MITSUBISHI POWER

Steam Power Plants

Mitsubishi Heavy Industries, Ltd.
Energy Systems

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METP-01ST01E1-A-0, (1.0)21-09, ZEG

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

MOVE THE WORLD FORWARD 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.

Steam Power Plants

Mitsubishi Power designs and delivers highly efficient and environmentally friendly power generation facilities, including boilers, steam turbines, and generators.

Up to 1,200 MW

Large Capacity Power Plants

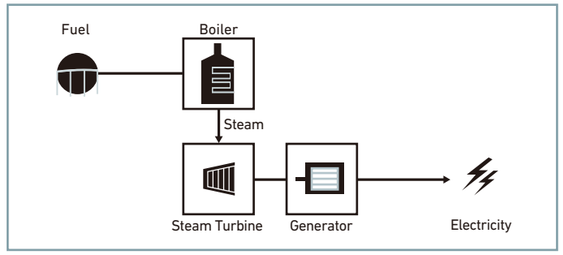
Integrated Customer Service

From Design to Delivery of an Entire Power Generation Facility

Co-generation Power Plants

Effective Use of Electricity and Steam

What is a steam power plant?



A steam power plant consists of a boiler, a steam turbine, a generator, and other auxiliaries. The boiler generates steam at high pressure and high temperature. The steam turbine converts the heat energy of steam into mechanical energy. Through proper integration of all equipment, Mitsubishi Power designs and delivers highly efficient and environmentally friendly power plants.

Large Capacity Power Plants

Applying ultra-supercritical pressure technology for highly efficient power generation

Mitsubishi Power has an impressive track record in the field of supercritical and ultra-supercritical pressure coal-fired power plants and has achieved a high level of trust in the market due to the high efficiency and reduced emissions of these plants. Capitalizing on its successful operating experience with this advanced technology, Mitsubishi Power will continue to contribute to the stable and reliable supply of electric power globally, while minimizing the environmental impact.

What is ultra-supercritical pressure?

Under normal atmospheric pressure (0.101 MPa), water boils at 100°C. As the pressure increases, so does the boiling temperature of water. When the pressure is increased to 22.12 MPa, and at a temperature of 374°C, water converts directly from liquid to steam, without the intermediate boiling stage. This is called the critical point, and the pressure above this critical point is called supercritical pressure. Supercritical pressure with a temperature equal to or more than 593°C is called ultra-supercritical pressure.

Integrated Customer Service

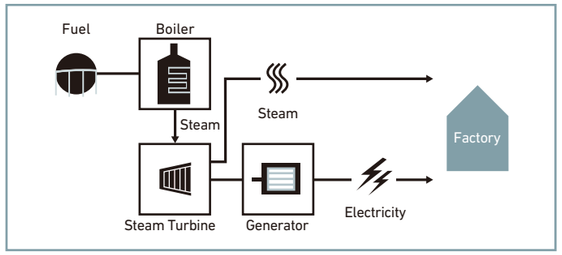
Supplying power plants matching customers' needs

As an EPC contractor, Mitsubishi Power will design, manufacture, deliver, and install entire power plants. From main plant equipment to auxiliary air quality control systems, Mitsubishi Power can integrate the complete plant system to optimize equipment design and efficiency. Main plant equipment, such as boilers, steam turbines and generators, is custom designed to meet customers' needs. New units added to an existing power generation station will be seamlessly integrated with existing plant equipment and optimized to meet the specified requirements.

Cogeneration Power Plants

Paving the way for effective use of energy

In some industrial applications, excess energy is produced as part of the normal operating process. In many cases this energy is wasted. If economically justifiable, another option is to utilize this free source of energy to produce steam and electric power. Utilization of surplus energy as fuel for the production of steam and electrical power is called cogeneration. When optimized and properly integrated with the industrial process, power supply stability improves and impact to the environment is minimized.



Manjung 5 — One of the world's most advanced power plants

Manjung Unit 5
World-class high electrical output and highly efficient power generation

Mitsubishi Power provided ultra-supercritical variable pressure once-through boiler, a steam turbine/generator and flue gas desulfurization (FGD) system, including a seawater FGD for a power plant construction project in Malaysia. A Korean company, Daelim Industrial Co. Ltd. concluded the package contract through a consortium to build an ultra-supercritical coal-fired power plant in 2013. The equipment was delivered to a Malaysian power company, Tenaga Nasional Berhad (TNB) for an ultra-supercritical coal-fired power plant built in Manjung, Perak, located about 300km northwest of Kuala Lumpur, the capital city of Malaysia. This plant is capable of generating 1,000 MW and is the largest of its kind in Malaysia.

Mitsubishi Power signed a supply contract to deliver equipment for this first ultra-supercritical coal-fired power plant in Malaysia and dispatched technical advisors as well as support staff, with many years' experience working with overseas power plants, for installation and operation. It began commercial operations on September 28, 2017, three days ahead of its target date. On October 16, 2017, Mitsubishi Power received a letter of appreciation from Mr. Young Cook Kang, CEO of Daelim Industrial Co. Ltd. In this letter, he indicated that TNB greatly appreciated the strong technical capabilities of the Mitsubishi Power team throughout the project.

Mitsubishi Power has a proven track record in the field of coal-fired power generation with its high-efficiency system for curbing CO_2 emissions. We will continue helping to provide stable power and to reduce environmental impact through our highly-efficient equipment and systems, while effectively responding to various market needs in Malaysia and Southeast Asia and around the world.

