RO PLANT OPERATION UNDER HARMFUL SEA WATER CONDITIONS

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Abstract

The operation of a 3 MLD plant under BOO model since April 2014 has shown that with a proper design and the right O&M philosophy is possible to perform in a satisfactory way even with tough raw water conditions. Located in an industrial area in the Sultanate of Oman, the plant is equipped with pretreatment by MF membranes and two different RO membranes in order to compare the performance of both manufacturers under the same sea water conditions. Harmful algae bloom happens in the coast at least once per year impacting on the sea water quality. What should have been a test bench has been replied at full scale with good results.

The paper presents the results of the membrane pretreatment and the comparison of the RO membranes performance with the same raw water and operation conditions, so as the achievements in the BOO contract commitments.

I. INTRODUCTION

The plant objet of this case is located at Sohar Industrial Port in the Sultanate of Oman in the Arabian Peninsula.

Oman borders the Kingdom of Saudi Arabia to the west, the United Arab Emirates to the north, and the Republic of Yemen to the southwest. With an area of over 300,000 square kilometers, geographically, Oman is one of the most diverse countries of the Arabian Peninsula.

Oman's coastline borders the Sea of Oman and the Arabian Sea. The strategically important Strait of Hormuz is the only stretch of water between the Gulf and the Indian Ocean and is, therefore, a vital route for the transportation of crude oil, gas and cargo.

Sohar is the third city of Oman and actually is the second port of the country and considered as the Gateway to the Gulf due to an enviable position outside the Strait of Hormuz, sitting at the center of global trade routes between Europe and Asia. The Port's three major clusters – logistics, petrochemicals and metals – will soon be joined by Oman's first ever terminal to be dedicated to the handling of agricultural bulk. Oman Oil Refineries and Petroleum Industries is expanding the capacity of its refinery, from 120,000 to 180,000 barrels per day and five ferrochrome smelters are under construction on the port.

1.1 BOO project

MAJIS, a Government owned company, provides water and wastewater services, including process water, to the industrial tenants within the SOHAR INDUSTRIAL PORT AUTHORITY (SIPA).

MAJIS used to purchase from third parties its requirements of process and potable water for onward supply to these industrial tenants. However, these current arrangements were not satisfactory due to a lack of security of supply and the cost of water procured in this manner. Accordingly, MAJIS has constructed a Permanent Facility designed to produce 12,000 m3/d of potable water and 8,000m3/d of process water for other clients. However, due to an increased process water demand Majis decided to reduce potable water production from this Permanent Facility and to produce more process water leaving a shortfall in the potable water supply which it intends to fulfil through this contract by having interim sea water RO plant of 3MLD capacity.

