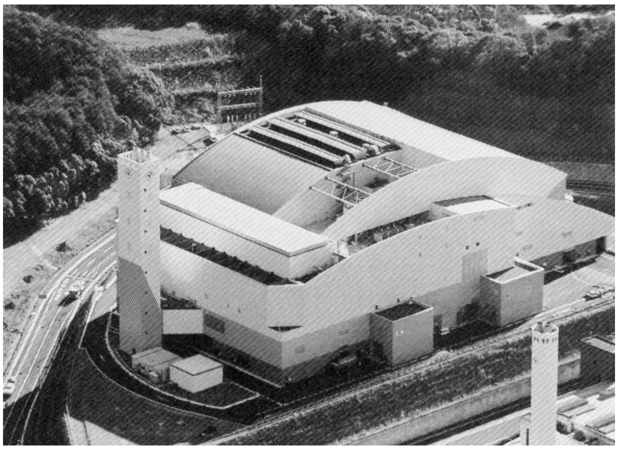

Systems and Equipment for Realizing Clean Environment

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1. Introduction

Through the high economic growth period of the 1960s, Japan faced ever-worsening air pollution and an increasing discharge of waste as Japanese society shifted more and more towards heavy industry. In response to this social trend, Mitsubishi Heavy Industries, Ltd. (MHI) promoted the development of technologies for flue gas treatment and waste treatment.

With regard to this point, this article describes the concept and the current state of products and technological development relating to flue gas treatment, CO_2 recovery, PCB treatment, soil remediation, and waste treatment for assuring a clean environment.

2. Flue gas treatment

The shift towards a heavy industry oriented society accelerated with the high rate of economic growth that occurred during the first half of the 1960s. The accompanying increase in air pollution enhanced the legal system fulfillment as a preventive measure and encouraged the development of technologies concerned with the flue gas treatment. In this regard, MHI began production of electrostatic precipitators (ESPs) in 1960, and commercialized a wet type flue gas desulfurization (FGD) system in 1972.

Japan entered a period of full-scale market introduction of the FGD system in the 1970s, and the system came to be applied to coal fired power generation plants at the end of the 1970s.

At the initial stage of the FGD system introduction, MHI adopted a grid-packed tower as the absorber of the FGD system. In the 1980s, however, demand shifted from a momentary boom to rationalization. In order to cope with this shift in demand, MHI developed a double-contact flow scrubber (DCFS) in which the internal grid packing were eliminated, and both the performance and maintainability of the system were improved. MHI introduced the new system to the market during the first half of the 1990s.

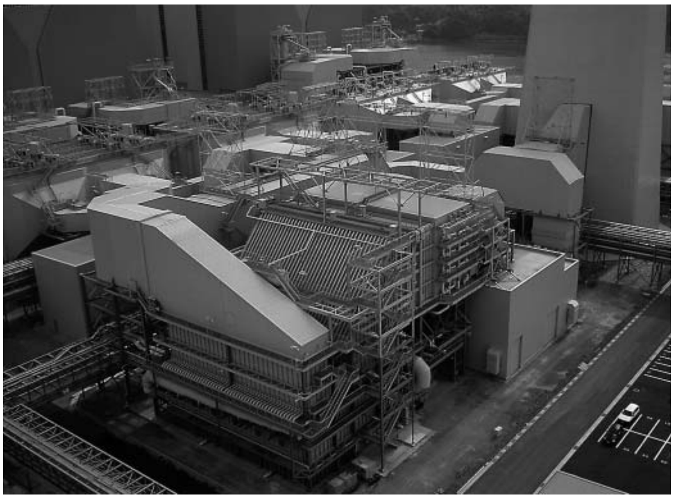

Fig. 1 Flue gas treatment facility
Flue gas treatment facility at Unit 1 of the Tachibana Wan Power Station of the Electric Power Development Co., Ltd.; 1 050 MW, the largest capacity coal fired power generation plant in Japan; A single tower type absorber (double-contact flow scrubber); Desulfurization efficiency 95%

MHI succeeded in improving total flue gas treatment systems combined with ESPs, increasing the performance of dust removal through the combined use of a non-leak type GGH (gas to gas heater) and colder side ESP (in a range of 90ºC to 110ºC), and reducing the concentration of dust at the inlet of the absorber, where dust concentrations also impact the desulfurization performance. Furthermore, the quencher is eliminated in this system, thereby achieving simplified system facilities. In the latter half of the 1990s, MHI applied the improved system to coal fired power generation plants of the utility industry during and after the period as the forerunner in the world. The system became the standard one used in the succeeding domestic coal fired power plants among manufacturers.

