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Different designs in energy savings of SWRO Plant of Las Palmas III

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ABSTRACT

This paper aims to show the development and design changes that have been done in SWRO Las Palmas III to achieve improvements in energy savings from the start-up in 1996 until today. We want to present the evolution of the different energy recovery systems and new technologies that have been adapted to this facility in operation for the last 20 years. The plant began working with a production of 36,000 m^3/day with 45% recovery and six trains in two stages, with 300 ft^2-surface membranes and Francis turbine as energy recovery device, getting a specific energy consumption of 6.16 kWh/m^3. In 1999, the plant increased production to 39,000 m^3/day maintaining recovery and the number of trains, mainly due to changes of membranes with an area of 315 ft^2. Besides it got a specific consumption decreased to 5.18 kWh/m^3 due to the installation of a new energy recovery system, Pelton wheels. In the year 2000, Emalsa installed for first time in the world interstage pumps (so called booster pumps), increasing production to 44,000 m^3/day and recovery to 48%, reducing the specific consumption to 5.10 kWh/m^3. At 2001 and 2002, production is increased to 57,000 m^3/day with the installation of a new RO train and with the addition of a new row of pressure vessels and membranes in all trains that increased recovery to 50% and decreased the specific consumption to 4.95 kWh/m^3. From 2002 to 2007 plant increases production to 81,000 m^3/day, adding new more efficient trains increasing global recovery to 52% and reducing specific consumption to 4.6 kWh/m^3. Since 2008, the company began to replace the Pelton wheels for isobaric energy recovery systems, replacing in 2008 the first two Pelton wheels with a single isobaric system of two trains, reducing the specific consumption of these two trains more than 20%. In 2009, two new isobaric systems were installed, one per train, getting the plant a total of 86,000 m^3/day and a total specific consumption of 4.15 kWh/m^3. Currently, the company made a new train design, which improves the operating conditions when Pelton wheels are replaced for isobaric systems. This project will be operational in November 2010 and it has been predicted a decrease in specific consumption below 4 kWh/m^3. With all this improvements, it can be said that Las Palmas III SWRO plant has been a pioneer in the world of desalination and a lively look at the history of energy recovery in SWRO plants.

Keywords: Improve energy savings; Designs; Production capacity; Quality of water

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1. Introduction

1.1. Background

The company Emalsa, holding by Valoriza Water, from the Spanish group Sacyr Vallehermoso, operates the most important SWRO plant of the Canary islands, which supplies to Las Palmas de Gran Canaria City, with a population of 400,000 inhabitants. The above-mentioned installation produces a daily average of 86,000 m^3 and is considered cutting-edge enterprise in continuous improvements in the design and operation ways.

The SWRO plant of Las Palmas III has been characterized for implementing technological measures that have taken advantage of the shortage of available space to increase the production, to improve the quality of the produced water, and to reduce the energy consumption.

1.2. History of the water in the city

The history of Las Palmas de Gran Canaria City has passed parallel with the fight of its inhabitants against the lack of a vital element such as the water.

The deficiencies in the supply necessitated a law that was promulgated in 1906, which declared the public usefulness of the water supply to the city. The topographical and technical difficulties to drive water from the mountains and the need to construct, near the city, a great regulatory storage tank to guarantee a service without disruptions, did precisely to award, in 1912, the concession of the service of supply to the English company "City of Las Palmas Water & Power Company Limited."

It was necessary to wait until 30 March 1946, in order to sign in London the contract of completion of the concession, in which the Municipal Service of Water supply took charge of the Regulatory Storage Tank of the Llano de Las Brujas (64,000 m^3), of more than 30 kms for distribution networks and of 10,000 flow meters renting installed.

Between the period 1960 and 1975, tourism, flourished which led to the increase in the population of the city, and generated important problems of water supply. Because of the inability to obtain sufficient flows from the traditional methods, adoption of new technologies became necessary for the production of drinking water by the treatment of seawater. So that, in 1970, the SW plant Las Palmas I was opened, with a 20,000 m^3/day of production and, in 1980 joined the SW plant Las Palmas II, with a daily production of 18,000 m3/day. And finally, in 1989, SWRO plant of Las Palmas III with a daily production of 36,000 m^3/day was officially opened.

The system of municipal management continued until 1989. With the need to optimize the service of water supply and adapt it to a city in continuous development, the Las Palmas de Gran Canaria Town Hall sold 66% of its shares, initially to the entities Canaries Electrical Union (33%) and Societé D'Amenagement Urbain et Rurally (33%).

