Inda News Vol.16 (4) Vol. 17(1) Oct-Dec 2008 / Jan - Mar 2009

THE KEY ELEMENTS OF SEAWATER DESALTING BY REVERSE OSMOSIS*

Regardless of location, the predominant component of the seawater is sodium chloride, which experience has taught us requires materials that resist attack by the chloride ion.

Pretreatment

Perhaps the most critical factor in the design of a successful seawater RO facility is acquisition and pretreatment of the source water. If the proposed plant capacity is sufficiently small (<5 mgd), extracting the seawater feed from a beach well or through a constructed infiltration gallery is preferable to open intake because the pretreatment challenges will be less demanding. For large plants, surface water intake facilities are required. These are similar to intakes used for coastal power plant cooling water, and are governed by a variety of regulatory requirements connected to the protection of fauna in the marine environment. If the desalination facility is to be coupled with an existing power plant, this intake protocol is already in place, and the feedwater can be extracted from the existing cooling water system. The power plant intake is designed to remove the large chunks, and exclude fish and other marine life, but beyond that will still contain a significant quantity of suspended solids and small marine life such as plankton etc. Assuming the feed source is an open seawater intake, the proposed pretreatment scheme must consider the following:

- Control of plugging and colloidal fouling;
- Control of organic fouling; and
- Control of biological activity and fouling.

Traditionally, seawater pretreatment has consisted of flocculation and coagulation with a ferric salt, sometimes applied in conjunction with a polymer, sedimentation and filtration. Depending upon the circumstances, a continuous chlorination and dechlorination procedure sometimes is employed. Intermittent chlorination and dechlorination is also practiced. Chloramination has been used in the Middle East, and is being tested in pilot scale elsewhere. Filtration has typically been practiced as a two-stage process using dual or multi-media beds. When sizing the filtration equipment, capacity for the production of backwash water must be included. Other filtration methods have been employed over the years. Currently, membrane filtration is receiving a lot of attention. Membrane filtration systems are normally supplied complete with automatic controls for backwashing, and in the case of hollow-fiber devices, online membrane integrity testing.

Common characteristics

Microfiltration Pore Size 0.05 to 0.5 micron; Materials polypropylene, poly sulphone, PVDF, ceramic etc.

Ultrafiltration Pore Size 0.001 to 0.1 micron; Materials polysulphone, PVDF, cellulose acetate, ceramic

It should be noted that in a typical membrane filtration application, some form of coarse screening is employed ahead of the membrane system to protect it from large debris. This would not be necessary if the system was preceded by a media filter, but it is present when taking water from a surface water source directly in to the membrane system. Biological and organic fouling must also be controlled through the pretreatment process. Disinfection using chlorine, chloramine or ultrafiltration must be carefully designed and integrated into the process.

Design considerations

The effect of water temperature on RO membrane operations is well understood. In the push to lower the cost of seawater desalting, a popular approach has been to coupled the desalination facility with a power plant. This approach can significantly reduce the capital cost by sharing the power plant cooling water system for feedwater intake and concentrate disposal. An added avantage is reducing process energy but taking advantage of the elevated temperature of the outgoing cooling water. In many cases, this can be as high as 100 to 104°F. There are several drawbacks to this approach that must be considered in process design.

- High temperature makes biological fouling control more challenging;
- The solubility of calcium carbonate with temperature is an inverse function;
- There is a significant increase in salt passage with temperature; and
- There is the possibility of permanent flux decline due to compaction of the support structure of the membrane.