Project summary

Project	Malaysia TNB Manjung Five Sdn Bhd Fast Track 3A Project Manjung Unit 5
Customer	Malaysia TNB Manjung Five Sdn Bhd
Prime Contractor (EPC)	Daelim Industrial Co. Ltd. of Korea
Mitsubishi Power supplied equipment	Ultra-supercritical variable pressure once-through boiler, Steam turbine/generator, FGD
Steam turbine/generator output	1,065 MW x 1
Fuel	Sub-bituminous
Main steam/Reheated steam temperature	600°C/610°C
Start of operation	September 2017

Huadian Zouxian Unit 7 & 8
(China)

Customer	China Huadian Corporation
Output	1,000 MW x 2
Fuel	Coal
Start of operation	2007/2008

Hitachinaka Unit 1 & 2
(Japan)

Customer	JERA Co., Inc.
Output	1,000 MW x 2
Fuel	Bituminous coal & sub-bituminous coal
Start of operation	2003/2013

Neurath Power Station
(Germany)

Customer	RWE
Output	1,100 MW
Fuel	German lignite coal
Start of operation	2012

Rajpura Unit 1 & 2
(India)

Customer	L&T
Output	700 MW x 2
Fuel	Indian coal
Start of operation	2014

Paiton III
(Indonesia)

Customer	PT Paiton Energy
Output	866 MW
Fuel	Sub-bituminous coal
Start of operation	2012

Kozienice Unit11
(Poland)

Customer	ENEA Wytwarzanie S.A.
Output	1,075 MW
Fuel	Bituminous coal & sub-bituminous coal
Start of operation	2017

Steam Turbines

Globally contributing to power generation for more than a century with our highly efficient and reliable steam turbines that have undergone strict in-house testing.

Combined Output: Over 360,000 MW (2,600 units)
Proven Track Record

Flexible Configurations
Meets Any Requirements

Provides Higher Efficiency
High Temperature Steam

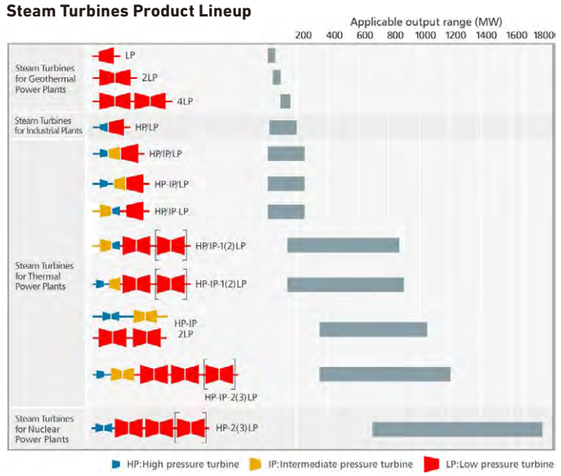
Contributing to power generation globally for more than a century
Mitsubishi Power steam turbines are built upon more than a century of R&D and manufacturing experience, and our track successful record of delivering strictly tested, highly reliable, and efficient steam turbines to customers globally is unmatched.

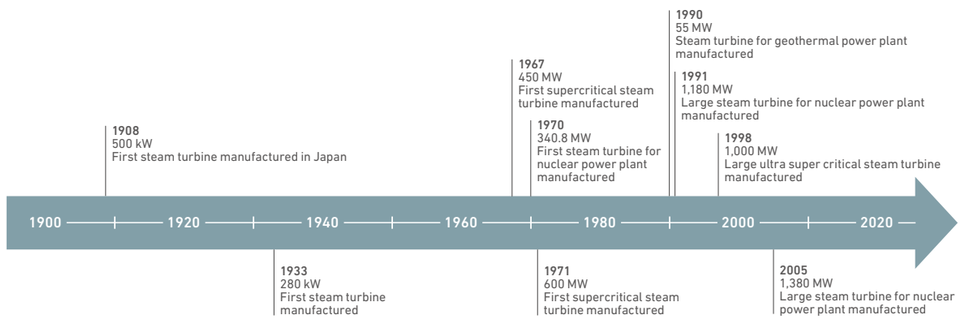
We offer a comprehensive lineup of steam turbines that include small and mid-sized steam turbines for industrial applications, large steam turbines for thermal power plants, nuclear power plants, and geothermal power plants.

Our highly efficient steam turbine lineup features different applications to meet various operational requirements while contributing to the global CO_2 reduction.

History of Development
Mitsubishi Power has over a century of achievements in the manufacturing of steam turbines. By further developing and upgrading cutting edge technologies, we design and manufacture highly reliable "Japan Quality" steam turbines that hold up to long-term use and continue to gain the support of customers around the world.
The steam turbine has long been a crucial component of power generation plants and has played a vital role in their operation.
Mitsubishi Power has led the world in putting cutting edge technologies into practical applications, such as the manufacturing of a power generation plant capable of operating at steam temperatures of 600/620°C, thereby fulfilling customer expectations.
Mitsubishi Power will continue its ceaseless technology development and keep offering steam turbines that are environmentally friendly and highly efficient.

Steam Turbines Product Lineup





Steam Turbines

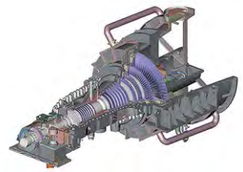
Up to 250 MW
Exhaust steam exits the turbine from only one direction (single-flow). By utilizing a longer last stage blade (LSB), a single flow turbine with axial exhaust is possible in comparison to a double-flow turbine with downward exhaust. An axial exhaust reduces hood losses, thus allowing higher efficiency to be achieved as compared to a downward exhaust.

In addition, as a single welded (or mono-block) rotor is used, the high pressure (HP), intermediate pressure (IP) and low pressure (LP) sections can be contained within a single casing. This compact frame turbine of (SRT: Single cylinder Reheat Turbine) can reduce construction costs for the turbine building and foundation. A smaller number of components also reduce time required for inspections and number of spare parts, thus allowing easier maintenance.

