to join the European Union (EU), both countries must focus on lowering emissions in compliance with the EU Industrial Emissions Directive to receive acceptance into the EU. Mitsubishi Power is providing value-added solutions to bring these plants into compliance and extend their lifespans.

In Republika Srpska in Bosnia and Herzegovina, the state-owned power company Elekroprivreda of Republika Srpska (ERS) has operated the lignite-fired Ugljevik thermal power plant since 1985. Providing 8% of generating capacity in Bosnia and Herzegovina and 23% in Srpska, the plant emits nearly 60 times the amount of SO_2 allowed under the Industrial Emission Directive (IED). Facing closure if it was unable to achieve compliance, the company created an environmental action plan to construct a flue gas desulphurization (FGD) unit that would reduce SO_2 and dust pollutants by 98.4%. To meet this stringent air quality target, ERS chose Mitsubishi Power AQCS for its high desulfurization efficiency technologies with the ability to cut up to 99% of SO_2 emissions. Agreement on the project was reached in 2016.

Advanced Mitsubishi Power AQCS technologies offer a cleaner air future

Following on the Ugljevik project, Mitsubishi Power was engaged for a similar project in Serbia, at the Nikola Tesla A. The lignite-fired power plant operated by Public Enterprise Electric Power Industry of Serbia, Serbia's state-run power utility. First commissioned in 1970, the six generation units have a combined capacity of 1,720MW. The plant generating approximately 25% of Serbia's electric power makes it a critical source for ensuring a stable power supply in the country. However, the low-grade lignite coal used for fuel has a high sulfur and ash content. Public Enterprise Electric Power Industry of Serbia wanted to take urgent measures to reduce air pollutants including SO_2, NOx and dust.

The project, organized by the Japan International Corporation Agency and financed by the Japan Official Development Assistance, calls for the installation of two FGD units, each with a capacity of 650 MW. Mitsubishi Power, supported by its European subsidiary based in Duisburg, Germany, is responsible for project management, design, supplying the main systems and dispatching technical advisors for installation. With these units, which are among the largest in the world, the project aims to slash SO_2 emissions to less than 200mg/Nm^3 to be in compliance with the IED when completed in 2021.

Key factors for the selection of Mitsubishi Power for this critical AQCS project include its value-added solutions in line with the customer's strategy, advanced FGD technologies for lignite-fired boilers and a successful track record of supplying more than 300 units worldwide.

Through projects like this, Mitsubishi Power AQCS solutions contribute to sustainable development providing access to affordable power, improving the quality of life and supporting economic growth in various countries. Mitsubishi Power continues to work to reduce the environmental impact of power and industrial plants in Europe and around the world by offering high-performance, high-efficiency air quality control systems that enable customers to meet the world's most stringent emissions regulations.

Hirono Unit 5 & 6 (Japan)

Client	TEPCO Fuel & Power Inc.
Fuel	Coal
Generating Power	600 MW
Start up	#5 July 2004, #6 December 2013
Product	AQCS Total Solution

Soto de Ribera Unit 3 (Spain)

Client	EDP ESPANA, S.A.U.
Fuel	Coal
Generating Power	361 MW
Start up	July 2017
Product	SCR

Kozienice PS Unit 4 thru 8 (Poland)

Client	Electrownia Kozienice S.A.
Fuel	Coal
Generating Power	Equiv. to 800 MW (200 MW x 4)
Start up	December 2006
Product	FGD

Fast Track 3A (Manjung #5) (Malaysia)

Client	TNB Western Energy Berhad
Fuel	Coal
Generating Power	1,000 MW
Start up	September 2017
Product	Seawater FGD

China Huadian Zouxian Unit 8 & 7 (China)

Client	China Huadian Zouxian Power Co. Ltd.
Fuel	Coal
Generating Power	1,000 MW x 2
Start up	#8 August 2016, #7 July 2017
Product	High Efficiency AQCS Systems

Izdemir (Turkey)

Client	Izdemir Enerji Elektrik Üretim A.Ş.
Fuel	Coal
Generating Power	350 MW
Start up	December 2014
Product	Moving Electrode Type Dry ESP

Total AQCS Solutions

Mitsubishi Power's comprehensive AQCS solutions enable power plants to meet stringent environmental standards.

