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Experimental analysis and techno-economic study of once through long tube MSF desalination plants

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ABSTRACT

Recently, a high temperature (HT) once through long tube (OT-LT) MSF has been considered for a large scale thermal desalination plant with high energy efficiency (i.e., high performance ratio (PR)). This study has been conducted as a 4-year collaboration project between Saline Water Conversion Corporation (SWCC) and Doosan Heavy Industries & Construction which was started in June 2012 and scheduled to be finished by June 2016. In this study, a HT OT-LT MSF pilot plant was designed with 20 stages and built in SWCC-Desalination Technology Research Institute (DTRI), Jubail, KSA. The OT-LT MSF pilot plant was operated to optimize dosing rate of newly developed antiscalant at the top brine temperature (TBT) of 130°C and to evaluate the viability of HT OT-LT MSF technology from scale and corrosion issue. As a result of the first optimization experiments, the dosing rate of new antiscalant was optimized based on visual inspection, chemical analysis, and heat transfer measurement. Also, one month operation has been carried out to validate the stable operation of HT OT-LT MSF without scale formation, which shows a stable and successful operation with the optimized dosing rate. Also, a techno-economic analysis was conducted to evaluate levelized cost of water (LCOW) of high capacity HT OT-LT MSF using a detailed thermal and economic model. It reveals that the HT OT-LT MSF has significant improvement in HTC and reduction in CAPEX, and OPEX, leading to LCOW saving of 16% compared with Brine Recycle Cross Tube (BR-CT) MSF. Furthermore, a long term corrosion test for five months has been carried out in the absence of a deaerator as an on-going research, which is expected that corrosion risk can be verified at high temperature operation (130°C) and adequate selection of corrosion resistive materials can be available. Accordingly, HT OT-LT MSF can be considered as a competitive future large capacity and high energy efficiency desalination plant.

Keywords: Desalination; Once through long tube (OT-LT) MSF; High TBT; Scaling; Corrosion; Techno-economic analysis; Levelized cost of water (LCOW)

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1. Introduction

The main thermal desalination systems employed in Gulf Cooperation Council (GCC) countries are multi-stage flashing (MSF), multi-effect distillation (MED), and MED with thermal vapor compression (TVC) desalination processes. Thermal desalination processes have 56% of the GCC market share [1]. Although the current market share is dominated by the seawater reverse osmosis (SWRO) process due to relatively lower levelized cost of water (LCOW), thermal desalination processes such as MSF and MED have been still required in the view of reliable operation regardless of feed water quality (i.e., high turbidity, and algae blooming) and operation and maintenance (O&M) experiences in GCC countries.

MSF desalination plant was initiated with a once through long tube (OT-LT) MSF type in which its tubes are aligned in the same direction as the brine flow, contrary to a brine recycle cross tube (BR-CT) MSF type in which the tubes are arranged perpendicular to the brine flow [2]. The main two reasons behind this shift from OT-LT MSF to BR-CT MSF as a conventional technology were (1) high amount of consumption of a costly antiscalant, (2) non-availability of cheaper corrosion resistant materials for preventing shell side from corrosion effects of CO_2 and O_2 in the brine, which consequentially needs an additional deaerator for separating corrosive gases from seawater feed. Even though BR-CT MSF has a limitation of the capacity less than 20 MIGD (90,921 m^3/d) due to restriction of chamber load, bundle size, tube length, and available sheet size in the market, it has been widely used as a conventional mature technology due to above two reasons.

However, there is an economy of unit size moving toward the large unit size, and recently reached the maximum possible unit size of 20 MIGD in BR-CT MSF technology. In order to overcome this limit of the unit size, the OT-LT MSF can be considered as a competitive technology to BR-CT MSF under the cost and quality changes of antiscalant chemical and steel material. First of all, recently, corrosion resistant materials are available in the market at a reasonable cost. Secondly, several tests for antiscalant dosing rate optimization have been conducted by Saline Water Conversion Cooperation (SWCC) and have been led to successful operation at a low antiscalant dosing rates. In 1981, antiscalant dosing rates of 9 and 3 ppm for top brine temperature (TBT) of 110 and 90°C, respectively, are initially recommended by SWCC. But, as shown in Fig. 1, those are currently reduced to only 1 and 0.8 ppm for the respective temperatures as an optimal dosing rate [3]. Also, its unit cost has been significantly reduced [2,4].