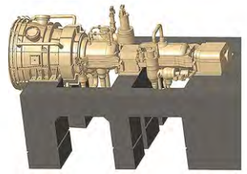
Specifications

No. of casings	Single casing (HP/IP/LP Turbine) Double casing (HP/IP Turbine - LP Turbine) Double casing (HP Turbine - IP/LP Turbine)
Output	Up to 250 MW
Main steam	Up to 16.5 MPa / Up to 600°C
Reheat steam	Up to 600°C
Revolutions per minute	3000 min^{-1} (50Hz) / 3600 min^{-1} (60Hz)

Downward exhaust can also be designed if the customer has such requirements.



Single Casing (SRT) Turbine
(HP/IP/LP Turbine)

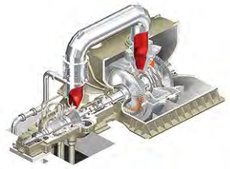


Two Casing Turbine
(HP Turbine - IP/LP Turbine)

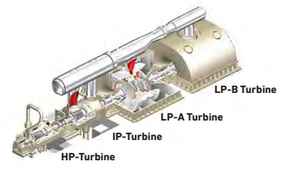
Up to 1,200 MW
The length of optimal last stage blade (LSB) and the number of casings are selected based on the steam exhaust conditions. By combining the high pressure (HP) turbine and intermediate pressure (IP) turbine into a single casing, the turbine can be made more compact, thus reducing the number of components and required area for installation. On top of reducing costs related to civil construction and installation work, maintenance is also easier due to both a reduced number of spare parts and required inspection periods. For steam power plants, to increase overall plant efficiency, up to nine extractions for feedwater heating is possible. For the low pressure (LP) turbine, exhaust direction is not limited to downward exhaust, but can also be designed for sideward exhaust.

Specifications

No. of casings	Two Casings (HP/IP Turbine - LP Turbine) Three Casings (HP/IP Turbine - LP Turbine ×2) Three Casings (HP Turbine - IP Turbine - LP Turbine) Four Casings (HP Turbine - IP Turbine - LP Turbine×2) Five Casings (HP Turbine - IP Turbine - LP Turbine×3)
Output	Up to 1,200 MW
Main steam	Up to 28.0 MPa / Up to 600°C
Reheat steam	Up to 630°C
Revolutions per minute	3000 min-1 (50Hz) / 3600 min-1 (60Hz)

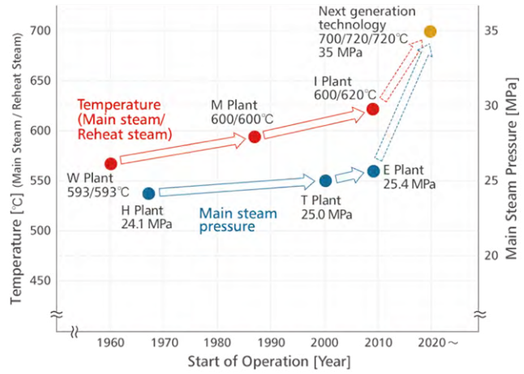


Two Casing Turbine
(HP/IP Turbine - LP Turbine)
For GTCC Plant Applications (312 MW)



Four Casing Turbine
(HP Turbine - IP Turbine - LP Turbine ×2)
For Conventional Power Plant Applications (1,000 MW)

Breakthroughs in steam conditions
Mitsubishi Power has steadily contributed to the development of highly efficient steam power plants by raising the operable temperature range of its steam turbines through technology development of turbines. We had already manufactured and delivered many turbines capable of operating at supercritical main steam temperatures of 600°C range, and currently reheat steam temperatures of 620°C is applied to commercial power generation. On top of this, Mitsubishi Power continuously strives for the next generation technology development with the aim of making turbines capable of operating at ultra-supercritical steam conditions in the 700°C range and 35 MPa for even higher efficiency.



Boilers

Mitsubishi Power supplies boilers that boast world-leading quality and performance based on stable quality developed over many years and state-of-the-art technologies.

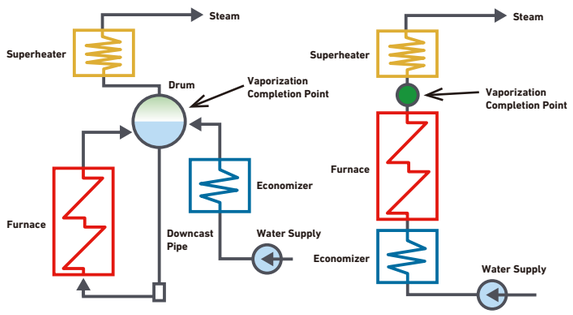
In 1968	More than 5,500 units delivered	Tower Boiler	Optimized for Various Types of Coal
Delivered the First Supercritical Pressure Boiler	Proven Track Record	Large and High-Efficiency Lignite Combustion	From Anthracite to Lignite

Boilers for power generation projects convert the chemical energy contained in fossil fuels such as coal, oil, and gas into heat energy through combustion reactions, and also convert this into high-temperature, high-pressure steam-based heat energy to be supplied to steam turbines used in power generation. This makes a boiler one of the key components of a thermal power plant. Large boilers can reach as many as 80 meters tall, weigh some 13,000 tons and comprise over one million components.

Types of boilers

While various types of boilers are produced depending on the amount, pressure and temperature of the steam they produce and the fuel they use, boilers generally come under one of two categories: drum boilers and once-through boilers.

The furnace that encloses the combustion field is the part of a boiler system exposed to the harshest conditions. Other key components include the superheater, which allows steam to pass through up to a designated temperature, and the economizer, which preheats the water supplied to the boiler.



