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Energy recovery consideration in brackish water desalination

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HIGHLIGHTS

- Turbocharger is a simple ERD but with very narrow optimum performance range.
- Turbocharger performance point selection must be very close to the real conditions.
- Isobaric ERD has high efficiency along the wide operational range.
- ERD type selection in BWRO is based on the plant Life Cycle Cost estimation.

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ABSTRACT

In brackish water RO desalination, the low feed water TDS and relatively low brine flow make the use of energy recovery devices ambiguous. The decision to implement energy recovery device must always be based on the Life Cycle Cost estimation of the plant. Design considerations concerning the energy recovery device selection and field experience in Lahat brackish water desalination plant (40,000 m^3/day) are presented in this article.

Two types of energy recovery device are generally considered in the brackish water RO desalination, turbocharger and isobaric energy recovery devices. Taking into consideration the simplicity of the turbocharger, it was selected for the 1st phase of the Lahat brackish water desalination plant with the design recovery range of 80%–88%. The turbocharger was designed for max recovery and external bypass line was added to operate the plant at low recoveries. For such wide recovery range the turbocharger entire efficiency range of 30%–40% was achieved.

Due to the limitation of the turbocharger to operate efficiently at the broad recovery range and Life Cycle Cost benefits of isobaric energy recovery device, the isobaric energy recovery device was selected for the 2nd phase of the Lahat brackish water desalination plant.

1. Introduction

Energy recovery devices (ERDs) are well known and widely used in the sea water reverse osmosis (RO) desalination whereby energy costs make up to 40% of the operating cost [1]. In brackish water RO desalination, the low feed water total dissolved solids (TDS) content and relatively low brine flow make the use of ERDs ambiguous. The decision to implement ERD in the brackish water desalination is always based on the Life Cycle Cost (LCC) estimation of the plant.

Sea water RO process configuration significantly differs from brackish water RO. Traditional seawater RO consists of single stage membrane process with single feed, single product and single brine streams, whereas brackish RO can have two or even three stages with much higher number of streams. Given this difference in process configuration, the ERD will have to be configured differently as well. In addition, RO brine stream in sea water applications is almost constant and corresponds to about 50–60% of the RO feed stream, whereas in brackish water RO, the brine steam varies significantly, between 15 and 30% of the RO feed stream. Therefore in brackish RO, ERD will have to be designed for a wide range of flow rates.

Two types of ERD are generally considered in the brackish water RO desalination, centrifugal turbocharger and isobaric ERD. Turbocharger is a hydraulic device that consists of a pump section and a turbine section, both of which contain a single stage impeller or rotor. As liquid from the brine stream flows into the turbine section of the turbocharger, the turbine rotor extracts the hydraulic energy of the brine and converts it to mechanical energy. The pump impeller then converts the mechanical energy produced by the turbine rotor back to hydraulic energy in the feed stream. Thus the turbocharger is entirely energized by the reject stream. The overall efficiency of the turbocharger that is the product of the efficiencies of the turbine and pump impellers ranges between 50 and 80% [2].

ERD that avoids the efficiency losses associated with multiple energy-conversion steps is isobaric ERD. The isobaric ERD uses the principle of positive displacement to achieve energy transfer from a high pressure brine stream to a low pressure incoming feed stream. There

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Table 1
Raw water data.

Parameter	Unit	Value
TDS	mg/L	1852
pH		7.40
Alkalinity	mg/L as $CaCO_3$	325.6
Calcium	mg/L	86.3
Magnesium	mg/L	77.1
Sodium	mg/L	425.7
Potassium	mg/L	5.8
Barium	mg/L	0.106
Chloride	mg/L	664.5
Sulfate	mg/L	110.7
Nitrate	mg/L	53.9
Fluoride	mg/L	1.7
Silica	mg/L as SiO_2	29.4
Boron	mg/L	0.8

are two types of isobaric ERD — rotary and piston. In rotary type, the high pressure brine stream comes in direct contact with low pressure feed stream. The energy transfer occurs in the rotor ducts. By rotation, the ducts are first exposed to low pressure feed water, which fills the duct and displaces the brine water. The rotor continues to rotate past the sealing area and is then exposed to the high pressure brine, which fills the duct and displaces the feed water at high pressure. Direct contact between feed and brine streams causes the mixing between these steams and as a result the salinity increases in the feed stream to membranes. This salinity increase causes operating pressure to increase by approximately 1–2 bars [3,4]. Piston type ERD operates similar to rotary type ERD, however, instead of rotor, positive displacement pistons, housed in pressure vessels, are used. The pressure vessels exchange the functions by means of special valves. In one of the pressure vessels the high pressure brine displaces the feed water at high pressure. In another pressure vessel, the low pressure feed displaces the brine water [5].

