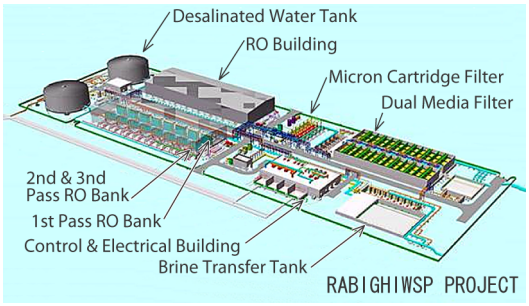
World's First Large Full Triple-Pass RO Seawater Desalination Plant



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1. Introduction

The independent water, steam, and power (IWSP) project that was completed on January 1, 2009 in the Rabigh District of Saudi Arabia and has commenced commercial operations is intended to supply water, steam, and electricity to a large petrochemical complex (Petro Rabigh) co-invested equally by Sumitomo Chemical Company and Saudi Arabian Oil Company (Saudi ARAMCO), the national petroleum company of Saudi Arabia. An order was placed Mitsubishi Heavy Industries, Ltd. (MHI) on a full turnkey basis from supplying the equipment up to execution of site work/commissioning, including civil work. In recent years, customers require high pure water and high efficiency for desalination facilities. In response to this trend, remarkable developments have done actively in new processes and new membranes for the reverse osmosis (RO) method of seawater desalination, by the engineering, procurement, and construction (EPC) contractors and RO membrane manufacturers. Therefore, we would like to introduce our own technology, called a full triple-pass RO process, which we developed to meet these requirements.

2. Development and significance of full triple-pass RO process

The Rabigh IWSP Project is one of the largest seawater RO desalination plants in the world, with a water production capacity of 168,000 m^3/day during normal operations and 192,000 m^3/day at maximum capacity. As the product water is used mainly for cooling water make up, high pure water, the same water quality as that produced by the evaporation method (TDS < 10 mg/l, Cl^- < 5 mg/l) was required. Even though it was really difficult for the conventional RO process to produce such high pure water, MHI enabled to apply the RO method to this project by using a full triple-pass RO method which was uniquely developed by ourselves.

In addition, the total number of trains could be reduced by scaling up the RO train capacity, which eliminated restrictions on the application of RO to large scale seawater desalination plants. The RO method has been deemed to be superior to the evaporation method in terms of the delivery period and its competitive price, as less high-alloy metals, such as nickel, chromium, and copper are used for RO method which are less affected by steep increases in metal prices. The development of this large-scale full triple-pass RO process means that it will assume a dominant position in the high pure desalinated water market, which has been monopolized by the evaporation method. The RO technology will be expected to have a big impact that will change the power balance between the multistage flush evaporation method, the multi-effect desalination method and the RO method in the seawater desalination market.

3. Features of the full triple-pass RO

The features of the full triple-pass RO process (patent applications are pending in Japan and overseas) are described below:

(1) The triple pass RO process combines high-pressure RO membranes for seawater service with low-pressure RO membranes for brackish water. Different types of high-pressure RO membrane for seawater can be used, regardless of whether they are the hollow fiber type or spiral wound type.

(2) Smooth start-up/shut-down is enabled by eliminating the intermediate tank at the outlet of each RO pass. Consequently, it is necessary to install a three-way valve or exclusive-use valve to dump permeate outside the system, and then to avoid bio-fouling in the intermediate tank.
(3) By installing a three-way valve or exclusive-use valve to dump brine, brine from each RO pass can also be recovered to the upstream RO pass.
(4) MHI has developed a unique operation system that uses its own hardware and software products for a distributed control system (DCS), enabling automatic start-up/shut-down of a complex RO system.
(5) When required, a bypass operation can also be selected considering the dispersion of RO membrane performance by adding a bypass line of permeate to each RO pass.

These features enable the long-term commercial operation of the system with almost no burden on the operators. MHI and the RO membrane manufacturers guarantee RO performance for 8 years, allowing long-term operation and maintenance service if customers request it, and these services support the diffusion of this full triple-pass RO seawater desalination plant.

4. Example of the first large-scale commercial operation in the world

As stated in the introduction, we completed the first full triple-pass RO seawater desalination plant in the world which was constructed in Rabigh on schedule, and obtained excellent results during commissioning and demonstrated the excellence and reliability of this unique MHI technology. The customers and end users highly appreciate this reliable system, and we anticipate that it will be adopted for similar new projects.

The actual commercial operation in Rabigh can be described as follows. Seawater is filtered through a dual-media filter and fed to the RO unit, which consists of three passes in series. This plant uses high-pressure membranes manufactured by Toyobo Co. Ltd., a company that has a lot of stable operation experience during long years around the Red Sea area for the first pass, and low-pressure RO membranes manufactured by Nitto Denko Co., which possess high performance for salt rejection for the second and third passes.