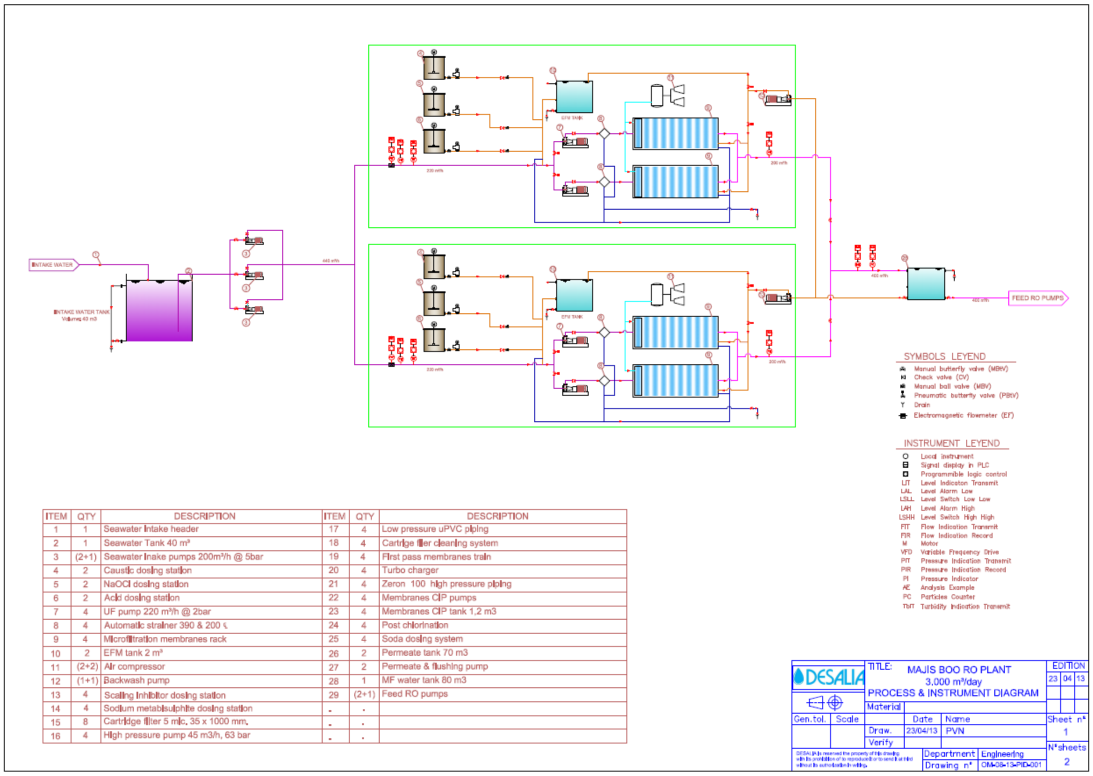
In this context, MAJIS decided to engage a specialist developer and producer of potable water on a BOO basis to supply 3000 m3/d of process water for a period of twenty three months (23) which may be extended for a further period depending on demand and ability of Majis to satisfy this demand through other means.

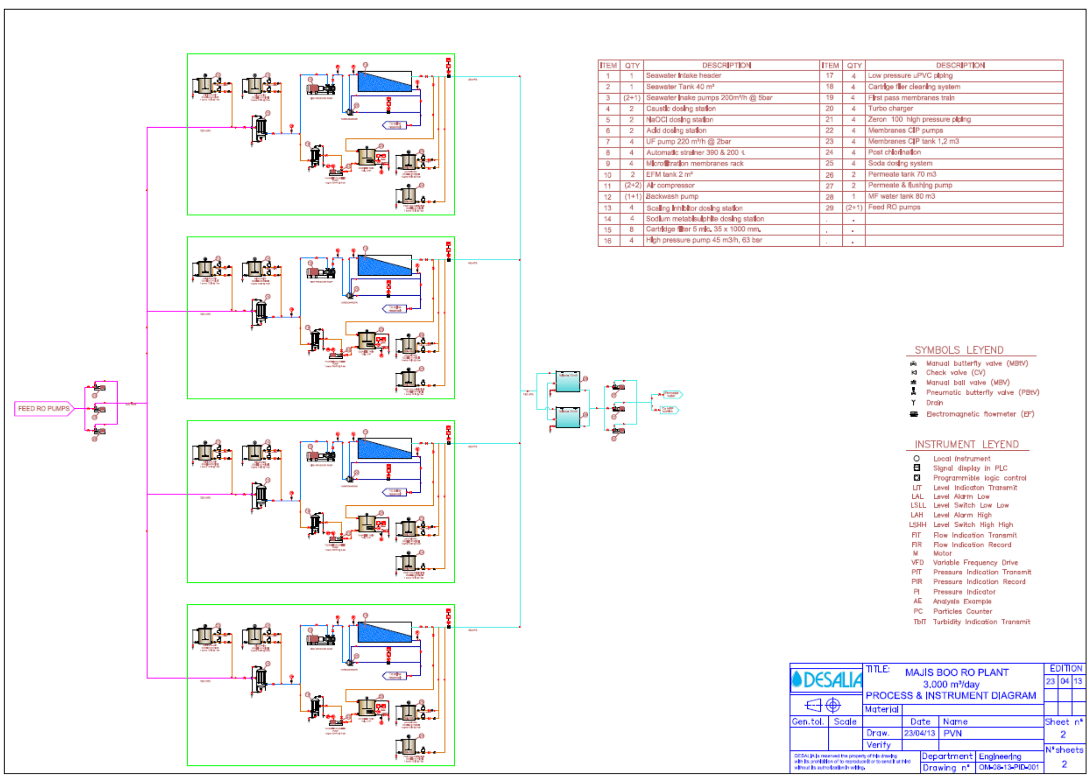
The Project involves the design, engineering, procurement, supply, delivery, construction, installation, commissioning, operation and maintenance, of the seawater desalination plant for the production of potable water at the SIPA.

