Facility Engineering Action Based on Total Civil and Plant Engineering for Mitsubishi Heavy Industries Group's Product to Offer Customers a Wide Range of Services

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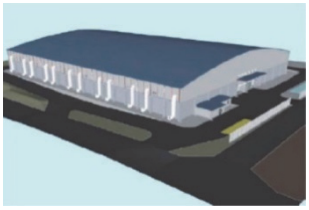
Mitsubishi Heavy Industries (MHI) Group provides a total package of equipment and products for optimal business operations using equipment and products manufactured and sold by the group and combining comprehensive engineering capabilities of the group in the fields of civil engineering, construction and plant engineering in its "Facility Engineering" activities. It is a collaborative project of MHI Group, and this report presents the Facility Engineering activity cases in which Mitsubishi Heavy Industries Transportation and Construction Engineering, Ltd. was engaged.

1. Introduction

We, Mitsubishi Heavy Industries Transportation and Construction Engineering, Ltd., have accumulated technological capabilities by promoting construction projects, mainly plants and buildings for Mitsubishi Heavy Industries (MHI) Group companies and their affiliated partner companies. In addition, we have been involved in many plant construction projects in various fields, including the MHI Group's thermal, geothermal, biomass, and other power generation projects, as well as chemical, environmental, nuclear, and transportation-related projects, and have cultivated comprehensive engineering capabilities centered on civil engineering, construction, and plant engineering.

Table 1 shows the representative collaborative plant project cases of MHI Group companies and us so far.

Table 1 Representative collaborative plant project cases of MHI Group companies and us

	From 2017 to 2018	From 2020, currently under construction	From 2021, currently under construction
Collaboration counterpart	Mitsubishi Heavy Industries, Ltd.	Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd.	Mitsubishi Heavy Industries, Ltd.
Facility	Kuju Geothermal Plant Civil engineering and construction work (Oita)	Kyoto Environmental Preservation Public Corporation Civil engineering and construction work (Kyoto)	Chokai Minami Biomass Power Station Fuel warehouse construction work (Yamagata)
Exterior view			

In recent years, MHI Group has been developing group companies' collaborative projects in which MHI Group's products and comprehensive engineering capabilities of civil engineering, construction, and plant engineering are combined to solve customers' problems in a one-stop manner. These are collectively called “Facility Engineering” activities.

In these activities, MHI Group works with the customer to provide optimal solutions for the

project from its initial stage, such as energy saving at the facility, cost reduction, and shortening of construction period. By enabling customers to place a collective order for plant equipment and buildings, their workload can be reduced.

These activities were started as sales expansion activities of MHI Group companies, and have been expanded nationwide while strengthening cooperation of the Plant and Infrastructure Domain, the Logistics, Thermal, and Drive Domain, as well as corporate sectors in the head office of Mitsubishi Heavy Industries, Ltd. and branch offices. As a result, these activities have been highly evaluated by customers (**Figure 1**, **Figure 2**).