Recovery

The third process parameter that must be considered is recovery. Recovery is defined as the ratio of permeate flow to feedwater flow. One of the key factors is the impact of recovery on the concentration factor, and thus the osmotic pressure on the concentrate side of the membranes. In the case of seawater systems, where the salt rejection of the membranes is very

Compilation by Shri V.K. Srivastava, Head TDS, Desalination Division, BARC

high, the concentration factor can be based on 100% salt rejection. Therefore, the impact of the recovery on concentration factor can be seen. Historically, the goal in seawater membrane development was to produce a membrane that combined good specific flux with high sodium chloride rejection. Since the first composite polyamide membranes installed in a plant in the late 1970s, there has been a continuous improvement in seawater RO membrane performance. With early membranes, recovery was limited to about 30% to produce a permeate of <500 mg/TDS. Currently, commercially available seawater membranes combine good specific flux with exceptional salt rejection, so much so that single pass desalting to produce drinking water quality permeate can be achieved at higher than historic recoveries. This advance has had the beneficial effect of significantly reducing the power requirement of the RO feed pump; however, increased recovery has its drawbacks. Because of the almost perfect concentration factors, and because the osmotic pressure is such a significant factor in defining seawater RO costs, operating at the highest possible recovery may not always be the most cost-effective option. Clearly there is an energy advantage in increasing recovery. This has always been the case in RO operations. It can be seen that even at 60% recovery, in a single stage the permeate quality is still acceptable. However, the pressure required drives the mechanical components of the system into the next pressure class, and the values of first and last element flux must be viewed with some apprehension. Clearly a more technically sound approach to high recovery would be to go to a two-stage system, with interstage boost.

Energy recovery

The use of energy recovery devices in seawater RO systems is now virtually universal, even for smaller systems. Every cost study performed has shown that the payback period is relatively short, although the devices are relatively costly. Efficiencies have improved, and the materials used allow for a reasonably long life and relatively low maintenance requirements. There are basically two types of devices in widespread use today—the work exchanger and the pressure exchanger. The work exchanger converts the work available in the exiting concentrate into a feedwater pressure boost. The rough calculation is fairly easily performed. The restraint on the recovery of the brine work content is the efficiency of the device itself, with typical efficiencies ranging from about 70 to more than 85%, depending on the device chosen and the conditions of its application. The pressure exchanger, as its name implies, converts the pressure in the outlet concentrate stream to an equal or slightly lower pressure on the feedwater. Because there has been a pressure loss in the system, a boost pump is required to add back the lost pressure. This requires that the feed flow into the system be split, with a flow equal to the permeate flow going to the RO feed pump, and a flow equal to the concentrate flow going to the work exchanger and then through the boost pump. Two manufacturers are commonly considered, and the device efficiencies are generally 85 to 90%.

As with other process design considerations, the application of each type of device to a specific site must be carefully evaluated. Recoverable energy in the concentrate stream can represent 30 to 45% of the energy input needed for the RO system. This is a significant benefit, particularly in areas where electric power costs are high, and represents a significant reduction in overall water cost.

Post treatment

Post treatment of the permeate generated by a seawater RO system is very critical because the permeate is essentially a dilute solution of sodium chloride, devoid of hardness and alkalinity, and with an aggressive pH. The occurrence of trace components, such as boron (WHO limit is 0.5 mg/L), is also important, and may require that part of the permeate receive additional treatment in the form of a third-pass RO system, or a process such as selective ion exchange. Other considerations may be in the future because WHO is in the midst of a study of the health effects of drinking desalinated seawater. As far as stability is concerned, calcium hardness and bicarbonate alkalinity must be added to permeate, together with some pH adjustment, to protect the distribution system and domestic plumbing from corrosion. If the water is to be introduced into an existing system with other sources of drinking water, it may be necessary to match the quality of the two waters. This may require additional desalting to further reduce chlorides.

To successfully add bicarbonate alkalinity to the RO permeate, carbon dioxide (CO_2) must be present in the water. Lime slurries or granular limestone beds may be used to introduce calcium hydroxide to the water, but CO_2 must be present to convert hydroxyl alkalinity, which does not contribute to corrosion resistance, to bicarbonate alkalinity, which does. The CO_2 can be introduced in two ways. In high recovery systems, it is likely that some feedwater scale inhibition will be required to control calcium carbonate scaling. Acid in the feedwater can be used for this purpose, but it should be applied to minimize CO_2 losses through the RO system. Recarbonation of the permeate is the other alternative, in which case a scale inhibitor would be required in the feedwater. Other post treatment will allow local practice, and may include disinfection, fluoridation and the use of a corrosion inhibitor.

• • •