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AQCS (Air Quality Control System) for Thermal Power Plants Capable of Responding to Wide Range of Coal Properties and Regulations

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Generally coals used in coal-fired power plants in India and China have high ash contents, and along with the strengthening of PM (particulate matter) control regulations, high PM removal performance is required. To demonstrate the Mitsubishi Hitachi Power Systems (MHPS) Group's high-performance PM removal system, the PM removal performance under high PM concentration conditions was evaluated at the 1.5MW pilot test facility, and the system was applied to the retrofit project at Zouxian Power Station in China (1,000MW) and achieved the PM concentration of 5mg/m^{3}N or less at the stack outlet. In addition, our proprietary high-performance Moving Electrode type Electrostatic Precipitator (MEEP®) was applied to the retrofit project of the dry Eloctrostatic Precipitator (ESP) at Rihand Super Thermal Power Station in India (500MW x 2), and through modification of the existing space, the PM concentration at the ESP outlet was reduced from 500 to 600mg/m^{3}N to 50mg/m^{3}N or less.

1. Introduction

In recent years, in developing countries with soaring electric power demand, particularly in India and China, the increase in the PM concentration in the atmosphere has been a problem, and the control of PM emitted from thermal power plants has been increasingly strengthened. Generally, the coal used in thermal power plants in India and China has an ash content of about 30% to 45%, which is very high compared with the coal generally used in Japan, Europe and America (which has an ash content of around 10%). Therefore, high dust removal performance is required. At thermal power plants in India and China, general precipitators for PM removal have already been installed, and to cope with the strengthening of regulations, many customers want to modify the existing precipitators in their limited site areas.

The promising technologies for meeting these needs are the MHPS Group's proprietary technologies: (1) high-performance PM removal system which combines a heat exchanger and the ESP to adjust the flue gas temperature, thereby achieving high particulate collection efficiency, and (2) an ESP equipped with MEEP®. These technologies were field-proven in many projects both inside and outside Japan, but there was no track record in using them with high ash content coals such as Indian coals and Chinese coals. This report introduces an overview of the two aforementioned high-performance PM removal technologies and the results of their application to high ash content type coals.

2. High-performance PM removal technologies

2.1 High-performance PM removal system

Figure 1 shows the flow of the high-performance PM removal system and the conventional system. In the conventional system, a gas cooler is installed between the ESP and the flue gas desulfurization equipment (FGD), and the flue gas temperature at the ESP is in the range of 130°C to 160°C. On the other hand, in the high-performance PM removal system, a non-leak type and finned-tube gas cooler is installed in front of the ESP, and the flue gas temperature at the ESP is

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lowered to 90°C to 100°C. The ESP uses electrostatic force for particulate collection, and PM which is charged with negative ions emitted from the discharge electrode is moved to the collecting electrode on the positive side and is collected, and then a shock is imparted to the PM by hammering for detachment and collection.

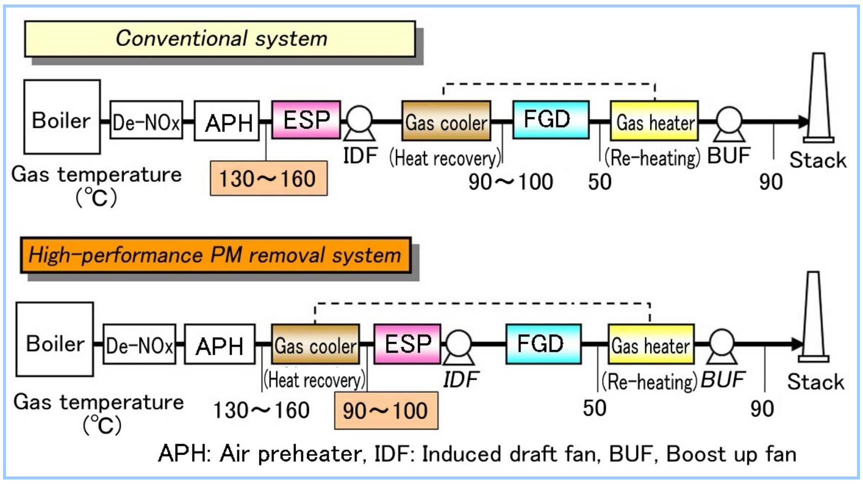

Figure 1 Configurations of the conventional system and the high-performance PM removal system
In the high-performance PM removal system, a gas cooler is installed at the front stage of the ESP and the flue gas temperature at the ESP is 90°C to 100°C.

