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High Recovery / High pressure Membranes for Brine Conversion SWRO Process Development and its Performance Data

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ABSTRACT

Toray Industries and Toray Engineering have developed new type Reverse Osmosis (RO) Membranes and its process for sea water desalination, which brings advantages of high water recovery, low energy cost and less plant installation cost.

The new type RO Membranes, that is called "Brine Conversion Reverse Osmosis Membrane (SU-820BCM)", shows a superb performance at a high pressure more than 9.0MPa and a high salt concentration more than 5.8% concentrated seawater.

The newly developed "Brine Conversion Seawater Reverse Osmosis Desalination System (BCS system)" takes the fresh water from the concentrated brine water (salt concentration 5.8%, produced under 6.5MPa) of first stage RO modules. The newly developed "Brine Conversion Seawater Reverse Osmosis Desalination System" (BCS system) can obtain 60% recovery of fresh water, taking from the concentrated brine water (salt concentration 5.8%, produced under 6.5MPa) of first stage RO modules in addition to a conventional system desalination (40% recovery).

The cost of producing fresh water can be saved approximately 15-20%. The space of plant is also reduced approximately 30% due to reducing the space of pretreatment process.

The continuous operating performance with SU-820BCM has been proved in good conditions in the BCS pilot plant in Japan for more than 2 years. The total capacity of this plant is 210 m^3/d with 60% recovery, and the quality of the produced fresh water has been maintained in the level of less than 200ppm TDS, which is satisfied their designed specifications for drinking water.

INTRODUCTION

A reverse osmosis (RO) seawater desalination system has much advantage in point of saving energy and less installation space, and become regular technology to obtain fresh water.

This RO technology produces enough amount of fresh water without building new dams. However, in order to be recognized as a popular method for supplying fresh water world widely, it is necessary to develop higher water recovery, less energy and installation cost.

Toray, as a leading company in membrane technologies, have developed new type RO membranes and its process for seawater desalination, which obtain 60% recovery of fresh water [1)-3)]. Ohya and Nakao, et al [4) 5)] also suggest that higher recovery of RO seawater desalination is most effective technique in saving energy and less operating cost.

This paper describes development of high recovery RO seawater desalination system (Brine Conversion System: BCS) and its performance data of pilot plant for more than 2 years.

GENERAL DESCRIPTION OF NEW RO SEAWATER DESALINATION SYSTEM

A conventional system of RO seawater desalination system generally consists of pretreatment part, high-pressure pump and RO modules (Fig.1).

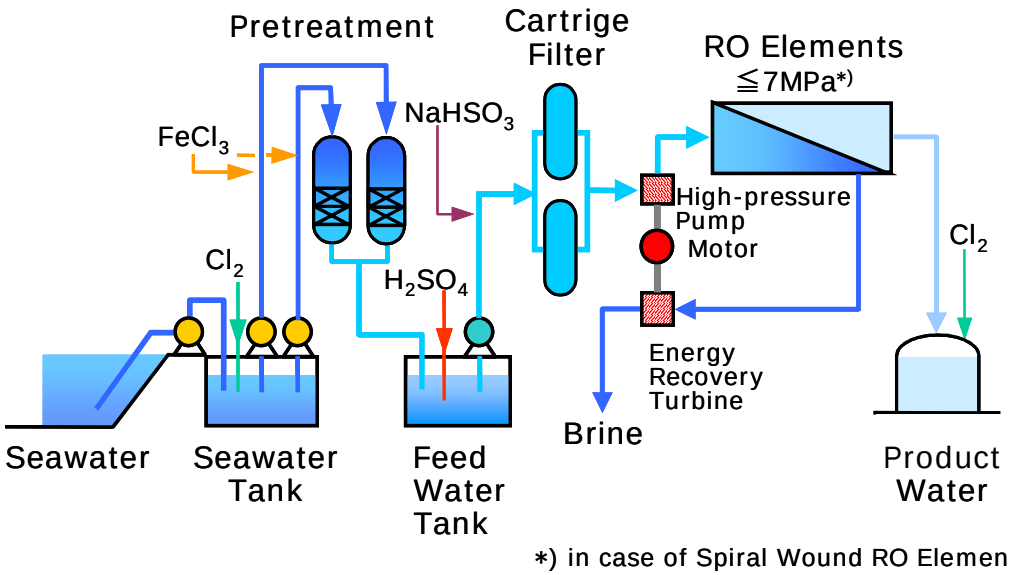

Fig.1 Flow Diagram of Conventional Single Stage RO Seawater Desalination System (Water Recovery 40%)

Most seawater reverse osmosis desalination system in use today is confined to approximately 40% conversion of the feed water (salt concentration 3.5%), since most of commercially available RO membrane did not allow high pressure operation more than around 7.0MPa.