Figures 1 and **2** show the RO units for each pass installed at the site. The water flow rate for each RO unit is 504 m^3/h and 16 units are available (14 duty plus 2 standby). The recovery ratio (Rc) is 43% for the first pass RO and 90% for the second and third pass ROs. The brine seawater from the first pass RO is discharged outside the system, while the brine from the second and third pass ROs is circulated obtaining an overall Rc of 40%.

Figure 1 The first-pass RO modules
These employ cellulose triacetate hollow fiber-type RO membranes with a good reference for long, stable operation in the Red Sea area.

Figure 2 Low-pressure RO modules for the second and third passes
These employ polyamide spiral wound-type RO membranes with high salt rejection performance.

Figure 3 shows an example of the results of a performance test. The electrical conductivity of the permeate in the first, second, and third pass ROs are 280, 26, and 11 μS/cm, respectively; the equivalent value of total dissolved solids (TDS) are 140, 13, and 5.5 mg/l respectively. Consequently, excellent high pure water was achieved even though the plant is still in the initial operating stage. Although seawater with a higher salinity than the original design salinity was supplied continuously, a flow rate of 508 m^3/h was actually achieved, which exceeds the guaranteed water flow rate of 504 m^3/h with a sufficient margin.

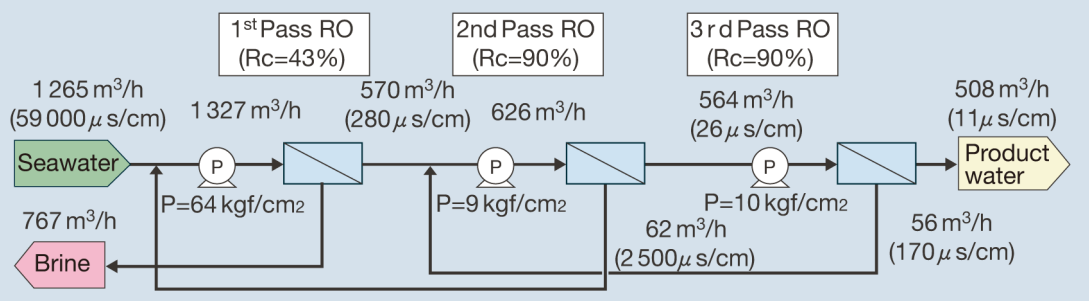


Figure 3 An example of the water quality and water flow rate during a performance test
Despite being conducted during the initial stage of operations, we achieved excellent water quality, and the flow rate of 508 m^3/h exceeded the guaranteed water flow rate of 504 m^3/h.

Figure 4 shows the product water quality of 16 RO units during commissioning. The water quality from each RO unit was excellent, achieving the guaranteed value for each unit. These results confirmed that our full triple pass RO plant will ensure the supply of utilities to the petrochemical complex with high availability.

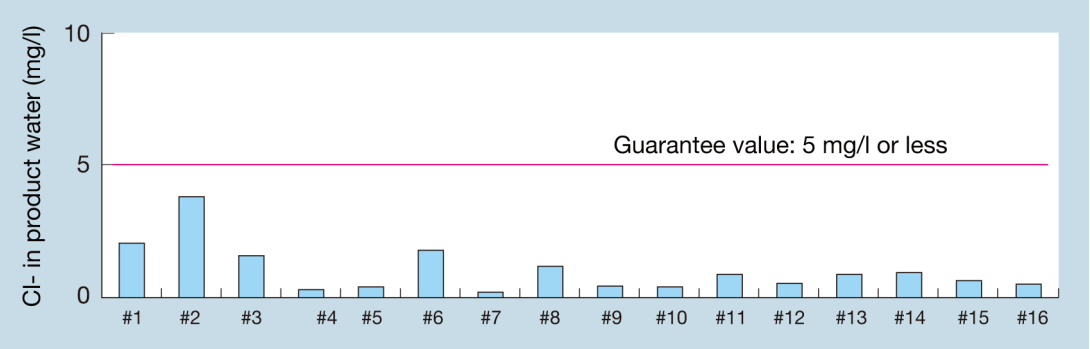
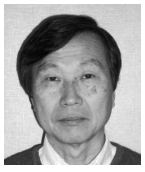


Figure 4 The water quality of 16 units during commissioning
The water quality of each unit satisfied the guaranteed value. The dispersion of the values arose because the performance of each RO unit was under adjustment.

5. Conclusion

In recent years, customers have required high pure water, and larger size, and higher efficiency from RO plants. Consequently, MHI developed our own full triple-pass RO technology. When this plant started operation, it was the second largest RO plant of many large RO seawater desalination plants. We are proud that this has prompted the adoption of the RO method for the large high-purity desalination market, which had been monopolized by the evaporation method. To meet the diverse future needs of customers, we will continue to develop seawater desalination systems using the RO method, which is environmentally friendly and easy for operation and maintenance.

Authors



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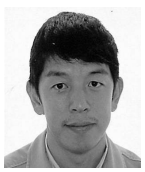

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