Toward the Realization of Low Carbon Coal-Fired Power Plant for the Sustainable Low-Carbon Society

Development of carbon capture technology based on a chemical absorption process

To achieve both mitigation of climate change and stable supply of electricity at the same time, it is essential to reduce CO_2 emissions from coal-fired power plants. This article describes the latest accomplishments of our activities to commercialize carbon capture technology based on a chemical absorption process.

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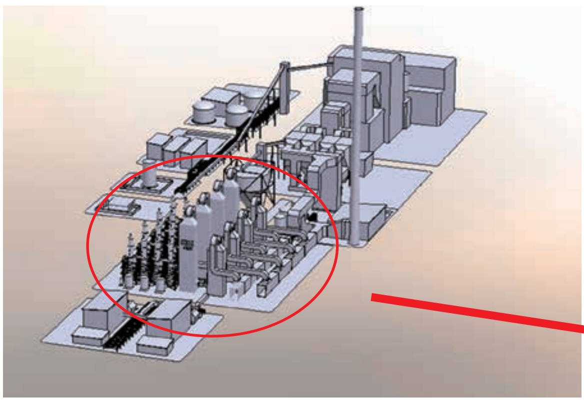
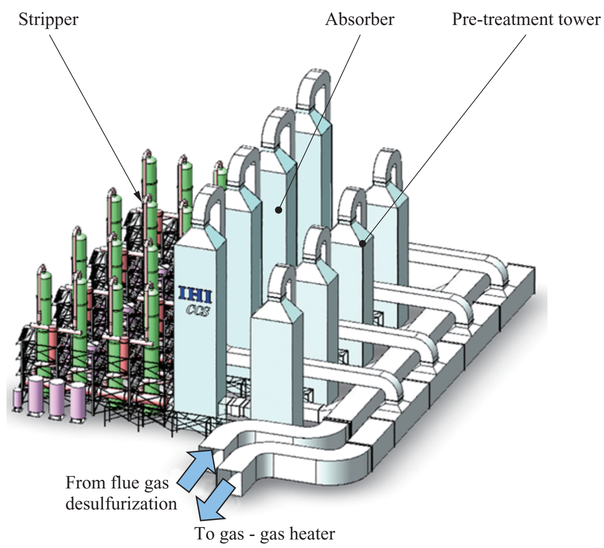




CO_2 capture plant based on a chemical absorption process

Introduction

Environment of world energy supply is significantly changing. For example, nuclear power generation projects in Japan, Europe, and other regions have been under review after the Great East Japan Earthquake, and the shale gas revolution originating from North America has been advancing.

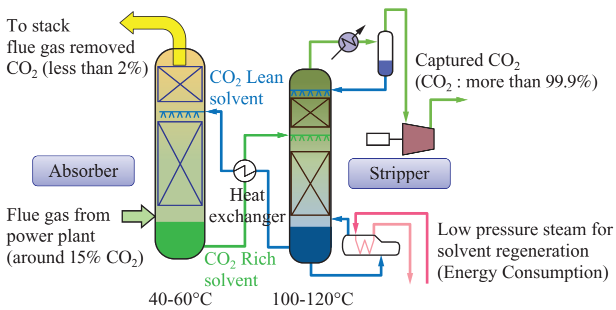
Coal-fired power generation, which is superior in that its fuel can be stably and economically procured, is a major power source that provides electricity accounting for approximately 40% of the world's total generated energy. It is expected to continue playing an important role in the future. To continue to use coal-fired power generation, however, we must reduce CO_2 emissions from coal-fired power plant. The technical development of CCS (Carbon dioxide Capture and Storage) as well as that of high-efficiency coal-fired power plant and co-combustion with biomass are carried out assiduously.

CCS technologies in the power sector are roughly classified into three categories: oxyfuel combustion, Post-combustion capture, and Pre-combustion capture. IHI has been developing both oxyfuel combustion and Post-combustion capture technology using a chemical absorption process (hereinafter, referred to as PCC technology). In contrast to pre-combustion capture technologies, these technologies are applicable to both new power plants and existing power plants. The above-mentioned PCC technology is suitable for CO_2 capture from flue gas of coal-fired power plant that is under almost atmospheric pressure with a CO_2 concentration as low as 15%. It is applicable not only of full capture, in which all the flue gas is processed, but also partial capture, in which deals a part of the flue gas is processed. Therefore the PCC technology is suitable for flexible operation in response to needs for CCS. For example, it can be used in such a manner that the amount of capture will be increased according to regulations while reducing initial investment.

What is the PCC technology?