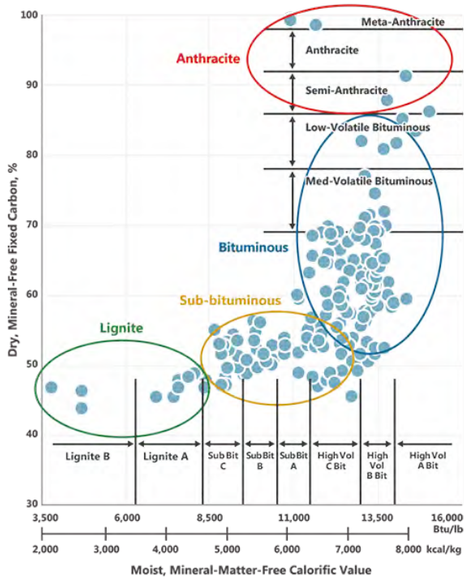
Drum Boiler Fluid Path Diagram (Simplified)

Once-through Boiler Fluid Path Diagram (Simplified)

In a drum boiler, to ensure reliability of the furnace area, a steam drum (an enormous tank) that continually supplies water to the furnace system is set up. On the other hand, a once-through boiler comprises a simpler structure that eliminates this steam drum.

Types of coal

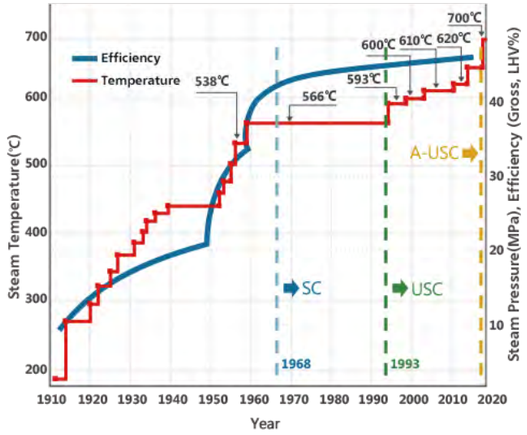
Various types of coal can be used, from anthracite with its high carbon content to bituminous coal, sub-bituminous coal and lignite (brown coal), an even younger coal. Power generating equipment needs to be optimized for these different types of coal. Mitsubishi Power is able to supply the optimum power generating equipment to match any variety of coal, from anthracite to lignite.



Once-through boilers

Overview

Once-through boilers are able to produce steam at higher pressures and temperatures than drum boilers. In steam power plants, raising steam conditions (pressure and temperature) can enable efficiency gains in power generation equipment, allowing an operator to reduce its fuel consumption and CO_2 emissions. Mitsubishi Power delivered its first supercritical pressure once-through boiler in 1968, and followed up in 1981 with delivery of the first supercritical variable pressure once-through boiler. In 1993, Mitsubishi Power sought to further improve steam conditions, culminating in the delivery of the first ultra-supercritical variable pressure once-through boiler. Mitsubishi Power boasts an extensive track record of both supercritical and ultra-supercritical variants and conditions to deliver highly reliable boilers.



2-pass boilers

2-pass boilers are designed to fire various kinds of fuel while delivering optimum conversion efficiency at lower emissions.

Performance advantages

• Low fuel consumption • Lower emissions (CO_2, Sox, NOx, dust, ash) • Less auxiliary power consumption • High reliability

Fuel sources

• Solid: Bituminous, sub-bituminous, lignite, anthracite coal, petroleum coke, biomass • Liquid: Heavy oil, vacuum residue, solvent de-asphalting pitch • Gas: Natural gas, petroleum gas, blast furnace gas, coke, oven gas, or other low BTU process waste gas streams

Technical advantages

< Furnaces >

• Optimized for specific types of fuel • Various burner system layouts for good combustion

< Burners >

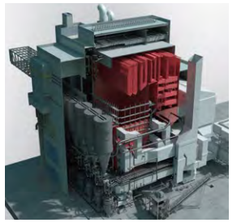
• Low NOx and less unburned carbon • Advance combustion technology

< Pulverizers >

• Vertical mill for high classification performance at low power consumption • Highly durable and easy to maintain

Specifications

Output	~1,070 MW
Main steam flow rate	~3,210ton/hr
Steam temperature	~600/610°C
Steam pressure	~31MPa



Tower boilers

Tower boilers are designed to fire various kinds of fuel and are ideal for plants using highly erosive, high ash coal.

Performance advantages

• Proven technology and high reliability for combustion with lignite and low-heating-value coal

Fuel sources

• Lignite, sub-bituminous, bituminous, biomass

Technical advantages

< Furnaces >

• Optimized to accommodate specific types of fuel • Small footprint

< Burners >

• Low NOx and less unburned carbon • Advanced design based on experience with coal-fired power generation in Europe

< Pulverizers >

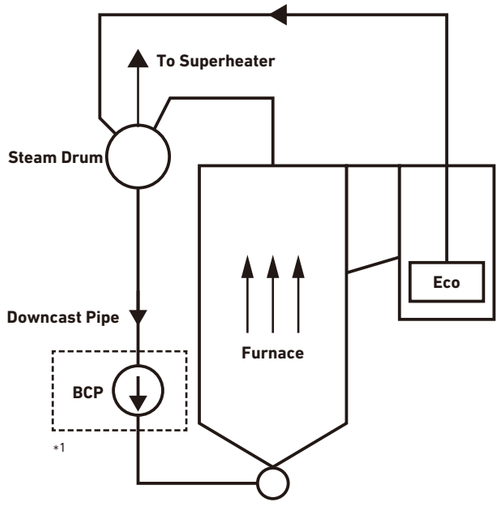
• Pulverization system for lignite and low-heating-value coal combustion • Vertical mill for high classification performance at low power consumption

Specifications

Output	~1,100 MW
Main steam flow rate	~2,939ton/hr
Steam temperature	~600/620°C
Steam pressure	~30.5MPa

Drum Boilers

In a drum boiler, the circulation of water is produced through the density difference of water in the downcast pipe and the water/steam mixture in the furnace water wall. In low-pressure boilers where this density difference is large, the circulating force is high and a high volume of circulation can be ensured. However, since it becomes difficult to sufficiently maintain circulation volume when the density difference between the two drops due to higher pressure, a pump is installed in the downcast pipe to supplement circulating force. The type that circulates water using only the density difference is known as a natural circulation boiler, while the type that includes an installed pump is known as a forced circulation boiler.



