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ENERGY RECOVERY IN SEA WATER REVERSE OSMOSIS PLANTS, STATE OF THE ART

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Sea Water desalination using RO membranes, is the most used system today. Fifty years ago, this technology was starting, and the energy involved was very high (close to 5 kWh/m3).
Since 1960..70, energy recovery systems have been developed under 3 following typical arrangements

- **CENTRIFUGAL RECOVERY SYSTEMS (CRS)** using first a FRANCIS turbine, and in a second time a PELTON Turbine in order to recover the residual energy present in the concentrate (cf. fig.1). The PELTON turbine was directly shafted to the high pressure pump, in the same way than the electrical motor. This arrangement was able to recover about 30% of the energy (cf. fig. 2 & 3)

FRANCIS TURBINE

PELTON TURBINE

Fig. 1 - Two types of turbines

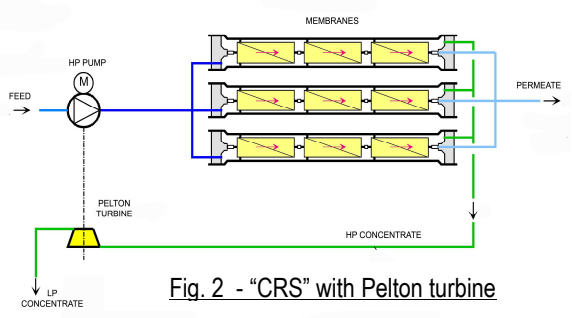

Fig. 2 - "CRS" with Pelton turbine

Fig.3 - HP pump with Pelton turbine

A second Centrifugal system was also used it was a two steps pumping, a first step with a high pressure pump having full feed capacity but with only 65..70% of the needed head. The second step was assumed by a TURBOCHARGER adding the complementary head. The pump was driven by an electrical motor and the TURBOCHARGER directly by the high pressurized concentrate flux (cf. fig.4 & 5). The energy recovery was very close to the PELTON arrangement

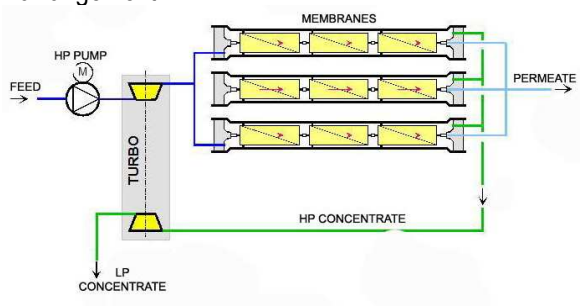

Fig.4 - "CRS" with Turbocharger

Fig 5 – Turbocharger (PEI/ERI picture)

The "CRS" equipment has been used until 2000... 2005, and replaced by Hybrid Recovery Systems.

- **HYBRID RECOVERY SYSTEMS (HRS)**, using centrifugal pumps and isobaric pressure exchangers, are based on the following principle (cf. fig. 6)
The HP pump is sized for a capacity equal to the permeate capacity and full feed pressure. With a pressure drop of about 1.0…1.4 Bars, the available pressure and a flux of about 50 up to 60% of the total feed, the complementary sea water to be desalinated, is pressurized trough an isobaric pressure exchanger

working as an hydraulically actuated positive displacement pump. The total pressure drop of the system (membranes, isobaric pressure exchanger, pipework and valving) is compensated by an additive centrifugal booster pump with about 3 Bars differential head

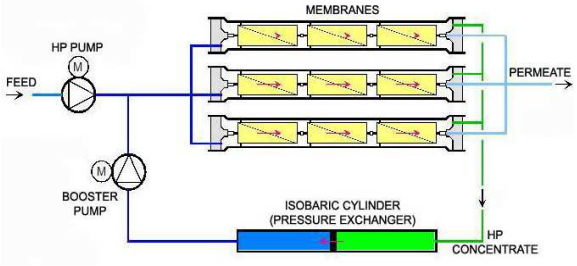

Fig 6 – "HRS" System

Two systems are regularly installed

- The **SYSTEM PX** (Pressure eXchanger) from ERI COMPANY. It's a rotating system with rotor and stator made of ceramic. (cf. fig. 7 & 8)

