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Performance enhancement of MSF desalination by recovering stage heat from distillate water using internal heat exchanger

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Abstract

The paper presents an attempt to enhance unit performance of an existing 1274 m^3/h Multi Stage Flash (MSF) desalination plant through sensible heat recovery from hot distillate water at the MSF stages to warm up the make-up seawater using internal heat exchange. The extraction of the distillate from stages could increase water production by 2% and reduces steam consumption by 5%. In addition, a reduction of seawater feed flow which also results in a drop of pump power consumption were observed. Environmentally, the modification could decrease CO_2 emissions by 2300 tonnes annually.

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Keywords: MSF Desalination; heating; energy; enhancement.

1. Introduction

Because of population growth, increased urbanization, geographical location and industrialization in Arab cities, desalinated water is considered the main source of water supply in this area [1]. Global Water Intelligence (GWI) showed that between 1994 and 2010 MSF desalination technology is the main producer of desalinated water in Middle East and North Africa (MENA), representing 53% of total cumulative contracted capacity [2].

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MSF desalination is characterized by high capacity, reliability, simple operation, high purity product and less feed water treatment [3]. However, this technology is flawed by scale deposition, high power consumption, high CO_2 emissions (10 kg CO_2/m^3 of water produced) and low exergy efficiency [4, 5].
Despite MSF desalination being one of the oldest desalination technologies (commercialized in the 1960s), limited studies on unit improvement have been found [6]. Fig. 1. describes an MSF evaporator previously investigated [7]. The studied unit was designed to supply 1274 m^3/h distillate water with 8.47 gain output ratio and powered by low pressure steam (2.3 bar A and 124 ºC) extracted from steam turbine of the combined power plant.

It is necessary to emphasise that, as produced distillate moves to the next stage, part of it is re-flashed again at the lower pressure. Therefore, it is mixed with the vapour produced from the stage brine which uses part of the installed heat transfer surface, thus reducing stage vapour condensation rate. Consequently, stage performance degradation may become significant at further stages as the cumulative distillate increases [8, 9]. On the other hand, this distillate will slightly increase brine recirculation temperature in the tubes so that extracting this distillate could raise the MSF unit steam consumption. Sommariva et al [6] found extracting this distillate from the unit at the early stages enhanced unit production due to decrease of stage irreversibility and increase of the flashing range. Moreover, the hot extracted distillate water could be used to raise the temperature of the makeup water after mixing with recirculating brine through the heat exchanger, resulting in reduction of unit steam consumption [6].
In this regard, the invention proposed by Awerbuch and Sommariva (WO 2006/021796) confirmed that extraction of distillate from the last stage of heat recovery to power lower temperature Multi Effect Desalination (MED) could produce additional water from MED with no effect on the original MSF performance ratio [8]. Distillate extraction from the last stage heat recovery section was implemented at Sharjah Layyah MFS desalination unit 9 and played a major role in improving distillate quality with 2% improvement on unit production [10]. Similarly, Helal et al [10] discussed similar capacity enhancement of Umm Al Nar East MSF unit 4-6 through using an Excel Solver model. One suggested modification was extracting hot distillate to avoid further re-flashing of distillate in the heat rejection stages [10]. The study highlighted the necessity of utilizing the enthalpy from the extracted hot distillate to offset the enhancement cost. Partial hot distillate extraction was implemented at Shuwaihat cogeneration plants in Abu Dhabi to warm up brine recycle (just before brine heater inlet). The authors highlighted the simplicity of distillate extraction which was found to cost less than 0.1% of distiller cost [11].
Therefore, this study aims to investigate MSF desalination performance enhancement through recovering the heat from stage distillate water to warm up the make-up stream or brine recycle through Internal Heat (IH) exchanger and the environmental impact resulting from this recovery.

2. Results and discussion

The previous developed model [5] was modified by adding a heat exchanger on make-up stream as highlighted on Fig 1. Fig 2. illustrates the extracted distillate flow and temperature from stage 1 to 8. The internal heat exchanger NTU and effectiveness were kept constant at 1.95 and 0.85, respectively. It was observed as the number of recovered distillate stages increases, the MSF unit production rises due to increases of the flashing range of the heat recovery stages (T_{14}-T_{15}). In contrast, steam consumption reduces as a result of increase of brine heater inlet temperature (T_{13}). Therefore, this heat exchanger could in principle be located downstream of the brine recycle pump, but further investigation is required for this. Both curves (steam consumption and distillate production) start to flatten at stage 8 as can be seen from Fig 3 which indicates it is the optimal stage for distillate extraction in this case, which agrees with results found previously e.g [5], with 2.0 % increase on unit production and 4.9% decrease on steam consumption respectively. Therefore, MSF performance ratio increases linearly from 8.4 at original configuration to 9.1 with extracted distillate from stage 8 powering internal heating.