In the year 2005, Valoriza Water (Sacyr-Vallehermoso Group) acquired 33% of the Canaries Electrical Union shares, joining a part of the shareholders of Emalsa.

2. Facilities' description

2.1. General comment

Emalsa arranges its SW desalination facilities in the industrial estate of Piedra Santa, Jinamar, in the city of Las Palmas de Gran Canaria (see Fig. 1).

Fig. 1. Facilities situation.

These facilities began in 1969 with the installation of a SW desalination plant based on a MSF plant Wespoor of low temperature with $4 \times 5{,}000\,m^3/day$, which was named Las Palmas I. immediately afterwards, in the year 1981, Emalsa installed a SW desalination plant based on MSF Babcock Wilkox of high temperature with $2 \times 10{,}000\,m^3/day$, named Las Palmas II.

In 1989, Emalsa installed a SWRO plant with 4 trains $\times$ 6,000 m^3/day, which was named Las Palmas III. In 1992, Emalsa installed two new trains $\times$ 6,000 m^3/day that became the large desalination plant in Europe, which was designed and built by companies from Canary Islands.

On the other hand, and to replace the first MSF (Las Palmas I) Emalsa built a SW desalination plant based on the last generation of evaporation system (MED) with $2 \times 17{,}500\,m^3/day$, connected to the thermal power station of Las Palmas I, with a maximum power generation of 24 MW.

Emalsa like the concessionaire company to do the operation and maintenance of the facilities has made huge modifications that have been improving the performance, suit the demographic changes of the city, to the new energetic markets, to strict requirements of quality and, especially, optimizing the scanty available space that prevents the growing. So that, Emalsa is required to keep itself in the forefront of new desalination technologies that allow an increase of the production capacity, of the recovery of the plant and an improvement of the specific consumption of the process.

2.2. Evolution of SWRO plant of Las Palmas III

Below, there will be enumerated the different steps that have marked the long history of the SWRO Plant of Las Palmas III, which have allowed substantial improvements in capacity of production, quality of the water, recovery of the plant, and specific energy consumption.

2.2.1. The beginning

Between 1989 and 1992, the first six SWRO trains were installed, each one with a daily capacity of 6,000 m^3/day. Originally these modules had got two stages without intermediate pumping, where the second stage was treating directly the rejection of the first one, obtaining recoveries about the 45%. This design operated with the same type of membranes as in the first stage as in the second stage, and used as recovery system of the second stage brine, Francis turbines which were connected directly to the axis of the high pressure pump (see Fig. 2).

2.2.2. Replacement of Francis turbines

From 1996 to 1997, Emalsa began to realize actions aimed to improve the quality of the water. First of all, Emalsa proceeded to replace 4,896 membranes for others from the best available technology and systems.

In 1997, Emalsa began to replace the six Francis turbines with Pelton wheels, a system with a major

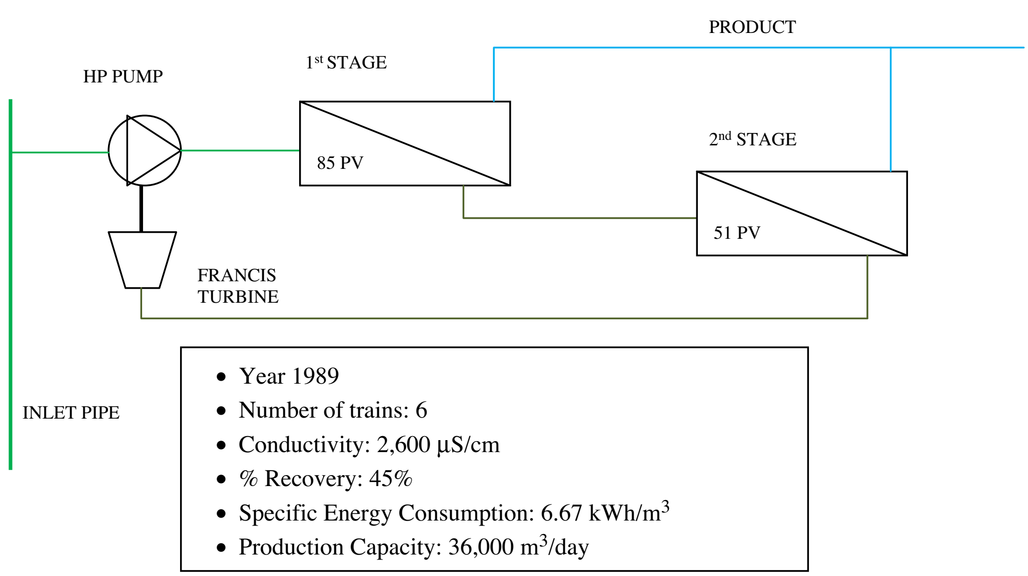


Fig. 2. Hydraulic scheme of the trains with Francis Turbines.

