MHI Group's Recent CO_2 Capture Technology for Carbon Neutral Society

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Here is a high level of global interest and social needs regarding decarbonization, and technological development in this field is progressing rapidly. We, Mitsubishi Heavy Industries Engineering, Ltd., have been engaged in the CO_2 capture business in response to that trend, and completed the commercialization of our new amine-based solvent KS-21™ and received orders for our commercial compact CO_2 capture systems as outcomes from the engagement. We are also considering expansion of various CO_2 capture forms such as direct air capture (DAC). We will contribute to the realization of a carbon-neutral society by adapting the high-performance CO_2 capture technologies we have cultivated so far to meet a wide range of social and market needs, accelerating the development of the technologies, and putting (commercializing) them on the market.

1. Introduction

In October 2020, Japan declared its aim to realize a carbon-neutral and decarbonized society by 2050, and efforts toward decarbonization have been accelerating in the power-generation, industrial and other various sectors. In order to realize a carbon-neutral society, it is necessary to reduce the amount of CO_2 emitted artificially as much as possible, while the CO_2 amount that is still inevitably emitted needs to be offset to zero by absorbing or removing the same amount of CO_2.

Mitsubishi Heavy Industries Group (MHI Group) has made a declaration to achieve carbon neutrality by 2040, and started efforts with the goal of achieving "Mission Net Zero". This aims to reduce CO_2 emissions (Scope 1 and Scope 2 (Note 1)) by 50% from our group's production activities by 2030 (compared to 2014 levels) and to achieve net zero CO_2 emissions by 2040.

As a company group responsible for social infrastructure, MHI Group specializes not only in technologies and products that can contribute to controlling and reducing emissions of CO_2, a greenhouse gas, but also in technologies and products that capture CO_2. Our CO_2 capture technology, KM CDR Process™, leads the world in terms of delivery record, boasting a global market share of more than 70% with respect to volume of CO_2 captured from post-combustion flue gas at commercial plants. We have already delivered the world's largest CO_2 capture plant capable of capturing up to approximately 5,000 tons of CO_2 per day, and are intensifying our efforts to deal with large-scale emission sources such as ones in the power generation sector through further innovation. One of our latest achievements is the commercialization of KS-21™, our new amine-based CO_2 solvent.

In addition, the realization of a carbon-neutral society requires the capture of CO_2 not only from large-scale greenhouse gas emission sources but also from relatively small-scale emission sources such as ones in industrial sectors. To meet these needs, we are working on the development of compact CO_2 capture systems with a CO_2 capture capacity of 0.3 tons to 200 tons per day that

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can be applied to various industrial sectors. We are working to realize integrated support from system installation planning to after-sales service in addition to cost reduction and shorter delivery time by standardizing compact CO_2 capture systems so that customers working on decarbonization can introduce CO_2 capture systems more familiarly and easily.

Furthermore, it is expected that negative emission technology, which is a technology to reduce CO_2 that already exists in the atmosphere, will be realized, and we are also working on direct air capture (DAC), a technology that directly captures CO_2 present in the atmosphere.

This report presents our efforts for the early realization of a carbon-neutral society.

2. New amine-based solvent KS-21™

2.1 Development process and features of new amine-based solvent KS-21™

We have newly developed "Advanced KM CDR Process™" as a next-generation version of "KM CDR Process™", which has proven to be highly reliable through its abundant delivery record, by making significant improvements including cost reduction. For this Advanced KM CDR Process™, new amine-based solvent KS-21™, which was developed in collaboration with The Kansai Electric Power Co., Inc. (KEPCO) can be used.

The development process of KS-21™ began in 2014 with a two-year screening to find candidate substances. After that, tests were conducted at the development and research facility and Nanko Power Station of KEPCO, while parameter tests, optimal operation tests, etc., were completed using pilot equipment in 2019. Then, the demonstration test on KS-21™ conducted in Norway, one of the most advanced countries in the field of CO_2 capture, produced good results in 2021, and the commercialization of KS-21™ was completed with this.