Forced Circulation Boiler Fluid Path Diagram (Simplified)

*1 BCP: Boiler Circulation Pump
Without BCP, it is Natural Circulation Boiler Fluid Path Diagram (Simplified)

Bubbling Fluidized Bed (BFB) Boilers

A bubbling fluidized bed (BFB) boiler is a boiler that can also handle fuels that are difficult to pulverize or less combustible. The fuel is introduced into a mixture of sand flowing at high temperatures, allowing the fuel to be efficiently combusted. Since Mitsubishi Power delivered its first commercial BFB boiler in 1984, it has established an impressive track record of deliveries. Customers can choose the optimum BFB boiler based on desired power generating output and the characteristics of the biomass to be used. In this way, Mitsubishi Power responses to a diverse range of customer needs.

Supports a wide variety of fuels
In BFB combustion, a material with a large thermal capacity such as sand is used as the flow medium. This allows for the stable combustion of a wide variety of fuels, from moisture-rich fuels to those with low combustibility. In addition to coal, our BFB boilers support a wide array of fuels from wood biomass such as waste wood and construction waste materials to industrial waste such as tires.

Stable emissions of foreign particles
At the bottom of the BFB, the bed drain extraction method is used based on the amount of foreign particles in the fuel. At the same time, the use of an appropriate furnace bottom shape and air nozzle shape ensures that foreign particles carried through the BFB are expelled outside the system in a stable manner, preventing poor flow associated with sedimentation inside the BFB.

Low environmental impact
As BFB combustion allows for sufficient combustion under lower temperatures up to around 900°C, the release of nitrogen oxides (NOx) and other pollutants can be reduced.

Chemical Recovery Boilers

A chemical recovery boiler is a type of biomass boiler that combusts black liquor produced as a by-product in the pulp manufacturing process at paper mills. Black liquor is a fuel derived from wood chips and is regarded as renewable. A chemical recovery boiler not only effectively uses the thermal energy gained by combusting black liquor, but also recovers sodium (carbonate) ingredients that are reused in the pulp manufacturing process, and thus plays an important role in a pulp manufacturing plant. Since it delivered the first such chemical recovery boiler in 1951, Mitsubishi Power has delivered more than a hundred units in over a half-century and continues to be one of the leading companies in the field.

High-pressure, high-temperature steam conditions
In 1983, Mitsubishi Power was first in the world to develop and deliver a high-pressure, high-temperature chemical recovery boiler that produced steam at 10 MPa and 500°C. Producing steam at higher pressures and temperatures helps to boost generating efficiency in turbine generating equipment. The highest steam conditions we have delivered to date are a steam pressure of 13.3 MPa and steam temperature of 515°C. Even today, these levels persist as the highest steam conditions for a chemical recovery boiler.

Corrosion protection
With a chemical recovery boiler, the furnace wall pipes and superheater tubes are exposed to a harsher corrosion environment compared with other fossil fuel-burning boilers. This harsh corrosion environment is due to the chlorine, potassium, sodium, and sulfur contained in the black liquor used as fuel. Our recovery boilers employ the following anti-corrosion measures to improve the reliability and durability of boiler equipment.

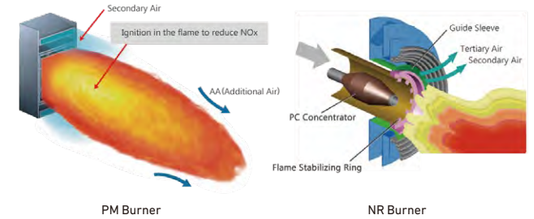
- Furnace wall pipes: Covering with overlaying of 25Cr steel
- Superheater tubes: Use of 25Cr steel tubing

Low NOx combustion
By employing a multi-stage air input method that adds fourth-stage air to the conventional primary, secondary and tertiary air, and eliminating localized regions of excessive air inside the furnace, low NOx combustion can be achieved.

Technical Information

Mitsubishi Power maintains proprietary boiler technologies designed to achieve high reliability and reduce environmental impact.

Low NOx burners
Mitsubishi Power offers low NOx burner technologies for solid, pulverized fuels by combustion method and different firing systems. For coal fired burners, PM burners are the jet burners which are used for the swirl combustion method in boilers with tangential or all-wall firing systems, while DS® and NR burners are circular swirl burners used for in boilers with the opposed firing method. The basic concepts for improving combustibility, however, are the same for PM, DS® and NR burners. By improving ignitibility in rich fuel flame areas and producing moderate combustion in moderate flame areas, the production formation of NOx emissions is reduced. Combustion air is added to the flame in subsequent stages in order to limit formation to its minimum. At the same time, an excellent burn out ratio is achieved. Mitsubishi Power also offers low NOx burners, both jet and swirl type, for boilers utilizing low rank coal (lignite).



PM Burner NR Burner

Combustion test facility
Mitsubishi Power maintains world-class combustion test facilities utilized to develop even more sophisticated combustion technologies that form the basis of boiler performance including lower nitrogen oxide (NOx) emissions, less unburnt fuel, and a reduced excess air ratio. We are particularly focused on enhancing the following two functions of our combustion test facilities to support cutting-edge technological development.