On the other hand, new process of seawater desalination to raise conversion of feed water, brine conversion two stage RO seawater desalination system (BCS system, Fig.2) was developed. The concentrated brine water (salt concentration 5.8%, produced under 6.5MPa) from the first stage RO modules is pressurized to 8.0-9.0MPa by pressure booster, then this brine water is supplied to the

second stage RO modules. In this second stage RO modules additional fresh water is obtained and the brine water is finally concentrated to approximately 8.7% (produced under 8.0-9.0MPa) at the end of second stage RO modules. It can obtain total 60% recovery of fresh water, in which 40% from the first stage RO modules and last 20% from the second stage.

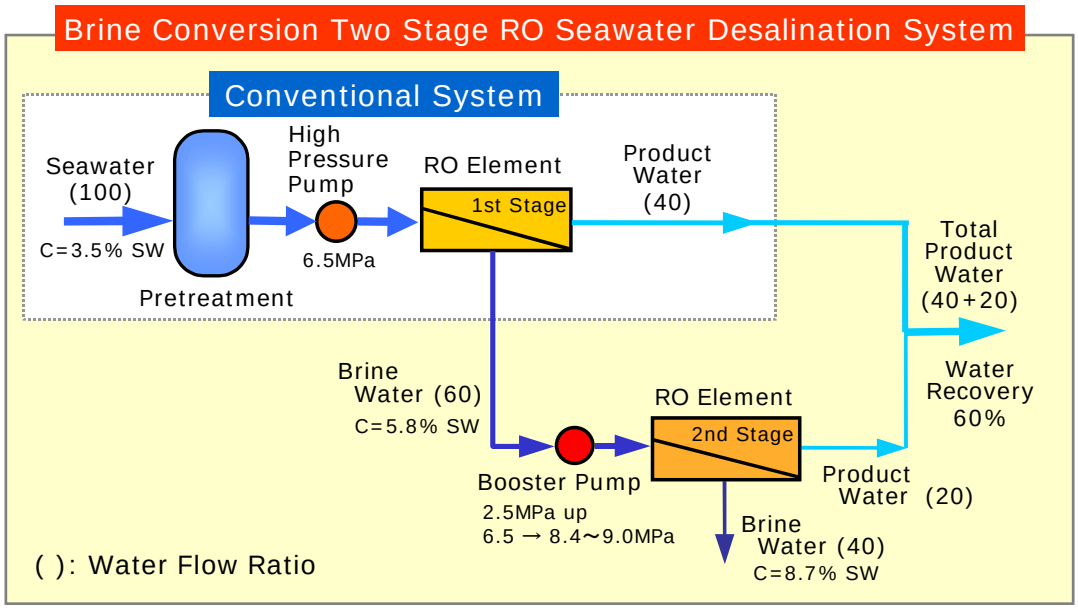

Fig.2 Flow Diagram of Brine Conversion Two Stage RO Seawater Desalination System (BCS system, Water Recovery 60%)

The structure of operating BCS system is as follows:
1.The number of stage of RO modules is two.
2.The operating pressure of second stage RO modules is 8.0-9.0MPa.
3.The total recovery of fresh water is 60%.

The total recovery is decided considering the precipitation phenomena in seawater, and the operating pressure is decided to enable to desalt second stage brine water (the concentration is approximately 8.7%) (Fig.3). The increase of stage number of RO modules can reduce energy to operate high-pressure pump, but 2 stage RO unit can minimize the total cost that includes both capital cost and running cost (Fig.4).

In point of saving energy, BCS system can obtain high recovery so that this new system can reduce total amount of feed water than conventional RO system in producing same amount of fresh water.

Pressure booster, such as high-pressure pump or turbo charger, boosts the brine water pressure from 6.5MPa to 9.0MPa as the concentrated brine water of first stage RO modules already has high pressure energy (almost 6.5MPa). The authors calculate that a use of this new system can save approximately 15% of cost of producing fresh water when a plant of producing 7,500m3/d fresh water works.

