American Membrane Technology Association

America's Authority in Membrane Treatment

Energy Recovery Devices

Overview

The use of Energy Recovery Devices (ERDs) continues to become more commonplace as the cost of power continues to increase throughout the world. System designers are more frequently being asked to minimize the Specific Energy Consumption (SEC) even in areas where the cost of power is relatively low. By far the largest contributor to the decrease in SEC over the past three decades has been the advancements made in energy recovery technologies. All ERDs used in the water treatment industry reduce power by harnessing the energy in the concentrate (or brine) waste stream and transferring it to the feed side via various methods.

History

Historically, the Achilles heel of seawater reverse osmosis (SWRO) systems, brackish water reverse osmosis (BWRO) systems, and industrial water systems has been the energy intensive nature of the membrane separation process. Over the past 30 years, the industry has seen a decrease in SEC from SWRO installations without energy recovery devices operating close to 8kWh/m3 (for the RO portion of the process only) down to 2.5kWh/m3 in today's state-of-the art facilities (Chart 1). Today, all medium to large-scale SWRO facilities have adopted ERDs into their process designs and have benefited from the reduction in SEC.

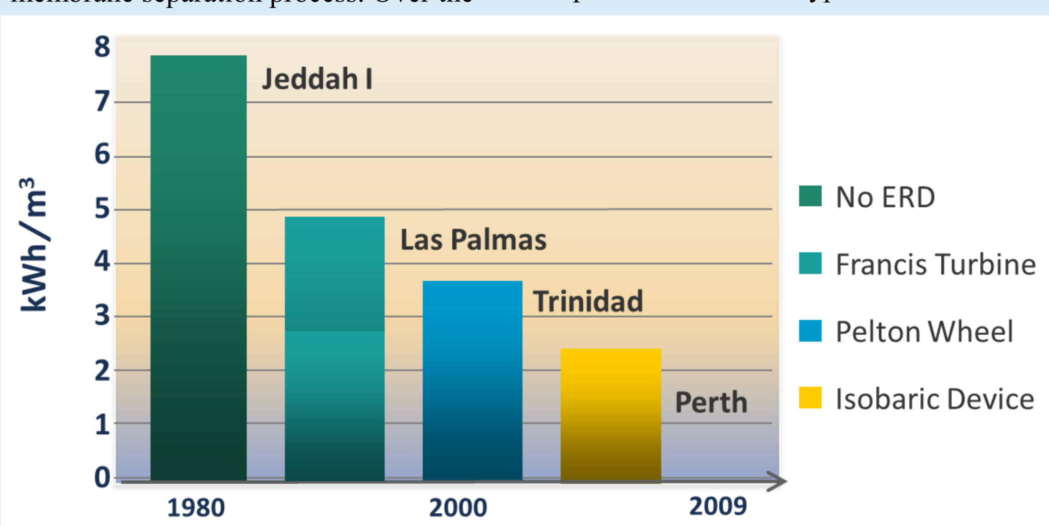

Chart 1 – Specific Energy Consumption Trend (RO portion only)

Photo 1 – Turbocharger

Types

Energy Recovery Devices can be broken up into two major sub-categories: centrifugal and positive displacement isobaric type.

Centrifugal ERDs include reverse running pumps, impulse type turbines and turbochargers. The turbocharger device consists of a pump section and a turbine section. Both pump and turbine sections each contain a single stage impeller. The turbine impeller extracts hydraulic energy from the brine stream and converts it to mechanical energy. The pump impeller converts the mechanical energy produced by the turbine impeller back to pressure energy in the feed stream. Thus, the turbocharger is entirely energized by the brine stream. It has no electrical requirements, external lubrication, or pneumatic requirements.

Isobaric ERDs include rotary type pressure exchangers and piston type work exchangers. The pressure exchanger device consists of a rotor, moving between the high-pressure and low low-pressure stream, which displaces the brine and typically replaces it with an equal volume of seawater. Pressure transfers directly from the high pressure membrane reject stream to a low-pressure seawater feed stream without a physical piston in the flow path. The rotor spins freely, driven by the flow at a rotation rate proportional to the flow rate.

Photo 2—Pressure Exchanger

Desalination Energy Reductions

Seawater

SWRO systems typically work at recovery rates ranging from 30% up to 55%. This means that reject brine flow accounts for the 45% up to 70% of the total membranes feed flow. Additionally and due to the high salinity of the treated water, operating pressures can be as high as 1200 psi (82.7 bar) in some cases with lower values at around 725 psi (50 bar). Therefore, the highest reductions in energy consumption are obtained in SWRO systems because there is a high flow of residual brine at a high pressure. Energy reductions can be as high as 67% depending on the operating conditions and ERD technology used.