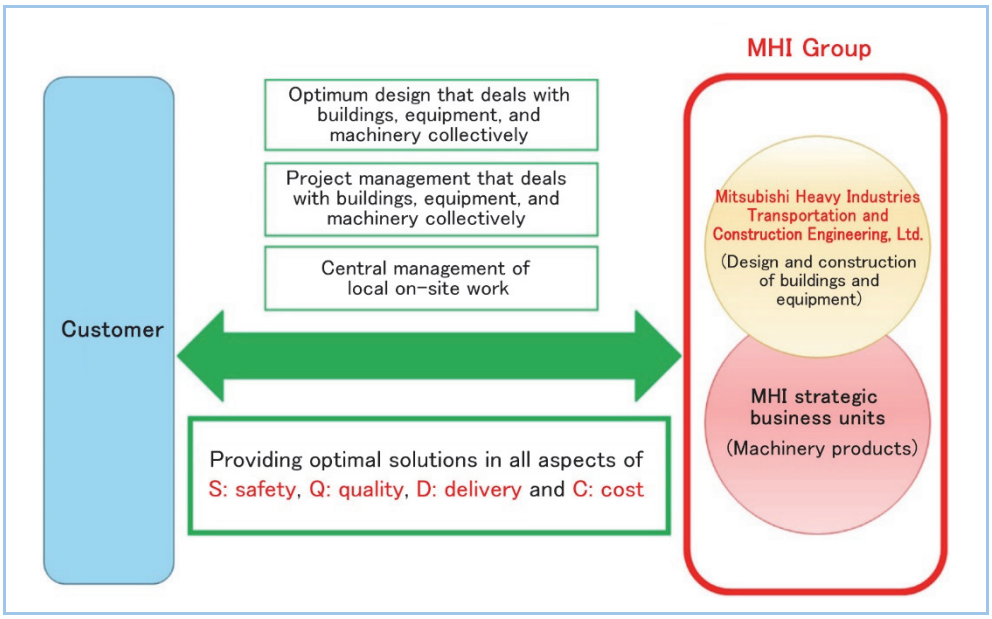


Figure 1 Providing optimal solutions to customer

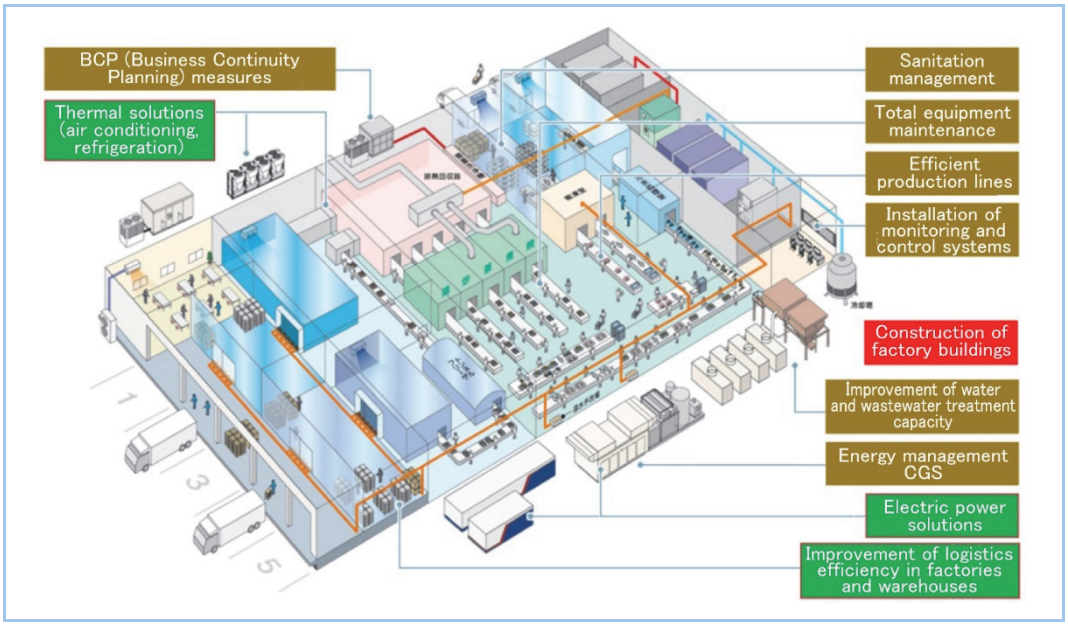


Figure 2 Illustration of solutions for food factory

2. Achievements of Facility Engineering

Table 2 shows representative Facility Engineering cases in which we were engaged in collaboration with MHI Group companies.