Mitsubishi Power is the only AQCS solution provider successfully developing its own technologies for the total AQCS area. In addition, Mitsubishi Power can help make power plants become environmentally compliant to meet future strict regulations.

High efficiency AQCS

We have developed a new flue gas treatment system consisting of an ESP, FGD and non-leakage gas-gas heater (GGH) which achieves effective treatment of flue gas so that the system can control dust emissions to be well within stringent regulations.

Furthermore, in urban areas where even more stringent limits are required, wet ESP can be installed downstream of the FGD. With a GGH installed upstream of the ESP, the dust removal efficiency of ESP can be improved markedly.

Mechanisms for high efficiency AQCS

High efficiency AQCS has the following additional features:

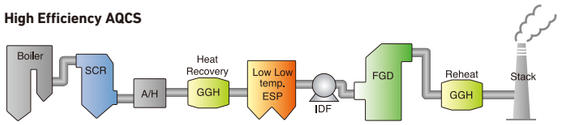
1. Improved ESP Performance and Lower Dust Emissions

Decreases ESP Inlet Gas Temp.
▼
Decreases Electrical Resistance of Dust
▼
Improves ESP Performance

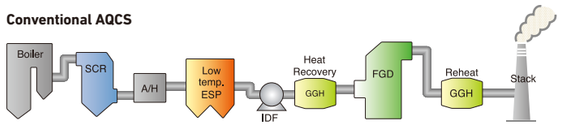
2. Higher SO_3 Removal Performance

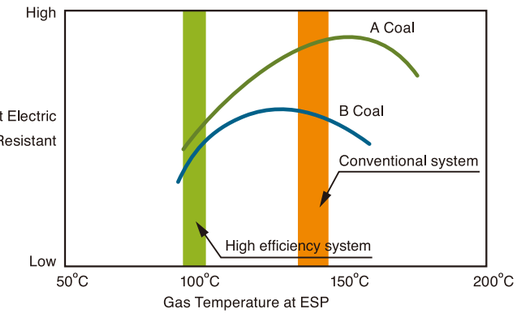
Effective removal of SO_3 contributes to additional enhancements including protecting equipment from corrosion and preventing blue plumes.

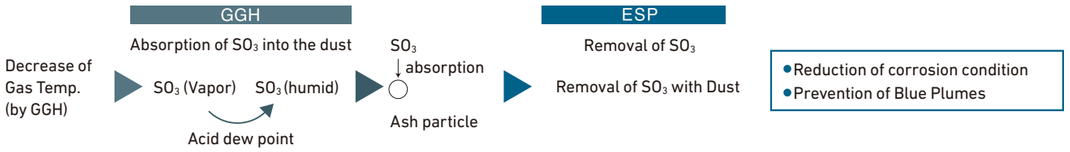
High Efficiency AQCS



Conventional AQCS

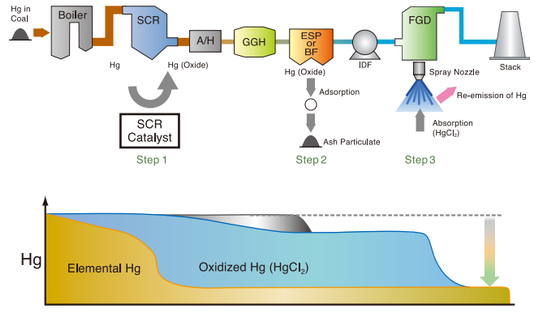






Addressing the global demand for mercury control solutions

In addition to our NO_X, SO_2, SO_3 and particulate control technologies, Mitsubishi Power has developed mercury (Hg) control technologies that satisfy the global demand for managing multiple pollutants.