Contrary to the BR-CT MSF, the OT-LT MSF configuration can be considered as a large scale thermal desalination plant more than 20 MIGD, which has long tube arrangement and lower concentration at all stages. The following features will be achieved in OT-LT MSF [5]: (1) A higher TBT operation leading to smaller heat transfer area and lower power consumption; (2) Lower boiling point elevation losses due to less water salinity, which improves performance and reduces heat transfer area; (3) Less fouling potential of calcium sulfate scale because of lower concentration factor of OT plant operation [6]; (4) Reduction in the number of pumps and specially elimination of the large brine recycle pump in BR-CT MSF; (5) Elimination of heat rejection section with its control system and the water boxes on both sides of the flashing chamber; (6) Easy operation and start up control.

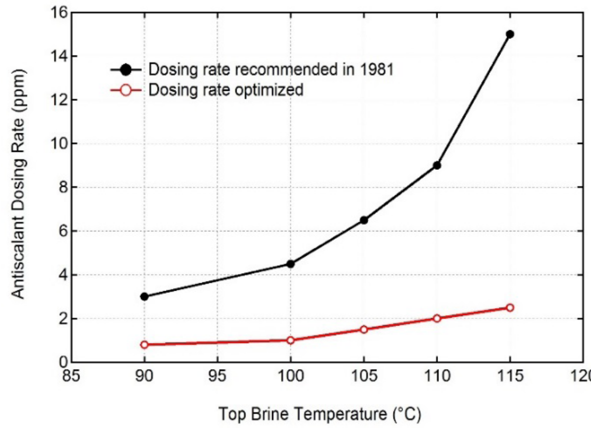


Fig. 1. Optimized dosing rate of antiscalant for different TBT [3]..

Hilal et al. and Tusel et al. surveyed several OT-LT MSF evaporators and proposed the future design of super large MSF plants [2,7]. It is found that long tube arrangement is a viable alternative to cross tube type at the condition of higher capacity than 9,500 ton/d and more than performance ratio (PR) of 6 [8]. The OT-LT MSF design is characterized by its simplicity over the conventional BR-CT MSF design. Also, it is experimentally and theoretically verified that the increase of TBT from 112°C to 130°C can be possible by reducing brine recirculation salinity from 60,000 ppm to 45,000 ppm using a tubular heat exchanger test and scale formation model, respectively [9,10].

This study has been conducted as a collaboration project between Saline Water Conversion Corporation (SWCC) and Doosan Heavy Industries & Construction which was started in June 2012 and scheduled to be finished by June 2016. In this study, the several experiments were conducted using OT-LT MSF pilot plant and techno-economic analysis was carried out using a detailed thermal and economic model.

The objectives of this study are (1) to assess the efficiency of a newly developed antiscalant and optimize its dosing rate of HT OT-LT MSF at TBT of 130°C, (2) to validate the stable operation of HT OT-LT MSF without scale formation and corrosion risk in the absence of a deaerator, and finally, (3) to evaluate the LCOW of high capacity HT OT-LT MSF compared with conventional BR-CT MSF.

2. Materials and methods

2.1. OT-LT MSF pilot plant description

The OT-LT MSF pilot plant with 20 stages was designed and built in SWCC-Desalination Technology Research Institute (DTRI), Jubail, KSA. A schematic diagram and photo of the pilot plant are shown in Figs. 2 and 3, respec-