performance, which produced an improvement in the specific energy consumption (about 12.3%). This replacement caused the modification of the HP Pump impellers to fit to the system (see Figs. 3 and 4).

2.2.3. Booster pump between stages installation

Until 2001, the RO desalination plants, with standard membranes (82 bars of maximum pressure), were limited to a maximum recovery of 45%.

The need, already mentioned, for optimizing the seawater, with the purpose of increasing the production capacity of the plant, made the company take an effort into looking for technical solutions to improve the limitation in the recovery.

As fruit of this effort, emerged the patent P200102300, OPTIMIZATION OF RO PLANTS BY MEANS OF INTERMEDIATE BOOSTER PUMPS, granted on 15 October 2001, which was immediately put into practices with satisfactory results, an increase of *8%* in the recovery of the SWRO Plant of Las Palmas III and an improvement of *12.65%* in the specific energy consumption (see Figs. 5 and 6).

2.2.4. Extension of the number of desalination trains

The increase in the water demand determined the Emalsa's investments plan, directing the efforts at increasing the production capacity of Las Palmas III.

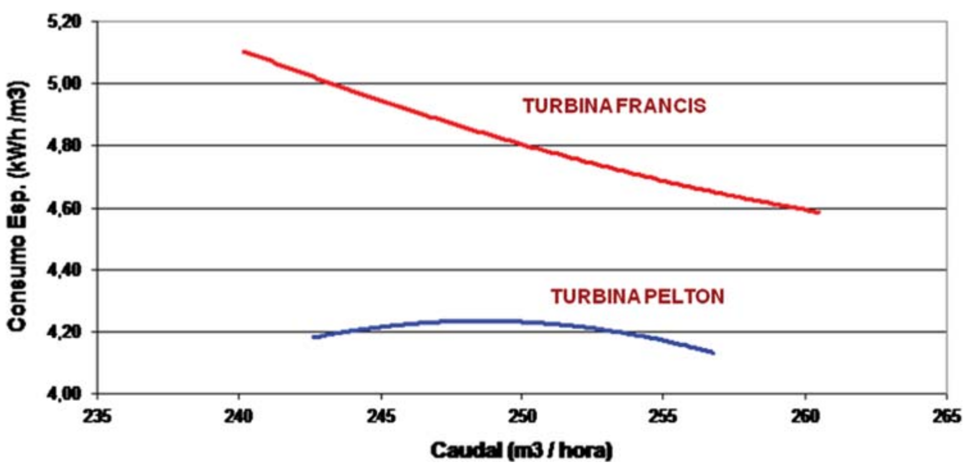


Fig. 3. Improvement of the performance between Francis Turbine vs. Pelton wheels.