The system is expected to be successively adopted in China, the U.S., and Europe, where there are strong needs for flue gas desulfurization. To match the system with the conditions of individual new markets, MHI is endeavoring to realize further rationalization of the system.

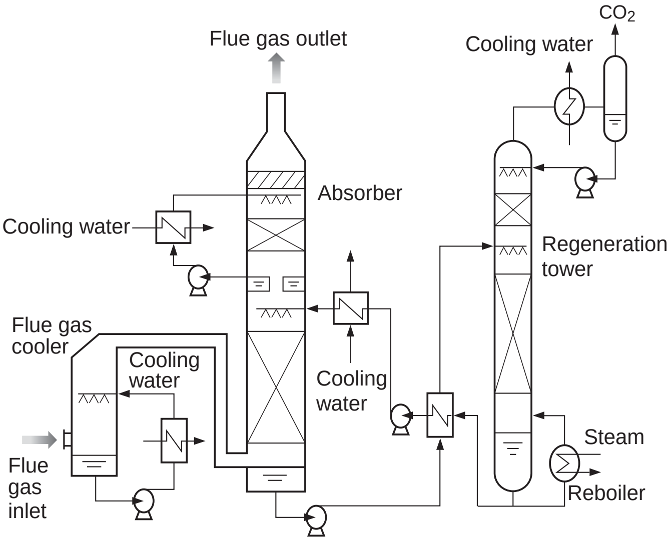

Fig. 2 CO_2 Recovery facility
Flowchart of CO_2 recovery from flue gas of boiler, etc.

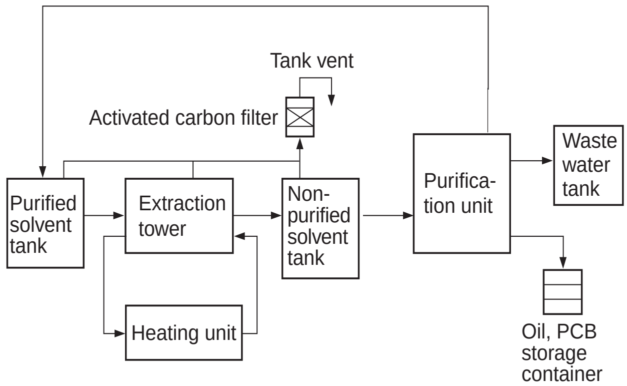

Fig. 3 PCB contaminated soil remediation facility
Flowchart of PCB contaminated soil remediation by solvent extraction process

3. CO_2 recovery

Japan ratified the Kyoto Protocol adopted at COP3 (the Third Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change) in May 2002. The ratification is to lead to the enhancement of activities that serve as effective countermeasures to global warming. The most effective and basic measure for addressing CO_2 emissions, which is the main component of greenhouse gases, is to reduce the amount of such gas discharged, particularly the amounts emitted as carbon combustion gas. However, another important approach is to recover emitted CO_2.

The separation and recovery of CO_2 has long been conducted in the fields of natural gas and synthetic gas. The CO_2 recovery from the combustion flue gas, however, was only given limited attention. With respect to this subject, MHI recognized the effectiveness of CO_2 recovery from combustion flue gas as a measure for addressing global warming related issues, and has been conducting development studies jointly with the Kansai Electric Power Co., Inc. since 1990. Compared with existing technologies that use monoethanolamine (MEA) as the absorbent, a new absorbent has been developed that consumes less energy and results in less degradation and loss. The CO_2 recovery system with this new absorbent has already been commercialized at a urea production plant in Malaysia. Furthermore, the joint team developed packing, which significantly reduces the pressure drop in the flue gas route, and also developed a means to reduce the amount of absorbent loss.