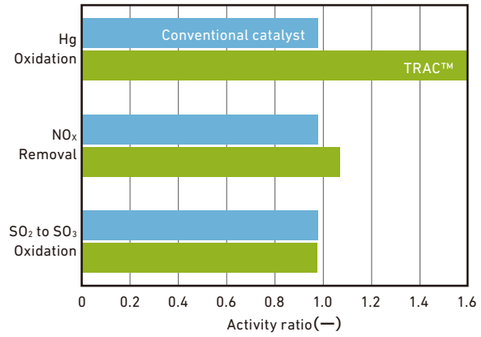


Mercury control mechanisms

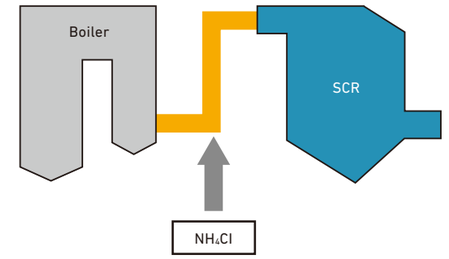
Step 1: Oxidation of gaseous mercury using SCR catalyst
Step 2: Absorption and neutralization of mercury on ash particles, captured by ESP or BF
Step 3: Control and absorption of mercury ($HgCl_2$) at wet FGD

Major mercury control methods and technologies

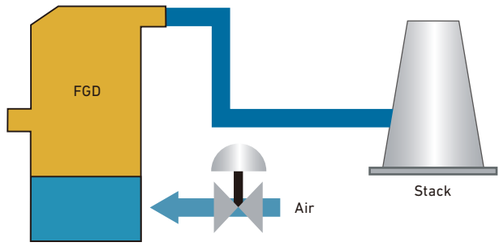
- Mercury Oxidation Catalyst: TRiple Action Catalyst (TRAC™)
  Mitsubishi Power's proprietary TRAC™ optimizes the oxidation of mercury and reduction of NOx, and achieves similar levels of SO_2 to SO_3 oxidation.



- Halogen injection
  Our halogen injection technology enhances mercury oxidation in the SCR. Mercury chloride is removed by the wet scrubbers.



- Technology to prevent re-emission of mercury in wet FGD
  Our Oxidation-Reduction Potential Control prevents the re-emission of mercury chloride in limestone-gypsum slurry in wet scrubbers.



SCR

Mitsubishi Power's suite of advanced SCR systems offer highly-efficient solutions for cleaning flue gases.

Maximum Capacity	Max. NOx Removal Efficiency	Low Environmental Impact	SCR Catalyst
1,075+ MW	**95%+**	**Slip NH_3 < 2ppm**	**High Reliability High Durability**

Mitsubishi Power selective catalytic reduction (SCR) systems remove NOx from flue gas emitted by power plant boilers and other combustion sources to help prevent air pollution at the source. With more than 40 years of operational experience, supplying highly reliable SCR catalysts, Mitsubishi Power's advanced SCR systems provide efficient, reliable treatment of flue gases.

Special features

Here are some attributes that drive demand for Mitsubishi Power SCR systems:

- High NOx reduction meets strict emission standards for various fossil fuels at the single-digit level of NOx concentration
- Integrated NOx reduction linked with boilers and HRSGs
- Optimization of catalysts to the customers' requirements
- Multiple pollutant control including mercury and low sulfur trioxide
- High reliability
- Longer intervals of catalyst maintenance

SCR catalyst

The SCR catalyst is the heart of our SCR system. We provide both plate-type and honeycomb-type catalysts depending on our customer's specific needs, fuel type, system configuration, and other variables.

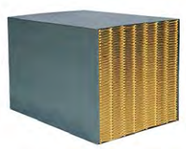
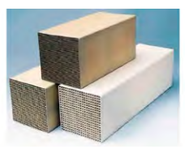


Plate-type Catalyst



Honeycomb-type Catalyst

SCR for Thermal Power Plants

Application Range

NOx Removal Efficiency: Max. 95%
Treated Gas Flow Rate: 3,140,000 Nm^3/h, wet
Fuel: Coal, Oil, Gas, Residual Oil Fuel, etc.