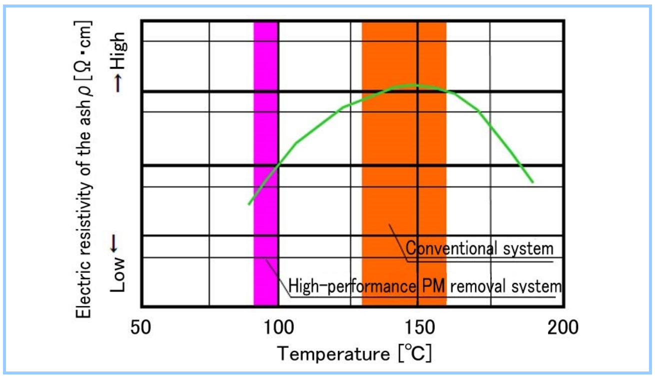

Figure 2 Relationship between the flue gas temperature and the electric resistivity of the ash
The electric resistivity of coal ash fluctuates with the flue gas temperature. In the temperature range of the high-performance PM removal system, the electric resistivity becomes lower than that of the conventional system.

Figure 2 presents the relationship between the electric resistivity (ρ) of PM emitted from coal firing and the flue gas temperature. ρ is the factor that most greatly affects the particulate collection performance of the ESP. In the conventional system which operates at a temperature ranging from 130°C to 160°C, ρ is in a high region, while in the high-performance PM removal system which operates at 90°C to 100°C, ρ is lowered. The higher ρ becomes, the stronger the adhesion force of PM to the collecting electrode becomes, which makes it difficult to shake off PM by hammering. This causes a back corona in which positive ions with the reverse polarity are discharged from the inside of the layer of PM accumulated at the collecting electrode into the particulate collection area, resulting in a rapid decline of the particulate collection performance of the ESP. Therefore, to maintain the high particulate collection performance, it is necessary to take countermeasures for the back corona caused by PM with high electric resistivity. In the high-performance PM removal system in which the ESP operates at a temperature ranging from 90°C to 100°C, ρ is lowered to the range where PM is easily detached by hammering, resulting in the improvement of the particulate collection performance compared with the conventional system. This allows the ESP equipment to be made compact, and the decrease of the inflow of PM into the FGD improves the quality (purity) of by-product gypsum from the FGD.

So far, it was demonstrated in the tests using the pilot test facility and actual units that the high-performance PM removal system is more effective than the conventional system in the substantial removal of not only PM, but also toxic trace elements such as mercury (Hg) and selenium (Se), as well as sulfur trioxide (SO_3), which causes bluish plumes or acid rain.[1] However, to apply the high-performance PM removal system to high ash content type Indian and Chinese coal, it is necessary to demonstrate that the gas cooler which is a key unit in the high-performance PM removal system can operate without problem under the condition with a high PM concentration. For that, the relationship between the state of the ash accumulated in the gas cooler, which has a high PM concentration atmosphere, and the heat transfer characteristics, as well as the wearing speed of the finned tube, are evaluated.

2.2 Moving Electrode type Electrostatic Precipitator (MEEP®)

In a conventional ESP, which is comprised of only general fixed electrodes, fine PM is entrained in the flue gas and re-emitted during hammering for the detachment and collection of PM accumulated at the collecting electrode, resulting in an increase of the concentration of PM emitted from the stack. In addition, PM with high electric resistivity has a strong adhesion force to the collecting electrode and a strong cohesive force between particles, and it is difficult to detach by the impact of hammering, resulting in degradation of the performance of the electrode due to contamination over time.

