CO_2 Capture Technology Applied for Varied Fields such as Manufacturing Industries and Energy-related Facilities

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In Mitsubishi Heavy Industries (MHI) Group, Mitsubishi Heavy Industries Engineering, Ltd. has a CO_2 capture technology that uses a proprietary absorption solvent and has constructed the world's largest-scale CO_2 capture plant (about 5,000t/day) in the United States(3). However, this CO_2 capture technology has so far only been applied to flue gas from coal-fired power generation and flue gas generated in chemical plants. To respond to the recent social needs for the reduction of CO_2 emissions, MHI has commenced with applications of this technology to flue gas in the industrial sector to which it has yet to have been applied. Our case studies so far and future efforts are introduced in this report.

1. Introduction

Amid global efforts to reduce CO_2, goals have been set for a reduction in anthropogenic CO_2 to one third in 2040 (compared to 2014) and for the achievement of so-called carbon neutrality in 2060(1). CO_2 emissions in 2014 were 34.3 Gt, about 40% of which was generated by the power generation sector including thermal power generation, about 30% was emitted by the transportation sector including automobiles and ships and about 25% was generated by the industrial sector from industries such as steel and cement (**Figure 1**)(2).

The main factor in CO_2 emissions is the use of fossil fuels and the conversion of fuel to hydrogen or ammonia and the utilization of renewable energy sources such as solar power and wind power have been studied. The implementation of these measures, however, requires significant capital investment for the replacement of existing facilities/equipment, the improvement of social infrastructure, etc., as well as systemic changes. It is very difficult to promote these efforts at a speed that allows CO_2 reduction targets to be achieved. Furthermore, the energy density of electricity and hydrogen fuel is low and application to large facilities requiring high temperatures poses many issues. Consequently, we more or less have no choice but to rely on fossil fuels.

One of the CO_2 reduction technologies that makes the most of existing facilities is CO_2 capture technology. The application of this technology allows the removal and capture of CO_2 from flue gas generated by the combustion of fossil fuels. Accordingly, a CO_2 capture system can be installed for flue gas treatment in a stage downstream of an existing combustion facility, thereby realizing CO_2 reduction.

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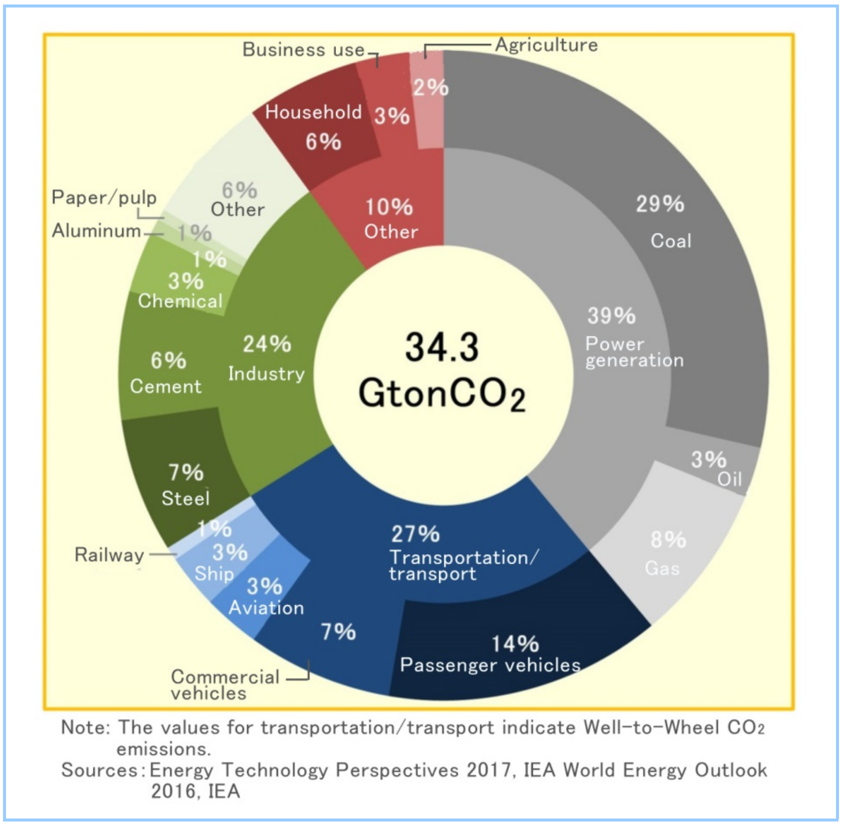