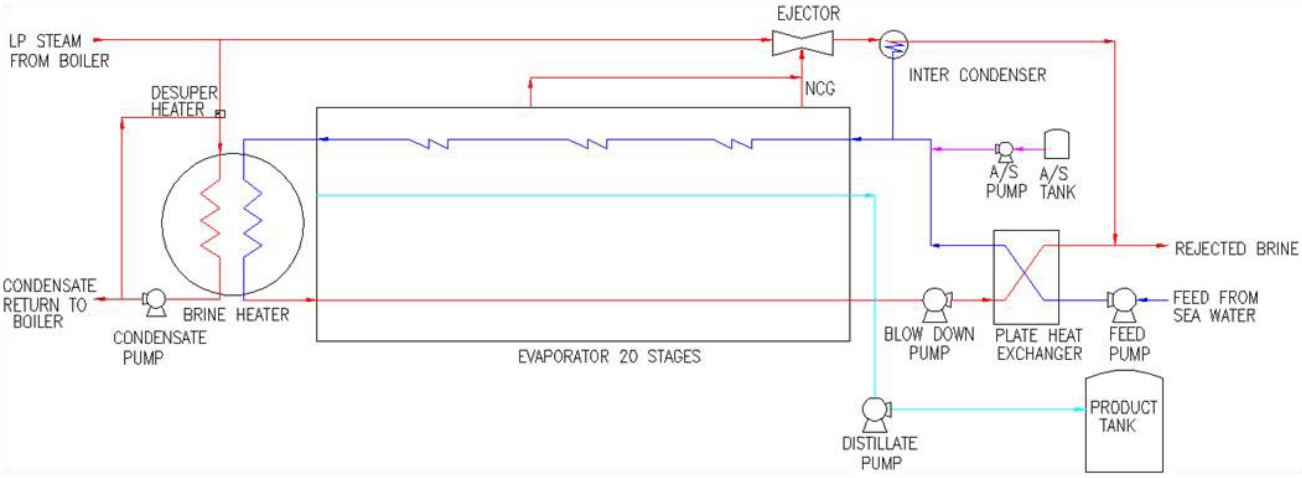


Fig. 2. Schematic diagram of OT-LT MSF pilot plant.

Fig. 3. OT-LT MSF pilot plant in SWCC-DTRI, Jubail, KSA.

Table 1
Specification of OT-LT MSF pilot plant

Configuration	Once through long tube (OT-LT MSF)
Feed seawater flow, ton/h	10
Capacity, ton/h	1
TBT, °C	130
Number of stages	20
Shell Material	UNS31803
Tubes material	Titanium ASTM B338 Gr 2
Scale treatment	Antiscale treatment + sponge cleaning ball
Main equipment	Brine heater, Evaporator, Inter condenser, Antiscalant dosing system, Automatic ball cleaning system, Plate type heat exchanger, Pumps

tively. Also, Table 1 shows the specification of the OT-LT MSF pilot plant. The distillate production of this pilot is 1 ton/hr with feed seawater flow of 10 ton/h. The materials for shell and tube are UNS31803 and Titanium ASTM B338 Gr 2, respectively. Antiscalant dosing and sponge ball cleaning are applied to prevent its tubes from scale formation. The pilot plant consists of two basic sections, a heat addition section of brine heater and a heat recovery section which includes condenser tubes, distillate collection trays, and flashing chamber. In the OT-LT MSF, the seawater is heated up by rejected brine passing through plate heat exchanger. Then it enters condenser tube (i.e., top side of evaporator) to condense the vapor and gain heat. Finally the heated seawater enters brine heater to reach TBT of 130°C, and is sent to evaporator flashing chamber. The distillate is produced by brine flashing in each stage. The evaporator stages are equipped with non-condensable gases (NCG) vents.

2.2. Experimental methods

In order to optimize antiscalant dosing rate, OT-LT MSF pilot plant was operated at TBT 130°C and seawater salinity of 43,750 ppm while antiscalant dosing rate was gradually reduced from 4.5 ppm to 1.5 ppm (i.e., 6 experimental cases – 1.5, 2, 2.5, 3, 3.5, 4.5 ppm). Each experiment was followed by (1) visual inspection of scale deposition on the tubes in brine heater and evaporator; (2) scale analysis of tubes and coupons samples located after brine heater (with and without cleaning ball); (3) thermal performance calculation. The duration of each step is approximately 10 d. After establishing the optimum antiscalant dosing rate, one month operation was carried out to confirm the effectiveness and the credibility of the optimized antiscalant dosing rate in controlling scale formation.

Performance of OT-LT MSF pilot plant can directly be related to the condition of heat transfer surfaces. Scale deposition on these surfaces degrades the performance and increases the heat transfer resistance.

Thermal Performance Calculation: Scale measurements can be determined by measuring four parameters:

temperature, pressure, salinity, and flow rate. Data acquisition and control are performed using a SCADA control unit. The control program for the SCADA is run from a local PC. The measured parameters are recorded at the interval of 10 s, which are used to calculate heat transfer coefficient (HTC), fouling factor (FF), and plant performance factors such as gain output ratio (GOR) and performance ratio (PR).