The Scope of Work includes but is not limited to all main and auxiliary equipment and systems, Interconnecting piping, cabling, instrumentation and interface work with existing facilities and operational system.

Tendered during 2013, the project was signed at the end of September 2013 and executed in just 6 months starting the operations in April 2014. The Contract requested the supply of 3,000 m3 per day of desalinated water for drinking purposes as per Omani and WHO standards with production and energy consumption guarantees for two years.

1.2 Project description





1.2.1 Process description

The major requirements conditions and characteristics which most specifically affect plant design and sizing:

- Raw water salinity 35,000 to 40,000 ppm
- MF pre treatment 2 racks of 4000 m3/d each of filtrated water
- RO Recovery of 40%
- 4 racks of 800 m^3/d each with a total capacity of 3,200 m^3/d
- Design temperature: 28-37 ^oC (max. 37 ^oC)
- Membrane age: 3 years
- SDI (2.5 min): 35-40

1.2.1 Raw water analysis

The raw seawater data used for the design are based on the parameters shown in Table 1

Parameters	**Unit**	**Design**
Seawater total dissolved solids (TDS)	mg/l	40.098
pH at 25 ºC		7.9- 8.3
Chloride	mg Cl /l	21.764
Sodium	mg Na/l	15.400
Calcium	mg Ca/l	35
Magnesium	mg Mg/l	25
Potassium	mg K/l	14
Strontium	mg Sr/l	6
Iron	mg Fe/l	0.1
Silica	mg/l	1
Boron	mg B/l	5
Bicarbonate	mg/l as HCO3	121
Sulphate	mg SO4/l	2750

Table 1

II. PRETREATMENT

The system consists of Potable Water approved Microza Membrane Filtration modules. These modules use proprietary highly crystalline PVDF (Polyvinylidene fluoride) hollow fiber membrane technology with high and stable flux rates and advanced bonding techniques for an exceptionally strong module design. The Microza Membrane Filtration Modules operate in an outside-in mode. Solids retained on the filter are removed via periodic backwashing, air scrubbing and chemical cleaning.

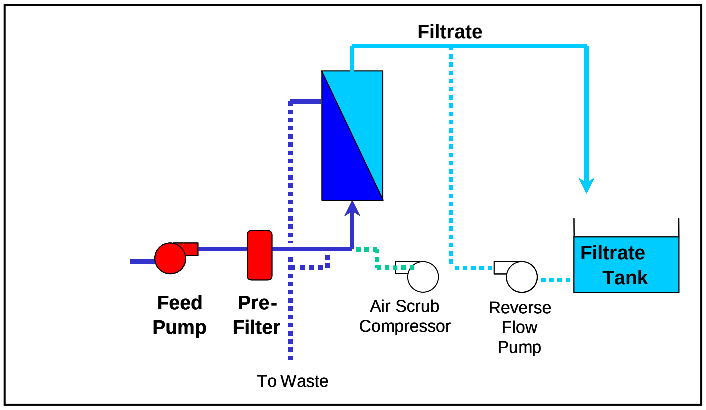
Microza Membrane Filtration (hollow fiber) membranes provide:

- A very high filter area (50m^2) per module
- A small footprint
- Low energy requirements
- Low system hold-up and efficient regeneration
- High porosity membranes

The raw water is supplied to the unit pressurized at 2 bar inlet pressure. The flow through the units controlled either by the variable speed drive on the feed pump or a modulating control valve. The unit can monitor the level in either a feed tank or a filtrate tank and adjust the flow rate through the plant proportionally.