Figure 1 CO_2 emissions from energy sources by sector (2014)

2. CO_2 capture technology and conventional applications

Figure 2 presents the CO_2 capture technology using MHI Group's proprietary amine absorption solvent, KS-1™/KS-21™. The system consists of a flue gas quencher, an absorber and a regenerator. At the quencher, the flue gas is cooled to a predetermined temperature and fed into the absorber. The absorber is filled with filling material for coming into contact with gas and liquid and the flue gas is passed upward through the filling material. The amine absorption solvent, KS-1™/KS-21™, is sprayed from the top of the absorber and absorbs CO_2 from the flue gas while running down through the filling material. After the CO_2 is absorbed in the solvent, the remaining flue gas is discharged from the top of the absorber. On the other hand, the absorption solvent in which CO_2 is dissolved is fed into the regenerator. In the regenerator, the absorption solvent is heated and CO_2 is stripped from the absorption solvent and regenerated as gas. From the top of the regenerator, CO_2 with a purity of 99.9% is released. After the CO_2 is stripped, the remaining absorption solvent is fed back into the absorber and recycled.

MHI started the development of this technology in 1990 and delivered and started operating its first commercial plant for a Malaysian chemical plant in 1999. Since then, MHI has delivered commercial plants to chemical plants and coal-fired power plants (**Figure 3**). We have made continuous efforts to improve reliability by increasing the recovery rate and promoting energy saving through process improvements and by overcoming problems found through long-term operation. In 2016, MHI delivered the world's largest-scale CO_2 capture plant (4,776t/day) to a coal-fired power plant in Texas in the United States and has the world's top share in the market.