In the field of CO_2 fixation or CO_2 utilization, there are existing general applications such as the injection of CO_2 at oil fields adopted as an Enhanced Oil Recovery (EOR) process, chemical use of the gas in the urea production process and other processes, and use in the production of various carbonated beverages. The total amount of CO_2 consumed in these applications is, however, very little compared with the total amount of CO_2 actually discharged, and there is still a great need to develop full scale CO_2 fixation technology. With respect to new fixing targets, research and development efforts are focussing on methane gas replacement in coal strata and deep ocean sequestration. As countermeasures to global warming caused by CO_2, MHI recognizes that full scale CO_2 fixation technology is absolutely necessary if it is to be applied practically. In addition, MHI is also developing new approaches to this matter, not limited to a CO_2 recovery system, but also to combining with a fixation system, for example, recovering CO_2 from CO_2 emission sources such as boiler adjacent to an oil field to apply the CO_2 thus recovered to EOR.

4. Soil remediation

Soil is an important component to the structure of the environment along with water and the atmosphere, and the prevention of contamination and the prompt treatment of contaminated soil are important to conservation of the soil. Nevertheless, actions and the establishment of an effective legal system to address problems have been delayed because soil belongs to individuals.

The legal systems are being established in the United States and Europe. Surveys in Japan undertaken during the redevelopment of closed plant sites have revealed the existence of contaminated soil distributed in many places around the country. It was against this background that social concern increased, and the Soil Contamination Countermeasures Law came into force in 2002.

Taking the opportunity to clean soil that had been contaminated by volatile organic compounds in 1996, MHI successively introduced technologies for cleaning soil. These technologies involved the solvent extraction method for remediation of oil and PCBs contaminated soil from the Terra-Kleen Response Group, Inc. of the U.S., and the thermal treatment of soil contaminated by volatile organic compounds, oil, dioxins, etc. using an externally heated kiln from Tech Trade GmbH of Germany. In this way, MHI thus established an integrated system covering from survey and analysis, and countermeasure, to environmental monitoring. From 2000, MHI began full-scale activity in the soil cleaning business.

With regard to cleaning technologies, MHI has completed development of cleaning soil contaminated by PCBs, which has drawn much attention. In addition, the solvent extraction process, which is in the demonstration test stage, has also drawn the attention of related industries. The solvent extraction process is based on PCB extraction technology using a solvent introduced from the Terra-Kleen Response Group, Inc. in the U.S. in 2001. It complements the solvent distillation and fractionation technologies used in the solvent recovery system with which MHI has experience, thereby realizing a system of low temperature, low pressure, free of flue gas generation. Owing to these features, the solvent extraction process is an epoch making treatment technology that is suitable for the on-site treatment of contaminated soil and that makes it possible for treated soil to be reused. To verify the practical applicability and impact on the environment, the technology is currently undergoing a demonstration study for the first in Japan by a joint team of Kobe City, the National Institute for Environmental Studies and MHI. Transportable equipment was placed at a storage yard of the contaminated soil in Kobe City, and the cleaning test began in July 2002.

Technical development is scheduled to verify the treatment performance and safety data that have already been acquired in laboratory tests at the commercial scale test, and to complete the cleaning treatment process by the end of December 2002.

Furthermore, MHI plans to complete a supersonic wave applied contaminated soil cleaning technology in order to respond to social needs.

5. PCB treatment

Since PCBs, which had been produced during and after 1929, have advantageous characteristics such as chemical stability and electrical insulation, they were used in great amounts as insulation oil in transformers and other applications. After that, PCBs were found to have a bad impact on human body and the environment, and the production of PCBs was banned. Currently, however, a large number of equipment and devices containing PCBs still exist, and the government has moved to treat them in an adequate and appropriate manner.

The hydrothermal decomposition process developed by MHI is a technology that injects PCBs with sodium hydroxide in hot water at high temperature and high pressure (at a level of 380°C, 26 MPa). The goal is to enhance the dechlorination and oxidation decomposition of the chemical using the surface activity of deposited sodium carbonate, so as to breakdown the PCB into harmless water, sodium chloride, and carbon dioxide.

Detoxification of PCB, however, requires suitable technologies not only to treat the PCB liquid but also to properly treat the metals such as contaminated capacitor containers, paper, and wood used, the cloth used to wipe off any PCBs on the surface of the equipment of the PCB treatment facility, and the activated carbon packed in the exhaust gas treatment system.