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	2016 to 2018	2017 to 2018	2019 to 2020
Collaboration counterpart	Mitsubishi Heavy Industries Air-Conditioning and Refrigeration, Ltd.	Mitsubishi Heavy Industries Machinery Systems, Ltd.	Mitsubishi Logisnext Co., Ltd. (ML)
Facility	Kawashima Food Co., Ltd., Refrigerated Warehouse in Factory 2 (Tokyo)	Kamotsuru Sake Brewing Co., Ltd., Bottling Factory (Hiroshima)	Japan Engine Corporation, Automated Warehouse (Hyogo)
Exterior or interior view			

This chapter explains the following two recent achievements as representative example cases of Facility Engineering activities:

(i) Cogeneration equipment for Fusogosei Co., Ltd., which was a collaborative project of Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET) and us

(ii) Refrigerated warehouse for Kyoto Enkangyo Oroshi Kyodo Kumiai, which was a collaborative project of Mitsubishi Heavy Industries Air-Conditioning & Refrigeration, Ltd. (MJR) and us

2.1 Gas engine cogeneration equipment for Fusogosei Co., Ltd.

Fusogosei Co., Ltd. is one of the leading companies in Japan that manufactures and sells building interior materials (floor materials, wall coverings, etc.) and home furnishings (tablecloths, shower curtains, floor mats, and other products). In 2021, we installed cogeneration equipment that uses an MHIET gas engine as its main engine in the Kuki Factory of Fusogosei Co., Ltd. in Kuki City, Saitama Prefecture.

(1) Project outline

The Kuki Plant had been using a gas engine cogeneration equipment on a fixed-term lease contract and purchased electricity needed for production.

In recent years, the demand for electric power for their production equipment has been increasing, and the reconstruction of the power source with an eye on the future has become an issue. For this project, MHIET and we asked the customer about its intentions and proposed a plan to install new cogeneration equipment consisting of two 1000kW gas engines (produced by MHIET) since the existing equipment is aging and received the order.

Table 3 Project outline of gas engine cogeneration equipment for Fusogosei Co., Ltd.

Construction site	Fusogosei Co., Ltd. Kuki Factory in Kuki City, Saitama Prefecture (**Figure 3**)
Installation area	Approximately 430m2 (22.9m x 18.5m)
Gas engine generator	1,000 kW x 2 units (including steam and hot water recovery and power failure response functions)
Absorption chiller	90RT x 1 unit (using hot water)
Auxiliary equipment	Cooling tower, pump, water softener, deaerator, sound proof wall
Overall construction period	November 2019 to January 2021 (2019/2020 subsidy multi-year project)
On-site construction	June 2020 to December 2020
Test operation and delivery	End of February 2021

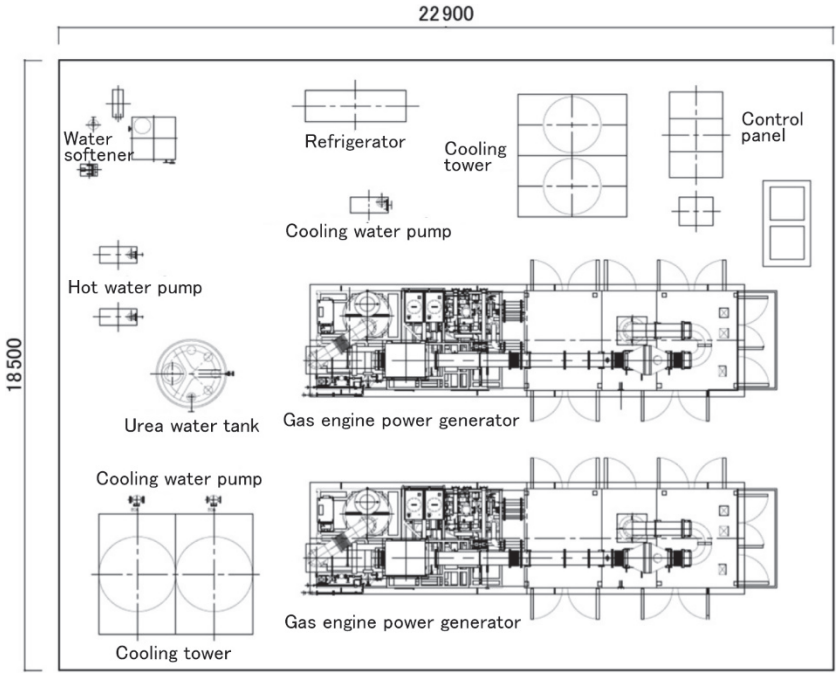

Figure 3 Installation layout

(2) Technological issues

The customer had a plan to construct sound proof walls surrounding the outer periphery of the new power generation equipment area as a measure against noise emissions to adjacent areas to reduce noise by 20 dB on the boundary line of the site by installing gas engines (**Figure 4** (b)).