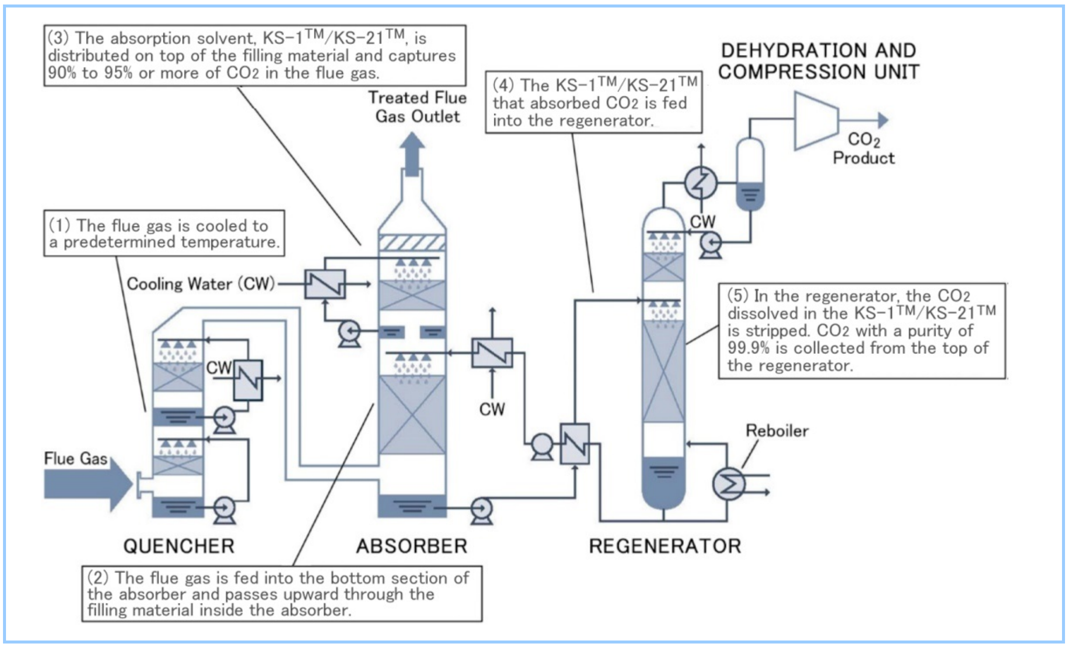

Figure 2　Schematic diagram of CO_2 capture process

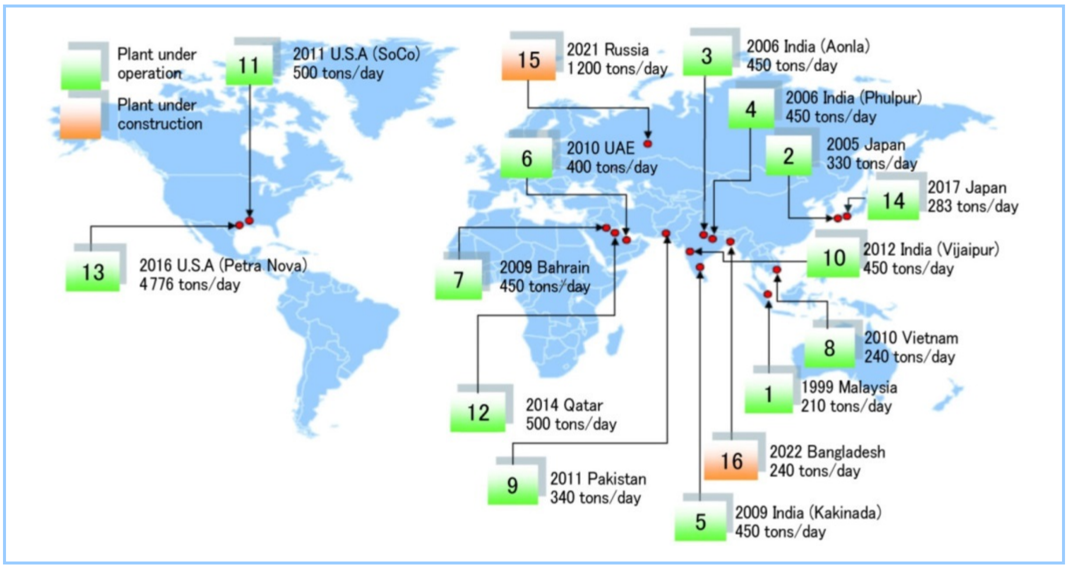

Figure 3　Delivery records of CO_2 capture plants

3. Study of new applications

As previously described, to respond to the social needs for the reduction of CO_2 emissions, MHI has commenced with applications of CO_2 capture plants to other new industrial fields in addition to conventional coal-fired power plants and chemical plants.

3.1 Marine engine

As part of the assistance project for "Research and development of technological advancements in marine resource development" by the Ministry of Land, Infrastructure, Transport and Tourism, MHI conducted a demonstration test at sea for CO_2 capture from flue gas of a heavy oil-fired boiler using a small-scale mobile CO_2 capture plant installed on a coal carrier (**Figure 4**). The mobile pilot plant is a transportable small-scale plant as shown in Figure 2 to which the CO_2 capture technology using the amine absorption solvent, KS-1^{TM}, is applied. Flue gas from the heavy oil-fired boiler was branched before reaching the stack and partially introduced into the mobile pilot plant for use in the CO_2 capture test.