In our ESP, as shown in **Figure 3**, the general fixed electrodes are installed at the front stage to roughly remove PM of several tens of thousands mg/m^3N floating in flue gas to a certain degree, and our proprietary MEEP® technology is installed at the rear stage to remove the remaining fine PM and high electric resistivity PM. As a result, the concentration of PM at the ESP outlet can be reduced to several tens of mg/m^3N. **Figure 4** shows the structure of MEEP®. While the collecting electrode element is rotated by the driving chain, the electrostatically-collected PM on the element surface is scraped off using a brush installed in the hopper in which no flue gas flows. Therefore, MEEP® exerts a superior particulate collection performance for high electric resistivity PM at the general fixed electrode which is difficult to detach by hammering or for fine PM which is entrained in the gas flow and re-emitted by hammering. Accordingly, when MEEP® is applied to a retrofit project for the purpose of enhancing the capability of the existing ESP, the performance can be improved without increasing the ESP installation area, and the use of MEEP® is a very effective measure to cope with the recent strengthening of flue gas regulations in various countries around the world..

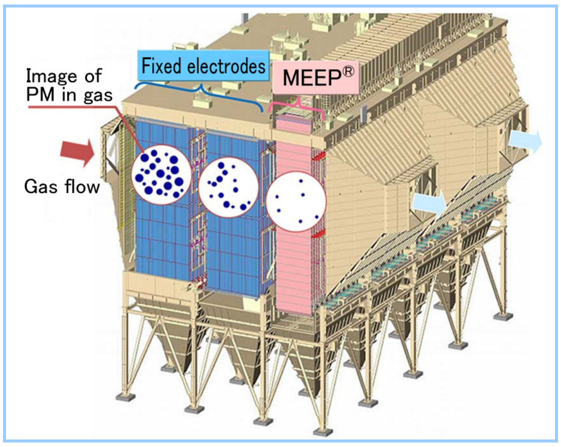

Figure 3 Structure of our ESP (one example)
One example of the structure of our ESP equipped with MEEP®

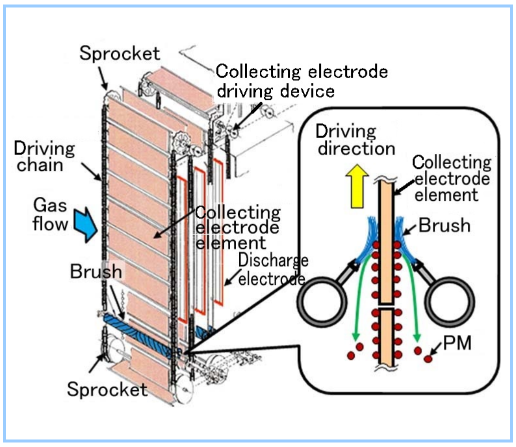

Figure 4 Structure of MEEP®
By scraping adhered ash with a brush when the collecting electrode is driven, high PM collection performance is maintained.

3. Demonstration of high-performance PM removal system and example of application to actual units in China

3.1 Demonstration of high-performance PM removal system using high ash content coal at our pilot test facility

Using the 1.5MW pilot test facility introduced in a previous report[1], the particulate collection performance of the ESP, the heat transfer characteristics of the gas cooler and the wearing speed of the finned tube during firing of high ash content Indian and Chinese coal were evaluated.[2] As shown in **Figure 5**, this facility is, as with an actual coal-fired thermal power plant, thoroughly equipped with a furnace, heat exchanger, NOx reduction catalyst, gas cooler, gas heater, ESP (a fabric filter can also be used by bypass) and wet-FGD, and the operating conditions of each device can be arbitrarily changed, allowing various kinds of tests. Therefore, we used the facility from the development stage of the high- performance PM removal system.