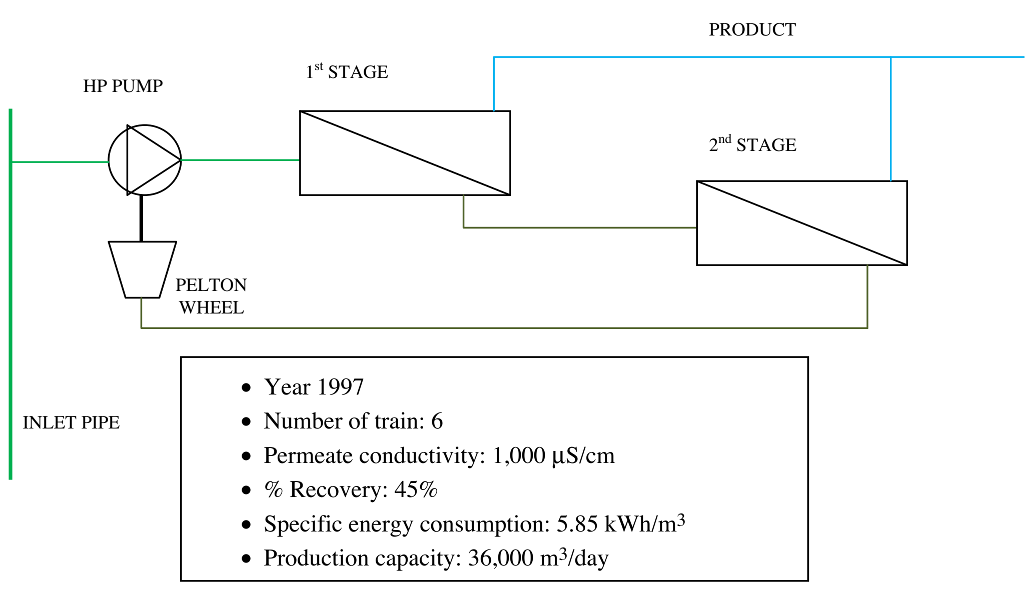


Fig. 4. Hydraulic scheme of the trains with Pelton wheels.

Fig. 5. Interstage booster pump.

The first part of the 2000 decade was marked by the installation and starting up of four new RO trains with the same configurations as before.

The modern technology used in these new trains, as well as the installation of last generation membranes, allowed to obtain an important evolution in the parameters of quality and efficiency of Las Palmas III.

The first extension took place in the year 2001 with the installation of the seventh train.

Later, in the year 2003, the eighth train, was installed in an attached building near the original one of Las Palmas III, became a global recovery plant of 51.16%, with a specific energy consumption of 4.76 kWh/m^3, as well as a production capacity of 65,000 m^3/day.

Finally, in the year 2006, it completed the installation of 9th and 10th trains, reaching a production capacity of 79,000 m^3/day, recovery of 52.8% and a specific energy consumption of 4.63 kWh/m^3 (see Fig. 7).

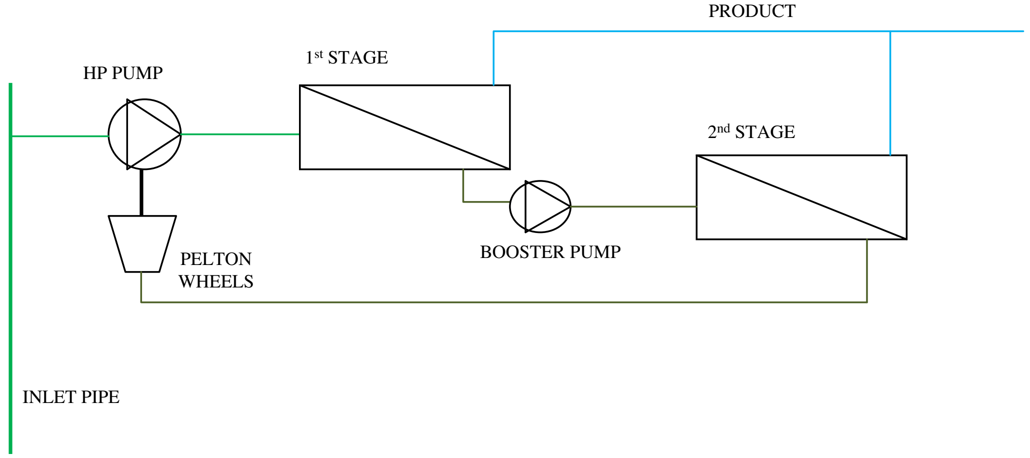


Fig. 6. Hydraulic scheme of the trains with booster pump between stages and Pelton wheels.

Fig. 7. Location of the facilities.