In the period of about 40 days during which the carrier sailed back and forth between Japan and Australia, we made an assessment on the effects of rocking and vibrations of the shipboard pilot plant on its CO_2 capture performance using the amine absorption solvent. The results showed that the predetermined CO_2 removal rate and purity could be achieved. One issue to be addressed is the removal of dust and acidic constituents contained in flue gas. It is considered that toward commercialization, the installation of appropriate pre-treatment equipment is needed.

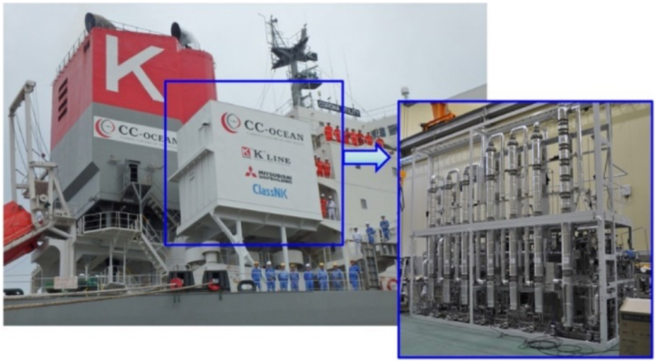

Figure 4 Application example to marine engine

3.2 Biomass-fired power generation

In the UK's BECCS (Bio Energy with Carbon dioxide Capture and Storage) project, MHI, jointly with Drax Group PLC, one of the UK's leading power companies, conducted a CO_2 capture test with flue gas from biomass power generation. For this test, a mobile plot plant similar to the one used for the marine engine was installed at a biomass power plant in North Yorkshire, UK (**Figure 5**).

In this test, the pilot plant was intermittently operated for about 4,000 hours and the predetermined performance and effects of impurities (alkali metal, chlorine, sulfur, etc.) contained in the flue gas from biomass combustion were assessed. According to the data obtained so far, the effects of the impurities are slight and can be coped with by the conventional design method. In addition, since this test was conducted during the COVID-19 pandemic, it was difficult for operators to stay at the site. Therefore, a remote monitoring system (TOMONI which is a monitoring system for the operation of gas turbines) was used to monitor the operational state and acquire data. Currently, the test is being carried out using KS-21^{TM}, an improved type of absorption solvent.

In CO_2 capture from biomass-fired power generation, power generation which can achieve carbon neutrality by using plant-derived fuels and CO_2 capture from the flue gas from the power generation are combined, resulting in "negative emissions (CO_2 emissions can become negative)". By putting this technology to practical use, MHI aims at realizing the world's first implementation of negative emissions power generation on a commercial scale.

Figure 5 DRAX's biomass power generation plant[4]

4. Future efforts and issues

MHI has also been studying extensive applications of CO_2 capture plants for gas turbines, iron making plants, cement kilns, refuse incineration plants and gas engines. **Figure 6** depicts the new applications of CO_2 capture plants, which are arranged according to the scale of the CO_2 capture plant and the degree of difficulty that was estimated with coexisting substances in flue gas as a measure. There are two issues to be addressed in the future:

(1) Assessment of effects of coexisting substances in flue gas

The coexisting substances contained in the flue gas from marine engines or biomass power generation are dust, alkali metal, chlorine, sulfur, etc. It is necessary to assess the effects of similar substances in the flue gas from cement, iron making and refuse incineration plants.

(2) Product lineup adaptable to various scales of facilities

Compared to coal-fired power plants and chemical plants in which many CO_2 capture plants have been adopted, gas turbines generate a larger amount of flue gas and require the capture of a larger amount of CO_2. On the other hand, gas engines and refuse incineration plants generate a smaller amount of flue gas and require small-scale and compact products.

The use and handling of captured CO_2 also pose major challenges. At the world's largest-scale plant in the U.S., the captured CO_2 is used for Enhanced Oil Recovery (EOR). In the UK, plans call for the captured CO_2 to be injected into the North Sea oil fields. There are also significant regional differences in the utilization of CO_2, although these differences vary by the scale of utilization. Therefore, technological development of both CCS (Carbon Capture Storage) and CCU (Carbon Capture Utilization) is required.