Gas Turbine Simple Cycle (GTSC)

Application Range

NOx Removal Efficiency: Max. 95%
Treated Gas Flow Rate: 1,560,000 Nm^3/h, wet
Fuel: Gas, Oil

Gas Turbine Combined Cycle (GTCC)

Application Range

NOx Removal Efficiency: Max. 95%
Treated Gas Flow Rate: 2,820,000 Nm^3/h, wet
Fuel: Gas, Oil

FGD

Mitsubishi Power's advanced FGD Systems enable power plants to meet today's toughest environmental regulations.

Maximum Capacity	Max SO_2 Concentration of Inlet	Max SO_2 Removal Efficiency	
1,100+ MW	**80,000+ mg/Nm^3** (Coal fired)	**99.9%+**	**Proprietary Technology**

Mitsubishi Power's flue gas desulfurization (FGD) plant removes sulfur dioxide (SO_2) from flue gas produced by boilers, furnaces, and other combustion sources, contributing to the effective prevention of air pollution. Our Seawater FGD and Wet Limestone-Gypsum FGD systems can both treat a large range of SO_2 concentrations, for greater plant reliability and improved operational economics.

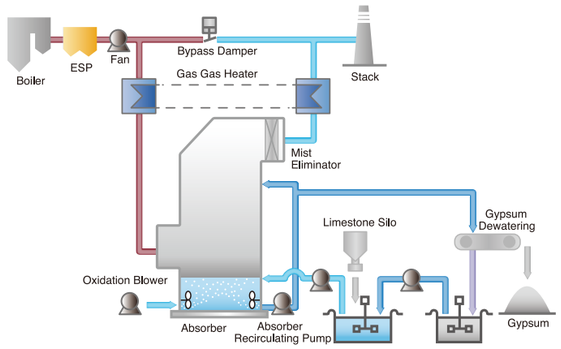
Market leading features

With over 300 FGD plants in operation worldwide, Mitsubishi Power has a leading share of the global market. Here's why:

- Excellent SO_2 removal efficiency that meets stringent emission standards for all kinds of fossil fuels
- Multiple pollutant control with associated environmental control equipment
- High reliability
- Savings on energy and utilities

Wet limestone-gypsum FGD system

Suitable for large-scale flue gas treatment, this system uses limestone as a low-cost absorbent and produces gypsum powder as a stable and valuable by-product.

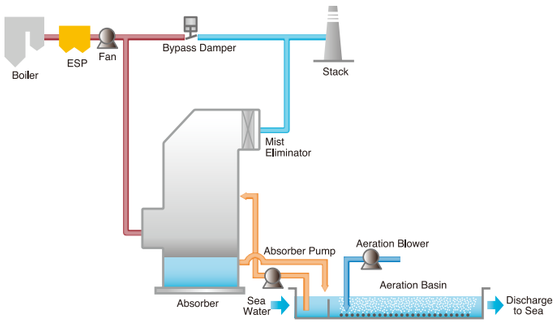


Seawater FGD system

This system is a good choice in regions with softer regulations on SO_2 emissions. The simple equipment configuration contributes to a lower initial cost compared to a wet limestone-gypsum FGD system.

Major components of seawater FGD

The seawater FGD system consists of two major components: a grid tower scrubber, or a double contact flow scrubber (DCFS), and an aeration basin. In the DCFS, seawater absorbs SO_2 from the flue gas. It is then pumped to the aeration basin, where the SO_2-rich seawater is treated to make it suitable for discharge back into the sea.



ESP

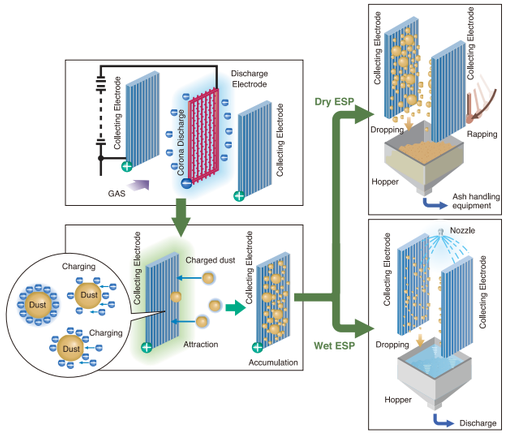
Advanced ESP technologies for collecting flue dust realize cost-efficient air pollution control.

