HORIZONTAL TUBE MULTIPLE EFFECT - STACKED DESIGN

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Contents

Summary

The stacked design - though possible in principle for MSF is particularly interesting for ME systems since high gain ratios can be achieved with a lesser number of stages.

The effects are placed on top of each other - the gravity and pressure difference are utilized for the brine transport from effect to effect.

In this contribution all important design parameters such as heat exchanger (tube bundle) geometry, brine distribution, critical wetting rates, and the influence of non-condensables on overall heat transfer are discussed in detail for the most common type - the HT evaporator. Seeding, a special technique of interest in cases where concentrates of RO brackish water desalination units or waste water are to be concentrated by HT ME units, is also discussed.

Details of two plants, the HT MES solar powered plant in Abu Dhabi (VAE) and the Al-ain (VAE) MES pilot unit based on thin sheet welded plate heat exchangers, are presented.

1. Introduction

In "stacked" plants, which were first introduced by Bongard and Muylle (1970) and Takada (1976), the effects are placed vertically on top of each other. In this case, the

gravity and pressure difference between the effects can be utilized for the transport of the brine from effect to effect - only one major pump is necessary for pumping the feed through the feed heat exchanger to the top of the stack (see Figure 1) (Takada 1972; Rautenbach and Arzt 1985a).

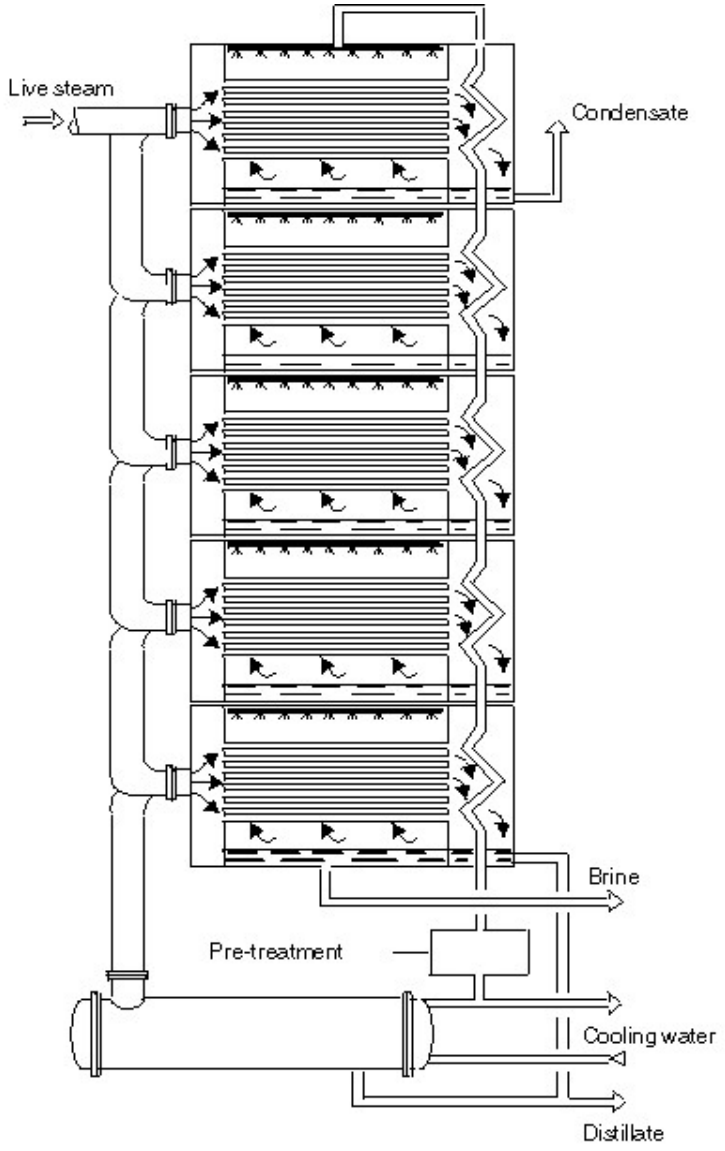

Figure 1. The MES process (Takada 1972; Rautenbach and Arzt 1985a).