On this point, MHI uses an integrated treatment system that also ensures the safety of operators by reducing the amount of adhering PCB. This consists of starting with a rough washing of the transformers and capacitors, after which the washed equipment is disassembled and classified. A finish washing is applied to those parts that are not impregnated with any PCBs, such as containers, ceramics, cores, and copper wires. Finish washing consists of applying a combined metal surface treatment washing and solvent washing so that any PCBs remaining in narrow gaps on the metal surface are surely removed. All paper and wood generated during the treatment stage, along with organic matter such as wash wastewater, as well as contaminated cloths and activated carbon are slurried and detoxified by the hydrothermal decomposition process, since washing alone cannot fully remove PCBs from these materials.

As described above, the MHI system is based on a complete detoxification and integral treatment process that centers on the hydrothermal decomposition process to detoxify all contaminants. The Nagasaki Shipyard & Machinery Works of MHI is the first site to carry out integrated in-house treatment of PCB liquid and contaminated equipment and material in Japan. In order to assure safety and improve operation and control performance, the integrated treatment plant monitors concentrations of PCBs in flue gas and wastewater using an exclusively developed PCB meter. The PCB meter for flue gas determines PCB concentrations through the use of an irradiating laser on the sample gas that is directly introduced in the meter, thereby making it possible to count the number of ionized PCB molecules. Use of the meter makes it possible to reduce measurement time significantly to one minute without degrading measurement accuracy, compared with two days using the regulatory method. Use of the PCB concentration monitoring system in wastewater, which includes automating the pretreatment of the GC-ECD (Gas Chromatograph Electron Capture Detector) method, a measurement method similar to that used in the regulatory method, significantly reduces measurement time to two hours without degrading measurement accuracy, compared with two days for the regulatory method.

A notable feature of the hydrothermal decomposition process is its ability to breakdown persistent organic compounds. Thus, the process is applicable to fields other than PCB treatment, and the process can be expected to