BCS system can obtain a fresh water recovery of 1.5 times, in comparison with a conventional system. The space of plant is reduced to approximately 2/3 due to reducing the space of pretreatment process by using this system.

Further more, first stage RO system of the new two stage RO system has same specification as the conventional system. For this reason, the authors can easily build the second stage RO modules in addition to the conventional RO system, and save space of plant and plant installation

cost. However, 1.5 times of producing fresh water by using conventional system needs more installation cost and space for not only RO modules but also pretreatment process.

The advantage of this BCS system compared with the conventional (40% recovery) system, is as follows:

1. Fresh water producing cost can be reduced approximately 15%.
2. Plant installation space can be reduced to 2/3.
3. Plant capacity is easily expanded to 1.5 times by only adding BCS second stage into the conventional plant.
4. Disposed concentrated brine water is reduced to 2/3, so that cost for dispose can be reduced.

In these reasons, this new brine conversion two stage RO seawater desalination system is very useful way to save space of plant, energy and cost.

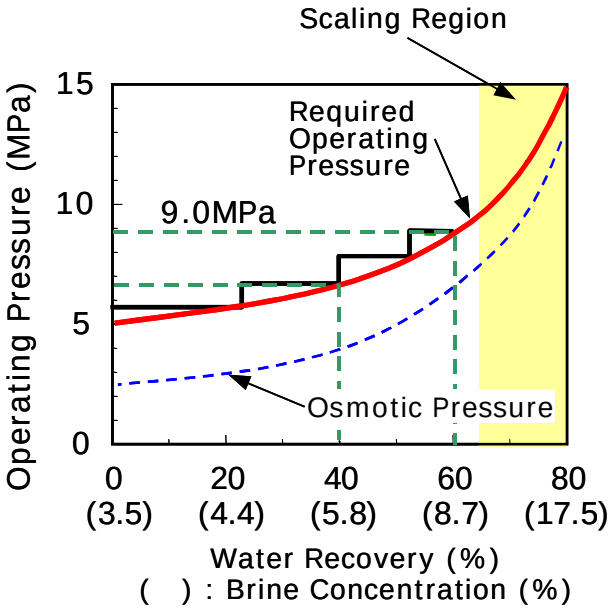

Fig.3 Calculated Results of Relationship between Operating Pressure and Product Recovery of RO Seawater Desalination System

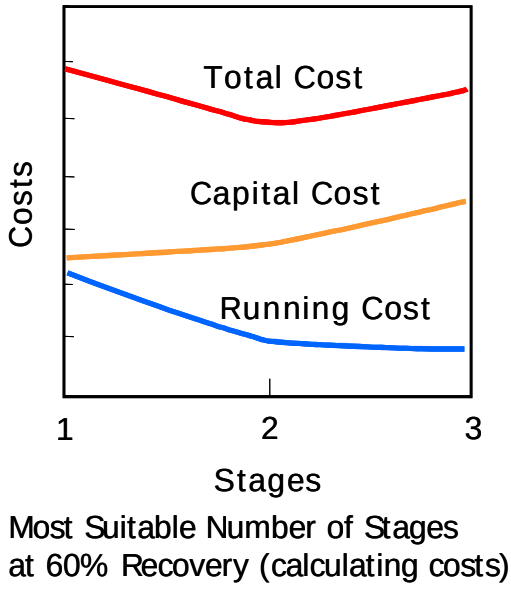

Fig.4 Calculated Results of Relationship between Water Cost and Stage Number of RO Unit

NEW TYPE REVERSE OSMOSIS MEMBRANES AND ELEMENTS

High performance RO membranes for seawater desalination has been developed by Toray Industries, Inc., [6)-8)]. A crosslinked fully aromatic polyamide ultra-thin composite membrane, designated UTC-80, has an excellent feature using 1,3,5-triaminobenzene (TAB) as a polyamine component.