Gained output ratio (GOR) typically defined as the number of kilograms of distilled water produced per kilogram of steam consumed i.e.

$$GOR = \frac{\dot{m}_{product\ water}}{\dot{m}_{steam}}$$

Performance ratio (PR) is a closely related measurement, but slightly more technically defined.

$$PR = \frac{\dot{m}_{product\ water}}{\dot{m}_{steam}} \times \frac{2326kJ}{Latent\ heat\ steam}$$

Visual inspection: Visual inspection enables to give an easy and clear inspection about the condition of heat transfer surfaces. Inspection was performed at the end of each step with the reduced dosing rate in order to evaluate the performance of antiscalant.

Scale analysis: The scale is analyzed by means of X-ray fluorescence (XRF) in order to identify and quantify chemical elements in the scale samples. After each test, tube and coupon samples were detached from test section and scale deposits on their surfaces were collected and used for chemical analysis. The characteristics of these samples are given in Table 2.

2.3. Techno-economic analysis

A detailed techno-economic model is adapted to investigate thermal performance, design of a 25 MIGD (113,652 m^3/d), and LCOW of the unit by calculating process stream characteristics (mass, temperature, and pressure), the heat transfer surface area (number of tubes), evaporator size, internal dimensions, and rated cost.

3. Results

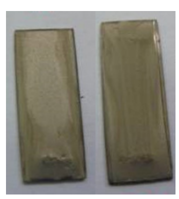
3.1. Optimization of new antiscalant dosing rate

The experiment for optimization of antiscalant dosing rate was started at a dosing rate of 4.5 ppm based on previous results obtained by Amr et al. [9] followed by stepwise reduction of 0.5 ppm to reach 1.5 ppm dosing rate. The evaluation of optimized dosing rate was based on the thermal calculation results, chemical analysis and visual inspections at the end of each step. The main experimental results are summarized in Table 3. As a result of thermal evaluation of antiscalant at a dosing rate varying from 4.5 to 2 ppm, it is shown that HTCs of both evaporator and brine heater sections were consistent. Also, the results of visual inspection and chemical analysis revealed no scale in these cases, which is confirming thermal calculations results. However, in the case of 1.5 ppm, it is shown that the trend of HTCs of both evaporator and brine heater sections was gradually decreasing with time. Reduction in HTC was calculated to be 24% and 12% for brine heater and evaporator, respectively. Similarly to the result of HTC, visual inspection and scale analysis also showed the presence of both hard and soft scale in brine heater tubes. Accordingly, antiscalant dosage rate of 2 ppm was selected as an optimum dosing rate and the one month operation was conducted to confirm the reliability of the pilot at the optimized dosing rate.

Table 3
Experimental results of new antiscalant dosing rate optimization

Antiscalant dosing rate (ppm)	Visual inspection	Performance analysis	Chemical analysis
4.5	No scale	No scale	No scale
3.5	No scale	No scale	No scale
3	No scale	No scale	No scale
2.5	No scale	No scale	No scale
2 (Optimal)	No scale	No scale	No scale
1.5	Scale in brine heater and evaporator	Presence of scale in brine heater and evaporator	Traces of scale

Table 2
Tube/coupon sample characteristics for scale analysis

Samples	Dimension	Photo	Purpose
Tube samples With sponge cleaning ball Tube samples Without sponge ball	Material: Ti Length = 40 cm OD = 16 mm Thick = 0.5 mm		Visual inspection Scale analysis
Coupon samples With sponge cleaning ball Coupon samples Without sponge cleaning ball	Material: Ti Length = 5 cm Width = 1 cm Thick = 1.5 mm		Visual inspection Scale analysis

3.2. One month operation with the optimized antiscalant dosing rate

3.2.1. Thermal performance

The thermal performance of the pilot plant was evaluated by calculating HTC, FF, GOR, and PR. Fig. 4 shows (a) the variation of seawater flow rate, distillate flow rate, blowdown flow rate, and steam mass flow rate; (b) GOR and PR; (c) TBT, brine heater inlet temperature, evaporator inlet temperature, and flash range according to time at optimized antiscalant dosing rate of 2 ppm. The operating conditions such as seawater flow rate, steam mass flow rate, and TBT were stable, leading to reliable performance of distillate flow rate, PR, GOR during one month operation without significant variation.

