Desalination 254 (2010) 170–174

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

# Comparative study on stand-alone and parallel operating schemes of energy recovery device for SWRO system

Xiaopeng Wang, Yue Wang *, Jianping Wang, Shichang Xu, Yuxin Wang, Shichang Wang

*Chemical Engineering Research Center, School of Chemical Engineering and Technology, Tianjin University, State Key Laboratory of Chemical Engineering, Tianjin State Key Lab of Membrane Science and Desalination technology, Tianjin 300072, China*

ARTICLE INFO

*Article history:*
Received 12 September 2009
Received in revised form 23 November 2009
Accepted 27 November 2009
Available online 6 January 2010

*Keywords:*
Energy recovery device
Seawater reverse osmosis
Parallel operation
Rotary fluid switcher

ABSTRACT

As known, positive displacement (PD) energy recovery device (ERD) transfers hydraulic energy from the ejected brine of the RO modules directly to the seawater feed and its energy recovery efficiency achieved can be as high as 95% or more. The PD type ERD has been concerned widely in the market place and globally adopted into seawater reverse osmosis (SWRO) desalination plant by designers and operators. Usually, to satisfy the needs of large to super-large SWRO plant capacity, parallel operations of ERD facilities are the most convenient and effective way that can be chosen. In this article, a PD type ERD, named FS-ERD was introduced and a parallel FS-ERD setup was designed and built. Operating schemes for stand-alone operation and parallel operation of the setup were developed and experimentally compared for different test capacity.


## 1. Introduction

Seawater reverse osmosis (SWRO) desalination systems are widely used to produce potable water from the sea nowadays. However, the excessive power consumption is still an emergent problem to be solved for the system. As is known, the SWRO is a pressure-driven membrane process and the main power consumption arises from the high pressure (HP) pump, which accounts for at least 35% of operating costs in total system [1]. Since more than half of the hydraulic energy supplied by the HP pump are incorporated in the ejected brine of the RO modules with a traditional conversion rate of 35–45%, so it is important to recover the thus lost hydraulic energy of the brine through the energy recovery approach.

Currently in the market place, there are principally two categories of energy recovery device (ERD), the positive displacement (PD) type and the centrifugal type. The PD type ERD transfers hydraulic energy from the ejected brine of RO modules directly to the seawater feed and due to its direct transfer manner, the energy recovery efficiency achieved is higher than that of the centrifugal type, and can be as high as 95% or more [2]. Currently the PD type ERD has become one of the most efficient ERDs in the market place and has been globally adopted into seawater reverse osmosis (SWRO) desalination plant by designers and operators [3].

As the development and maturation of RO technology, large or even super-large SWRO plants are established around the world, and the per train size has reached to 10,000–15,000 $m^3$/d. To satisfy the increased needs of SWRO plant capacity, many efforts have been put into practice, including enlargement of the ERD per unit size, and also parallel operations of ERD facilities [4,5]. Attentively, the parallel operation is considered the most common and effective way to be chosen, which is because the parallel operating mode not only extends the device's capacity, but also has the potential to significantly reduce or even eliminate fluctuations of the ERD working streams [6].

## 2. Experimental setup

### 2.1. Working principle of the FS-ERD

In this work, a newly developed PD type ERD named FS-ERD was investigated. The FS-ERD was mainly composed of three portions, a rotary fluid switcher, two pressure cylinders and a check valve nest. The core component of the FS-ERD is the rotary fluid switcher, which is featured with four joint ports and two working phases similar to a two-position four-way valve. Fig. 1 gives the working principle of the FS-ERD in phase**I**. Under this condition, the HP brine stream is imported into cylinder 1 and therein the pre-filled low pressure (LP) seawater feed is pressurized and pumped out, which is called the pressurizing stroke. Simultaneously, HP brine stream in cylinder 2 would be depressurized and was drained out by the incoming LP seawater feed, and the process is called depressurizing stroke. Thereafter, when the FS-ERD accomplishes its pressurizing stroke (and also the depressurizing stroke), the switcher would rotate to working phaseIIat a low speed of 7.5 rpm driven by motor, which denotes that the stroke modes in cylinders are alternated to each other.

* Corresponding author. Tel./fax: +86 22 27404347.
*E-mail address:* tdwy75@tju.edu.cn (Y. Wang).