Maximum Capacity	Lowest Dust Emission	Wide Application Range	
1,100+ MW	**Dry ESP: ≤ 10mg/Nm³ Wet ESP: ≤ 1mg/Nm³**	**Moving Electrode Type ESP Pulse Energization**	**High Reliability**

Mitsubishi Power electrostatic precipitators (ESP) collect dust in the flue gas produced by boilers and other combustion sources to meet air pollution control and meet environmental standards at thermal power plants, steel plants, and various other industrial plants.

Basic principles of ESP

1. A high voltage is applied to the discharge electrode, generating a corona discharge that produces negative ions.
2. The electrically charged dust is accumulated on the collecting electrode by an electrical field.
3. The accumulated dust is removed by rapping hammer (dry ESP), scraping brush (dry ESP) or flushing water (wet ESP).



Dry ESP

Mechanisms for removing dust from the collecting electrode

Fixed and moving-type electrodes have different mechanisms for removing accumulated dust from the collecting electrode.

Fixed electrode type

A rapping device removes the dust accumulated on the collecting electrode.

Moving electrode type

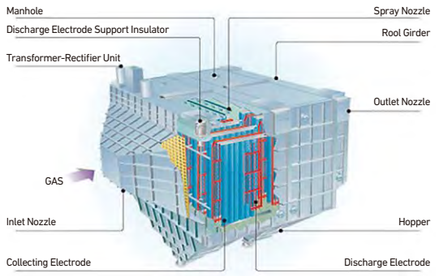
In a moving electrode system, the collecting electrodes consist of short strip elements joined by chains, which slowly move in the flue gas.

The dust that accumulates on the strip elements is scraped off by brushes integrated into the dust collection hoppers.

Wet ESP

Advantages of the Wet Electrostatic Precipitator

- Wet ESPs suit applications requiring a higher degree of gas purity at the flue outlet than can be achieved by dry ESP.
- By using water to remove the collected dust, a wet ESP achieves high dust removal efficiency (down to 1 mg/Nm^3) without being adversely affected by the high or low electrical resistivity of dust.



Structure of Wet Type Electrostatic Precipitator

Services

Mitsubishi Power's comprehensive range of AQCS services economically and efficiently optimize Mitsubishi Power and third party AQCS system performance over their life cycles.

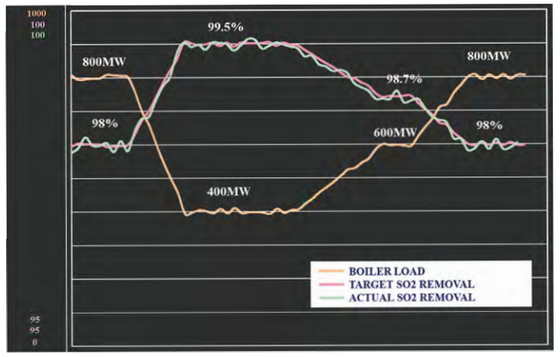
TOMONI™ optimizes AQCS operations

TOMONI supports not only boilers and steam turbines but also contributes to the efficient and economic operation of AQCS. The entire plant and each piece of its equipment are remotely monitored with Mitsubishi Power simulators continually analyzing and evaluating operational data. Potential problems can be detected early and rapidly addressed to ensure normalization of the plant performance, avoiding unplanned downtime.

Modifying plants with our comprehensive integrated AQCS services

Our comprehensive integrated AQCS plant services enable our customers' plants to meet current and future regulations for NOx, SO_2, dust and wastewater quality. Our services include upgrading existing AQCS to meet new standards or manage deterioration of aging plants.

Our service teams have wide-ranging experience not only with Mitsubishi Power AQCS technologies and equipment, but also with equipment and plants of third party technologies.