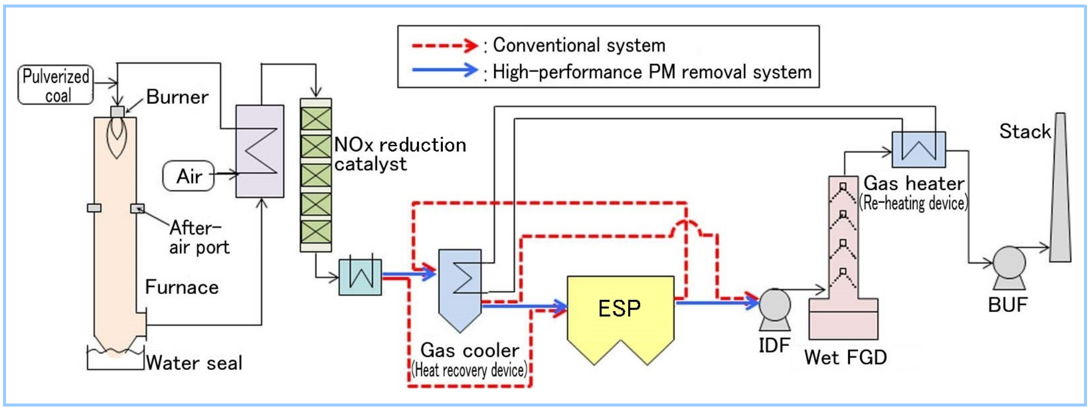

Figure 5 Flow diagram of our 1.5MW pilot test facility
As with the actual equipment, our test facility has all general devices such as a furnace through stack..

Indian coal and Chinese coal were used in the conventional system and the high-performance PM removal system to compare the PM concentration at the ESP outlet, and the results are shown in **Figure 6**. As with the previous findings, in the high-performance PM removal system, even when high ash content coal is used, the ESP temperature is lowered, and it exhibited an improved particulate collection performance. Concerning the electric resistivity of Indian coal ash and Chinese coal ash (**Figure 7**), it was found that the electric resistivity of the ash was lowered in the treatment flue gas temperature range of the ESP in the high-performance PM removal system.

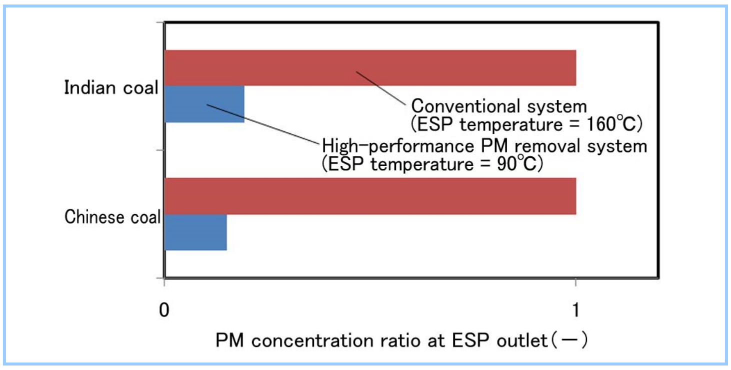

Figure 6 Changes in the overall coefficient of heat transfer of the gas cooler in the high-performance PM removal system
By lowering the flue gas temperature of the ESP for both Indian and Chinese coal with a high ash content, the particulate collection performance was improved.

Figure 8 shows the structure of the gas cooler at the pilot test facility. It is a non-leak type and finned-tube gas cooler, which is the same as the actual unit. Ash adhered to the finned tube can be removed by soot blow. The change of the overall coefficient of heat transfer α, which indicates the heat exchange performance of the gas cooler when Indian coal is fired in the high-performance PM removal system is shown in **Figure 9**. The PM concentration of the flue gas at the inlet of the gas cooler is high, 30g/m^{3}N, and the overall coefficient of heat transfer α tended to be lowered over time. Through the periodical soot blow, however, the accumulated ash could be easily removed, and it was found that the overall coefficient of heat transfer α could be recovered to the initial value. In addition, a carbon steel test piece, which has the same material as the finned tube, was installed at the inlet of the gas cooler, and the wearing caused by PM was evaluated as the thinning speed. As a result, it was found that the thinning speed of the conventional system and that of the high-performance PM removal system were the same, and it was confirmed that there was no problem in applying the high-performance PM removal system to high ash content type coal.

