TECHNOLOGY
of
REVERSE OSMOSIS
DESALINATION

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16th December, 2014 at Kuwait
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5. Water Quality of Reverse Osmosis desalination
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7. Activity of WRPC for Desalination & Others
Classification of Desalination Technologies

Desalination processes

Phase change
[Feed] → [Product]
Liquid → Vapor → Liquid → Solid → Liquid

Non-phase change
[Feed] → [Product]
Liquid → Liquid

Thermal desalination
Multi Stage Flush (MSF)
Multi-Effect Distillation (MED)
Solar Distillation
Ice crystal separation
Reverse Osmosis (RO)
NanoFiltration (NF)
ElectroDialysis (ED, EDR)
Electrodeionisation (EDI)
Forward Osmosis (FO)
New types of membranes
Phenomenon of Reverse Osmosis

Osmosis

Fresh Water → Seawater

Water Flow

Semipermeable Membrane

Reverse Osmosis

Fresh Water → Seawater

Pressure

Semipermeable Membrane
Relations of pressure and the water recovery in the RO system

- Pressure (MPa)
- Osmotic Pressure
- Effective Difference Pressure
- Feed Pressure
- Recovery Ratio (%)

Graph showing the relations of pressure and water recovery in the RO system.
RO module consists of 2 RO membrane elements in 1 pressure vessel.
Structure of Spiral Wound RO Membrane Module
Flow Diagram for Reverse Osmosis Desalination Plant

Advantage
There are fewer energy consumptions than other method.
A start stop and control is easy.
A construction period is short.
Because it is driven at normal temperature, there is little corrosion.

Fault
Operating pressure depends on seawater temperature and the density.
Exchange of membrane is necessary.
Pretreatment is necessary.
There is membrane degradation by fouling.
## History of Development of Main Technologies for RO desalination

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<tbody>
<tr>
<td>Conceptual design by Dr. Reid at 1953</td>
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<tr>
<td>Material</td>
<td></td>
<td>CA</td>
<td>CTA</td>
<td>PA</td>
<td>APA</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Structure</td>
<td></td>
<td>SM</td>
<td>ASM</td>
<td>CM</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Type (system)</td>
<td></td>
<td>SW</td>
<td>HF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage</td>
<td></td>
<td>One</td>
<td>Two</td>
<td>More than Two</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>For Sales</td>
<td>JAPAN, 1978 -</td>
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</table>

### Materials
- CA: Cellulose Acetate
- CTA: Cellulose Tri-Acetate
- PA: Polyamide,
- APA: Aromatic polyamide

### Structures
- SM: Symmetric Membrane
- ASM: Asymmetric Membrane
- CM: Composite Membrane

### Types (system)
- SW: Spiral Wound
- HF: Hollow Fiber
- One: Single stage or One Pass
- Two: Double Stage or Two Pass

By WRPC
In 1973, Water Reuse Promotion Center is organized and will push forward technology development of seawater desalination and the waste-water treatment reuse.

It was started in Chigasaki research facility, at 1974. The seawater desalination technology development was pushed forward mainly on the practical use of the Japanese membrane. Another technology development of the pretreatment system, energy recovery system, and membrane filtration system, etc.,
Trend of Desalination Plants in the world (SW+BW)

Annual Capacity (Right)

Accumulate Capacity 1980- (Left)

Operating Year


Trend of Desalination Plants in the world (SW+BW), 2014.11

Analysis: WRPC Source: GWI, Desaldata

Total Accumulate Capacity 65 MiCMD

RO 62%

ED 2%

Others 4%

MSF+MED 32%

Annual Capacity (Mil CMD)

Accumulate Capacity (Mil CMD)


Analysis by WRPC Source: Desaldata, GWI

Ref;

SW: Seawater

BW: Brackish
Trend of Desalination Plants in the GCC (SW+BW)

Trand of Desalination Plant in the GCC (1980-2014)

Accumulate Capacity (Mil CMD)