We conducted a noise simulation (Figure 4) to optimize the layout of the sound proof walls, and streamlined the area of the sound proof walls to 149m^2 (Figure 4(c)), reduced by 25% from the initially planned 197m^2, thereby reducing the required costs.

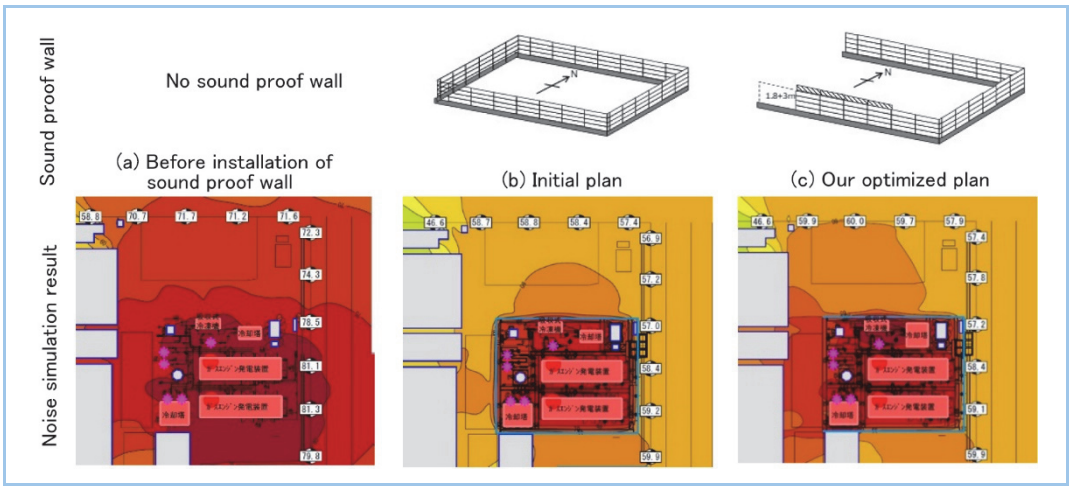

Figure 4 Sound proof wall shape and contour diagram of noise simulation result

We designed the optimum equipment layout in the limited site by fully utilizing 3D CAD. In addition, we developed the piping plan and piping isometric drawings by using the automatic function to improve the quality and efficiency of the design. **Figure 5** shows the 3D CAD plan drawing, and **Figure 6** shows a panoramic view of the completed facility. **Figure 7** shows a photograph of the sound proof walls installed. By effectively utilizing 3D CAD, we were able to respond precisely to the customer request and received a favorable reception.

