LAS PALMAS III, THE SUCCESS STORY OF BRINE STAGING

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ABSTRACT

Abstract

The desalination experience in Spain has been primarily initiated in the Canary Islands. A combination of scarce water sources and high water requirements to fulfill the two major industries, tourism and agricultural, has forced these islands to develop and experience with the major desalting technologies available. At the Jinamar plant, in the desalting pedigree was initiated in 1969 with the installation of 4 x5, 000 m3/d low temperature MSF Wespoor plants (Las Palmas I), followed in 1981 by the 2 x10, 000 high temperature Babcock Wilcox MSF plants (Las Palmas II) and finally the installation in 1989 of 4 x 6,000 m3/d R.O. plants (Las Palmas III), followed by an additional 2 x 6,000 m3/d commissioned in 1992. In 1995 Emalsa took over the operation of Las Palmas III. A new 8,000-m3/d train has been recently installed. This paper will present the performance of the latter plant after the major overhauls carried out to improving water quality and production performance and reducing energy costing, The Las Palmas III water intake has, because of its surface nature, substantial amounts of organic matter and consequently fouling is a major problem in the operation of the plant. A brief summary of steps taken to control/reduce this fouling will also be presented.

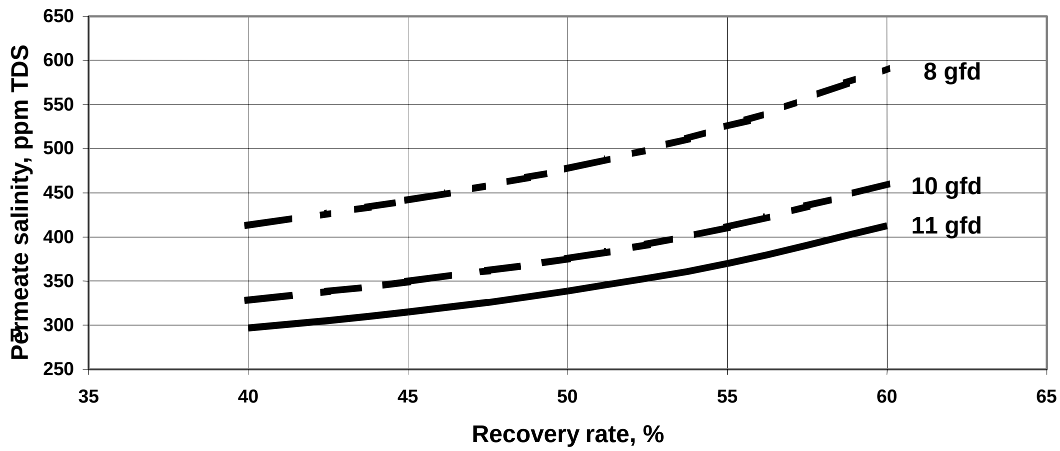
Introduction.

The economics of water desalting using reverse osmosis technology has been continuously improving. Due to the improvement of reverse osmosis membrane technology, the present cost of seawater desalting in a growing number of cases is competitive with conventional water supply. Even though the prices of seawater membrane elements are only slightly higher than the prices of brackish membrane elements, the cost of RO desalting of seawater is significantly higher than the cost of the RO process applied to treat the brackish feed. This is primarily because seawater systems require significantly higher cost pumping equipment and use more corrosion resistant piping made of expensive alloy steel. Also due to the nature of seawater feed from an open intake and relatively low recovery rate the pretreatment system is significantly more expensive than the one required in the brackish RO systems. The major water cost contribution results from the cost of process equipment and power consumption. The RO process parameter which has the largest effect on investment and operating cost is the permeate recovery rate. The feed flow is inversely proportional to the design recovery rate. Therefore, the recovery rate affects directly the size and cost of all process equipment and power consumption. However, in seawater RO systems, the recovery rate can not be increased at will, as higher recovery results in higher average feed salinity, which results in higher osmotic pressure and increased permeate salinity. With this in mind Emalsa has undergone an extensive investigation programmed in Las Palmas III to gradually increase recovery rates using conventional available seawater membranes to reduce costs.