Post-combustion capture technology using a chemical absorption process uses an alkaline aqueous solution of a substance, such as amine, as a medium to capture CO_2 through chemical absorption and desorb reactions between the solution and CO_2. Flue gas from a power plant is treated impurity in air quality control systems (NO_x, dust and SO_x reduction, etc.) and then is sent to an absorber. When flue gas included CO_2 are brought into contact with a CO_2 lean solvent in the absorber, CO_2 in the flue gas is selectively captured by the solvent because of the chemical reaction. Consequently, it becomes CO_2 rich solvent. The solvent is then sent to a stripper. When the CO_2 rich solvent is heated in the stripper, CO_2 is released as gas, and the solvent becomes CO_2 lean again. The released CO_2 is captured as almost pure CO_2. Repeating this cycle allows CO_2 to be continuously captured from flue gas with almost no solvent lost.

However, this technology requires a large amount of thermal energy in the process of desorbing CO_2 (regeneration) from CO_2 rich solvent. CO_2 capture from flue gas at power plants extracts part of the low-pressure steam of the process to use it as a heat source, causing a decrease in power output. Accordingly, it is necessary to develop a high-performance solvent and a heat management technology that reduce heat loss and improve energy efficiency.



Principle of CO_2 capture based on the chemical absorption process

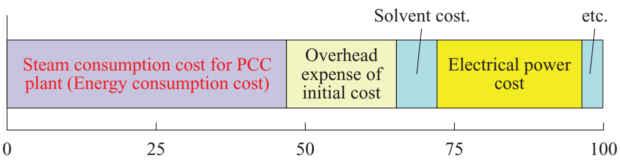
Technical development for energy saving

As described above, the PCC technology requires a large amount of heat to desorb CO_2 (hereinafter, referred to as regeneration energy). It is said that the cost for this heat accounts for approximately half the costs for CO_2 capture. Therefore, reduction in this regeneration energy is essential for disseminate of this technology.

The regeneration energy consists of three thermal energies, heat of CO_2 desorption reaction, the sensible heat of solvents, and the latent heat of vapor from stripper top. Since this reaction heat accounts for much of the regeneration energy, it is particularly important to develop a technology for reducing the reaction heat. Therefore, we need to develop a solvent that desorbs CO_2 with low reaction heat.

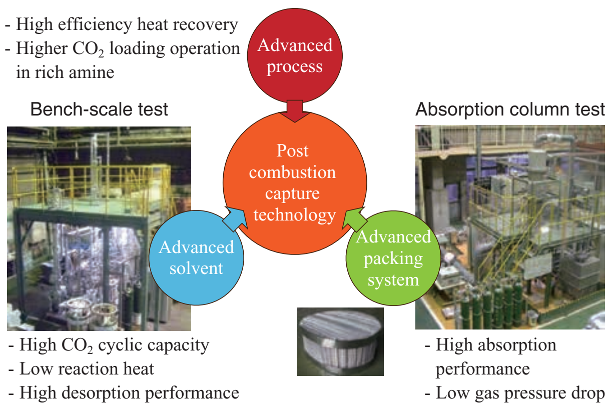
In addition, amine aqueous solution absorbs CO_2 slowly, so packing is installed in the absorber. In general, since it has been shown that a trade-off occurs between CO_2 absorption rate and reaction heat, reducing reaction heat needs high-performance packing compared with packing based on conventional technologies (hereinafter, referred to as conventional packing).

Furthermore, latent heat cannot be effectively recovered by



(Note) Source : FY2002 NEDO survey report (02004342 and 02004343)

The constitution ratio of the CO_2 capture cost (example)



IHI's key technologies of PCC for energy saving conventional technologies, and a heat recovery process for improving latent-heat recovery is required.

IHI has been developed by focusing on these three key technologies (① solvent desorbing CO_2 with low reaction heat, ② high-performance packing, and ③ effective processes for recovering latent heat).

Verification at a 20 t-CO_2/day pilot plant

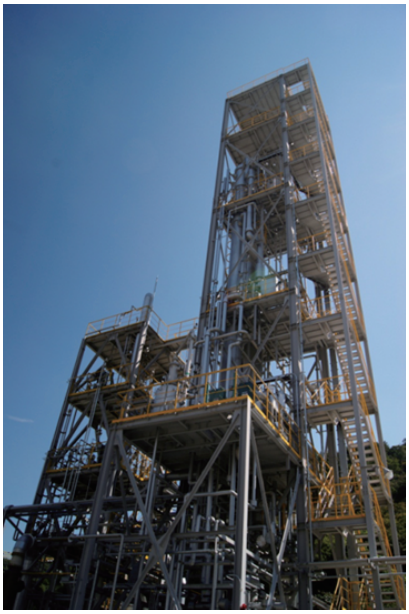
We performed evaluation tests on the three developed technologies mentioned above at a 20 t-CO_2/day scale Post-combustion capture pilot plant (hereinafter, referred to as pilot plant) constructed in IHI Aioi Works. This pilot plant is located near the coal-combustion testing facility in the 20 MW heat capacity, enabling evaluation with flue gas of coal combustion by collaborating with this facility. It is one of the largest test facilities for coal-fired power generation in Japan.