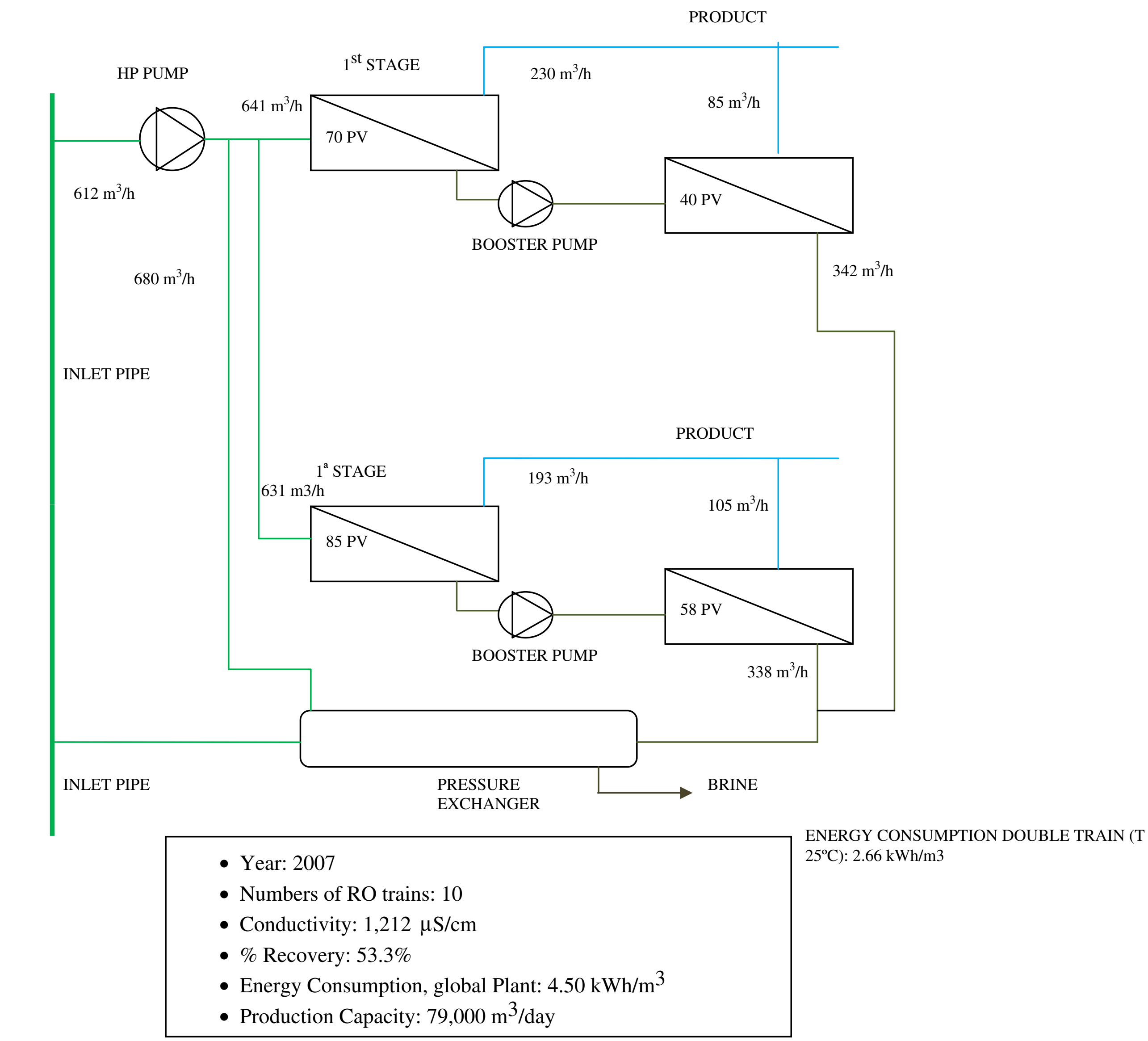


Fig. 8. Hydraulic scheme of the double trains with booster pump between stages and pressure exchangers.

2.2.5. Installation of pressure exchangers

Since the year 2001, a pilot plant for research was working in the SWRO Plant of Las Palmas III, where the possible benefits were evaluated that might generate the replacement of the Pelton wheels for energy recovery system based on isobaric chambers with performances that could overcome 90%.

It was not until the year 2007, coinciding with an improvement in the energy recovery system of the pressure exchangers technology, when SWRO Plant of Las Palmas III embarked on the first installation of this technology.

The above decision, prompted a complete change in the design philosophy of the trains, due to a turbine of recovery, Pelton or Francis, demanded that the whole feed water flow drove to the high pressure pump, whereas in case of the pressure exchangers, only drive the seawater flow equivalent to the production of the train, while the pressure exchangers pressurize part of the seawater equivalent to the rejection.

This fact required the company to consider two options, the first one, the need to replace the high pressure pumps with others which adapted to the new conditions, this option had the inconvenience of

Fig. 9. Installation of the pressure exchangers.

making an expensive new investment, and the second one, the need to modify by means of retrofitting the high pressure pump, this option has a reduced investment, but has the inconvenience of a reduction in the performance of this high pressure pump.