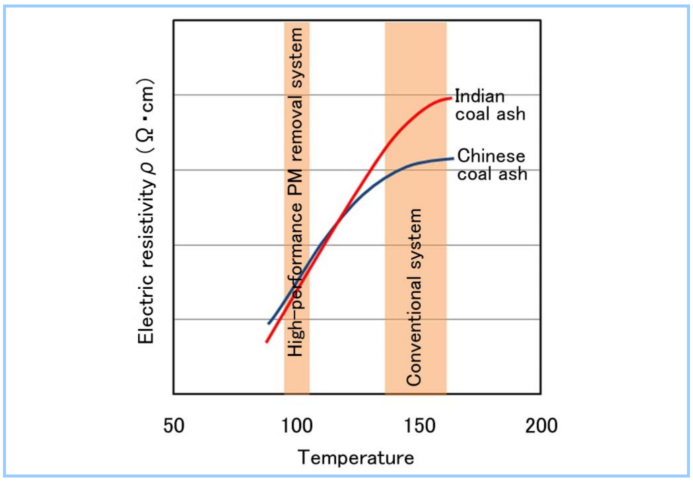

Figure 7 Temperature characteristics of electric resistivity of coal ash with a high ash content
The factor for the improvement of the particulate collection performance in the high-performance PM removal system is the reduction of the electric resistivity.

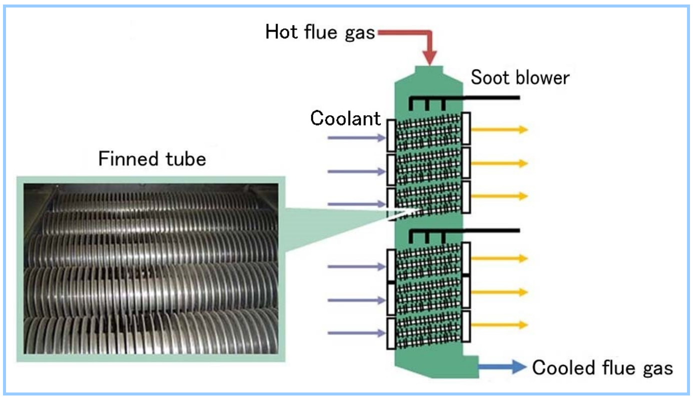

Figure 8 Structure of gas cooler
The gas cooler cools the flue gas by passing the coolant through the finned tubes arranged inside. Ash adhered to the tubes is removed by the soot blower.

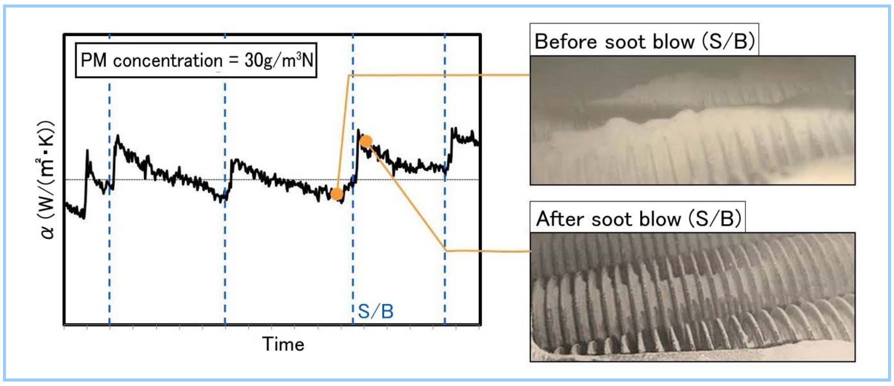

Figure 9 Changes in the overall coefficient of heat transfer of the gas cooler in the high-performance PM removal system
Even under the condition where the PM concentration in flue gas is high, for example, when Indian coal is used, ash accumulated on the finned tubes of the gas cooler can be removed by the soot blower and the overall coefficient of heat transfer is restored to the initial value.

