PRACTICAL ASPECTS OF LARGE-SCALE REVERSE OSMOSIS APPLICATIONS

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Contents

Summary

Practical aspects of RO applications in large scale industries are discussed comprising of seawater and brackish water desalination, waste water treatment, producing ultra pure water and a few other applications.

1. Seawater Desalination

1.1. Outline of Seawater Desalination Plant

According to the 1994 IDA Inventory Report No. 13 (Wangnick 1994), seawater desalination plants contracted by the end of 1993 were 459 plants with 1314 887m^3 d^{-1} capacity in total, or in other words their capacity is at least 100 (m^3 d^{-1}) per unit. Further, there are 32 large-scale desalination plants which have the capacity of at least 4000 m^3 d^{-1}. These are listed in Table 1, and are mostly located in the Middle East countries. Most of them are in Saudi Arabia and have a total capacity of 451 570 m^3 d^{-1} or 34.3 per cent, followed by the USA, Spain, Libya and UAE, respectively.

Country	**Location**	**Capac $m^3 d^{-1}$**	**Unit**	**Customer**	**User**	**Cn. Year**	**Op. Year**	**Manufacturer**	**Membrane Manufacture**
Saudi Arabia SA	Dhahran	4000	1		INDU	82	83	ENVIROGENICUSA	ENVIROGENICUSA
Bahrain BRN	Res Abu Jarjur	46 000	7	MEW	MUNI	82	84	SC/SAKURA J	DUPONT USA
Saudi Arabia SA	Umm Lujj	4400	1	SWCC	MUNI	82	85	FLUID SYST. USA	FLUID SYST. USA
Malta M	Ghar Lapsi	4000	1	Government	MUNI	85	86	Polymetrics USA	DUPONT USA
Malta M	Tingne	5000	1	Government	MUNI	86	87	Polymetrics USA	
Arab Emirate UAE	Bani Yas	4600	1	WED	MUNI	85	88	IRITECCNA I	DUPONT USA
Arab Emirate UAE	Darma	9200	2	WED	MUNI	85	88	IRITECCNA I	DUPONT USA
Malta M	Tingne	5400	1	Government	MUNI	87	88	Polymetics USA	
Saudi Arabia SA	Jeddah	56 800	10	SWCC	MUNI	86	88	MITUBISHI J	TOYOBO J
Spain E	Cl Gran Canaria	4000	1	Juliano Bonny	IRR	87	88	FLUID SYST. USA	FLUID SYS. USA
Bahrain BRN	Al Dur	45 000	8	SWCC MEW	MUNI	64	89	Weirsestgarthg	DUPONT USA
Oman OMA	Sur	4500	1	WED AUH	MUNI	87	90	AQUA ENG. A	DUPONT USA
Spain E	Cl Lanzarote	5000	1	Municipality	MUNI	89	90	PRIDESA/PASA E	FILMETEC USA
Spain E	Cl Lanzarote	5000	1	Municipality	MUNI	89	90	PRIDESA/PASA E	FILMTEC USA
Spain E	Cl LaS Palmas 3	12 000	2	EMALSA	MUNI	86	90	PRIDESA/PASA E	FILMTEC USA
Spain E	Cl LaS Palmas 3	24 000	4	EMALSA	MUNI	86	90	PRIDESA/PASA E	FILMTEC USA
MALTA M	Pembroke	26 930	5	Repubric HDI	MUNI	90	91	Polymetrics USA	
Neth.Antil NA		4542	1	GEBE	MUNI	90	91	AQUADESIGN USA	
Spain E	Cl Gran Canaria	10 000	2	AGRAGUA	IRR	90	91	CADAGUA E	DUPONT USA
Great Britain GB		15 925	3	Agiptiffeny	INDU	91	92	Weirwestgarthg	DUPONT USA
Italy	Sicily	18 000	4		MUNI	91	92	Snam Progetti I	DUPONT USA
Libiya LAR	Tripoli-West2	32 000	5	Municipality	MUNI	89	92	DVT D	
Spain E	Cl Del Rosario	4000	1	Municipality	MUNI	91	92	Fomento Obras E	
Spain E	Cl Aquimas	10 000	2	Municipality	MUNI	91	93	PRIDESA/PASA E	
Saudi Arabia SA	Jeddaha V	56 800	10	SWC	MUNI	91	94	MITUBISHI J	TOYOBO J

Egypt ET	Hurghada	4996	1	Scient Trading	TOUR	92	94	AES USA	FILMTEC USA
Malta M	Pembroke	8800	2	Government	MUNI	93	93	Polymetrics USA	DUPONT USA
Malta M	Pembroke	27 600	6	Government	MUNI	93	94	Polymetrics USA	DUPONT USA
Saudi Arabia SA	Al Jobail	108 000	10	SWCC	MUNI	93	95	Preussagnoell D	DUPONT USA
Saudi Arabia SA	Medina/YanbuII	128 000	15	SWCC	MUNI	92	95	MITUBISHI	TOYOBO J
Spain E	Cl Arucas-Moya	4000	1	Municipality	MUNI	93	94	PRIDESA/PASA E	FILMTEC USA
Sum		698 493	111						

Table 1. Large scale seawater desalination plant capacity 4000 m^3 d^{-1} and above.

The largest reverse osmosis (RO) plant in the world is Medina-Yambu Phase II (MY-II) with 122 000 m^3 d^{-1} capacity which was completed in 1995. It consists of 15 trains whose main items are shown in Table 2.

Another plant now operating is in Jeddah in Saudi Arabia with 56 800 m^3 d^{-1} which has been in service since 1987. It has faced some problems with chlorine oxidation by heavy metal catalyst (Ayyash 1993) in its early stage of operation, but is now operating successfully having adopting intermittent chlorine injection (Nada 1993).