0011-9164/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.desal.2009.11.038

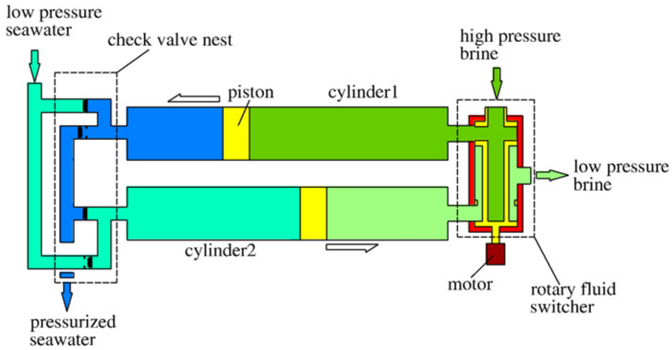


**Fig. 1.** Working principle of FS-ERD at phase I.

A piston is installed in each cylinder to isolate seawater from brine and ensure minimum mixing between them during the operation. Position of the piston is detected to judge whether the pressurizing or depressurizing stroke has been accomplished, and when the fluid switcher should be changed to the next working phase.

Further, an experimental parallel ERD unit, which comprises two identical FS-ERDs and can be operated independently, was set up as shown in Fig. 2. Here, the cylinders of the FS-ERD are made of polymethyl methacrylate for convenient observing of the experimental process. Fig. 3 gives the schematic diagram of the experiments, which is similar to the actual SWRO system, except that the RO membrane modules are not incorporated, and the operating pressures adopted are comparatively lower (below 0.6 MPa). Tap water is used as the working medium instead of actual seawater and brine in SWRO desalination plants.

Data acquisition system is designed and incorporated in the experimental system. Flow rates of LP seawater (Qsi) and HP brine (Qbi) feeding to the ERDs are measured by the flow transmitters respectively with a precision of ±0.5%. Pressures of the streams to and from the ERDs are also tested by the pressure transducers with measuring precision of ±0.5%.

### 2.2. Opening change mechanism of rotary fluid switcher

The rotary fluid switcher is the core subassembly of the FS-ERD unit and the switcher accomplishes its phase change by rotating its multi-channel rotor around the switcher's shell. Here a working phase is defined at the location where the specific channel in the rotor superposes accurately with the window in the shell. Departure from the working phase position, the channel in the rotor would not be sufficiently opened and thus the stream to and from the rotor channel will be influenced or even interrupted. Fig. 4 gives the opening change mechanism of the rotary fluid switcher. It can be seen that working phaseⅠand phaseⅡcorresponding to the full opening line alternate sequentially, and the duration time for working phaseⅠorⅡsigned as *T*1. The switch time of the switcher is defined as *T*2, which includes the switcher's response time and the full closure remaining time *T*3. Here the time *T*3 is determined by the channel size of the rotor, while the time difference between *T*2 and *T*3 decides from the rotating speed of the rotor.

In this paper, operating schemes of stand-alone operation and parallel operation are developed and uploaded in the PLC control system. Dynamic performances of the experimental setup under the two operating schemes were tested and comparatively analyzed.

**Fig. 2.** Experimental setup of the parallel FS-ERDs.

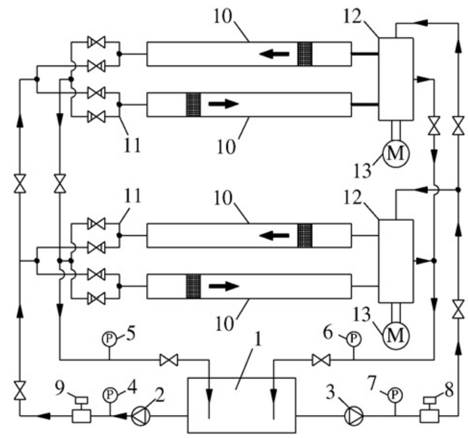


**Fig. 3.** Schematic diagram of the experiment.

## 3. Stand-alone operation experiments

In stand-alone operation, the fluid dynamics performances of FS-ERD device were studied at test capacity of 1.0 $m^3$/h and 2.0 $m^3$/h respectively.

### 3.1. Flow rate fluctuations of streams in stand-alone operation

Fig. 4 illustrates the flow rate fluctuations of LP seawater (Qsi) and HP brine (Qbi) at test capacity of 1.0 $m^3$/h. It can be seen that both Qsi and Qbi have a downward fluctuation periodically and also the amplitude of Qbi is significantly much larger than that of Qsi. Referring the opening change mechanism described in Fig. 4, it is believed that the periodical downward fluctuations of Qsi and Qbi streams derive from the cyclic switch of the fluid switcher and further the sudden interruption of streams during the switch process. The cause of the larger amplitude of Qbi is that the brine stream is directly

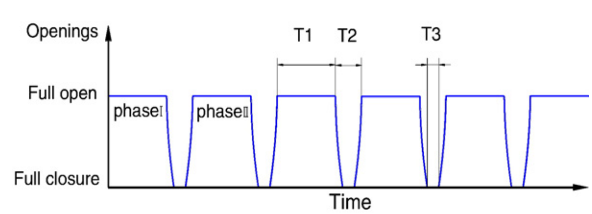


**Fig. 4.** Openings of the fluid switcher vs. time for stand-alone operation.