1. Functions to accurately recreate in-flame combustion phenomena in actual boilers
2. Functions to evaluate flow and combustion at high level of accuracy through precision measurement instrumentation

Combustion Test Facility (4t/h)

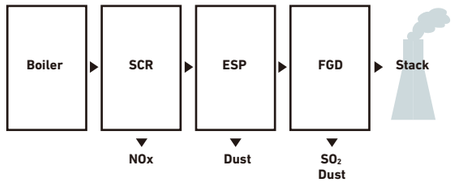
Air Quality Control Systems(AQCS)

Mitsubishi Power is the world's only AQCS solution provider able to develop its own technology for AQCS including SCR, FGD and ESP, and is capable of designing the total AQCS area to meet customers' commercial and environmental needs.

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 to reduce emissions. Mitsubishi Power provides advanced technologies to key industries with reliable air quality control solutions and continues to research better ways of meeting our customers' evolving needs.

Total Solution

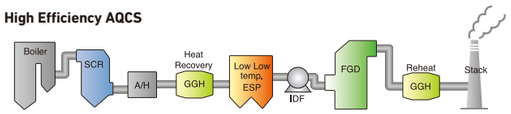


High-efficiency AQCS

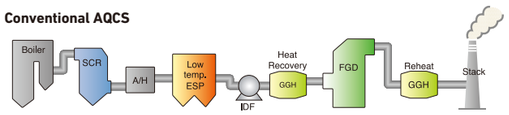
We have developed a new flue gas treatment system, consisting of the SCR, low low temperature ESP, FGD, and non-leakage gas-gas heater (GGH), which achieves effective treatment of flue gas so that it can control dust emissions within the scope of stringent regulations.

Furthermore, in urban areas where even stricter control is 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.

High Efficiency AQCS

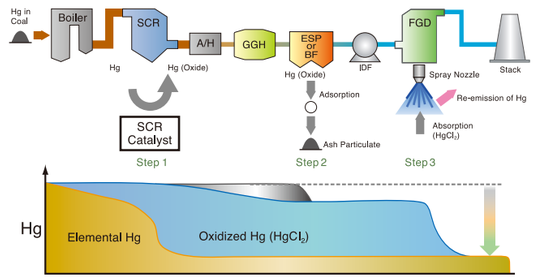


Conventional AQCS



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.

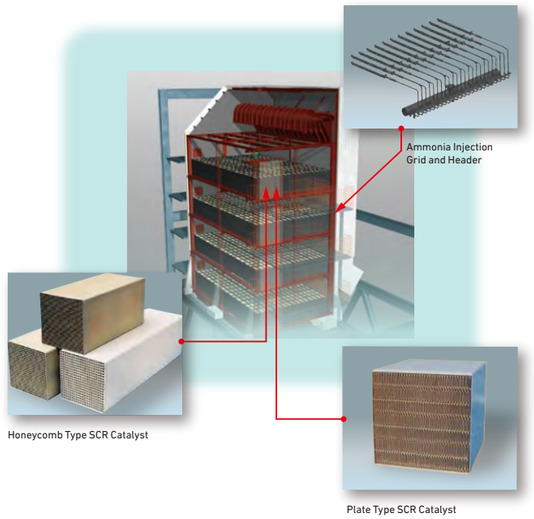
Selective Catalytic Reduction (SCR) System

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 meeting 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 according to the customers' requirements
- Multiple pollutant control including mercury and low sulfur trioxide
- High reliability
- Longer intervals of catalyst maintenance



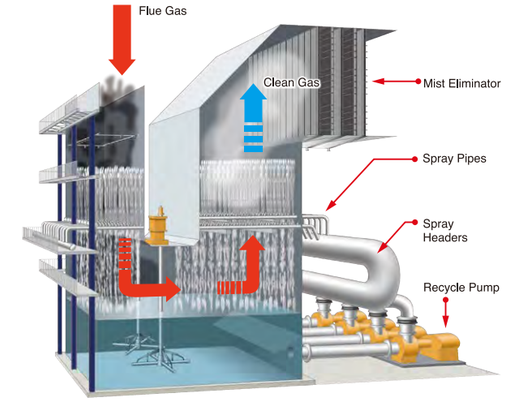
Flue Gas Desulfurization (FGD) Plant

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 wide 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 meeting stringent emission standards for all kinds of fossil fuels
- Multiple pollutant control with associated environmental control equipment
- High reliability
- Savings on energy and utilities

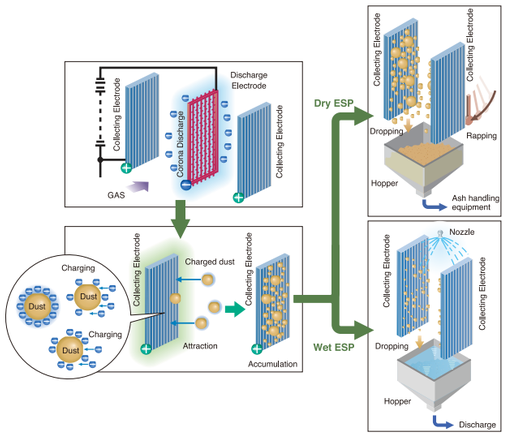


Electrostatic Precipitators (ESP)

Mitsubishi Power electrostatic precipitators (ESP) collect dust in the flue gas produced by boilers and other combustion sources to meet air pollution control and 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).



Dust collection performance and dust characteristics

Our accumulated know-how in evaluating characteristic assessments on various dust properties and flue gas conditions, together with extensive field experience, is reflected in the ESP design.

Services

Proposing services tailored to meet diverse customer needs

Solutions for Decarbonization

In order to reduce carbon dioxide emissions from steam power plants that use fossil fuels, Mitsubishi Power uses various fuel conversion technologies that allow conversion to carbon-neutral plant-derived biomass fuels, ammonia fuels that do not emit carbon dioxide when burned, and waste co-firing depending on customer needs.