To avoid this dilemma, since the recovery of the trains was more than 50%, the solution considered for the first installation of pressure exchangers in SWRO Plant of Las Palmas III was joining two trains, so that one high pressure pump and only one pressure exchangers system will feed the two trains. In this way, Emalsa installed a double train, with one design in the world, which allowed reaching a reduction in the specific energy consumption of the plant (see Figs. 8 and 9).

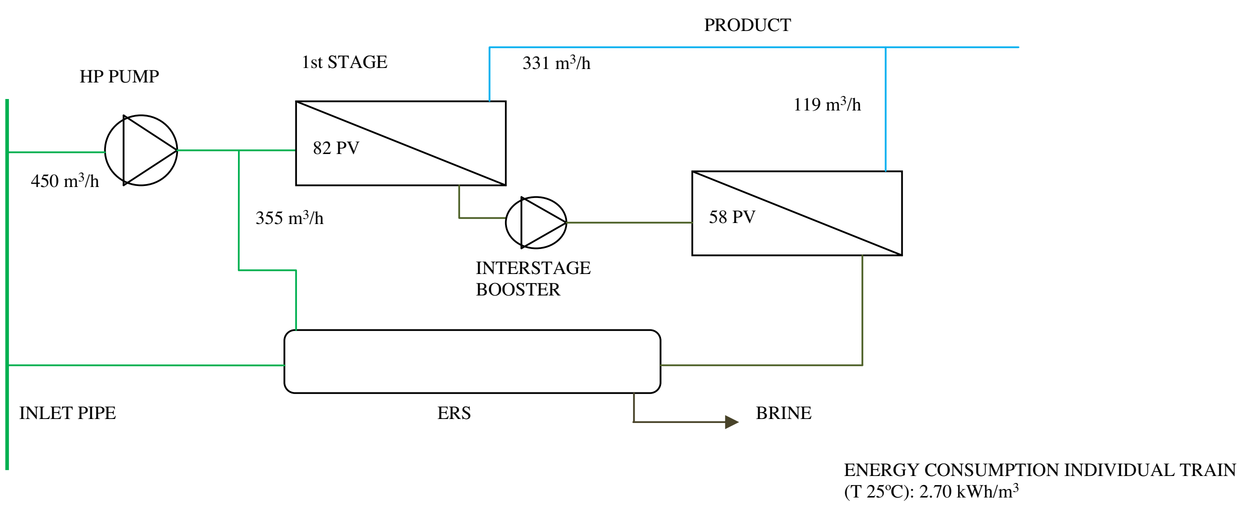
Looking at the reliability of this new system, with an improvement in the specific energy consumption of the plant, the company decided to start the replacement the Pelton wheels with pressure exchangers in SWRO Plant of Las Palmas III.

So, in 2009, other two lines were modified, but in this case, the company decided to install the pressure exchangers in two trains, with an individual way, to improve the flexibility of the desalination plant at the moment of carrying out maintenance works.

This fact came together with an important policy of changing membranes, as well as the installation of end caps, which originated in the plant, not only an improvement of the specific energy consumption, also an important improvement in the quality of the product water, adapted, in this way, to the new quality regulations (see Fig. 10).

2.2.6. New hydraulic design with ERS

In 2010, continuing the same philosophy of the previous years, improving the specific energy con-



- Year 2009
- Number of train: 10
- Conductivity: 518 µS/cm
- % Recovery: 50.75%
- Energy Consumption: 4.33 kWh/m^3
- Production Capacity: 85,000 m^3/daya

Fig. 10. Hydraulic scheme of the trains with booster pump between stages and pressure exchangers.