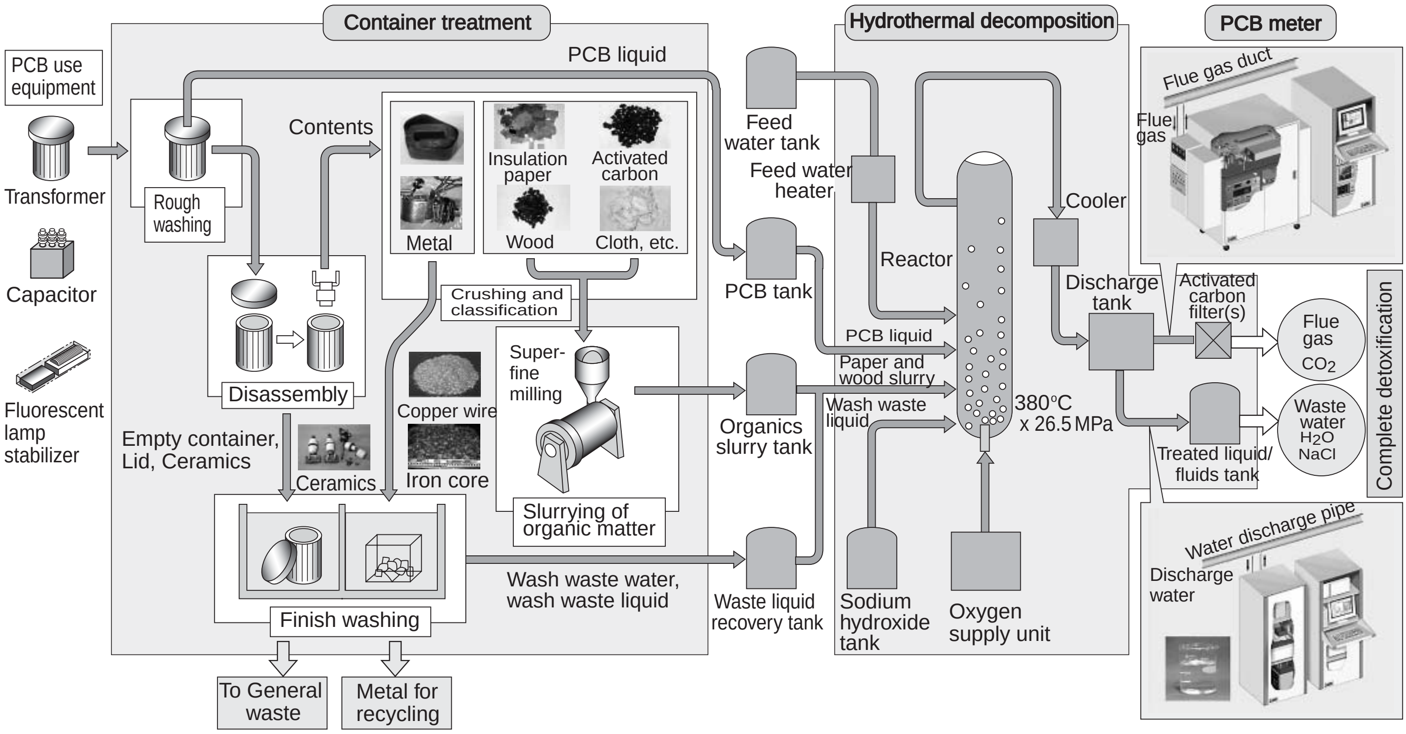

Fig. 4 PCB treatment flow Integrated PCB treatment flow including container, etc.

contribute significantly to the safe treatment of special organic compounds such as waste agricultural chemicals and waste fuels.

6. Waste treatment

The research and development of waste incinerators at MHI began in the 1960s when the rapid economic growth of Japan triggered an increase in waste, and the need to take suitable measures to address the increase in waste became an urgent issue. In 1964, MHI delivered its first waste incinerator to Sagamihara City. This system consisted of a CE-type moving bed stoker. After that, MHI developed a reciprocating grate stoker to improve the combustibility of waste.

In large urban areas such as Tokyo, Kawasaki, Yokohama, and Osaka, the demand for large furnaces increased in order to respond to the rapid increase in the volume of waste being generated. This led to designs for 600 to 900 t/d class incineration plants. In order to cope with these needs, MHI developed new type of furnaces and conducted surveys of overseas technologies. In 1971, MHI signed a technology cooperation agreement with Martin GmbH of Germany, which has global expertise in large furnaces. The first Mitsubishi-Martin type incinerator was delivered to the Tachibana Clean Center in Kawasaki City in 1974.

Since then, MHI has actively continued research and development into ways to reduce emissions by combustion control, automatic incinerator control, and facilities to remove various toxic substances in flue gas in response to social and environmental needs, including tighter regulation against pollution. Furthermore, MHI carried out research into a total flue gas treatment system that simultaneously removes NOx, SOx, HCl, and dust, and commercialized the system. This system adopted bag filters, which have actual field experience and provide the highest levels of efficiency in removing dust as a dry-type treatment system. A compact system design was achieved by placing the denitrification catalyst in a dedusting reactor, which led to the completion of the first low dioxin flue gas treatment system ever to be seen in the industry.

From the 1990s onwards, dioxins emitted from waste incinerators became subject to regulation. Against this background of ever-increasingly strict regulation of dioxins, MHI conducts not only development work into ways of reducing the output dioxins by flue gas treatment but also research into higher-grade waste incineration systems with the aim of reducing the total amount of dioxins that are discharged.

In the area of combustion control technology, MHI has developed a model-prediction control technology that applies a control method using new and high response rate sensors and a chaotic property of waste incineration. With respect to combustion technology, MHI has developed an “oxygen-enriched combustion system” in which the primary air is enriched with oxygen to enhance the combustion of the waste layer on the grate. This serves to improve the properties of the bottom ash, and a portion of the flue gas is recycled to the furnace in order to enhance the complete combustion cycle, thereby suppressing the generation of NOx and dioxins. As can be seen in Fig. 5, MHI is planning to combine the system with real time measurement of dioxin levels, currently

