Starting with Twin Power
~ Introduction to the RITE Carbon Capture Center and Biotechnology Manufacturing Laboratory Building ~

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Japan has declared its aim to be carbon neutral by 2050 and is taking various energy and global warming countermeasures in order to achieve CO_2 emissions reduction as well as economic growth and strengthened industrial competitiveness. As part of the efforts, the following is promoted:

(1) R&D on materials that can separate and capture emitted CO_2 at low cost and with low energy for industrial sectors where significant CO_2 emissions reductions are difficult

(2) Bio-manufacturing that produces chemical materials, fuels, and medicines, using the cells of microorganisms through recombinant DNA technology.

RITE has been working on this type of R&D for some time. In fiscal 2024, in response to the demands of the times, it built two new adjacent buildings: (1) the RITE Carbon Capture Center, which will accept external samples and evaluate CO_2 separation materials, and (2) the Biotechnology Manufacturing Laboratory Building, which aims to bio-produce high-added-value chemicals. With these facilities used as twin power, new initiatives have just been launched to promote further acceleration of R&D. This special feature will introduce these two facilities.

2. RITE Carbon Capture Center

2.1. Background of establishment

RITE has, to date, conducted R&D on various CO_2 capture technologies, primarily chemical absorption, solid sorbent, and membrane separation, and has successfully achieved commercialization of some of these technologies. Now we are undertaking an initiative to "establish a common base for evaluating the standards of CO_2 separation materials" in order to support fundamental research and promote industry collaboration in the R&D of CO_2 capture and utilization technologies, with a new platform.

In May 2022, in collaboration with the National Institute of Advanced Industrial Science and Technology, RITE was commissioned by the New Energy and Industrial Technology Development Organization (NEDO) to undertake a project named "Green Innovation Fund Project / Establish a common base for evaluating the standards of CO2 separation materials" (hereinafter referred to as "this project"). As part of this project, we established Japan's first test center capable of evaluating CO_2 separation materials using real gas, the RITE Carbon Capture Center (RCCC).

In countries such as the United States, Norway, and Australia, real-gas test centers are third-party organizations operated by governments or other organizations. These centers formed the International Test Center Network (ITCN), which facilitates mutual information exchange among members. Since 2017, RITE has been a member of the ITCN, participating in discussions and information sharing while pursuing the establishment of Japan's first real-gas test center. This long-standing goal has now been realized with the successful establishment of RCCC.

2.2. Facility overview

RCCC consists of a dedicated small-scale city-gas boiler and CO_2 separation test unit. In order to further enhance Japan's advantages in materials development, the center is designed to enable real-gas testing at the early stages of CO_2 separation material R&D, thereby accelerating the practical application of such materials in Japan.

As shown in Figure 1, the flue gas from the boiler is directed through a cooler, blower and chiller, and supplied to the testing processes including absorption, adsorption, and membrane separation. The center is equipped with test systems capable of capturing up to 100 kg of CO_2 per day from boiler combustion flue gas with CO_2 concentrations below 10%, offering performance evaluation well-suited to various separation materials under real gas. In Japan, CO_2 emissions from boiler combustion are estimated to account for several percent of total emissions, making it an important sector where carbon capture solutions will be increasingly needed.

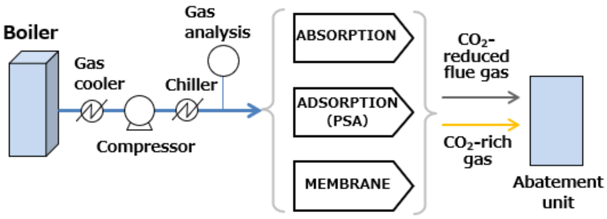

Fig.1 Scheme of RITE Carbon Capture Center

Figure 2 shows the layout of RCCC: (1) the Evaluation Building houses the absorption unit, the Pressure Swing Adsorption (PSA) unit, and the membrane module unit; (2) the outdoor Utility Yard contains the boiler and utility unit. In addition, there are plans to install a Temperature Swing Adsorption (TSA) unit in the currently unused space within the Evaluation Building.