Figs. 5 and 6 show the variation of thermal performance such as normalized FF and HTC in both the first module of evaporator and brine heater according to time, respectively. In Fig. 5, the normalized FF was maintained below the normalized design value of 1 during the entire operation period in the first module of evaporator (Fig. 5a). Also, the actual normalized HTC value is higher than the normalized design value, which indicates the scale control performance at dosing rate of 2 ppm for one month (Fig. 5b). In the brine heater, it is shown that the normalized FF value is less than 1 and the normalized HTC value is higher than 1 and they are maintained constant during the same period in Fig. 6. It is obvious to note that the fluctuation in normalized FF and HTC during the period ranged from 150 to 320 h due to interruption of cleaning ball. After insertion of new balls in the system, normalized FF and HTC values started to be recovered from 320 h to the initial conditions as shown in Fig. 6.

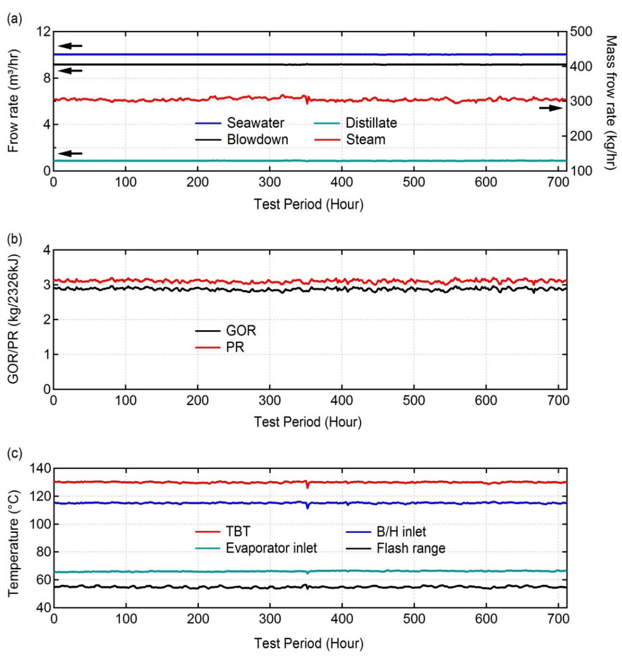


Fig. 4. Variations of (a) seawater, distillate, blowdown, and steam mass flow rate; (b) GOR and PR; (c) TBT, brine heater inlet temperature, evaporator inlet temperature, and flash range at antiscalant dosing rate of 2 ppm for one month.

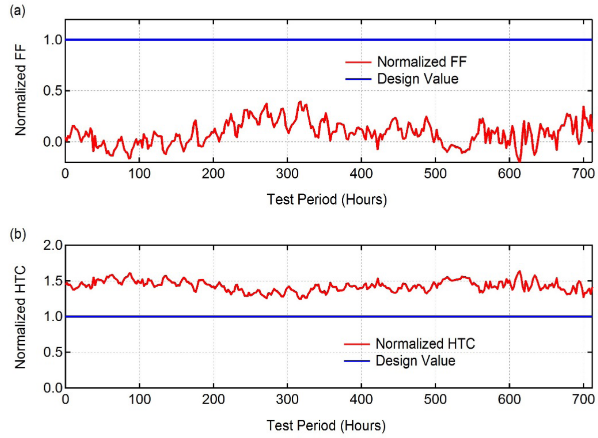


Fig. 5. Variations of (a) normalized FF and (b) normalized HTC of the first module of evaporator at antiscalant dosing rate of 2 ppm for one month.

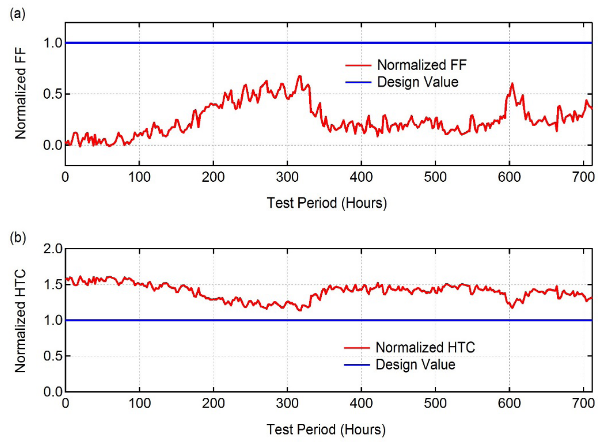


Fig. 6. Variation of (a) normalized FF and (b) normalized HTC of the brine heater at antiscalant dosing rate of 2 ppm for one month.