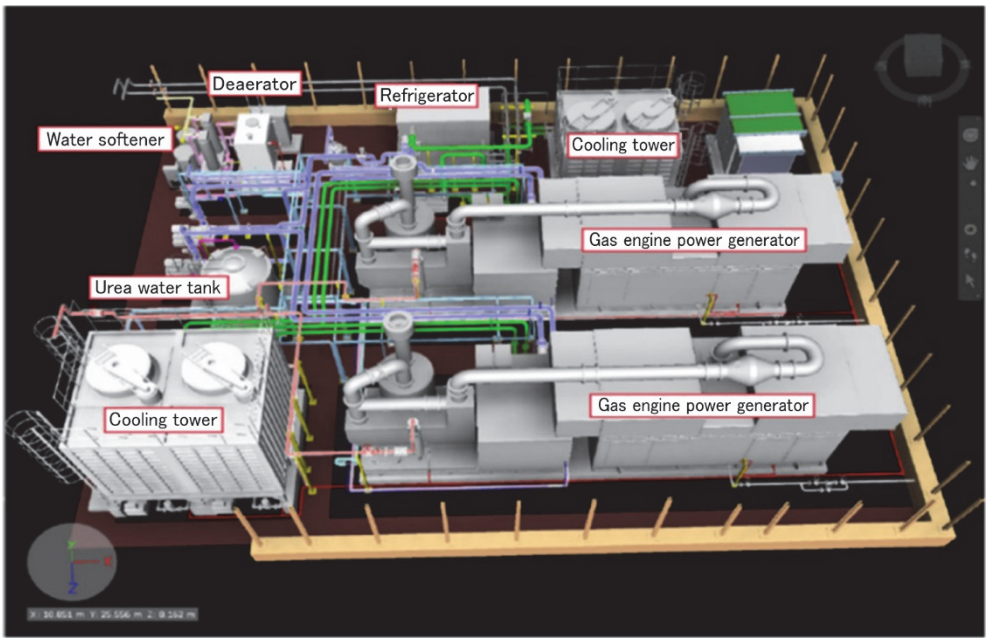

Figure 5 3D CAD output

Figure 6 Panoramic view of completed facility

Figure 7 Installation of sound proof walls

(3) Result

As planned, this equipment has been in full-scale operation since February 2021 and supplies electric power to the factory with both of the gas engines on weekdays and with one of the two gas engines on weekends.

Today, one year after completion, the equipment is operating steadily as planned.

In this project, we not only sold the gas engine, but also provided EPC work for the entire gas engine system, including the auxiliary equipment, foundation and civil engineering work, and test operation. Due to this, we were able to respond to requests in detail from the customer, who highly evaluated the result of this project as a one-stop activity of the MHI Group.

Fusogosei Co., Ltd. is also planning construction of various additional equipment. We will continue to propose Facility Engineering through MHI Group's one-stop activities.

2.2 Refrigerated warehouse for Kyoto Enkangyo Oroshi Kyodo Kumiai

Kyoto Enkangyo Oroshi Kyodo Kumiai is a cooperative association of wholesalers that handles northern seas products such as salmon, dried sarline such as small dried sardines, dried fish such as dried flounder, and boiled products such as boiled crabs at the Kyoto City Central Wholesale Market.

We participated in the project for building a refrigerated warehouse in collaboration with MJR.

(1) Project outline

We started to participate in this project after MJR, which was in the process of deciding on the equipment for the new construction of the customer's refrigerated warehouse, recommended us to the customer as a building construction company. Based on discussions between the customer, MJR, and us that had been repeated from the basic planning stage of the

facility, we realized streamlined specifications and cost reductions. As a result, we were contracted to design and construct the building in which the refrigerated warehouse is installed as a whole.

Table 4 Project outline of refrigerated warehouse for Kyoto Enkangyo Oroshi Kyodo Kumiai

Construction site	Kyoto City, Shimogyo Ward
Structure and scale	3-story steel structure, Building area 1,368m^2, Total floor area 3,757m^2 [Refrigerated warehouse specifications] 1st floor: -8°C, 2nd and 3rd floor: -25°C, Some areas of 2nd and 3rd floor: ±0°C to +10°C (**Figure 8**)
Overall construction period	Start: December 2021, Completion: December 2022
Cold storage equipment	Start of cold storage equipment work: May 2022, Start of freezing test run: December 2022 (start of cooling)