The testing was carried out between early May and late August 2021 at the Technology Centre Mongstad (TCM) (**Figure 1**) in Norway, which is one of the world's largest carbon capture demonstration facility. The performance test of KS-21™ was conducted with the CO_2 capture rate set to 95% to 98% (above the current industry standard of approximately 90%) with regard to flue gas emitted by a gas from the gas turbine at TCM's test facility. As a result, it was confirmed that this solvent has excellent energy-saving performance that far surpasses the general amine solvent (MEA : Monoethanolamine) used for chemical absorption methods and is higher than even our existing amine solvent KS-1™, as well as that its operating costs and amine emissions (Note 2) are lower. In addition, in the high CO_2 capture rate test conducted with the conditions changed, the KS-21™ solvent achieved 99.8%, the world's highest level of capture rate, and succeeded in capturing CO_2 from the flue gas to a level lower than the CO_2 concentration contained in the atmosphere (less than 100 ppm). The tests were also performed for flue gas emitted by a fluid catalytic cracker at the Mongstad refinery adjacent to the TCM, and similar results were obtained. In addition, in the demonstration test of KS-21™ at the TCM with state-of-the-art testing environment and high-level expertise, we were able to obtain useful operational data for further improvement and upgrading of KS-21™, such as the amount of deteriorated substances generated during operation and handling know-how, etc. as well as reliable emission measurement results provided by a third-party organization, which is necessary for future business negotiations in terms of environmental impact assessment. In the future, we will be able to utilize these data for making applications and obtaining permits/licenses for environmental assessments that are required in various countries, which will lead to further expansion of business opportunities.

Figure 1 CO_2 capture system at Technology Centre Mongstad (TCM)

KS-21^{TM} has advantageous features compared to KS-1^{TM}, such as lower volatility and higher stability against degradation, and is expected to improve economic efficiency for future deployment, such as by reducing operating costs. Specifically, KS-21^{TM} has the following features.

(1) The lower volatility can significantly reduce the amount of solvent that accompanies flue gas from the absorber tower and is released into the atmosphere as emissions.

(2) The higher heat resistance allows the regeneration tower to operate at a higher pressure. As a result, the power consumption of the CO_2 compressor installed next to the regeneration tower is reduced significantly and this can lower the equipment cost of the CO_2 compressor.

(3) The higher oxidation resistance can reduce the amount of solvent that deteriorates and consumed due to the reaction with the trace components existing in the flue gas. As a result, a greater diversity of flue gas sources can be dealt with independently of the type of flue gas.

(4) The amount of circulating solvent is slightly higher than that of KS-1^{TM}, but the reaction heat with CO_2 is lower than that of KS-1^{TM}, which results in more favorable utility consumption of the CO_2 capture system as a whole.

(5) Since we have experience with large commercial facilities, including experience of scaling up from bench-scale facilities with the conventional solvent KS-1^{TM}, we can immediately put KS-21^{TM} into practical use.

2.2 Application target of new amine-based solvent KS-21^{TM}

There has been an increasing need for CO_2 capture from a wide variety of emission sources such as biomass power plants, LNG liquefaction plants, cement factories, steel mills, gas engines, waste incineration facilities, etc. in addition to existing thermal power plants. We are actively working on basic design, pilot verification, licensing, etc., related to CO_2 capture projects in the power generation and industrial sectors in UK, EU, US, Canada and other regions based on the delivery record of 13 commercial CO_2 plants throughout the world and various technological capabilities. Moving forward, we will expand the application targets of KS-21^{TM} and contribute to the realization of carbon neutrality, by utilizing its advantages for meeting local regulations with very strict cost requirements and emission standards.

3. Compact CO_2 capture system

With the growing momentum toward decarbonization in recent years, there is increasing customer needs for curbing greenhouse gas emissions not only from large-scale emission sources such as thermal power plants, which have been drawing attention, but also from various industrial sectors, regardless of the size of the emission source. In order to respond to CO_2 reduction challenges that our customers are facing and to provide solutions, we are developing compact CO_2 capture systems having a CO_2 capturing capacity of 0.3 tons to 200 tons per day based on the highly reliable KM CDR Process^{TM}, which has been cultivated with our large-scale systems that have a CO_2 capturing capacity of 450 tons to 4,776 tons per day (**Figure 2**).