The SU-820 element using the UTC-80 membrane has been used in many seawater desalination plants around the world. However, since the maximum operating pressure of the UTC-80 was around 7.0MPa, it was not possible to apply this membrane to BCS system, which requires high pressure (8.0-9.0MPa) and high concentration (5.8-8.7%) operation. On these situations, Toray Industries has newly developed high performance membrane (BCM membrane element) which can be operated in such high pressure and high concentration conditions. The BCM membrane

elements are used in the second stage of the BCS system and the chemical structure of BCM membrane are basically same as that of UTC-80 which has been proved its good performance world widely.

Chemical structure of the BCM membrane and schematic figure of spiral wound RO membrane element is shown in Fig.5 and Fig.6, respectively.

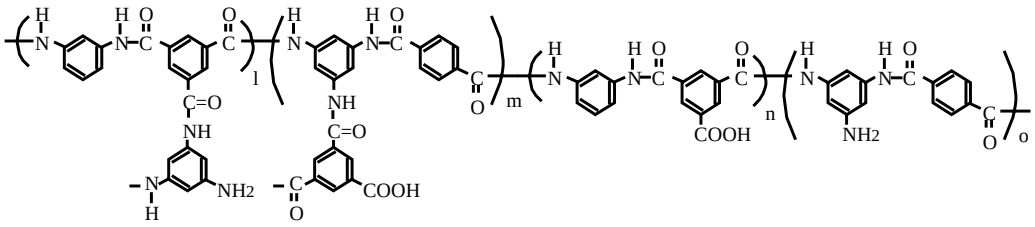

Fig.5 Chemical Structure of the BCM Membrane

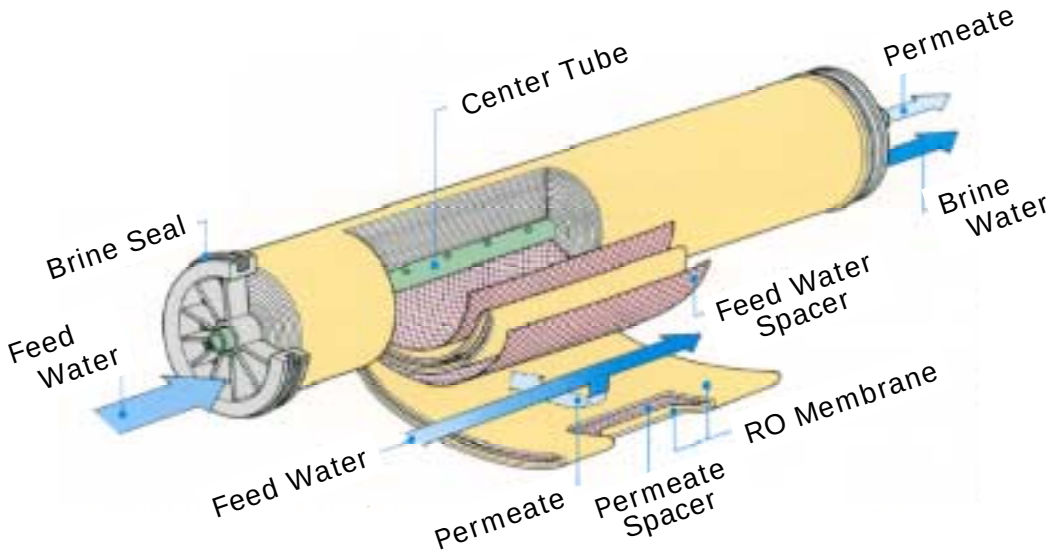

Fig.6 Schematic Figure of the Spiral Wound RO Membrane Element

PERFORMANCE DATA OF NEW RO SEAWATER DESALINATION SYSTEM

1. Ehime (Japan) pilot plant

A pilot plant of BCS system was installed and has been operated continuously for more than 2 years in Ehime Prefecture in Japan.

The plant consists of seawater intake, pretreatment unit and RO desalination unit (Fig.7). Dual media filter and polishing filter has been utilized to eliminate the suspended solids in pretreatment unit. At the starting time, RO desalination unit has two high-pressure pumps, one is for the first

stage RO module with 6.5MPa pressure, and the other is for second stage RO module increasing brine pressure of the first stage RO modules from around 6.5MPa to 8.0-9.0MPa. The seawater desalination RO elements used in this pilot plant are new development RO elements (SU-820BCM) for second stage RO modules and accomplished RO elements (SU-820) for first stage.