The raw water entering the system is filtered through an automatic backwashing filter of 150 micron. The automatic strainer is backwashed at the same time backwashing of the membrane system to save down time.

After the pre-filter, the water flows through a supply manifold to feed the vertically mounted membrane filters.



The system remains in filtration until the unit has filtered a pre-set quantity of filtrate. At this point a backwash is initiated. There is also a timer that runs in parallel that can also initiate the backwash sequence.

Periodically, each rack goes through a backwash cycle consisting of air scrub - reverse filtration (ASRF) to remove the particles and the organic matter accumulated on the feed side of the modules. One rack is backwashed at a time leaving the other units in filtration. The ASRF frequency is linked to the quantity of filtrate produced by the rack, to ensure that when overall system operates at lower than the design flow rate the percentage waste does not increase.

The filtrate for the RF is taken from the backwash or permeate tank. This flow is combined with compressed air being injected into the feed side of the modules. As the air bubbles up the outside of the fibers, the fibers are gently agitated, loosening the particulate adhering to the outside surface. The waste is diverted to the drain

After the ASRF, the membranes are subjected to a Forward Flush to remove from the modules all contaminants loosed by the above step.

The membranes will regularly require a more thorough cleaning than the ASRF. Cleaning chemicals will be added to the system and circulated as required to regenerate the modules. This is a short automatic operation which cleans one system at a time. This chemical wash eliminates virtually all the Trans-membrane Pressure increase that occurs during the filtration. The frequency of the Enhanced Flux Maintenance (EFM) can vary from once a day to once a month or even longer depending on the solids loading and quality of the feed water.
The chemical used for the EFM is commonly a solution of Sodium Hypochlorite at 30°C. The slightly elevated temperature increases the efficiency of the clean significantly. The chemical is injected into the warm water which is recirculated around the module rack. If required sodium hydroxide can also be added to the solution in the event of excessive organic fouling.

Following the chemical clean the membranes are back-flushed and then forward flow rinsed. On the completion of the forward flush rinse, the unit will go back into filtration.
If there is a mineral or metal ion fouling for example when filtering hard water or contaminated borehole water, an acid solution can be used in a similar way to remove this contamination.

If the EFM cleaning described above is well adapted to the contamination in the feed, the requirement to perform the longer CIP is, on clean water applications, almost eliminated. The operating procedure for a CIP is similar to that of the EFM described above however different chemicals are used.

Below outlines the steps involved with a typical procedure.

- Recirculate 1% NaOH + 0.05% NaOCl @ 30°C
- Flush system
- Recirculate 1-2% acid solution
- Flush system

Complete CIP takes approximately 5 hours.