3.2 Application example to the PM removal performance improvement project at Zouxian Power Station in China (1,000MW)

In China, the control of toxic substance emissions from thermal power plants has been tightened, and in particular the reduction of sulfur dioxide (SO_2) and PM emissions are required. Therefore, retrofit projects for existing flue gas treatment systems for the enhancement of capability have been increasing. This is one such retrofit project. In 2014, the ESP and the FGD were modified for the enhancement of capability by another manufacturer. To cope with the further tightening of regulations, Zhejiang Feida MHPS High Efficiency Flue Gas Cleaning Systems Engineering Co., Ltd. (FMH), which is part of the MHPS Group, received a retrofit order for the first time since its establishment in 2015.

Figure 10 illustrates the system flow starting at the ESP inlet before and after modification. Major improvements include the incorporation of a high-performance PM removal system by the rotating GGH (gas-gas heater) being removed, and the non-leak type GGH heat recovery device and the re-heating device being installed at the front stage of the ESP and the rear stage of the FGD, respectively. Other major improvements include an increase of the SO_2 removal performance and the PM removal performance of the FGD itself through the renewal of auxiliaries and internal parts – such as recirculation pumps, spray headers, nozzles and agitators – of the FGD.

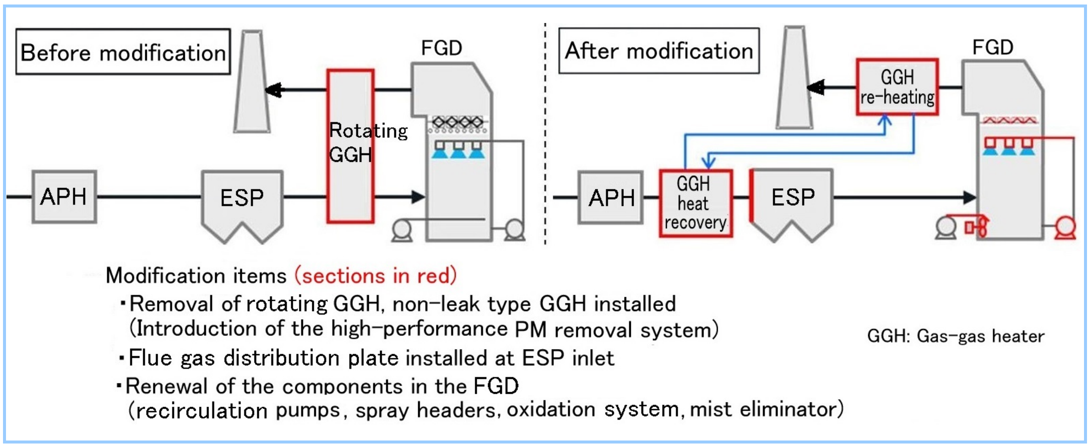

Figure 10 Overview of modification for reduction of PM emissions in China
Using our advantage as a supplier of entire AQCS, we satisfied the customer's desired values through the introduction of the high-performance PM removal system and an increase of the particulate collection performance and the SO_2 removal performance of the FGD.

Table 1 shows the result values after modification relative to the customer's desired values. The desired value for PM concentration has been set at 5mg/m^{3}N or less in view of future PM regulations, which is equivalent to the recent desired value for the concentration of PM emissions at thermal power plants in Japan. Moreover, the existing equipment that was installed by another manufacturer was the target equipment in the retrofit project, and therefore, a close preliminary investigation was needed. As such, this project required a high level of work, but leveraging our advantage as a supplier of furnace-to-stack air quality control systems, we modified the equipment as a comprehensive system and achieved the customer's desired values for both the particulate collection performance and the SO_2 removal performance.