Parameters of the RO process

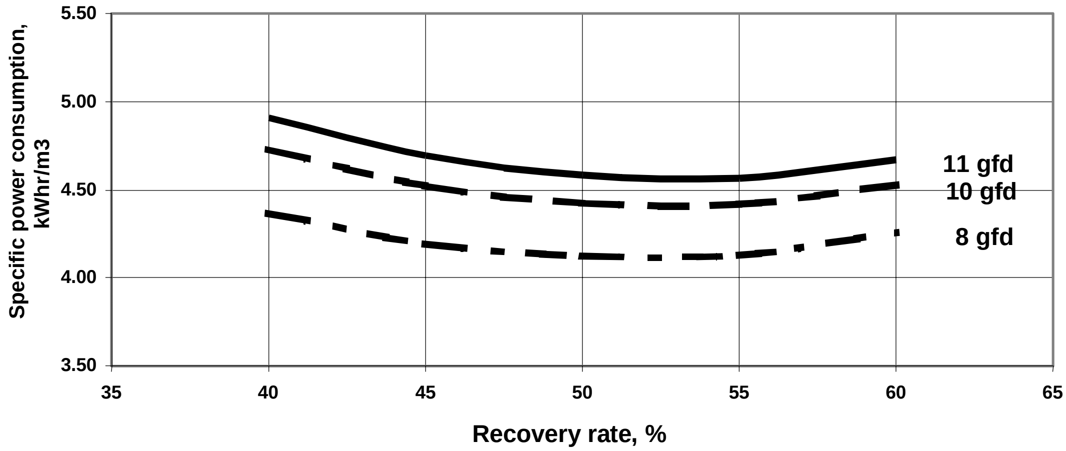
The operating parameters of seawater RO system are mainly function of feed water salinity and temperature. For example, for seawater feed of about 38,000 ppm TDS salinity and water temperature in the range of 18 - 28 C, the RO systems are designed to operate at a recovery rate in the range of 40% - 45% and with an average permeate flux in the range of 7 - 8 gfd (11.9 - 13.5 l/m2-hr). At the above operating conditions the feed pressure is in the range of 800 - 1000 psi (55 - 70 bar) and permeate salinity is in the range of 300 - 500 ppm TDS. For a given feed water salinity and salt rejection of the membrane elements used, the permeate salinity is a function of feed water temperature, recovery rate and permeate flux. An increase in feed water temperature results in an increased rate of salt and water diffusion across the membrane barrier at the rate of about 3% per degree Centigrade. Because RO plants usually operate at a constant flux rate, the changes of permeate salinity follow closely the changes in feed water temperature (1). Permeate salinity is inversely proportional to the average permeate flux. Higher permeate flux increases the dilution of salt ions which passed the membrane, and therefore results in lower permeate salinity. The average permeate flux rate in seawater systems is maintained at relatively low values: 7 - 8 gfd for surface seawater feed and 10 gfd (16.8 l/m2-hr) for seawater from beach wells. The difference in flux rates between the two water source types results from better quality of the well water and therefore, a lower fouling rate of the membranes. These flux values are relatively low and only about 50% of the permeate flux values used in brackish RO systems. Attempts to operate seawater systems at higher flux rates have usually resulted in irreversible flux decline. Until recently, the design recovery rate of new commercial seawater RO systems has been increased subsequently to the availability of membrane elements with increasingly higher salt rejection. So far, the maximum recovery in seawater RO systems has been mainly limited by the membrane salt rejection or the ability to produce permeate water of potable quality. Figure 1 displays permeate salinity as a function of recovery rate and permeate flux. The calculation were conducted for Atlantic seawater feed of salinity of 39,000 ppm TDS and feed temperature of 22 ºC for a recovery range of 40 - 60% and flux rate of 8 - 11 gfd. Nominal 99.6% salt rejection membrane elements were used. For calculations of permeate quality, the membrane salt passage was increased by 15%. This is to account for projected 5% per year salt passage increase during 3 years of an average membrane life (20% membrane element replacement per year). As expected, a higher recovery rate requires operation at an average flux rate above the standard value of 8 gfd. This is to maintain an acceptable permeate salinity; especially during the periods of high feed water temperature. The obvious questions are what is the optimum recovery rate of seawater systems in respect to product water cost, is such recovery achievable with the current performance of commercial seawater membranes, and is it possible to operate RO membranes on surface seawater at a higher flux rate.