The pilot plant enables evaluation not only of operation using flue gas of coal-combustion but also of operation using flue gas of propane-gas-combustion. We therefore tested and evaluated flue gas that was made equivalent in CO_2 concentration to flue gas of coal-combustion by recycling a part of the captured CO_2 to the upstream of the absorber.

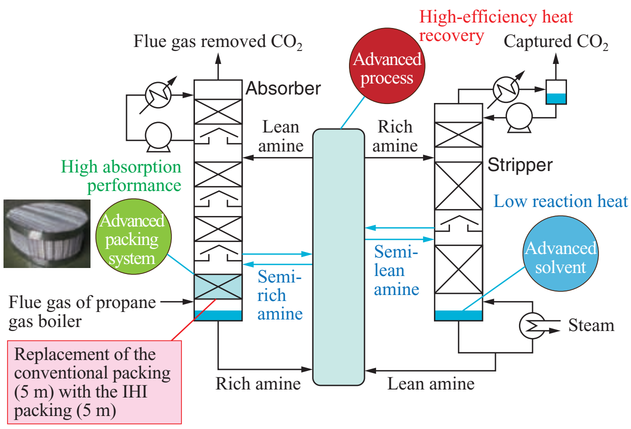
We first evaluated the performance of the IHI packing. The absorber has a 15 m packing portion consisting of three packing sections (the lower, middle, and upper stages, 5 m each). In the evaluation, the IHI packing was installed in the lower stage. The IHI packing has a simple structure in which metal plates excellent in wettability are arranged perpendicularly to fluid and gas flows, and both sides of the packing are therefore expected to effectively contribute to the reaction. In addition, it is capable of keeping gas pressure loss low even when the number of packed metal plates is increased compared with those of conventional packing to enhance performance.

Conventional packing was installed in the middle and upper stages. Two types of IHI solvents (ISOL-131 and ISOL-161) different in components were used.

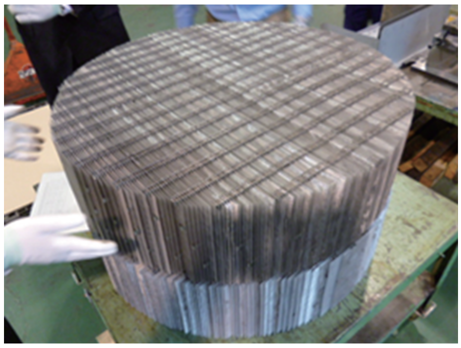
Test result 1 shows comparison of the regeneration energy necessary for achieving a CO_2 absorption rate of approximately 90% between ISOL-131 and ISOL-161 under different packing conditions. When ISOL-131 was used, the regeneration energy corresponding to the use of 5 m IHI packing is lower than that corresponding to the use of the 10 m conventional packing. This fact suggests that compared with the conventional packing, the IHI packing has two times or higher CO_2 absorption performance. When ISOL-161 is used, the CO_2



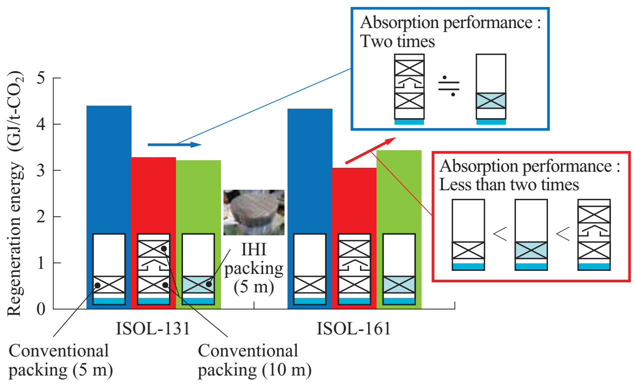
20 t-CO_2/day pilot plant



Flow diagram of the 20 t-CO_2/day pilot plant process with IHI advanced technologies



IHI packing



Test result 1. Comparison between the IHI packing and the conventional packing absorption performance of the IHI packing does not reach twice of that of the conventional packing. It turned out that the improvement rate of the performance was different depending on solvents. This test result suggests that the optimum packing structure and other matters depend on the physical properties of solvents. It is important to develop the packing suited for the solvents.