In addition, we are developing technologies that allow sustainable and stable power plant facilities to achieve net-zero carbon dioxide emissions through automatic optimal operation tuning using AI for various fuels including biomass, upgrading to high-efficiency turbines with high-performance blades and advanced sealing technologies, and technologies to absorb and fix carbon dioxide.

Decarbonization

Fuel conversion

- Biomass co-firing/100% biomass firing
- Ammonia co-firing/100% ammonia firing

Efficiency improvement

- Efficiency improvement of turbine

CCS/CCUS*

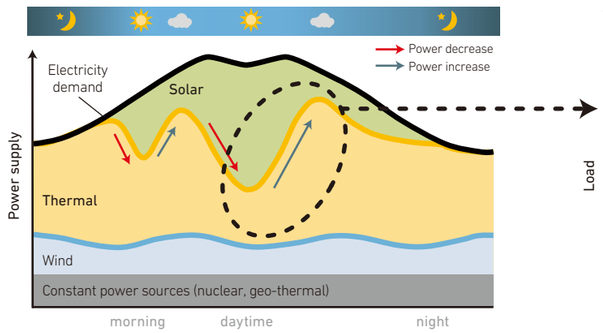
* CCS: Carbon dioxide Capture and Storage
  CCUS: Carbon dioxide Capture, Utilization and Storage

Example of Biomass Plant
Denmark/Avedore #1/250MWe

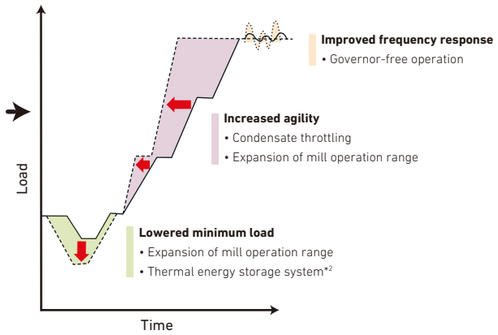
Solutions for the Spread of Renewable Energy

As interest in climate change increases, renewable energy sources such as solar and wind power are becoming more popular and widespread. Since the amount of power generated by these renewable energies is greatly affected by the season and weather, steam power is required to bridge the gap between fluctuations of renewable energies and electricity demand.
To achieve this, it is necessary to respond to rapid load changes and move away from conventional base-load operation.
Based on technology and experience accumulated over many years, Mitsubishi Power provides various steam power solutions that take the characteristics of plant systems and equipment into account and supports improving operation flexibility of existing plants in line with the spread of renewable energy.

Image of Daily Electricity Supply and Demand*1



Thermal Power Operation



*1 Source: Edited from "Japan's Energy (2019 Edition)" published by Agency for Natural Resources and Energy
*2 A system that recovers boiler heat output during extremely low-load plant operation by using a heat accumulator and uses it when the load rises to reduce heat losses associated with start-up and shutdown

Solutions for Maintenance Efficiency

Shortening outages and retrofit construction periods
Mitsubishi Power is working to shorten outages and construction periods in order to reduce construction costs for our customers.

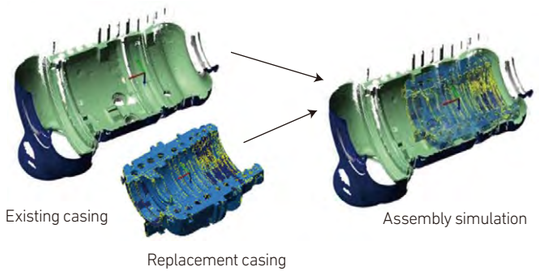
- **Outages**

We provide equipment modifications to shorten outages. For example, an advanced work platform inside the boiler can be utilized for easy access to suspended tubes.

- **Application of 3D measurement technology**

3D models are created using CAD based on the 3D measurement results of existing parts such as the outer casing. Small clearances that may cause interference are detected with existing 3D models of the inner casings, and necessary adjustments are made in advance to enable quick construction work. In addition, based on the 3D measurement results and stress analysis, construction periods are shortened by simulating the work conditions before actual construction.

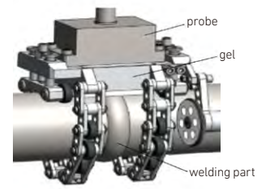
Example of 3D interface check of casing replacement



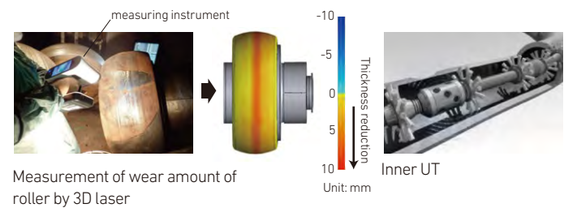
Special Inspection Technology
Mitsubishi Power is developing special inspection technologies that help shorten outage periods.
These include: drone inspection technology that eliminates the need for scaffolding, pencil ECT*3 that can efficiently detect surface defects even with a large number of tubes without scale removal, and post-welding inspection technology (RT alternate UT) that does not require a controlled area like radiation inspection.
Boiler soundness can be confirmed by using a 3D laser to measure mill wear amount, and by using the inner UT and inner ECT that use special sensors to inspect wear inside tubes.
*3 ECT: Eddy Current Test

Remote Services
Our experts can provide remote support for outages and construction work using advanced digital tools.