Figure 1. Projected permeate salinity for Atlantic feed, 22ºC



The combined effect of higher recovery and higher flux rate results in significant reduction of the investment cost components. These savings are transferred to the total water cost. However, the higher recovery rate and higher permeate flux require higher a feed pressure. Therefore, specific power consumption will be higher. The increase in feed pressure with recovery rate at a given permeate flux is due to the increase in the average feed salinity and osmotic pressure. For pressure calculations, a 20% flux decline has been assumed due to fouling and compaction. Figure 2 contains values of specific power consumption for increasing recovery rate. As shown in Figure 2, for a given flux rate, the minimum specific power consumption corresponds to a recovery rate of about 50%. Changing the design parameters from a 45% recovery rate and 8 gfd flux to a 55% recovery rate and 11 gfd results in increase of specific power consumption of the high pressure pump from 4.2 kWhr/m3 to 4.6 kWhr/m3. This difference of 0.4 kWhr/m3 at 18

Fig 2. Projected power consumption for Mediterranean feed, 18 C



C will decrease slightly at a higher feed water temperature. At a feed water temperature of 25 C (the high temperature limit for this evaluation) this difference will be about 0.3 kWhr/m3. Table 2 contains results of comparison of water cost components for operation at standard conditions with projected costs for operation at high flux, high recovery rate. For calculations of water cost the following economic parameters were used: interest rate: 8%, plant life: 20 years, replacement cost of 8" seawater membrane element: $800; maintenance: 3% of capital; power cost: $0.06/kWhr; plant load factor 95%. The cost of chemicals is based on the use of inorganic flocculant, and sulphuric acid in the pretreatment system. Operation at the high recovery rate and increased permeate flux improves process economics. However, maintaining stable membrane performance at the higher flux rate requires a significant improvement in feed water quality compared to the quality obtained from conventional pretreatment applied to surface seawater. The combined effect of lower investment and improved operating conditions is about 8% decrease of total water cost.

Table 2. Effect of recovery rate and permeate flux on total water cost in RO seawater system (in US$).

Water cost components	Reference design: 45% recovery, 8 gfd flux	HRF design: 55% recovery, 11 gfd flux	Water cost change, %
Capital cost	0.320	0.275	-4.0
Membrane replacement	0.050	0.037	-26.0
Maintenance	0.095	0.084	-12.0
Power consumption	0.252	0.276	+9.5
Chemicals & cartridge filters	0.060	0.050	-17.0
Labor	0.050	0.040	-20.0
Total water cost, $/m3	0.827	0.762	-7.9

Las Palmas III brine staging process.

The SWRO Las Palmas III plant was commissioned in October 1989. The initial capacity of the plant was 24,000 m3/d obtained via 4 trains of 6,000 m3/d each. Production capacity was increased by a further 2 x 6,000 m3/d by the end of 1992.

The configuration of the initial four trains was an 85:51 using 6 membranes per pressure vessel the type of membrane was Filmtec SW30HR-8040. Of the other two additional trains, one had same membranes and configuration of previous four and the last one was commissioned using a configuration of 75:46, 6 membranes per pressure vessel using Hydranautics SWC1 membranes. The total amount of membranes in this site was, therefore, 4,080 Filmtec SW30HR-8040 and 726 Hydranautics SWC1.

In 1997, as the production of the plant was around 32,000 m3/d, Emalsa underwent a major investment and gradually replaced all the membranes in the plant over a period of one year.