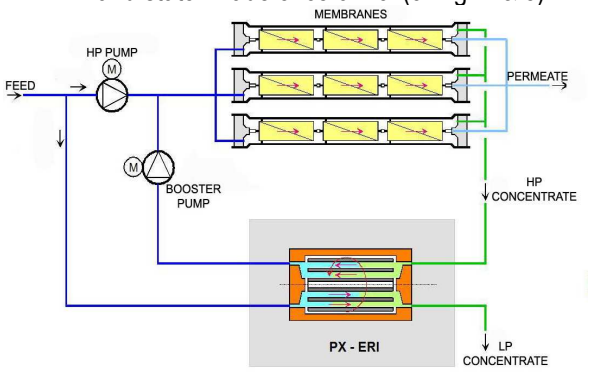

Fig 7 – "HRS" System – PX type

Fig 8 – PX rack on a 20 MLD line

- The **SYSTEM DWEER** (Double Work Exchanger Energy Recovery) from CALDER company (FLOWSERVE GROUP), which is an axial system with a double cylinder (cf. fig. 9 & 10)

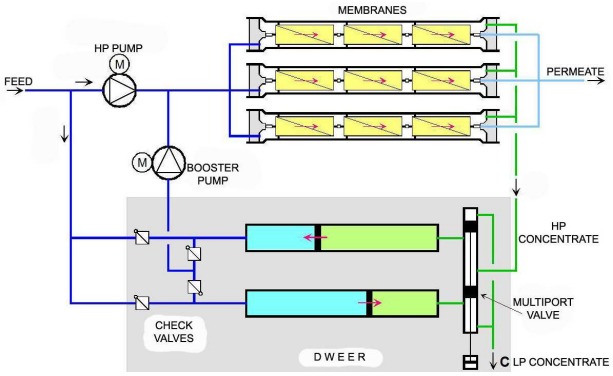

Fig 9 – "HRS" System – DWEER type

Fig 10 – DWEER rack on a 15 MLD line (Calder pictures)

A similar system has been developed by KSB under **SALTEC** name; only two systems are working with a maximum 4.50 MLD (cf. fig. 11). The main difference with DWEER system is a rotating concentrate valve instead of an axial multiport valve.

Fig 11 – SALTEC rack on a 4.50 MLD line (Abandoned equipment)

The HRS (Hybrid Recovery System) using one of the 3 above described systems is able to recover about 50% of the HP power. Typical results are from 2.2 up to 2.6 kWh/m3.
Small systems are also built using an HP multi-pistons pump and PX, with results about 2.40 kWh/m3.

The last development for HRS technology is the **OSMOREC** which is a triple isobaric cylinder using dissymmetric pistons. This configuration is working in the same way than the symmetric cylinders in terms of flux transmission but this type of arrangement is able to increase the back pressure, and to avoid the use of a booster pump.

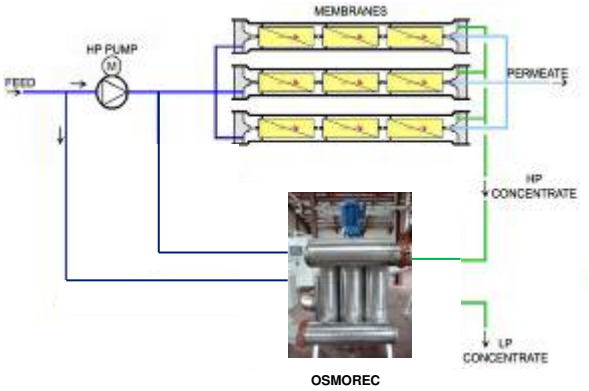

Fig 12 – "HRS" system – OSMOREC type (Abandoned equipment)

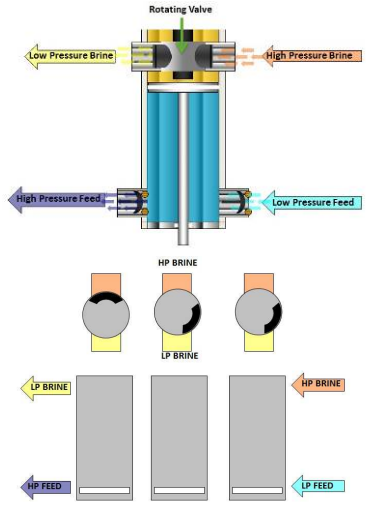

Fig 13– "HRS" system – OSMOREC principle

Energetic consumption with **OSMOREC** system is about: 2.10 up to 2.40 kWh/m3

- **VOLUMETRIC RECOVERY SYSTEMS (VRS)** using 100% volumetric equipment.