Pencil UT



RT alternate UT



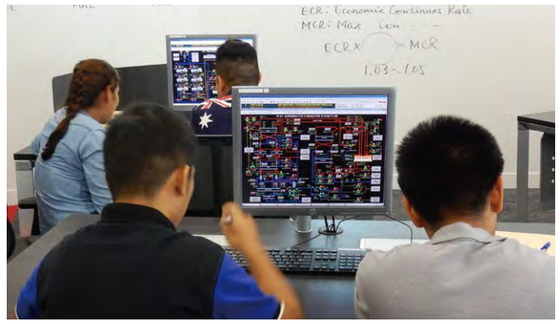
Measurement of wear amount of roller by 3D laser

Inner UT

Training Services

Mitsubishi Power provides customized training under the supervision of our experts to meet customer needs.
We support the training of your engineers and operators through technical training using actual steam turbines used in power plants, plant operation simulation training, and classroom lectures.

Maintenance training at the Steam Turbine Technical Training Center



Operation Training

INTELLIGENT SOLUTIONS

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

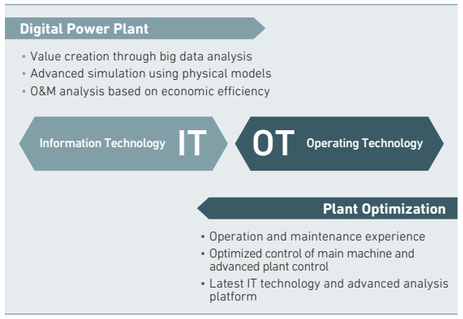
TOMONI, a Japanese word meaning “together with,” reflects the emphasis Mitsubishi Power places on collaborating with customers to solve their unique challenges. Mitsubishi Power works together with customers, partners and society to deploy solutions that support the decarbonization of energy and deliver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

Features of TOMONI

- TOMONI is composed of three solution categories: O&M Optimization, Performance Improvement, and Flexible Operation based on Data Foundation & Enablers. 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.

Intelligent solutions

Combining the latest AI technology with our extensive experience and knowledge in technology, R&D, design manufacture and maintenance of power generation equipment has enabled us to achieve optimal operations that meet the needs of our customers.



TOMONI Solutions: Functions and examples

O&M OPTIMIZATION	• Trouble management and prevention support • Predictive maintenance by understanding remaining life
FLEXIBLE OPERATION	• Efficiency improvement by optimized control
PERFORMANCE IMPROVEMENT	• Response to fuel and load changes
DATA FOUNDATION & ENABLERS	• PI system construction support • Cyber security support

TOMONI™

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

Solutions for Performance and Reliability Optimization

Mitsubishi Power provides maintenance services to improve performance and reliability by combining customers' operation data with design data and plant information supported by our extensive technology and design experience.

- Performance improvement
  - Predicting performance degradation status through operation data analyses
  - Proposing recommended actions for the next outage by analyzing performance degradation
- Reliability improvement and stable operation
  - Predicting remaining life and functional deterioration of crucial parts
  - Proposing parts replacement and modification to improve reliability

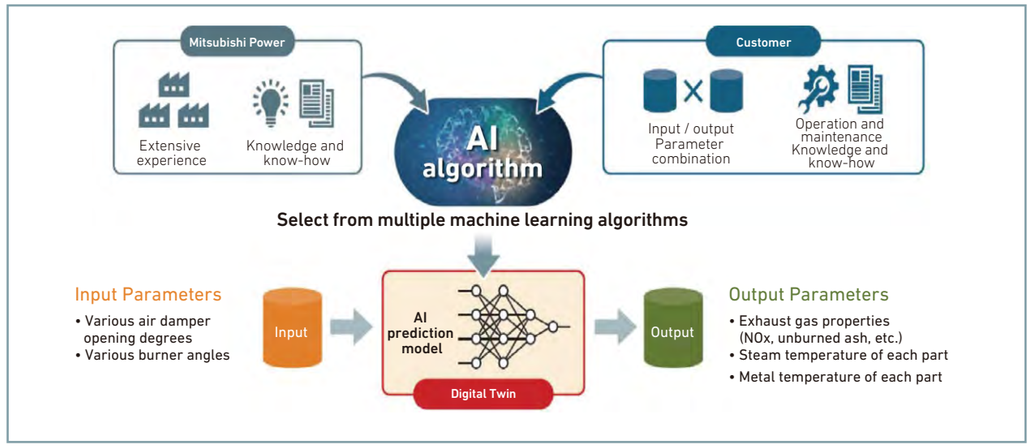
Boiler Smart Inspections

In addition to outage planning, there are issues such as human resource development and the transfer of skills from experts to the next generation.
In this service, we support our customers search maintenance records utilizing digital technology, human resource development, and outage planning.
Mitsubishi Power also encourages dialogue with our experts to help solve a wide range of equipment issues.

Solutions for Optimizing Operations using AI

Customers' needs for operation are changing and diversifying, such as high-efficiency operation and carbon-neutral fuel firing.

Mitsubishi Power can provide optimized operation solutions utilizing AI without having to dispatch experienced engineers.



Solutions for Operation and Maintenance

Mitsubishi Power provides solutions to various operation and maintenance issues based on our extensive technology, design and manufacturing knowledge.

Remote monitoring and operation support

Our TOMONI HUBs (Analytics and Performance Center) monitor the entire steam power plant 24 hours a day, 365 days a year. Our operation and maintenance experts provide full support throughout the plant life cycle.
Using our cutting-edge digital technology, intelligent solutions TOMONI, Mitsubishi Power meets customer needs by providing comprehensive solutions that ensure high availability and efficiency by not only monitoring operation data parameters but also diagnosing signs of anomalies utilizing AI.

Mitsubishi Power provides Long Term Service Agreements* utilizing remote monitoring data and outage records to assist with general plant optimization such as scheduling planned outages for long term and stable operation.

• Mitsubishi Power can offer tailored services depending on customer needs, including spare parts supply, turnkey outages, dispatch of technical advisors, and more.

TOMONI HUB in Nagasaki Shipyard & Machinery Works

TOMONI HUB in Alabang, Philippines