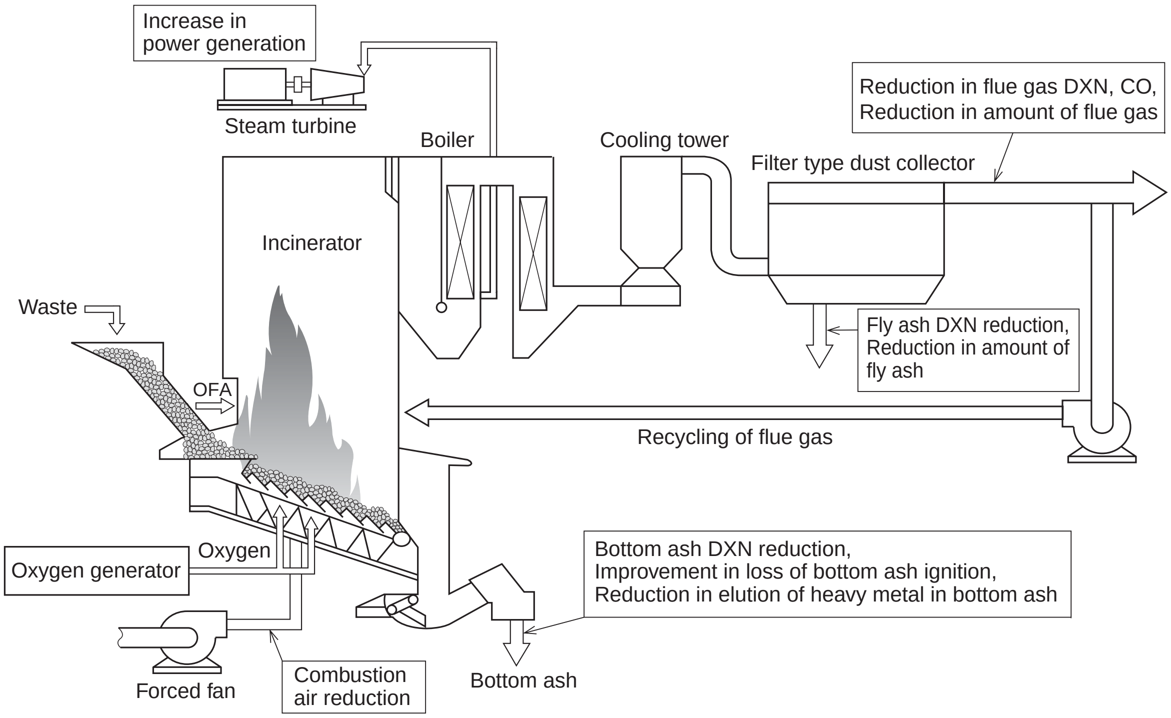

Fig. 5 Next generation stoker type oxygen-enriched combustion system
External view of an oxygen-enriched combustion system that can significantly reduce environmental loads

under development, and the most advanced control technologies using real time measurements. This will lead to the development of the next generation stoker system which combines these technologies with an economic ash treatment process.

Differing from existing stoker furnaces, the development of the Pyrolysis & Ash Melting System is an integrated process system in which the heat of the waste itself gives down to the fusion of ash. The system combines a fluidized bed combustion technology, which has seen significant on-site experience in sewage sludge incinerators and boilers, with the vertical swirl-flow melting technology developed by MHI. Research into this system began in 1996, and after verification through tests at pilot plants of various scales and demonstration plant tests, the system underwent a technological evaluation and was certified by the Japan Waste Research Foundation and Japan Environmental Sanitation Center. In this way, MHI has been responding to demand for gasification and melting furnaces.

As described above, MHI has developed various types of waste incineration systems. Stoker furnaces in particular have become established as a highly reliable system that has seen more than thirty years of actual field experience. MHI fully intends to continue making every effort in the research and development of ever more efficient and cost-effective waste treatment technologies and systems as a leading manufacturer of waste treatment facilities.

7. Conclusion

As a result of the pursuit for comfortable standards of social and welfare living, the latter half of the 20th century suffered increased degrees of pollution and an increased volume of waste. The 21st century, which is known as the “Century of the environment,” is expected to structure recycling-oriented society where the society is clean and gives low environmental load, that is, the target society defined by the Earth Summit. Under these circumstances, MHI declares its goal to accelerate the development of technology to respond effectively to social needs through the full-scale gathering, integration, and effective application of its total ability with respect to global environmental issues.

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