The features of the compact CO_2 capture system are as follows:

(1) Wide product lineup
(2) Low cost and short delivery time due to standardization
(3) Simpler sizing due to modular design
(4) Integrated customer support from installation planning to after-sales service

We have received an order from Taihei Dengyo Kaisha, Ltd., a plant construction and maintenance company, for our compact CO_2 capture system (CO_2 capturing capacity: 0.3 tons per day) to be used for their biomass power plant. The CO_2 capture system is designed to achieve a recycling-oriented and carbon-neutral society by separating and capturing CO_2 generated by biomass power generation and then using it for growing crops and other purposes (**Figure 3**).

Figure 2 Compact CO_2 capture system

Figure 3 CO_2 capture system with capacity of 0.3 tons per day

Our compact CO_2 capture systems consist of modular units that are transported by truck from the manufacturing factory and assembled at the installation site, thereby reducing introduction costs and shortening delivery time. This modular design is applied to all of our compact CO_2 capture systems with a capacity of 0.3 tons to 200 tons per day, so we can accommodate a wide range of needs for reducing CO_2 emissions even in relatively small facilities. Furthermore, these systems are expected to be applied to various industrial sectors such as biomass power plants, cement factories, steel mills, gas engines, waste incineration facilities, etc. in addition to our conventional customers, such as thermal power plants and chemical plants (**Figure 4**), where efforts to reduce CO_2 are expected to accelerate in the future.

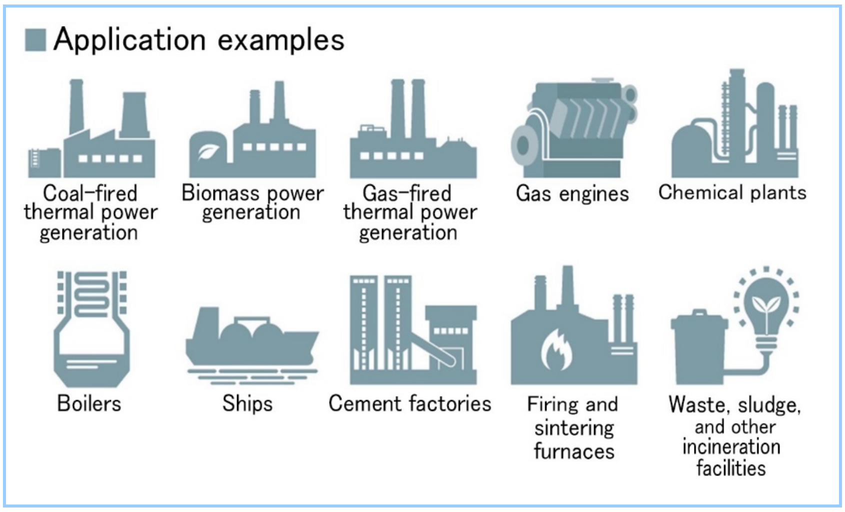


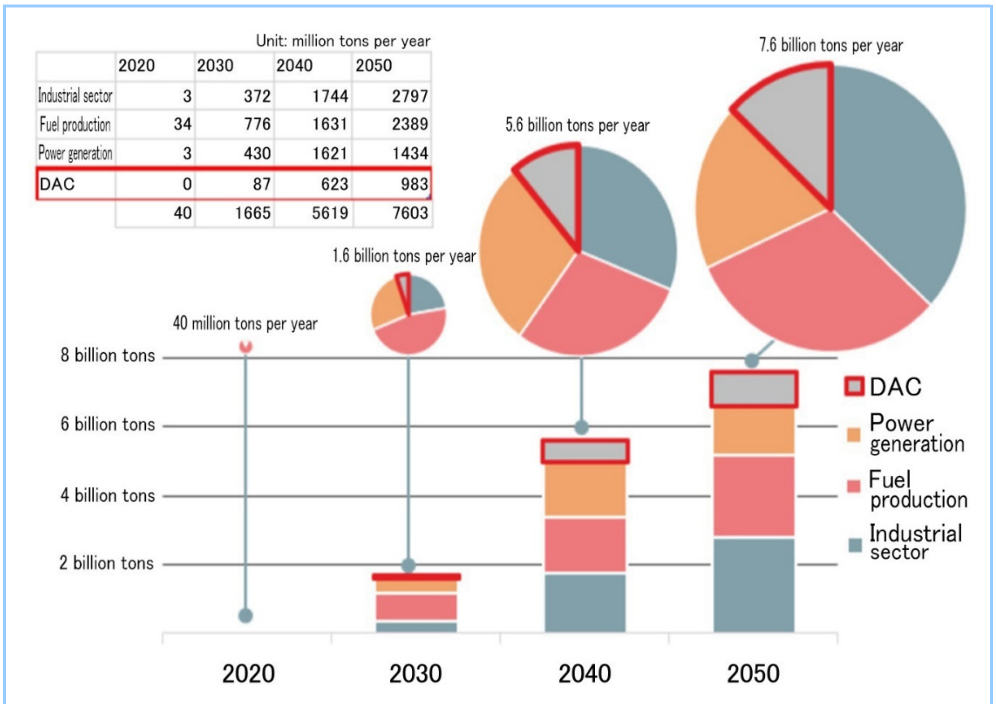
Figure 4　Application examples of compact CO_2 capture system