To ascertain pretreatment efficiency and to study cost reductions, Emalsa also invested on a sophisticated pilot plant, which was used to investigate major physical and chemical parameters using same seawater feed as per the municipal units. This pilot plant was designed according to the existing configuration, using 2540 SWC1 Hydranautics membranes.

A comprehensive protocol programme was agreed upon and lessons learned from this investigation were put gradually into practice so that performance of the plant has been bettered and a graphical summary of the parameters improved is presented in this paper.

The conventional pretreatment process.

The objective of the pretreatment process is to reduce the concentration of fouling constituents in the feed water to the level that would provide stable, long-term performance of membrane elements. In RO seawater systems membrane fouling can develop due to the presence in feed water of colloidal and particulate matter, dissolved organics, and as a result of biological growth in the RO system. The formation of inorganic scale, sometimes encountered in the tail position elements in brackish systems does not present a problem with the majority of seawater feeds. Precipitation of sparingly soluble salts from RO seawater concentrate is less likely to occur due to the relatively low recovery rate, high ionic strength, and low concentration of bicarbonate ion. Membrane fouling due to the first three fouling factors: i.e. particulate matter, organics and biogrowth, usually is most pronounced in the lead elements. It has been postulated based on results of recent research work on membrane fouling processes (2, 3) that colloidal fouling is accelerated by high ionic strength and permeate drag forces (permeate flux). The high ionic strength of a treated solution reduces mutual double layer repulsion between colloidal particles and between the particles and membrane surface. Permeate flux, which results in drag forces perpendicular to the membrane surface, forces colloidal particles and organic macromolecules into the membrane pores and the foulant layer on the membrane surface. In seawater applications, the combination of high ionic strength and the presence of colloidal particles and dissolved organics results in higher fouling rates at a lower permeate flux than encountered in the brackish applications. The fouling process affects membrane performance by affecting both water flux and salt passage. Under high fouling conditions permeate flux is reduced and a higher feed pressure is required to produce the design flow. Usually, there is a parallel increase in salt passage, resulting in a higher salinity of permeate. Advanced stages of particulate or biological fouling will result in blockage of feed channels and increased pressure drop.

The conventional pretreatment system for surface seawater feed usually consists of breakpoint chlorination, up to a residual of 0.5 - 1.0 ppm, followed by in-line coagulation and flocculation. Aggregated colloidal particles are removed in two stage pressure multimedia filters. The two-stage filtration, roughing filtration followed by polishing filters, is an effective configuration for producing a more consistent feed quality during backwash steps and also during periods of seasonal deterioration of raw water quality. After media filters, and ahead of the cartridge filtration unit, scale inhibitor and sodium bisulphite is added to the feed water. The above configuration of the pretreatment system is effective in reducing the silt density index (SDI) of the raw water from an unmeasurable values (complete plugging of the test filter) to a range of 2 - 3 SDI unit for the feed water. Regardless of the actual configuration of the pretreatment system, the above range of feed water SDI is very common for most of seawater plants receiving seawater from an open intake (4, 5, 8).
It was proven during the investigations at Las Palmas III that the lead elements' fouling was a function of the high flux rates that the plant had to operate with the existing configuration. To reduce the flux rates of the lead elements and to increase the efficiency of the second stage buster pumps between stages were installed. The buster pump effect was to hydraulically balanced out both stages. It also permitted to increased production capacity and recovery rates even at lower lead elements flux rates.

Summary.

An increase in recovery rate and permeate flux in seawater systems can improve the economics of the desalting process. Implementation of high recovery, high flux operation requires optimization of water flow through the plant so that so that the fouling rate of removal and the fouling rate of deposition can be controlled using a fixed surface area.
At the Las Palmas III plant, after membrane replacement and major overhaul was carried out it was proven that performance of a plant can be substantially improved if the lead element membranes can be operated under conditions where the rates of deposition and removal equal. To achieve this stages have to be hydraulically balanced.
. The combined energy consumption savings due to higher recovery rates and the reduction in cleaning frequencies due to fouling control has made Las Palmas III operation very viable. Further investigations to improving existing pretreatment are still underway.

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