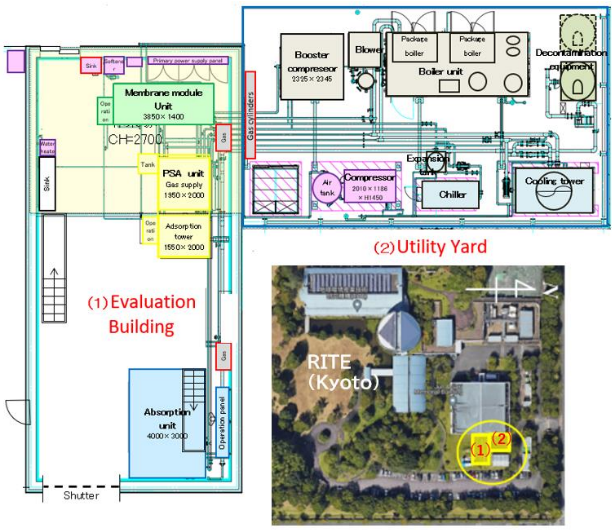

Fig.2 Layout of RITE Carbon Capture Center

The specifications of each test unit were determined by members of the Project Steering Committee.

The boiler unit is equipped with two city gas boilers, each equivalent to a steam output of 250 kg/h, enabling uninterrupted supply of combustion flue gas to the test systems even during mandatory inspections. The absorption unit consists of an absorption tower (packed section: 2 m in height × 0.2 m in diameter), and a regeneration tower (packed section: 2 m in height × 0.1 m in diameter), and approximately 70 liters of absorbent will be needed for testing. The PSA unit is equipped with three adsorption towers (each 250 A × 1800 L) and allows for testing with a dry flue gas at a dew point of −60 °C, under adsorption pressures ranging from 101 to 900 kPa and desorption pressures down to 10 kPa. The membrane separation system has space to install modules approximately 1 meter in length and is capable of testing with a flue gas controlled at a dew point between −15 to 80 °C, under the following conditions: temperature range of 30–85 °C; feed pressure of 101–900 kPa; permeate pressure of 10–101 kPa.

Fig. 3 Each Unit of RITE Carbon Capture Center

2.3. Future development

RCCC aims to be an actively utilized center capable of providing reliable, fair and neutral real-gas test data through the use of standardized evaluation methods established via testing with reference materials. In addition, by accommodating user-specified testing conditions with flexibility, we will conduct evaluations of externally provided samples. We hope that many users will apply for real-gas tests at this Center.

Through the evaluation of both standard reference materials and external samples, we are promoting the development of domestic CO_2 separation materials and to building and expanding a comprehensive database that supports international standardization of CO_2 capture technologies. We would be honored if our efforts contribute to accelerating the advancement of CO_2 separation material development in Japan.

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3. Biotechnology Manufacturing Laboratory Building

3.1. Background of establishment

Since March 2023, RITE has been implementing the NEDO-commissioned project “Green Innovation Fund Project: Promotion of Carbon Recycling Using CO_2 as Direct Raw Material through Biomanufacturing Technology”*1 in collaboration with Sekisui Chemical Co. This project focuses on developing a producer strain capable of bioconverting waste gas (CO_2) emitted from waste incineration facilities into high-value-added chemicals. By fully utilizing the smart cell creation technology, enzyme modification technology through genetic recombination, microbial resistance technology against fermentation inhibitors, and bioproduction technology that have been developed so far, we have initiated the development of a production strain capable of bioconverting waste gas (CO_2) emitted from waste incineration facilities into high value-added chemicals, as well as the development of a bioprocess using this strain (Fig. 4).