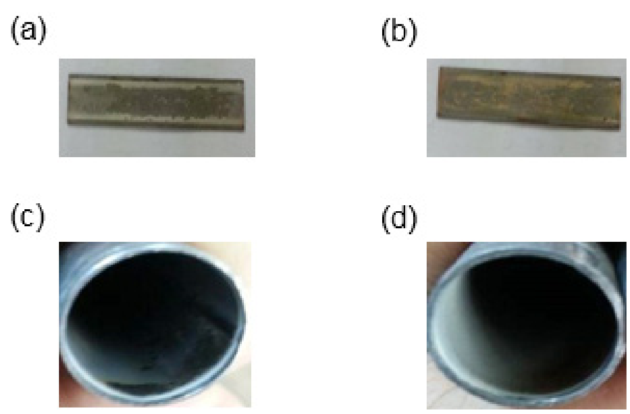


Fig. 7. Visual inspection after one month operation: coupon samples (a) with and (b) without cleaning ball, and tube samples (c) with and (d) without cleaning ball.

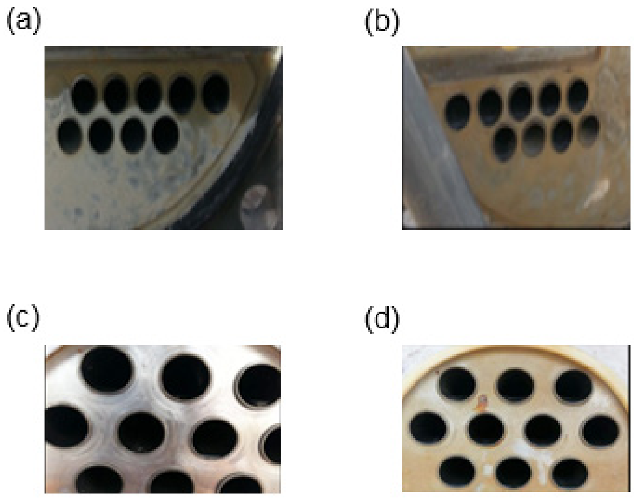


Fig. 8. Visual inspection after one month operation: tubes end of brine heater (a) before and (b) after one month; Tubes end of evaporator (c) before and (d) after one month.

3.2.2. Visual inspection

As shown in Figs. 7 and 8, visual inspection after one month operation at the dosing rate of 2 ppm was carried out. Although it was found that a thin layer of soft scale (amorphous form) was deposited on the surface of the tube and coupons (Fig. 7), it was easily removed by cleaning balls. Also, Fig. 8 shows a thin layer of soft scale covered the tube ends of brine heater and evaporator after one month operation.

Based on overall HTC and FF calculation as well as visual inspection for one month operation, it was proved that a dosing rate of 2 ppm was acceptable for a reliable operation with TBT of 130°C. Based on the results up to now, five months operation has been carrying out to verify the above scale investigation results as well as corrosion risk of HT OT-LT MSF in the absence of a deaerator as an on-going test.

3.3. Techno-economic analysis

A detailed techno-economic model is adapted to investigate thermal performance, design, and LCOW of a 25 MIGD OT-LT MSF unit. Numerical computations have been carried out using an in-house Microsoft Excel Visual Basic application using matrix technique to determine all process stream characteristics (mass, temperature, salinity), the heat transfer area (number of tubes), dimensions, and rated cost. The thermo-physical properties of steam and seawater were evaluated as a function of salinity and/or temperature [11]. The developed program includes all thermal losses as well as HTC.

In order to perform techno-economic analysis, three configurations were considered at the same total capacity of 100 MIGD (454,608 m^3/d) as shown in Table 4. As a reference of conventional system, the BR-CT MSF (PR 9.1) consists of 5 unit evaporators of which capacity is 20 MIGD. In the case of OT-LT MSF (TBT 130°C) with 4 unit evaporators of which capacity is 25 MIGD, two configurations were considered such as (1) Case 1 of 28 stages with relatively low specific area and similar PR 9.7 with BR-CT MSF; (2) Case 2 of 48 stages with relatively higher specific area and PR 13.5.