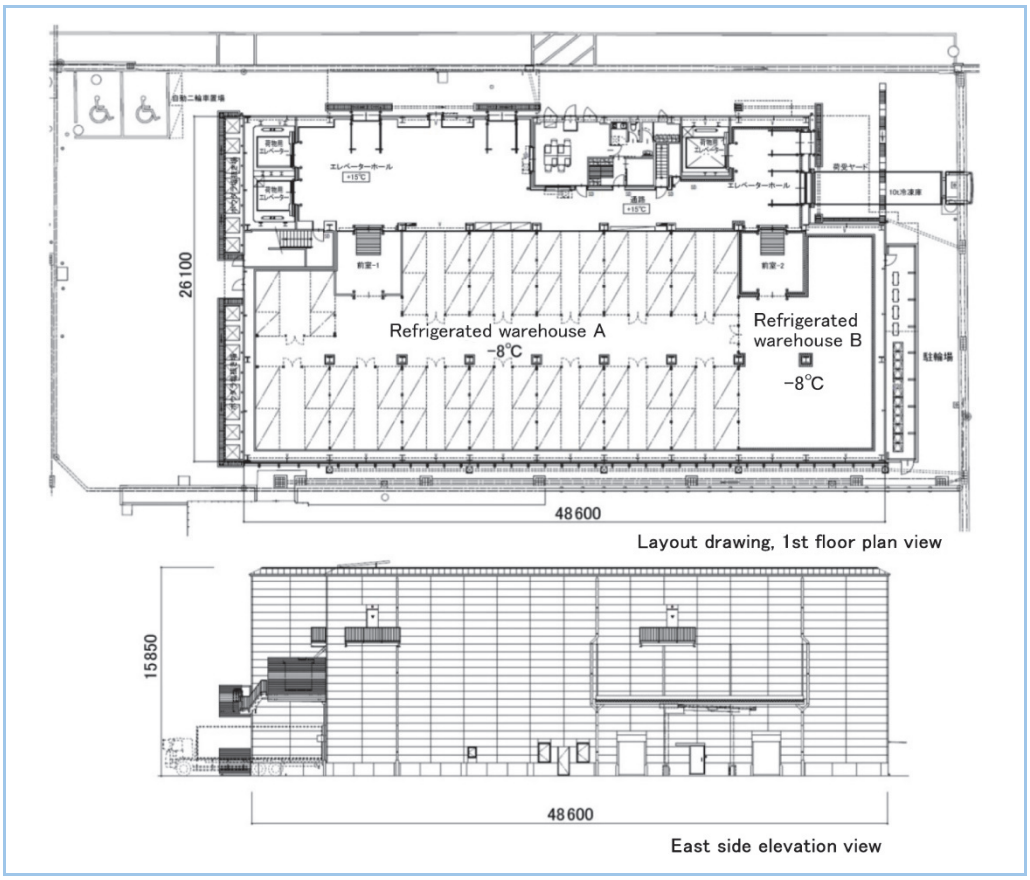

Figure 8 Design plan view and elevation view

(2) Technological issues

Considering the temperature difference between the refrigerated warehouse and the outside, drainage passages for dew condensation were installed between the outside Autoclaved Lightweight aerated Concrete (ALC) wall and the internal heat insulation panels.

This is a measure against the occurrence of dew condensation and is effective for preventing water leakage into the building.

In addition, frost heaving prevention pipes were installed at the bottom of the concrete slab in the first floor refrigerated warehouse, the temperature of which is -8°C, as a measure against the ground freezing.

The frost heaving prevention pipes are a measure to avoid frost heaving, which is a phenomenon where the water in the soil freezes and the volume expands and pushes up the floor when the underfloor of the cold storage is continuously cooled for a long time. The frost heaving pipes are laid before the floor is constructed. Ground control, in which soil is replaced with gravel, is one of the measures to prevent frost heaving, and this time it was adopted together with the frost heaving prevention pipes.

In the layout plan, the specifications, dimensions, layout position, etc., were determined based on past actual data, taking into consideration the internal temperature conditions (**Figure 9**).