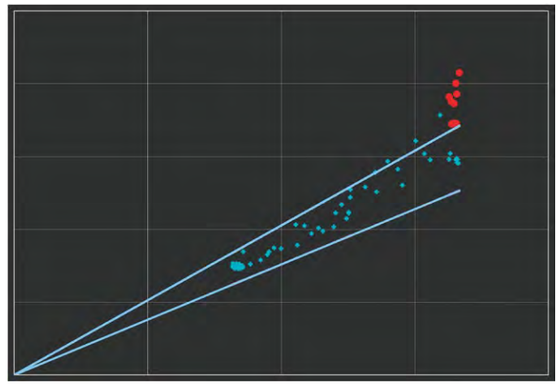


Optimizing SCR operation, maintenance and catalyst replacement

As an SCR system supplier, Mitsubishi Power offers an extensive range of customer-focused after-sales services including operation and maintenance efficiency plans and optimizing on-going SCR performance by evaluating catalyst samples against actual plant operating conditions and diversified flue gases.

The key to maintaining SCR system performance over time is the SCR catalyst, which requires maintenance and replacement as its active elements gradually deteriorate from flue gas composition over years of operation.

Mitsubishi Power offers a wide range of catalysts with high reliability that contribute to increased NOx removal efficiency with a low SO_2 to SO_3 conversion rate, low pressure loss, mercury oxidation and dioxin removal.



Example of removed SO_2 amount vs limestone consumption.

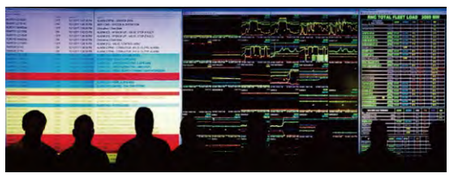
Honeycomb-type Catalyst

Plate-type Catalyst

TECH CLOSE UP

TOMONI™, a suite of intelligent solutions use advanced analytics and are driven by customer collaboration to deliver powerful financial and environmental advantages including decarbonization.

TOMONI, a Japanese word meaning “together with,” reflects the emphasis Mitsubishi Power places on collaborating with customers to solve their unique challenges. Mitsubishi Power works together with customers, partners and society to deploy solutions that support the decarbonization of energy and deliver reliable power everywhere.



Features of TOMONI

- TOMONI is composed of three solution categories: O&M Optimization, Performance Improvement, and Flexible Operation. The combination of these categories allows us to deliver optimal solutions.
- From utility to industry power plant, TOMONI is applicable to a wide variety of power plants.
- TOMONI is able to customize for a variety systems such as cloud and edge computing as well as customer's existing platforms.
- Combining with AI technology and Mitsubishi Power's knowledges secured over the long history has enabled to develop solutions to optimize the operation of the power plant to meet customer' demands.

TOMONI™

Roadmap for TOMONI

Autonomous Operation of Power Plants.

Autonomous Operation	**Optimize operations in response to changes in environment**
	Respond to diverse KPIs of power plant, automatic optimization with simulation technologies using high precision AI application (Digital Twin)
Advanced operation and maintenance	**Minimize maintenance costs, improvement reliability**
	Combine AI technologies and our continuous accumulated knowledge to assist O&M • AI identifies problems instantaneously and provides guidance • Assist operations optimizing performance and environmental impact mapped to equipment status and plant's operational plan
Remote monitoring / status visualization	**Provide high performance solutions through digitalization of information**
	Leverage IoT for remote monitoring, diagnostic applications • Remote monitoring • Detect abnormalities, offer solutions • Visualize equipment abnormalities, performance degradation, changes in status

Notes: TOMONI is a trademark of Mitsubishi Heavy Industries, Ltd. in the United States and other countries. (Trademark registration has been applied for)

Experience around the world

Since the early 1960s, Mitsubishi Power has delivered a wide range of environmental conservation systems, integrated flue gas treatment systems and gas-gas heaters to industrial and power customers around the world, installing more than 1,400 SCRs, 400 FGDs including marine Exhaust gas Cleaning System, and more than 3,300 ESPs.

SCR 1,475 Units (22 countries)
ESP 3,334 Units (31 countries)
FGD 380 Units (29 countries)
L: License

Data as of July 2020