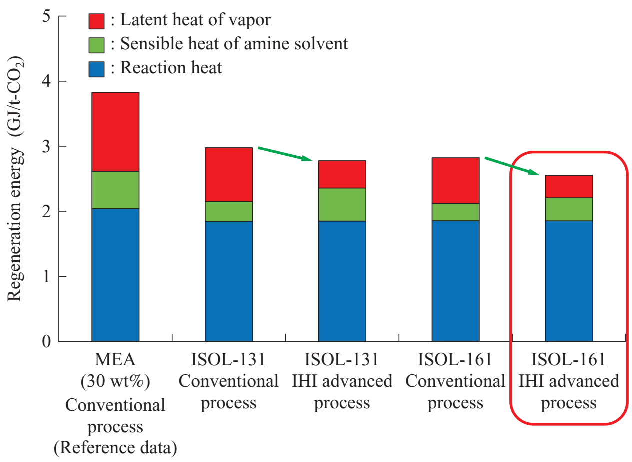
With both solvents, 5 m IHI packing is equivalent in pressure loss to 10 m conventional packing.

Next, we verified the effectiveness of the IHI advanced process. Test result 2 shows comparison of the regeneration energy necessary for achieving a CO_2 absorption rate of approximately 90% between ISOL-131 and ISOL-161 under different process conditions. In this test, the IHI packing was installed in the lower stage of the absorber. This test result suggests that with both solvents, regeneration energy is reduced by decreasing the latent heat of vapor from stripper top.

In addition, we have achieved one of the lowest regeneration energies in the world (2.5 GJ/t-CO_2) with ISOL-161 by combining the IHI packing and the IHI advanced process.

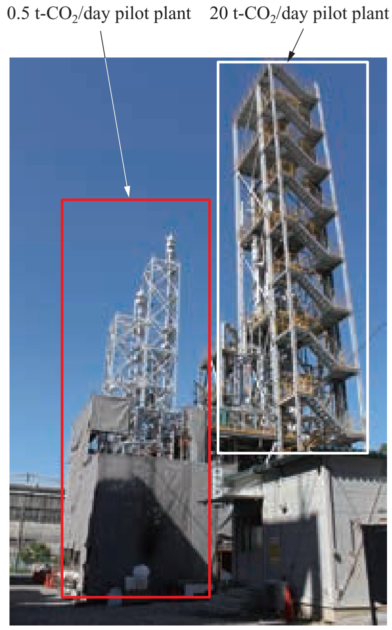
Toward realizing a sustainable low-carbon society (plans for the future)

When PCC plant is introduce to coal-fired power plant, it is important to comprehend how substances contained in flue gas, such as oxygen, sulfur oxides, nitrogen oxides, other trace elements, and dust, affect the performance and degradation characteristics of solvent, material corrosion, and other matters. And process technologies for controlling these substances are essential. With the support of Brown Coal Innovation Australia (BCIA), we will verify these technologies through joint research with AGL Loy Yang Pty Ltd., the owner of the Loy Yang A Power Station, which supplies 30% of the electricity used in Victoria, Australia, and Commonwealth Scientific and Industrial Research Organisation (CSIRO), the largest research institution in Australia. IHI manufactured the 0.5 t-CO_2/day scale pilot plant in IHI Aioi Works and confirmed its performance. The PICA pilot plant was transferred to the Loy Yang A Power Station in Australia and was commissioned successfully using flue gas from the power station in the second half of FY2015. Since the completion of commissioning on the industry standard capture solvent (monoethanolamine), IHI has performed long-term continuous operation using a solvent newly developed by IHI called (ISOL-162) and have successfully completed 5 000 hours of operation at the end of March 2017.



(Note) MEA : Monoethanolamine (Standard amine that is used for chemical absorption technologies)

Test result 2. Comparison between the IHI advanced process and the conventional process



0.5 t-CO_2/day pilot plant

Since further energy saving is essential to commercialize the technologies, we will advance development for reducing regeneration energy under the support of the "Strategic Innovation Program for Energy Conservation Technologies" of New Energy and Industrial Technology Development Organization (NEDO).

By combining the outcome of this technical development and the operational technologies established by the long-term test in Australia, we will proceed to demonstrate the 200 t-CO_2/day scale pilot plant, and carry out an FS (Feasibility Study) on commercial plant of the 2 000 t-CO_2/day scale, followed by FEED (Front End Engineering and Design: Basic design work performed after an FS). We will steadily advance our activities to push the developed technologies to practical stage and commercialize them, thereby contribute to realize a low-carbon society.

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