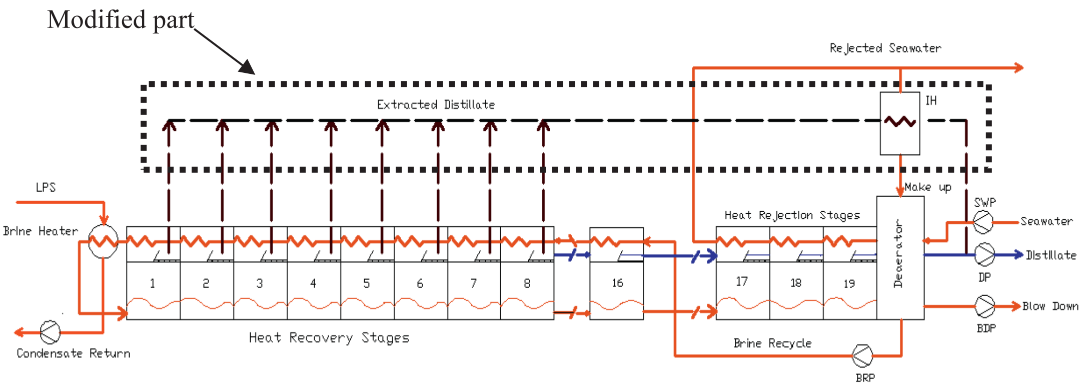

Fig 1: Modified MSF desalination model with internal heat exchanger (highlighted by red colour).

A decrease of seawater cooling water flow was observed as a result of extracting this distillate, which is in agreement with other studies [8, 9]. Thus, seawater feed pump power consumption reduces as shown in Fig 4, With around 7 kW power consumption decrease for every stage of distillate recovered. This decrease was because the heat of the accumulated distillate is normally rejected at the heat rejection stages to the feed seawater, so the distillate extraction reduces the amount of heat released to seawater and consequently seawater flow reduces.

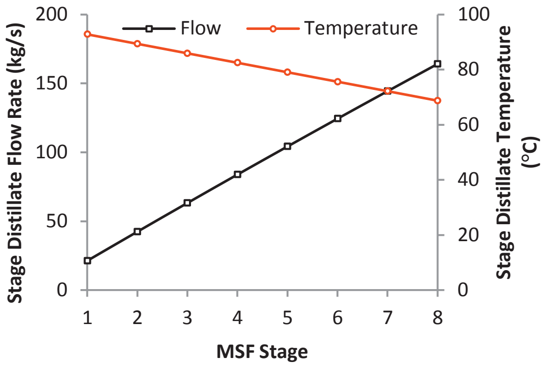

Fig 2: First 8 of 19 MSF stages distillate water temperature and mass flow rate [5]

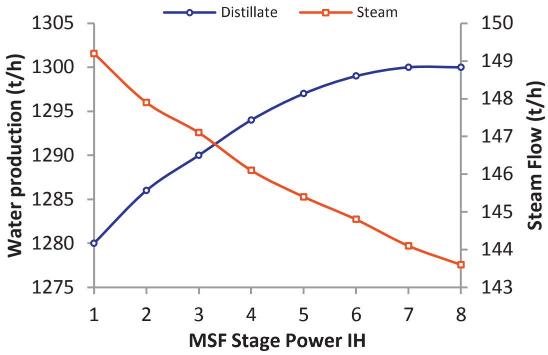

Fig 3: Effect of increasing number of MSF stages powering internal heating on unit production and steam flow.

Environmentally, CO_2 emissions are reduced, resulting from the increase of distillate production which is normally produced by supplying more steam that originally supplied by burning natural gas (Fig 5). It is important to point out that this study covered only the CO_2 saved from additional water produced [4]. However there are more savings that could be realised from steam consumption reduction but the estimation of this depends on the scheme of plant supplying the steam (either traditional boiler or combined cycle).

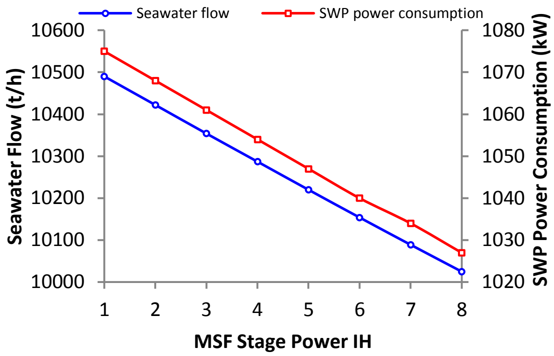

Fig 4: Reduction of seawater flow and seawater pump power consumption as MSF stages powering increases.

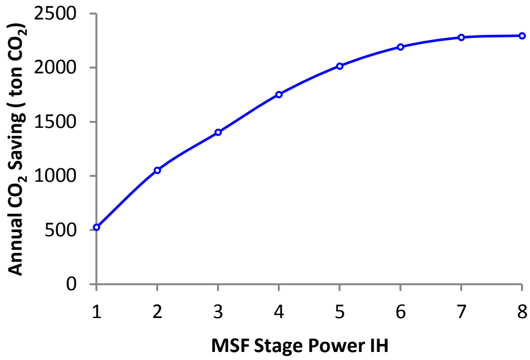

Fig 5: Annual CO_2 reduction resulting from modification.

3. Conclusion

MSF performance can be improved through utilizing MSF stages distillate sensible heat to warm up the make-up water temperature to enhance MSF water production by 2% and reduce steam consumption by 5%. Additional savings in CO_2 emissions (2300 tonnes/year) and unit power consumption were found.

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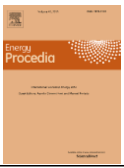

Biography

Dr Tian is a Lecturer at Newcastle University in England. His research interests are alternative fuels for internal combustion engine, free piston engine, innovative engine spray and combustion technologies, engine waste heat recovery and desalination process optimization.