- MSF
- RO
- MED
- total

Ref;
SW: Seawater
BW: Brackish Water

Analysis; WRPC, Source; GWI, Desaldata
# Energy Recovery Systems for RO Seawater Desalination

<table>
<thead>
<tr>
<th>Source of Energy</th>
<th>Recovery Method</th>
<th>Type of Recovery Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back Pressure of Brine</td>
<td>Axle (Revolution) Power Recovery</td>
<td>Reverse Running Pump (Francis Turbine)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pelton Turbine</td>
</tr>
<tr>
<td></td>
<td>volume exchange Recovery</td>
<td>Hydro-Turbo Charger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pressure Exchanger</td>
</tr>
<tr>
<td></td>
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<td>Work Exchanger</td>
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</table>
# Example of Water Quality of RO Desalination

<table>
<thead>
<tr>
<th></th>
<th>Feed in mg/L</th>
<th>Permeate in mg/L</th>
<th>System % Rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>282</td>
<td>0.5</td>
<td>99.88%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>850</td>
<td>1.5</td>
<td>99.88%</td>
</tr>
<tr>
<td>Sodium</td>
<td>6,670</td>
<td>55</td>
<td>99.46%</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>81</td>
<td>2.0</td>
<td>98.36%</td>
</tr>
<tr>
<td>Sulfate</td>
<td>1,800</td>
<td>3.1</td>
<td>99.88%</td>
</tr>
<tr>
<td>Chloride</td>
<td>13,300</td>
<td>97</td>
<td>99.52%</td>
</tr>
<tr>
<td>Bromide</td>
<td>48</td>
<td>0.41</td>
<td>99.44%</td>
</tr>
<tr>
<td>Boron</td>
<td>3.7</td>
<td>1.1</td>
<td>77.27%</td>
</tr>
<tr>
<td>TDS</td>
<td>23,064</td>
<td>161</td>
<td>99.54%</td>
</tr>
<tr>
<td>Conductivity uS</td>
<td>37,800</td>
<td>365</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.6</td>
<td>5.1</td>
<td></td>
</tr>
</tbody>
</table>
CAPITAL COST OF DESALINATION PLANT IN THE WORLD

Source: WDR/GWI, DesalData, Editing WRPC
WATER COST OF DESALINATION PLANT IN THE WORLD

Water Price from Desalination Projects since 2000
(more than 50,000m3/d)


Water Cost ($/m3)

$0.00 $0.50 $1.00 $1.50 $2.00 $2.50 $3.00

Source: WDR/GWI, DesalData, Editing WRPC

SWRO
MED
MSF

FuKuoka
Jeddah Barge
KSA
Australia
Cooperation project of Seawater Reverse Osmosis Desalination by WRPC & Middle East

**CASE 1 2002-2005**
Research and development of Seawater Reverse Osmosis Desalination in Oman

Sultan Qaboas University, Oman & Water Reuse Promotion Center, Japan

**CASE 2 2003-2007**
Seawater Reverse Osmosis Desalination for Hybrid System Application in Qatar
Qatar Electric Water Co. and Water Reuse Promotion Center

**CASE 3 2006-2011**
Development of Tri-hybrid NF/RO/MED Desalination System in Saudi Arabia
Saline Water Conversion Corporation & Water Reuse Promotion Center, Japan
Other Activities of WRPC on Overseas (Recently)

- Feasibility Study on Wastewater Reuse in Middle East (Qatar)
- Feasibility Study on Rehabilitation of Water Environment and Water Circulation (Venezuela)
- Study on Technical Support of Introduction of Production Water Treatment for Oil Industry in the Republic of Iraq (2010-2012)
- Study on Technical Support of Introduction of Formation Water Treatment for Oil Industry in the Republic of Iraq (2013-)
- The Training Course Program “Desalination Technologies and Water Reuse” For the Ministry of Electricity and Water, Kuwait (2013)
THANK YOU FOR YOUR ATTENTION!

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