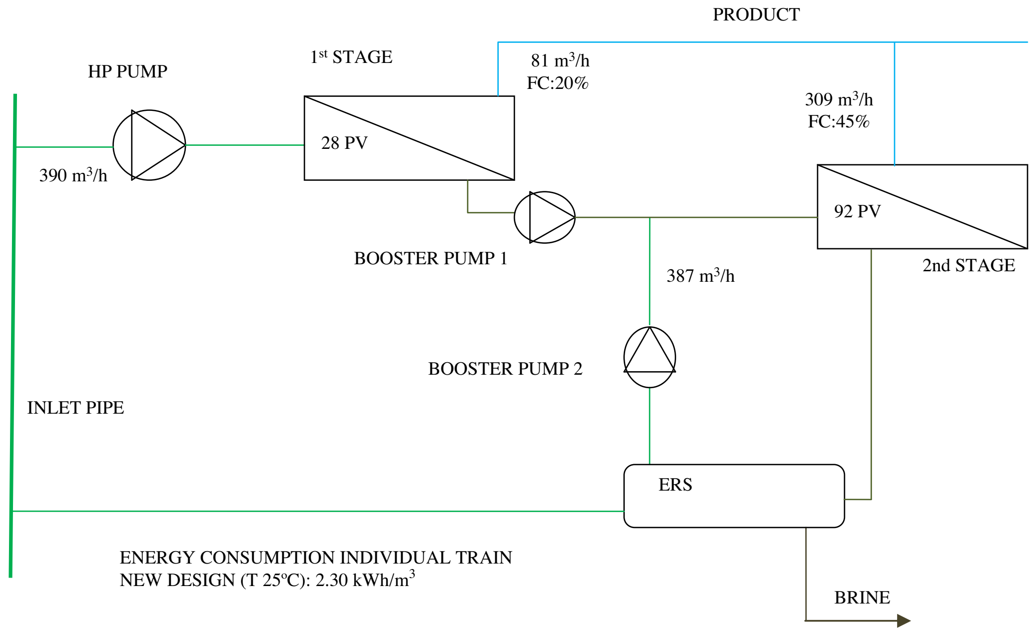


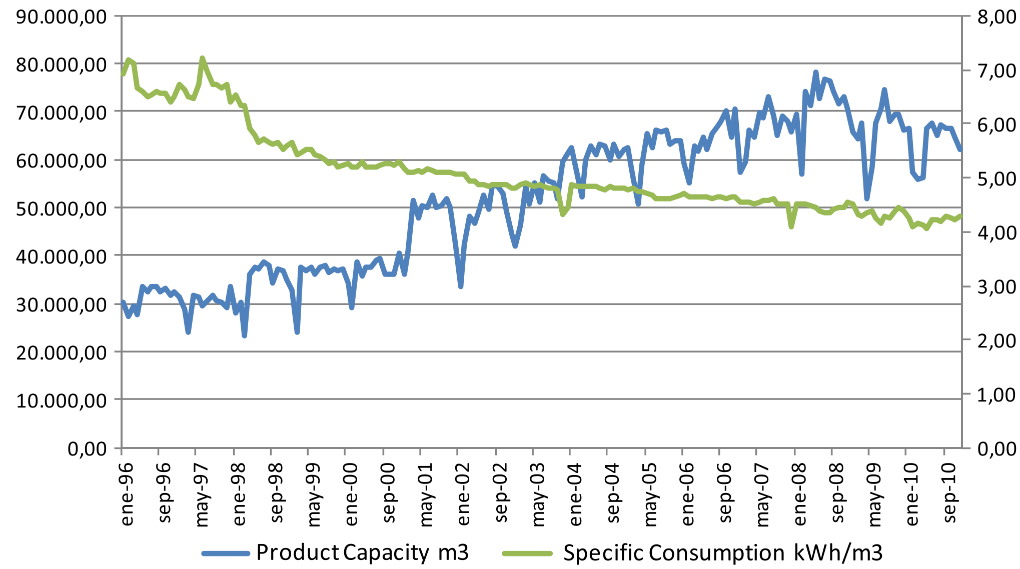
Fig. 11. Hydraulic scheme of the trains with two booster pumps. New Hydraulic design.