Centrifugal turbocharger and rotary type isobaric ERD were considered in the design of Lahat brackish water desalination plant. The design considerations as well as field experience are presented in this article.

2. Lahat plant phase 1 — overview

Lahat brackish water desalination plant is located near Talme Yafe community, South-Western area of Israel, southeast of Ashkelon. The plant is a part of the national program for solving the problem of land salinization as well as increase of the salinity in the upper layer of underground water [6].

The construction of the plant is designed to be in two phases of 20,000 m^3/day each so that the final capacity of the plant will be 40,000 m^3/day. The 1st phase of the plant was designed and built by the Global Environmental Solutions Company (GES) for Mekorot–Israeli National Water Carrier Company. The commissioning was completed in May 2011.

The plant is fed from the nine wells. The average design water composition is presented in Table 1.

Pretreatment of the plant consists of four screen filters (80 mesh) and four cartridge filters (5 μm).

The reverse osmosis section of the plant is designed with two independent trains of 10,000 m^3/day production each. Each train consists of two stages, first stage with 50 pressure vessels with three TM820C-400 elements plus five TM820S-400 elements per vessel; second stage with 18 pressure vessels with eight TM820S-400 elements per vessel. The design recovery is 80%–88%.

The Life Cycle Cost (LCC) process that predicts the most cost-effective solution, was implemented in the selection of the electromechanical equipment of the plant. Two alternatives, inter-stage booster pump and inter-stage turbocharger, were evaluated. The LCC evaluation equation approved by the Hydraulic Institute and Europump was utilized [7]. The following factors of two alternatives were compared:

- Initial costs, purchase cost (pump, system, pipe, auxiliary services)
- Installation and commissioning cost (including training)
- Energy costs (predicted cost for system operation, including pump driver, controls, and any auxiliary services)
- Operation costs (labor cost of normal system supervision)
- Maintenance and repair costs (routine and predicted repairs)
- Down time costs (loss of production)
- Environmental costs (contamination from pumped liquid and auxiliary equipment)
- Decommissioning/disposal costs (including restoration of the local environment and disposal of auxiliary services)

The major difference between two alternatives, as expected, was found in the energy cost factor. For 88% recovery, the energy savings of the inter-stage turbocharger alternative were estimated to be 0.08 kW/m^3 product while at 80% recovery, the energy savings were even higher, 0.15 kW/m^3 product. Other aforementioned factors have minor impact on the LCC evaluation therefore inter-stage turbocharger alternative was adopted for the 1st phase of Lahat brackish water desalination plant. The selected alternative scheme is presented in Fig. 1.

A degasifier for carbon dioxide removal was used as the last process stage for conditioning and pH adjustment of the final product. The final

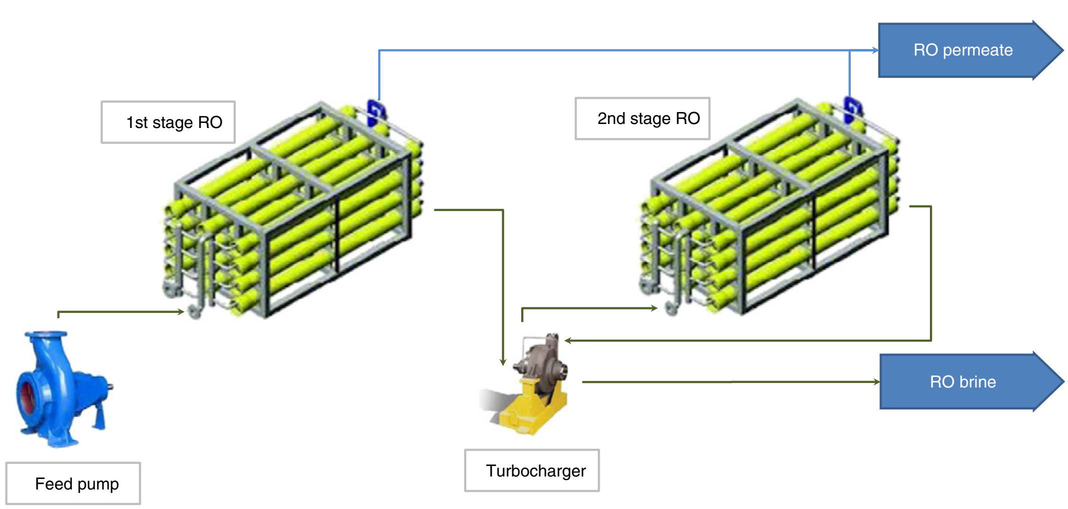

Fig. 1. RO with turbocharger scheme.