VRS is a recent development; it's in fact a multi-pistons positive displacement pump, with each cylinder built as an isobaric cylinder. Like HRS units, an electrical motor is actuating the pump for the direct pressurization of the equivalent permeate flux, plus the compensation of the several pressure drops of the system. Using only one pump of the volumetric type, the efficiency is better than centrifugal type arrangement using two pumps.

The principle of the construction is very close to a boxer car engine, with multiple pistons (from 6 up to 12) in reciprocating work.

VRS is able to reduce the specific energy of about: 0.40 up to 0.60 kWh/m3, in comparison with an HRS arrangement. Final specific energy involved is from: 1.80 up to 2.0 kWh/m3.

One full VRS arrangement was working as a full scale pilot unit in a MEDITERRANEAN ISLAND on a 5 MLD line (cf. data in the case history summary next page)..

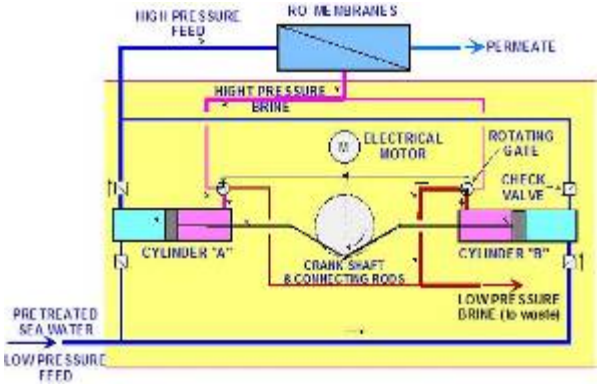

Fig 15 – VRS System – Boxer pump with 6 reciprocated pistons

Fig 16 – 5 MLD Boxer pump with Integrated Isobaric cylinders.

Conclusion:

VRS units are probably in the future decade, the new standard for a most affordable desalination way.

Drawings and Pictures are from HENRI LUGAN (except when specified)

CASE HISTORY

BOXER 6 CYLINDERS PUMP WITH INTEGRATED RECOVERY SYSTEM
5 MLD FULL SCALE VRS PILOT UNIT

The 5 MLD VRS unit installed in Test Desalination plant is a full scale pilot plant of the Boxer 6 pistons pump with integrated recovery system using isobaric cylinders type, also called "VRS BOXER PUMP"
The test plant is an old plant using CRS arrangement (PELTON Turbine from CALDER, connected to a multicellular DUCHTING pump).
The VRS pilot was connected in by pass to the CRS existing equipment. The total capacity of the test plant is 15 MLD splitted in 3 lines of 5 MLD each. Only one line is connected to the VRS BOXER PUMP.
Each 5 MLD SWRO rack is composed of 58 pressure vessels, each loaded with seven 8 inches membranes, working at 42% recovery rate.
At the start of the plant membranes were of the 380 ft2 size (34.8 m2), plant has been recently retrofitted with 440 ft2 size. After retrofitting, the flux declined from 14.53 LMH to 12.55 LMH (which is a very low flux), in the same time the energetic consumption decreased of about 13%.
With 2 lines running in CRS mode with PELTON turbines, and one line with the VRS BOXER PUMP, it was easy to compare the two systems (data collected on site in august 2011).
CRS lines using PELTON Turbines
- *LP feed pressure: 2.5 Bars g.*
- *HP pumps: 496 m3/h x 58.9 Bars g. (Efficiency: 83%)*
- *Pelton turbine: 288 m3/h x 58.1 Bars g. (Efficiency 68% for more than 10 years old turbines)*
- *Resultant specific energy: 3.041 kWh/m3*

VRS line using BOXER PUMP
- *LP feed pressure: 2.5 Bars g.*
- *HP pumping: 496 m3/h x 58.9 Bars g. (Efficiency: 96%)*
- *Isobaric recovery: 288 m3/h x 58.1 Bars g. (Efficiency 98%)*
- *Resultant specific energy: 1.824 kWh/m3*

The energy gap between CRS and VRS is: 1.217 kWh/m3.
With 0.11 EUR per kWh, the annual operating cost decreases of 427,000 EUR. For a 5 MLD line in plant like the test plant, the new VRS BOXER PUMP CAPEX can be balanced less than 2 years.
This type of VRS system is now under industrialization works.

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