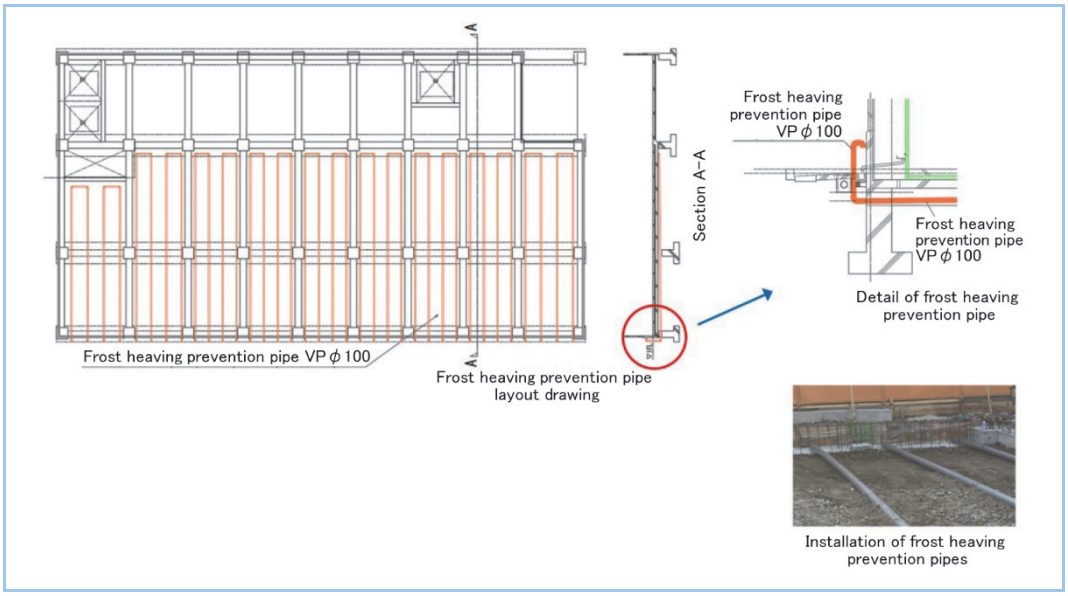

Figure 9: Frost heaving prevention pipe layout drawing and detail view

(3) Construction status

In February 2022, the installation of foundation reinforcing bars and the placement of foundation concrete were completed (**Figure 10**).

After that, backfilling work was carried out, frost heaving prevention pipe laying and slab work were performed, and as of April, erection of a steel frame is being undertaken (**Figure 11**).

The building construction will be completed in December 2022, and cooling of the refrigerated warehouse will be started in the same month (**Figure 12**).

Figure 10 Placement of foundation concrete

Figure 11 Erection of steel frames

Figure 12 Illustration of completed refrigerated warehouse

(4) Other collaboration in refrigerated warehouse field

In parallel with this project, we received an order for all-weather automotive environmental test equipment (an environmental wind tunnel) for a certain company (**Figure 13**) in collaboration with MJR. This case requires technologies to counteract noise during tests and create a low-temperature environment. We plan to provide better equipment and facilities to the customer by utilizing our know-how for simulating noise and handling low-temperature environments presented in this report.

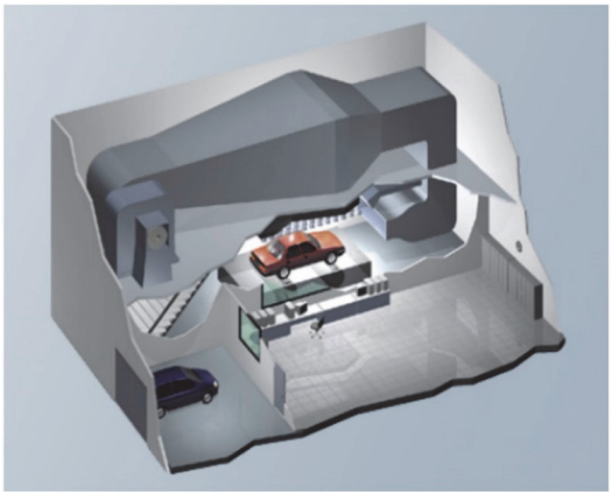

Figure 13 Schematic illustration of automotive environmental test equipment

3. Conclusion

As described in this report, we offer optimal factory and building construction by utilizing MHI Group's products and equipment and our comprehensive engineering capabilities centered on civil engineering, construction, and plant engineering, which are our strengths, in a collaborative manner, to provide customers with an efficient business environment and energy saving and resource saving for carbon neutrality. We will continue to promote "Facility Engineering" to optimize the world's infrastructure development and contribute to the realization of a safe, secure, and comfortable environment for the society in which people conduct their lives.