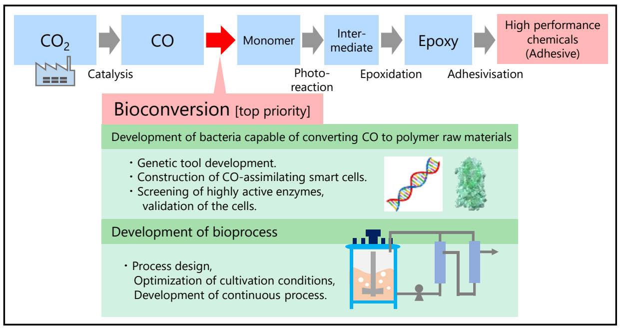

Fig. 4 Conceptual Diagram of the Project

CO_2 is an exceptionally stable compound that composes the end products of organic matter combustion. While we can harness plants to use CO_2 for biomass production as a raw material for biomanufacturing, it requires large facilities and a large site in order to uniformly provide light energy to microorganisms.

Thus, the RITE Molecular Microbiology and Biotechnology Research Group has shifted its attention on CO rather than CO_2. We utilize the power of CO-assimilating bacteria and flexibly tailor its metabolic pathway to confer its bioproduction ability. As a result, we have come up with the idea of bioproducing high-value-added chemicals from CO.

Meanwhile, Sekisui Chemical has succeeded in developing a technology that can convert CO_2 to CO with a high efficiency (>90%) using chemical catalysts. Thus, our final goal is to use RITE's bio-manufacturing technology to produce polymer materials for the company's high-performance chemicals (adhesives) from CO, thereby realizing a carbon-recycling society.

3.2. Facility overview

RITE had previously developed bioconversion technology using gas components as raw materials, but now we established a dedicated experimental building (Bio-manufacturing Experimental Building) for full-scale operations (Fig. 5).

Fig.5 Newly constructed bio-manufacturing experimental building

On the first floor, the culture facilities necessary for gas fermentation are built. A dedicated anaerobic chamber is installed for the genetic manipulation of oxygen-phobic CO-assimilating bacteria, which require an experimental environment with special gas components (Fig. 6).

Fig.6 Anaerobic chamber for genetic manipulation

The anaerobic chamber is a workstation for cultivating microorganisms in a varying gas composition environment. Since the equipment necessary for genetic modifications is stored in the chamber in advance, researchers can conduct various genetic modification and anaerobic cultivation (gas fermentation) experiments using the autotrophic bacteria through the glove.

Bioprocess development using the developed producer strains is conducted in cultivation facilities dedicated to gas fermentation (e.g., jar culture equipment installed in a local exhaust system). In this process, the composition of both feed gas and the fermentation exhaust gas can be quantified on-site, allowing timely evaluation of the CO utilization efficiency (Fig. 7). Using these state-of-the-art facilities, we are optimizing the fermentation conditions of the newly developed CO-assimilating strain and studying continuous process production method.

Fig.7 Research scene using a dedicated gas fermentation system

The second floor houses the essential equipment for extensive biofunctional analysis, smart cell strains improvement, by-products analysis, and bioprocess evaluation. In particular, an integrated HPLC analysis system has been updated to analyze various metabolites throughout cultivation process (Fig. 8).

The Biomanufacturing Experimental Building is equipped with a safety and sanitation environment that complies with various laws and regulations so that researchers can safely conduct research and development centered on gas fermentation.

Fig.8 HPLC for metabolite analysis

3. 3. Future development

The bioproduction method has many excellent features, including the ability to selectively synthesize high-value-added compounds that are difficult to produce by chemical methods due to isomeric byproducts, utilizing the continuous catalytic action of enzymes under mild conditions near room temperature and pressure. Accordingly, this method is expected to be implemented in a variety of fields. If this technological development enables biomanufacturing of various chemicals and fuels necessary for industrial activities using CO_2 captured and collected at DAC facilities and CO_2 emitted from waste incineration facilities, steel mills, thermal power plants, and various factories in the future, it will greatly contribute to the realization of carbon neutrality, which RITE aims to achieve. RITE believes that this will make a significant contribution to attaining our carbon neutrality target.

In order to meet the expectations of companies wishing to enter the bio-manufacturing industry, RITE will continue to develop new technologies, develop producer strains best suited for commercialization, and expand its research activities to supply production technologies.

*[1] This article is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

We will establish a manufacturing method to produce high value-added chemicals using CO_2 as a raw material, and we welcome all those interested in the effective CO_2 utilization.

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