Table 4
Techno-economic analysis of OT-LT MSF comparing to conventional BR-CT MSF

Description	BR-CT MSF	OT-LT MSF	
	Reference	Case 1	Case 2
Performance ratio (PR) (kg/2326 kJ)	9.1	9.7	13.5
Total capacity (Unit capacity × No of units)	100MIGD (20 × 5)	100MIGD (25 × 4)	100MIGD (25 × 4)
Stages	23	28	48
Tube diameter (mm)	50	15.88	19.05
Stage tube length (m)	25	4.2	5
TBT (°C)	112	130	130
Concentration factor	1.4	1	1
Specific HTA	100%	52%	72%
Layout	Single deck	Double deck	Double deck
Footprint for evaporator area	100%	36%	60%
Evaporator cost	100%	45%	73%
Capital cost	100%	77%	85%
Power consumption	100%	77%	89%
Steam consumption	100%	94%	70%
Chemical consumption	100%	197%	197%
LCOW	100%	87%	84%

The heat transfer area (HTA) of OT-LT MSF evaporator decreased relative to a conventional BR-CT MSF evaporator. Compared with the reference case, heat transfer area is reduced by 48% and 28% whereas PR is increased by 7% and 48% for Case 1 and 2, respectively. This is mainly due to the enhancement of both the heat transfer coefficient (HTC) and the increase in the logarithmic mean temperature difference (LMTD). The HTC is enhanced due to significant reduction in the tube diameter 68% and 62% for Case 1 and 2 respectively. The LMTD increases due to the TBT change from 112 to 130°C (16%) as well as reduction in boiling point elevation losses, caused by salinity reduction in case of OT (30%) [2,11].

Multi bundle design per stage were proposed for OT-LT MSF configuration to ensure better vapor distribution and hence less vapor velocity. Consequently, the number of tube rows is reduced which leads to improving vapor condensation phenomena and avoiding the flooding effect [12]. The total tube lengths are reduced from 575 m (reference case) to 118 m for Case 1 and 240 m for Case 2, respectively, resulting in lower power consumptions which are estimated to 23% for Case 1 and 11% for Case 2, respectively. The total stage width for OT-LT MSF is 20.6 m to keep the chamber load in a practical acceptable range (1,550 ton/hr/m) [13–15]. The stage lengths are 4.2 m for Case 1 and 5 m for Case 2.

The stage heights were reduced by 45% for Case 1 and 35% for Case 2, compared to the reference case [13], because both HTA and tube diameter significantly decrease leading to reduction of bundle size. This reduction enables to select a double deck arrangement for proposed OT-LT MSF configuration. This double deck arrangement gives a significant footprint saving estimated to 64% and 40% for Case 1 and Case 2, respectively.

Using updated material prices for tube and shell of evaporator, the cost of evaporator for OT-LT MSF configuration are 55% (Case 1) and 27% (Case 2) lower than that of BR-CT MSF. This is due to the reduction of the tube weight, shell height, and elimination of one evaporator unit. The total CAPEX for OT-LT MSF are 23% (Case 1) and 15% (Case 2) lower than that of the BR-CT MSF. The OT-LT MSF steam consumptions are less 6% (Case 1) and 30% (Case 2) compared to BR-CT MSF.

The economic study was conducted based on oil price of 24 USD/barrel, 30 year life time, a discount rate of 5%, and electricity cost of 0.04 USD/kWh for the reference and two Cases. Since CAPEX and OPEX (steam, power, chemical and O&M cost) of OT-LT MSF are lower than those of BR-CT MSF, the LCOW of OT-LT MSF is also lower than that of BR-CT MSF. As it is shown in Fig. 9, a reduction in LCOW of OT-LT MSF is estimated to 13% (Case 1) and 16% (Case 2) compared to conventional BR-CT MSF. Based on this techno-economic study, it is obvious that OT-LT MSF is a viable and cost effective solution for large capacity thermal plants.

4. Challenges and discussions

4.1. Corrosion risk

It is generally known that the increase of TBT influences on the increase of the potential of material corrosion. In this research, in order to investigate the effect of high TBT (130°C) on material corrosion, five month corrosion test with 960 coupons of different type of material compositions which are installed in vapor and brine sides has been carried out in the absence of a deaerator. It can demonstrate whether HT OT-LT MSF can be successfully operated without any corrosion issue and also ensure adequate selection of corrosion resistive materials.