Brackish Water

On the other hand, brackish water systems (BWRO) have a lot more variability on the raw water characteristics. High brackish applications require low recovery rates and high operating pressures similar to those SWRO systems where seawater is in the lower limit of salinity. Low brackish water applications can have recovery rates as high as 95% and operating pressures as low as a 50 psig (3 bar). The variability is so high that BWRO systems are typically designed to perform in a wide range of flows, pressures and recovery rates and the selection of the appropriate equipment for pumping and recovering energy can be very challenging. In some cases, technologies that were developed to save large amounts of energy in SWRO systems can become too expensive to be applied in brackish water, even when offering the highest energy savings. The selection of the proper ERD system for a BWRO must be analyzed in depth and on a case-by-case basis.

Photo 3—Small Turbocharger on RO Skid

Photo 4—Large Turbocharger

Photo 5—Motorized Turbocharger on RO Skid

The possible reductions range from 40% to 0% of the total energy spent in the osmosis process. Zero percent meaning that, for very low salinity BWRO systems, the best selection could be not including an ERD.

Additionally, the application of interstage ERD's have long been recognized as a way to improve membrane performance to achieve flux balance among multi-staged arrays. Interstage boosting helps to improve the production of the first and second stage to be more balanced, reducing the risk of fouling from poor hydraulic conditions within the membranes. It also helps to reduce 1st stage feed pressure hence reducing the required feed pump energy consumption. Also, when replacing an interstage booster pump an ERD can reduce or eliminate the energy consumption associated with the booster pump.

Other Considerations

The question is no longer whether we should use an energy recovery device, but what is the most economical ERD for a specific project. A comprehensive technical and commercial evaluation of ERDs needs to be considered to determine the most suitable ERD for a specific set of project conditions. Many times the initial capital expenditure is the only factor that is considered in deciding which ERD to select for a given project. This is a fairly common practice but can result in significant economic losses over the useful design life of the facility. The economics of ERD selection can be broken down into two primary categories of capital and operational expenditures. Both, capital expenditure (CAPEX) and operational expenses (OPEX) have many subsets that can be quantified and carefully analyzed to ensure maximum return on investment.

<u>CAPEX considerations include:</u>
Equipment Cost: Initial cost of equipment.

Installation Cost: ERD technologies vary tremendously on the amount of installation cost required to meet the manufacturers' specifications. Piston type ERDs require additional civil works, have independent PLC and hydraulic systems, and consume varying degrees of floor space (i.e., footprint). ERD racks and manifolds also add costs to each ERD offering. Centrifugal type ERDs tend to have the smallest footprint and minimal installation requirements.

Auxiliary Equipment Cost: Isobaric type ERDs require an additional circulation booster pump while centrifugal type ERDs do not. Connection types, number and size of connections, and instrumentation all need to be taken into account during the CAPEX analysis.

Other Costs: Depending on the type of ERD, there may be specific costs associated with a specific manufacturer or technology. Pelton-turbine ERDs may require an additional pump and sump system to displace the exhaust brine. Acoustical enclosures could be needed for ERDs that produce noise above 85 dB. Filtration and flushing requirements add other costs that are predominately ERD manufacturer-specific but can quickly add expenses to a proposed solution.

Photo 6—Pressure Exchange Skid

<u>OPEX considerations include:</u>
Maintenance: Fewer moving components will reduce the amount of maintenance required. Consider the device spare parts costs to maintain the ERD over its life span. Some ERDs may require specialized tools or shop equipment for routine maintenance, as well as downtime for repairs.

Durability: To ensure the long-term and trouble-free lifetime of the seawater reverse osmosis (SWRO) process and its enabling technology, it is essential to utilize the most advanced and reliable materials of construction. One of the more advanced and unique materials currently in use in SWRO desalination applications is high purity (>99%) aluminum oxide (alumina) ceramics.

Availability: Availability can be defined as the probability that a system or piece of equipment used under the specified conditions operates satisfactorily at any given time.

Future of ERDs

ERDs have become standard equipment for the reverse osmosis desalination process, both in seawater and brackish water applications. The future of these devices relate to improving performance across a variety of areas. For pressure exchanger devices, this would include decreased mixing of fluids, greater energy transfer efficiency, lower back pressure, higher turndown and higher per unit capacities. To improve the widespread adoption of ERD technologies, different purchasing strategies are being rolled out, such as a performance contract that would remove the CAPEX requirements for ERDs and instead require users to pay for the devices based on a portion of the energy saved. The economic justification or return on investment for ERDs can vary considerably based on a large variety of site-specific conditions and type of considered.

All manufacturers continue to push the envelope in developing the next generation of ERDs. Improvements in material science, hydraulic design, and reliability will continue to be the primary focus. The largest driver of innovation will be the lifecycle cost consideration of ERDs. System designers and end users will need to study the advantages and disadvantages of commercially available technologies. This evaluation typically has technical and commercial components to it.

This material has been prepared as an educational tool by the American Membrane Technology Association (AMTA). It is designed for dissemination to the public to further the understanding of the contribution that membrane water treatment technologies can make toward improving the quality of water supplies in the US and throughout the world.

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