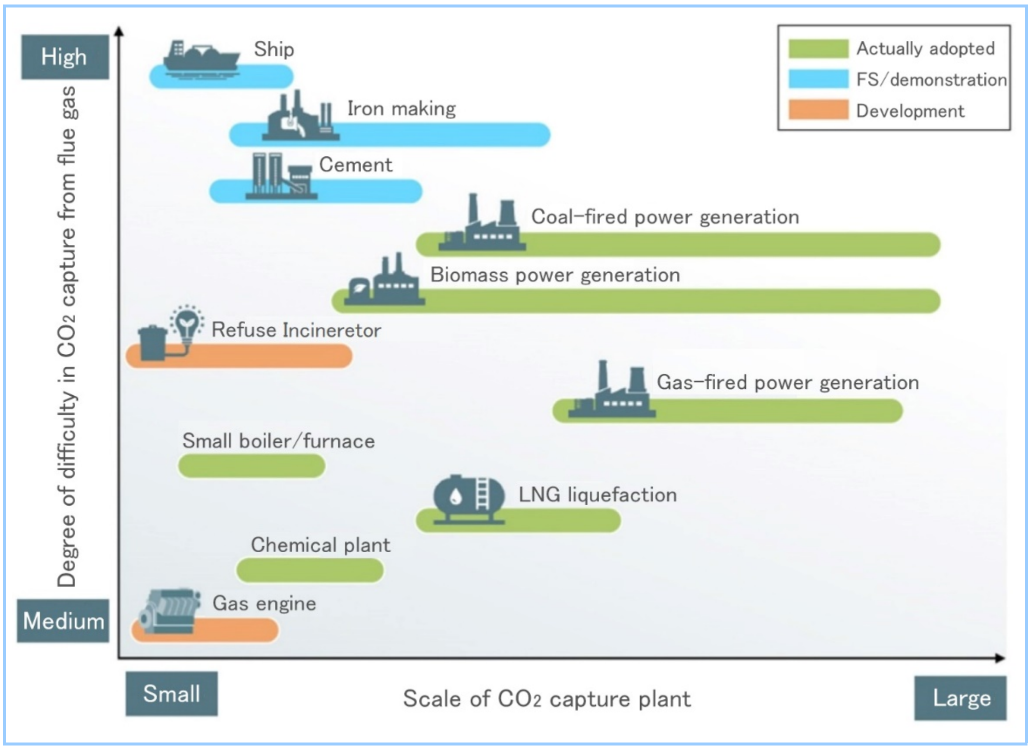

Figure 6 Applications of CO_2 capture plants

5. Conclusion

MHI has been studying applications of CO_2 capture technology using MHI Group's proprietary amine absorption solvents, KS-1™/KS-21™, to the manufacturing industry and energy-related plants. This report described cases studies of efforts to apply the technology to marine engines and biomass power generation.

(1) In the application tests, a small-scale mobile pilot plant was used and CO_2 capture tests were conducted using actual gas. We gathered important findings and data that could only be obtained from actual gas tests.

(2) In the future, application to gas turbines, iron making plants, cement kilns, refuse incineration plants and gas engines will be also studied in the same way.

The challenges to be addressed in the future are the assessment of the effects of coexisting substances contained in flue gas and the development of products adaptable to various scales of CO_2 capture. Furthermore, it is also necessary to develop CO_2 utilization and CCS/CCU technologies, as well as CO_2 capture technologies.

References

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(3) Masaki Iijima et. al, MHI's Energy Efficient Flue Gas CO_2 Capture Technology and Large Scale CCS Demonstration Test at Coal-fired Power Plants in USA, Mitsubishi Heavy Industries Technical Review Vol. 48 No. 1 (2011-1) p.24-29
(4) Drax Power Plant (Drax HP)