Hydraulic Turbo Charger (HTC) was then installed between first and second stage RO modules instead of high-pressure pump in March 1998. HTC can increase the brine pressure of the first stage RO by recovering the second stage RO energy without additional electric power, for supplying the high pressure first stage RO brine water to the second stage RO. Less consumption of energy and higher recovery operation can carry out by using HTC instead of using high-pressure pump.

At the starting time of the plant operation, sodium hypochlorite has been injected continuously to sterilize seawater at the point of an intake, and then sodium bisulfate has been poured before RO modules. Today, intermittent sodium hypochlorite injection and sulfuric acid dosing are carried out in this pilot plant, and the plant has been working well without biofouling problem.

Total capacity of producing fresh water is 210m3/d, 140m3/d from first stage RO modules and 70m3/d from second stage ones. The pilot plant started to operate since May 1997, and has been proved in good conditions, both quality and quantity of fresh water, for more than 2 years (Table.1).

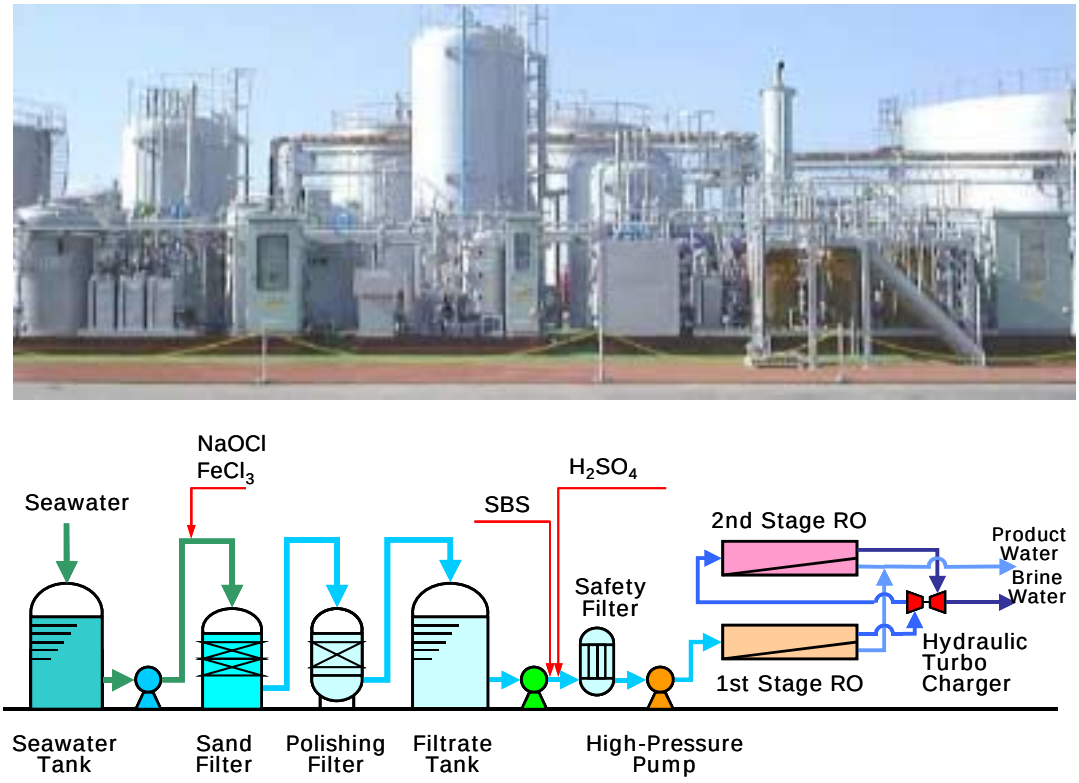

Fig.7 Flow Diagram of Pilot Plant

2. Las Palmas (Spain) RO seawater desalination plant

Brine conversion two stage RO seawater desalination system with SU-820BCM element has been operated in Las Palmas, a town in Gran Canaria Island, Spain. The conventional RO system in this plant consists of 4 RO module lines, one of them has 5,000m3/d capacity of producing fresh water, and another lines have 3,000m3/d each. The second stage RO modules in BCS system,

which capacity of producing fresh water is approximately 1,500m3/d, were accompanied with a 3,000m3/d RO system line and has been operated in good conditions since March 1999.