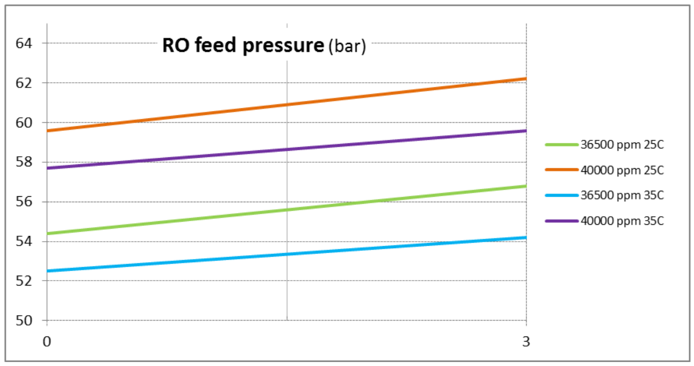
III. RO MEMBRANES COMPARISON

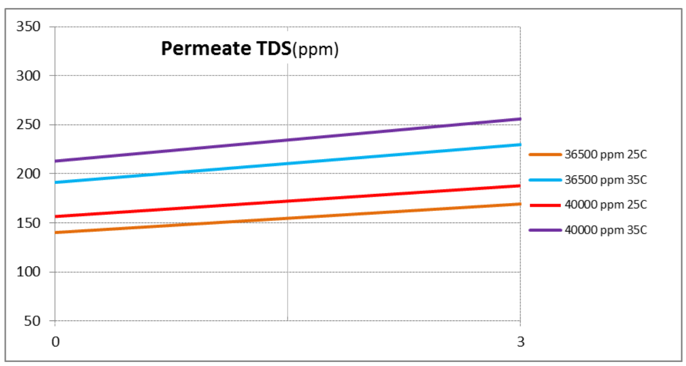
DESALIA made a complete analysis of the RO membranes in order to provide the optimum solution that guarantees the minimum operational cost for MAJIS.

Two different options have been considered with 8 pressure vessels with 7 elements per vessel at 40 % recovery, using the software provided by Hydranautics and NanoH20 to simulate the salt rejection and the water production with the raw sea water quality as per tender specification.

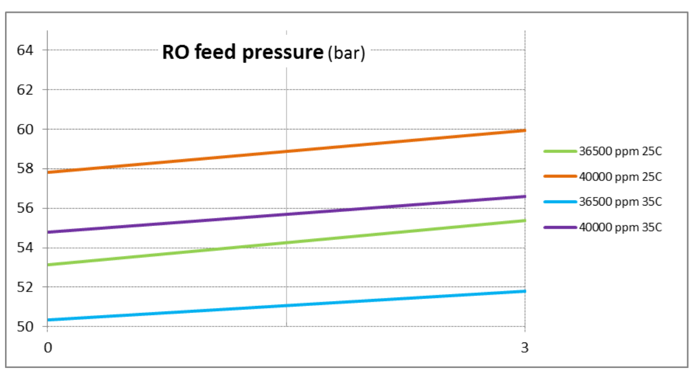
The projections have been made at 25 and 35 C of temperature and at 36,000 and 40000 ppm of seawater salinity as per design limits.

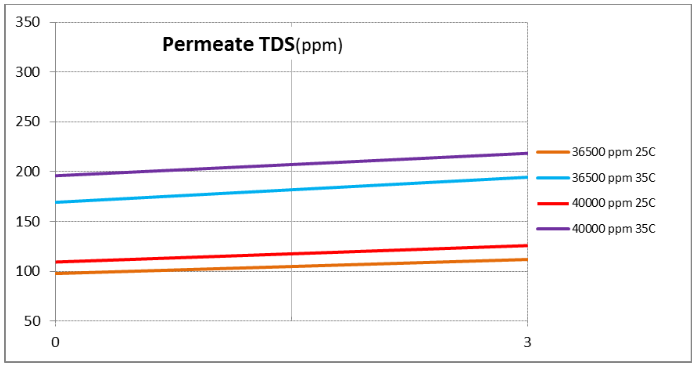
HYDRANAUTICS SWC4 MAX





NANO H20 SW 400 SR





Both membranes types were installed at site and commissioned at the same time being in operation same hours since the start up.

IV. OPERATION RESULTS

This paragraph will show the comparison between the normalized data of each membrane, the cleaning frequency and the performance data related to pressure, production and permeate quality.

V. CONCLUSIONS

1. The operation has been performed as per client requirements producing 5% more water than required at 18% less consumption than the guaranteed figures.

2. The design parameters of the plant combining MF pretreatment and low flux in RO membranes has allowed to operate beyond the guarantees

3. The comparison of two different RO membranes manufacturers at full scale under the same conditions have shown how important is the membrane selection in the results of a BOO project.

VI. REFERENCES