World's First Use of Liquefied CO_2 Freezing Method for Protection of Shield Arrival Area in Seabed

— Construction of Discharge Channel Tunnel, Ishikari Bay Shinko Power Plant Unit 1—

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Introduction

The discharge channel tunnel of Ishikari Bay Shinko Power Station constructed by slurry shield method is an undersea tunnel with an inner diameter of 4.7 m and a total length of 1,045 m that connects to the discharge outlet installed under the seabed. This paper reports the overview and construction results of the protective work for shield arrival area by the new freezing method using liquefied CO_2 as a secondary refrigerant.

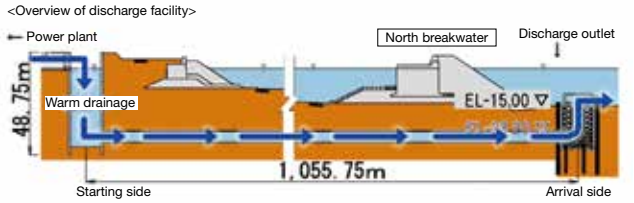

Fig. 1 Overview of discharge channel tunnel

1. Freezing Method Using Liquefied CO_2

Fig. 2 shows the comparison between the new and conventional methods. Conventionally, sensible heat generated by the thermal difference between antifreeze (brine) and ground was utilized, and CFCs, the subject of regulation, were used for primary refrigerant. In the new CO_2 freezing method, heat is taken from the ground not only by sensible heat but also latent heat due to the evaporation of the liquefied CO_2. The vaporized CO_2 is re-liquefied through heat exchange with NH3, a primary and natural refrigerant.

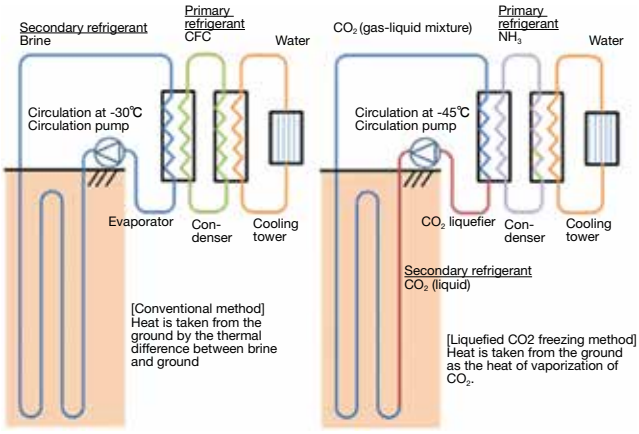

Fig. 2 Conventional (left) and new methods

Latent heat of CO_2 is larger than sensible heat of antifreeze solution, so it can form frozen soil of the same size at a flow rate of about 1/10 of the conventional. Also, the viscosity of CO_2 is about 1/90 of that of antifreeze solution, so the pipe diameter and the pump power can be reduced, and long-distance pumping is possible. Thus, CO_2 freezing method is extremely advantageous in terms of workability, work period and cost. It is a promising method with high environmental impact reduction effect.

2. Construction Results

Installation of the freezing plant was completed about a week after the shield machine arrived. Fig. 3 shows the layout of each facility. The main pipe for CO_2 was installed under the railroad sleepers to secure the flow line of the disassembled materials. The connecting work was carried out under constant monitoring of the freezing temperature. No flooding occurred at the time of connection and completion of construction.

(a) Main pipe

(b) Refrigeration system

Fig. 3 Layout of each facility

3. Short Construction Period

The freezing operation was carried out smoothly without interfering with the machine dismantling operation and the process was shortened by about one month compared to that of the conventional method. Power consumption was reduced by about 40%, contributing significantly to cost reduction and environmental impact reduction.

4. Conclusion

In this construction, the big challenge was safe connection of the shield machine and the undersea water discharge outlet under high water pressure. The liquefied CO_2 freezing method was adopted for the first time in the world as a protective work for shield arrival area, and the machine dismantling work was carried out in parallel. As a result, the work period was shortened by about a month, and quick and safe connection and disassembly operations were realized. It also contributed to mitigating global warming by reducing power consumption by about 40%.