We will expand our lineup of compact CO_2 capture systems to allow the capturing of CO_2 from diverse emission sources both in Japan and overseas. Furthermore, complemented by providing operation support services using our unique remote monitoring system, we will work to establish integrated customer support from installation planning to after-sales service in the future.

4. Our approach to DAC

As mentioned above, we have been actively developing CO_2 capture from flue gas, introduced it into society and expanded its market share, and are working on new compact CO_2 capture systems.

On the other hand, as the movement toward decarbonization has recently been accelerating on a global scale, the needs for capturing CO_2 from sources other than power plant emissions is expected to increase in the future as shown in **Figure 5**.



	2020	2030	2040	2050
Industrial sector	3	372	1744	2797
Fuel production	34	776	1631	2389
Power generation	3	430	1621	1434
DAC	0	87	623	983
	40	1665	5619	7603

Source: Data compiled by our company based on IEA Net Zero by 2050 A Roadmap for the Global Energy Sector(1)

Figure 5　Required CO_2 capture amount per year for realization of carbon neutrality

We are considering expanding various CO_2 capture forms such as dry CO_2 capture to respond to such needs, and in recent years we have been developing a system called DAC, which captures trace amounts of CO_2 in the atmosphere.

DAC has a feature to take in the air from the atmosphere as a source from which CO_2 is captured, so it can be installed anywhere. Furthermore, unlike technologies for reducing CO_2 emissions from flue gas, DAC is a negative emissions technology that captures CO_2 emitted into the atmosphere, so we believe that there are few restrictions on its adoption and that it will be widely accepted by society.

In addition, DAC has a smaller footprint among negative CO_2 emissions technologies currently under consideration and its capacity can be increased relatively easily, so we believe that this is a promising technology for actual use.

However, DAC also faces several challenges. For example, the concentration of CO_2 in the atmosphere is very low (approximately 400 ppm), so capturing highly pure CO_2 means treating a large amount of air, which inevitably results in excessive power consumption and high costs. In addition, in the case of capturing a small amount of CO_2 with high purity, it is necessary to minimize the mixing of air, which is fed to DAC, during treatment, which requires the development of precision equipment and accurate system construction.

These challenges will be dealt by taking full advantage of our development know-how in CO_2 capture technology we have cultivated thus far. In particular, reducing the energy consumption in CO_2 capture was one of the most focused factors in the development of technology for CO_2 capture from flue gas, and we will seek the possibilities of technological development therefrom. In addition, we will collect similar development cases not only from CO_2 capture technologies but also from various related fields, and proceed with the development of DAC aiming at its early introduction to society.

5. Conclusion

This report introduced our efforts and achievements toward the early realization of a carbon-neutral society. We will expand the application of KS-21™ by continuing efforts to realize cost reduction and CO_2 capture from various emission sources while maintaining the superiority we have cultivated thus far. For our compact CO_2 capture system, we will accommodate needs at relatively small facilities through taking advantage of their characteristics and establish integrated support up to after-sales service. We will also continue to develop DAC, which is a promising technology expected to be introduced in actual negative emissions technologies.

Note 1: Scope 1 and Scope 2 in the GHG protocol, which is the international standard for calculating and reporting greenhouse gas (GHG) emissions.

Note 2: A trace amount of amine substance released into the atmosphere from the absorber tower. The lower this is, the better the technology is with less environmental impact.

References

(1) IEA Net Zero by 2050 A Roadmap for the Global Energy Sector