Table 1
Results I

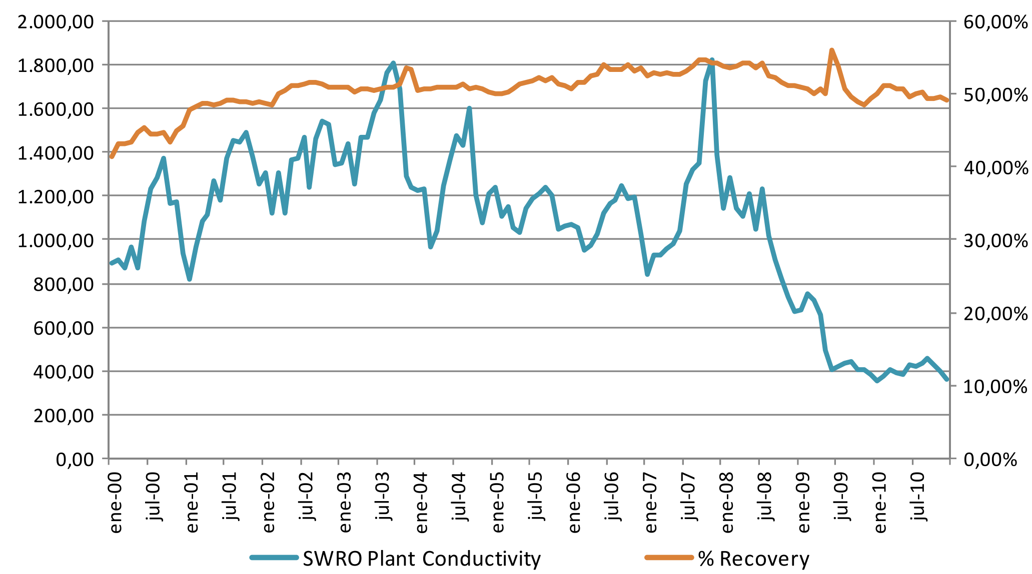
Design	Year	SWRO plant conductivity (µs/cm)	SWRO plant % recovery
Francis turbine	1989	2,600	45.0
Pelton wheels	1997	1,000	47.9
Booster high pressure pump	2001	1,234	48.6
Seventh train	2001	1,234	48.6
Eight train	2003	1,498	51.16
Tenth and eleventh train	2006	1,100	52.8
Double trains (5&6), PX installation	2007	1,212	53.3
End caps	2008	1,027	–
Individual trains (4&7): PX installation	2009	518	50.75
Train N#1	2011	404	50.08

Table 2
Results II

Design	Year	SWRO plant specific consumption (kWh/m^3)	SWRO plant % capacity (m^3/day)
Francis turbine	1989	6.67	36,000
Pelton wheels	1997	5.85	36,000
Booster high pressure pump	2001	5.11	50,000
Seventh train	2001	5.11	57,800
Eight train	2003	4.76	66,000
Tenth and eleventh train	2006	4.63	80,000
Double trains (5&6), PX installation	2007	4.5	80,000
End caps	2008	–	–
Individual trains (4&7): PX Installation	2009	4.33	85,000
Train N#1	2011	4.1	86,000



Graphic 1. Evolution of parameter in SWRO Plant of Las Palmas III (1).



Graphic 2. Evolution of parameter in SWRO Plant of Las Palmas III (2).

sumption of the plant and a constant improvement in the quality standards, the technicians of Emalsa designed a new hydraulic scheme in one of the trains of the SWRO Plant of Las Palmas III. This design incorporates a system of energy recovery by pressure exchangers, but optimizing the design to allow a major decrease of the energy consumption of the train, as well as an improvement in the quality of the product.

The new design connect the pre-treatment seawater, pressurized by the pressure exchangers, directly to the feed of the second stage, mixing with the brine of the first stage, while the first stage only receive the flow of seawater equivalent to the product water of the global train.

In this way, we have reached to improve the conductivity of the second stage product water, and even with the installation of the second booster pump, the specific energy consumption of the train has improved, about 36% if it compares with a classic design with Pelton wheels and 15% if it compares with the classic design of pressure exchangers (see Fig. 11).

This new design has got an international patent by the number of publication ES200902348 "SWRO Plant with energy recovery system and his procedure"

3. Resume of results

In the following table, we show a summary of the most significant information obtained in every one of the designs installed during the life of the SWRO Plant of Las Palmas III (see Tables 1 and 2; Graphics 1 and 2).

4. Conclusions

In the conclusions summary, we list the most significant information regarding every one of the designs installed during the life of the SWRO Plant of Las Palmas III.

- SWRO Plant of Las Palmas III is one of the most important benchmark regarding historical facilities on a worldwide scale, due to the number of years it had been in operation.
- The innovation and the technical advances in SWRO Plant of Las Palmas III have been directed to reduce the operation and maintenance cost, mainly in the energy and chemical consumption.
- SWRO Plant of Las Palmas III has proved its technical and economic feasibility with technical developments and new technical advances that reduce the energy consumption from values of 6.67 kW-h/m^3 in 1996 to values of 4.1 kW-h/m^3 actually. This translates into an annual reduction of 35.400 tons of CO2 less emitted into the atmosphere.
- This energy reduction has helped to cushion the important rise in the cost of energy and thereby the influence in the cost of producing desalinated water.
- The improvements in the membrane process were strengthened by the incorporation of new recovery system. The quality of the product was improved in small part thanks to the changes in the piping system (hydraulic system), but mainly with use of more efficiency membranes existing in the RO market.