Table.1 Results of Pilot Plant Operation

Items	Seawater	Product Water, 1st Stage	Product Water, 2nd Stage	Total Product Water
Actual				
Water Quantity, m³/d	350	140	70	210
Water Quality, ppm	35,438	165	173	168
Water Recovery, %	-	40	33	60
Target				
Water Quantity, m³/d	350	140	70	210
Water Quality, ppm	-	<350	<350	<350
Water Recovery, %	-	40	33	60

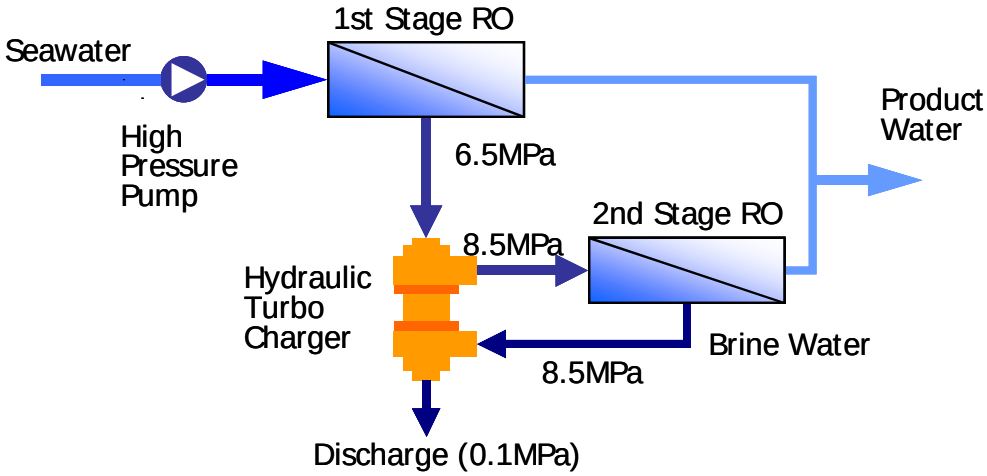

Fig.8 Flow Diagram of Brine Conversion Two Stage RO Seawater Desalination System with HTC (Hydraulic Turbo Charger)

FURTHER EXPANSION OF BRINE CONVERSION SYSTEM

Today, Brice Conversion two stage RO Desalination System is working in Ibiza(Spain) besides Ehime and Mas Palmas(starting operation in March 1999 with about 1,500m^3/d capacity). Now, the demand of BCS plant is expanding world widely, and this system will be the popular process of seawater RO desalination system. The list of plant installation plan is shown in Table.2 below, which consists of the location, type of plant, type of element, capacity, recovery ratio and completion data, respectively

Table.2 BCS Plant Installation List

Plant	Type of Plant	Type of RO Element	Capacity m^3/day	Recovery Ratio	Completion Year / Month
Toray Ehime (Japan)	Full Plant	SU-820 / SU-820BCM	210	60%	1996/10
Mas Palomas (Spain)	Retrofit	SU-820BCM	270	60%	1997/10
Ibiza (Spain)	Retrofit	SU-820BCM	270	60%	1999/ 1
Las Palmas 1 (Spain)	Retrofit	SU-820BCM	4,500	60%	1999/ 3
KAE Curacao 1 (Caribean)	Full Plant	SU-820 / SU-820BCM	5,700	57%	1999/ 9
KAE Curacao 2 (Caribean)	Full Plant	SU-820 / SU-820BCM	5,700	57%	1999/10
Las Palmas 2 (Spain)	Retrofit	SU-820BCM	4,500	60%	1999/11
Las Palmas 3 (Spain)	Retrofit	SU-820BCM	4,500	60%	1999/11
Tortla (Caribean)	Full Plant	SU-820 / SU-820BCM	690	60%	1999/11

CONCLUSION

1. Toray Industries and Toray Engineering have developed the Brine Conversion Two Stage RO Seawater Desalination system (BCS system), which brings advantages of high water recovery, low energy cost and less plant installation cost.
2. New type RO membrane elements, namely SU-820BCM, have developed which can operate on BCS conditions of high pressure (8.0-9.0MPa) and high feed water concentration (5.8-8.7%).
3. The continuous operating performance with SU-820BCM has been proved in good conditions in BCS pilot plant for more than 2 years and another seawater desalination plant with BCS system have been started its operation.
4. BCS high recovery seawater desalination system will be the popular process of the RO seawater desalination system in near future.

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