Table 1 Results of modification of actual unit in China (1000MW) for PM emissions reduction
The customer's desired values were achieved by the optimization of the whole system.

	Before modification	Customer's desired value	After modification
PM concentration at ESP inlet [mg/m^{3}N]	25000	—	—
PM concentration at ESP outlet [mg/m^{3}N]	30	≦30	10
PM concentration at the FGD outlet [mg/m^{3}N]	14	≦5	2
SO_2 concentration at the FGD outlet [mg/m^{3}N]	70-330	≦35	10-23

4. Application example of MEEP® to high concentration PM case

4.1 Overview of the retrofit project of the existing ESP in India

As an application example of MEEP®, the retrofit project of the existing ESP at Rihand coal-fired power plant owned by India's National Thermal Power Corp. (NTPC) is introduced here. In this project, the internal components of four ESPs installed in each of two 500MW boiler units shown in **Figure 11** were upgraded. The six-section type fixed electrodes had been in use for 25 years after the delivery. As shown in **Figure 12**, the front four sections were modified into fixed electrodes with our specifications, and the rear two sections were modified into MEEP®.

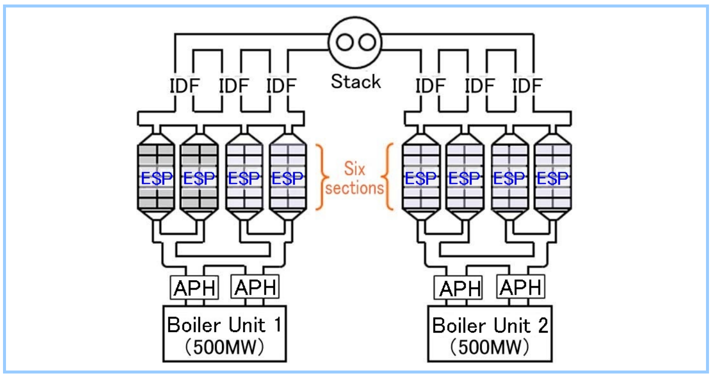

Figure 11 (Stage-I) Flow of the equipment at Rihand Super Thermal Power Station
Flow chart of ESP (Stage-I) equipment for which we received the order

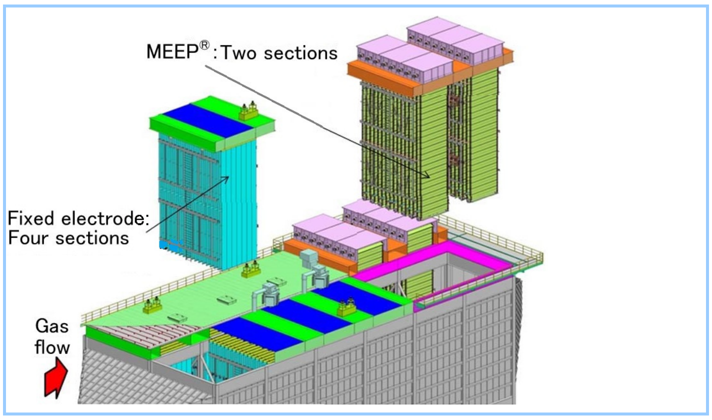

Figure 12 Renewal of the inside of ESP
The front four sections were modified into fixed electrodes with our specifications, and the rear two sections were modified into MEEP®.

The ESP planning conditions before and after modification are shown in **Table 2**. Since the ash content of the Indian coal used was about 40%, the PM concentration at the ESP inlet was high. In addition, as a result of a prior study, it was estimated that the PM emitted from this coal had a very high electric resistivity, and if the PM continued accumulating on the collecting electrode, the performance would be significantly reduced. It was estimated that if only fixed electrodes were used to meet the customer's strict performance requirement (outlet PM concentration of 50mg/m^{3}N or less), about twice the collecting area would be needed and a large-scale modification including the replacement of ducts would be necessary. On the other hand, MEEP® allows the collecting electrode to keep clean and exerts high PM collection performance for Indian coal that emits a high electric resistivity PM, enabling the ESP to be made compact. Therefore, in this project, MEEP® was applied to the rear two sections, and using only the existing space for modification, the customer's desired value could be satisfied.