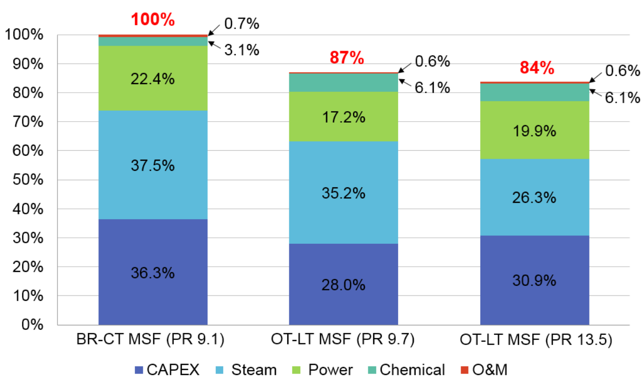


Fig. 9. The LCOW for both OT LT MSF (PR 9.7) and OT-LT MSF (PR 13.5) comparing with BR-CT MSF (PR 9.1).

4.2. Inter-stage tube sealing

Based on theoretical study, vapor inter-stage physical leak between the stages among the stages in case of OT-LT MSF configuration are estimated to be less than 1% of total vapor produced. Moreover, in long tube MSF commercial plant in Jeddah 4, KSA, it has been working properly since commissioned without installation of an inter-stage sealing [16].

4.3. Winter time operation

Differently from BR-CT MSF process, it is difficult to apply cooling water recycle concept during winter season in OT-LT MSF process, because full water is used as make-up and brine blow down in OT-LT MSF process.

Accordingly, a specific volume of the flashing vapor increases during winter season in OT-LT MSF, which would cause increasing the flash chamber size, because bottom brine temperature lowers by 15–20°C during winter season. Therefore, it is necessary to keep within the limitation velocities both a vapor velocity through a demister to prevent entrainment of brine droplets [11] and vapor velocity approaching to tube bundle to minimize a vapor induced tube vibration risk.

In this study, based on heat and mass balance the evaporator size of the last stage (22°C and 0.03 bar) was well designed to satisfy the limitation of demister vapor velocity and tube bundle approach vapor velocity equal to BR-CT MSF process. For bundle design, also, a finite-volume based CFD analysis using Ansys-Fluent15 solver [17], which is quite reliable tool to analyze and validate the unit design numerically was applied to design an adequate bundle design.

5. Conclusion

This study has been conducted as a four-year collaboration project between SWCC and Doosan Heavy Industries & Construction since June 2012. In this study, the improved OT-LT MSF configuration was proposed and discussed based on experimental results including thermal performance calculation, visual inspection, scale analysis and techno-economic analysis comparing with the conventional BR-CT MSF. Through this study, the following conclusions have been made:

- Currently, the high temperature OT-LT MSF configuration with the advantage of high capacity, PR, and lower LCOW needs to be considered under the availability of corrosion resistant materials and effective antiscalants at a reasonable cost.
- The high temperature (TBT 130°C) OT-LT MSF pilot plant was successfully operated for one month without any scale issue. In this operation, newly developed antiscalant was applied as the optimized dosing rate of 2 ppm and was very effective to prevent scale formation based on visual inspection, chemical analysis, and heat transfer measurement.
- Based on the techno-economic evaluation, it is demonstrated that the OT-LT MSF plant has significant improvement in HTC and reduction in CAPEX and

OPEX. Compared with conventional BR-CT MSF plant (PR 9.1) at the same total capacity (100 MIGD), the two Cases of OT-LT MSF plant such as Case 1 (PR 9.7) and Case 2 (PR 13.5) have the following benefits:

- Footprint saving: 64% (Case 1) and 40% (Case 2)
- Evaporator cost reduction: 55% (Case 1) and 27% (Case 2)
- CAPEX reduction: 23% (Case 1) and 15% (Case 2)
- Power consumption reduction: 23% (Case 1) and 11% (Case 2)
- Steam consumption reduction: 6% (Case 1) and 30% (Case 2)
- LCOW saving: 13% (Case 1) and 16% (Case 2)

- HT OT-LT MSF challenges such as corrosion risk, inter-stage tube sealing, and winter time operation were deeply studied individually and have been solved.
- A five month corrosion test has been carried out in the absence of a deaerator as an on-going research. Several kinds of material compositions of 960 coupons are installed in vapor and brine sides. A corrosion risk can be verified at high temperature operation (130°C) and adequate selection of corrosion resistive material can be available.
- Based on this study, a HT OT-LT MSF will be considered as competitive large capacity and high energy efficiency desalination plants.

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