Item	Unit	Description
Capacity	m^3 d^{-1}	127,825
No. of train		15 (1 Train 8525)
Seawater condition		
Temperature	°C	22.5-33
Salinity	mg l^{-1}	43,800
Recovery rate	%	35
Guaranteed item		
Production capacity	m^3 d^{-1}	> 127,825
Product salinity	Mg l^{-1}	250 as Cl
Power consumption	kWh m^{-3}	< 7.5
Membrane replacement	%	< 15
Sand filter type		Dual media, gravity
Chemicals dosing		
Disinfectant	mg l^{-1}	1.5 as Cl_2
Coagulant	mg l^{-1}	0.4 as Fe
Acid	mg l^{-1}	48 as H_2SO_4
Reductant	mg l^{-1}	0.6 as $NaHSO_3$
Membrane		
Material		Cellulose triacetate
Type	Kg cm^{-2}	Hollow fiber, double element
No. of module per train		214
Maximum-pressure		70
SDI		< 4

Table 2. Main item of Medina Yambu Phase II.

1.2. Process and Equipment Design

The sea water desalination process is conceptually identical in any plant, though a little difference is found between membranes applied

The typical process flow sheet is shown in Figure 1, and the special features of large-scale system are described as follows:

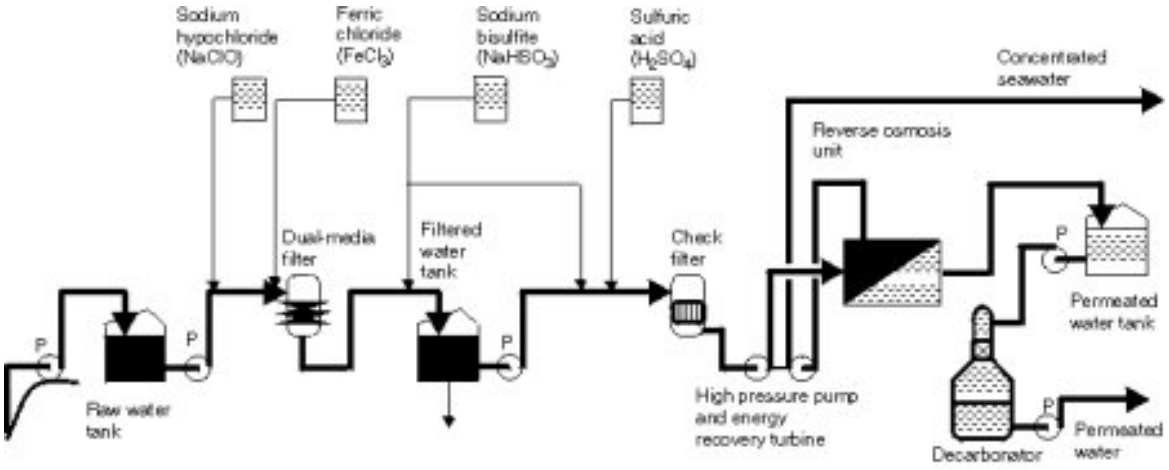

Figure 1. Process flow sheet.

1.2.1. Seawater Intake Facilities

Although smaller plants usually adopt beach wells, large-scale plants use a seawater intake pipeline in almost all cases. In the RO process, seawater consumption is relatively less than multi-stage flashing (MSF) process, so open channel type seawater intake system is not generally used.

In almost all cases, the sedimentation pond is not used because the use of sand filtration for pre-treatment can eliminate sand and other particulates from seawater.

In order to prevent the seawater intake and succeeding facilities from biological contamination, chlorine is dosed as the disinfectant.

In large-scale plants, the chlorine source is sodium hypochlorite solution obtained from electrolysis of seawater. Chlorine is a high potential disinfectant as well as an oxidizer which may degrade the RO membrane by oxidation.

To solve this problem, some alternatives have been developed as the disinfectant but have not been widely applied yet.

1.2.2. Pre-treatment Equipment

It is necessary to remove suspended solid particles from seawater, such as silt or microorganisms, to prevent their depositions on the RO membrane. Coagulation filtration is usually applied using a dual media filter, usually either pressure type or gravity type. However, for large-scale plant it is more general to adopt the gravity type as it has the advantages of low construction cost. The above mentioned MY-II Plant has 15 gravity sand filters. The main specifications are listed as Table 3.

Item	**Unit**	**Description**
Type		Gravity flow
No. of cell		24

Item	Unit	Description
Dimension Length Width Height	 m m m	 17 5.52 4.4
Filter media		
Support layer Size Height	 mm mm	Gravel 1-20
Lower layer Size Height	 mm mm	Anthracite 0.9 600
Filtering velocity		7.6
Backwash velocity Water	$m\ h^{-1}$	27
Air	$m\ h^{-1}$	70

Table 3. Dual media filter.

1.2.3. Chemical Dosing Facilities

Filtered water is conditioned with chemical dosing before entering the RO membrane module. At this stage, three kinds of chemicals are dosed.

- Mineral acid dosing to prevent alkaline scale formation ($CaCO_3$)
- Reductant dosing to protect the RO membrane from oxidation by residual chlorine
- Disinfectant dosing to sterilize the inside of the RO membrane module

Selection of these chemicals and dosing rate depends on the property of the RO membrane, and are not affected by plant scale.

1.2.4. Check-Filters

Check filters are provided to avoid unexpected trouble in pretreatment equipment in order to protect the RO membrane module from damage. The conventional cartridge type filter usually with nominal pore diameter of 10 μm inside an (Fiber Reinforced Plastics) FRP vessel is adopted. In a large-scale plant, the vessel is specifically designed to be able to accommodate the required filters. The pressure drop of a cartridge filter is usually within 0.1-0.2 Mpa.

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