Table 2 Flue gas conditions before and after modification of ESP
The flue gas conditions of the ESP before modification (customer's presented values) and after modification (planned values)

	Before modification (Customer's presented value)	After modification (Planned values)
Inlet gas volume [m^3/s]	1050	1050
Inlet gas temperature [°C]	160	160
Inlet PM concentration [mg/m^{3}N]	44000	56000
Outlet PM concentration [mg/m^{3}N]	500-600	≦50

4.2 MEEP® application results

The performance test was completed in March 2017, and the modified system is in operation. It was found during the test operation that PM collected by MEEP® was finer and had a higher electric resistivity than estimated in the plan, and the operating conditions of MEEP® were reviewed. As a result, in the performance test, both units achieved the PM concentration at the ESP outlet of 50mg/m^{3}N or less that was required by the customer, and the PM emissions were significantly reduced compared with the value before modification (outlet PM concentration: 500 to 600mg/m^{3}N). **Figure 13** shows the states of flue gas from the stack before and after modification. It is obvious that the performance was improved through modification with MEEP®, and it was demonstrated that the superiority of MEEP® could be exerted even at coal-fired power plants in India, which require the treatment of high concentration, high electric resistivity and fine PM.

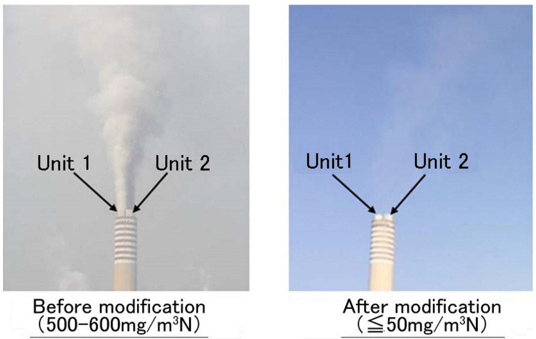

Figure 13 States of gas exhausted from the stack
Photos of the flue gas from the stack before and after modification of the ESP, by which we can observe that the PM concentration exhausted from the stack was obviously reduced.

5. Conclusion

In recent years, various environmental measures have been promoted all over the world, and under these circumstances, the importance of environmental technologies has been increasing. So far, we developed AQCS from the basic stage and demonstrated through pilot tests and tests using actual units that AQCS could remove PM and toxic trace elements in flue gas to a high degree, and could also be applied to high ash content coal. Accordingly, we applied AQCS to retrofit projects for actual units. In the future, as a supplier of furnace-to-stack air quality control systems, we will continue offering optimal systems corresponding to coal properties and regulations in the destination country or the state of the plant, and will develop technologies for reducing toxic substances not only in flue gas, but also in solid emissions (collected PM, FGD gypsum) and in wastewater as well as fixation technologies, so that environmental load can be reduced for entire thermal power plants. Finally, we are deeply grateful to the Japan Coal Energy Center (JCOAL), which cooperated with the demonstration test for Indian coal at the 1.5MW pilot test facility.

Note: MHPS Environmental Solutions, Ltd. took over all the precipitator businesses including MEEP® from Hitachi Plant Construction, Ltd. in October 2015.

References

1. Kikkawa et al., Highly-Efficient Removal of Toxic Trace Elements and Particulate Matter in Flue Gas Emitted from Coal-fired Power Plants by Air Quality Control System (AQCS), Mitsubishi Heavy Industries Technical Review Vol. 52 No. 2 (2015)
2. Nagarajan, S. et al., Experimental results of AQCS for Indian coal, Power-Gen India & Central Asia 2017