There are two important variations in multiple-effect system (MES) design: LTV (long tube vertical) and HT (horizontal tube). In any case, the advantages of MES are as follows.

(a) Even for higher concentration factors, the once-through principle can be realized. As a consequence, concentrated brine will be in contact only with the effects operating at lower temperatures.

(b) A simple mode of operation. Between maximum capacity and zero production, the distillate production is totally controlled by the amount of live steam flowing into the unit.
(c) Almost any combination with vapor compression is possible.
(d) Very high overall heat transfer coefficients can be realized, permitting small temperature differences between the effects at low costs of heat transfer area. This is particularly important for low-temperature waste heat utilization.

Regardless of the choice of MES design, the brine distribution, the brine/vapor phase separation and the venting of the non-condensable gases are of major importance for stacked units consisting of a high number of effects.

It should be mentioned that stacked design is not limited to ME evaporation. There are at least two examples of the stacked multistage flash (MSF) process, a seawater desalination plant at Texel, The Netherlands and a dumpsite leachate treatment plant near Lugano, Switzerland.

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Bibliography and Suggestions for further study

Akili D. Khawaji, Ibrahim K. Kutubkhanah, Jong-Mihn Wie, (2008), *Advances in seawater desalination technologies*, Desalination **221**, Elsevier, pp. 47-69.

Ali Al-Odwani, Essam E.F. El-Sayed, Mohamed Al Tabtabaei, Mohamed Safar, (2006), *Corrosion resistance and performance of copper-nickel and titanium alloys in MSF distillation plants*, Desalination **201**, Elsevier, pp. 46-57.

Anthony D (1989) Evaporate and crystallize. *Chem. Engng* 4, 138-144.

Arzt B (1984) Seawater Desalination by Multiple-effect-stack-evaporation - Process Evaluation and Design Studies. Ph.D. thesis, RWTH, Aachen.

Awerbuch L and Weekes M C (1990) Disposal of concentrates from brackish water desalting plants by means of evaporation technology. *Desalination* 78, 71-76.

Bongard W and Muylle R (1970) Application du procede horizontal tube multiple effect (HTME) et quelques considerations sur le cout de l'Eau. (3rd Int. Symp. on Fresh Water from the Sea, Vol. 1, pp. 235-246.

Bulang W (1982) Diesel engine powered low temperature desalination. *VDI-bericht* 442, 15-23.

Butterworth D (1981) Condensers: basic heat transfer and fluid flow in heat exchangers: thermal-hydraulic fundamentals and design. (ed. S Kakac, A E Bergles, F Mayinger). Hemisphere Publishing Corporation.

Cavalieri L and Nasser G (1983) Seawater desalination with very low energy consumption. *Desalination* 44, 143-151.

Corrado Sommariva ,(2010),COURSES IN DESALINATION, Thermal Desalination

Gainey R J et al. (1963) $CaSO_4$ seeding prevents $CaSO_4$ scale. *Ind. and Eng. Chem.* 55(3), 39-43.

Gebel J (1989) Zum Einsatz von Horizontalrohrverdampfern in Mehrfacheffektanlagen zur Eindampfung wäßriger Lösungen. Ph.D. Thesis, RWTH, Aachen.

Hammond R P et al. (1994) Seawater desalination plant for Southern California. *Desalination* 99, 459-481.

Joachim Gebel, Süleyman Yüce, (2008), *A new approach to meet the growing demand of professional training for the operating and management staff of desalination plants*, Desalination **220**, Elsevier, pp. 150-164.

Lorenz J J and Yung D (1979) A note on combined boiling and evaporation for liquid film on horizontal tubes. *Transactions of the ASME* 101(2).

M.A. Darwish , Iain McGregor, (2005), *Five days' Intensive Course on - Thermal Desalination Processes Fundamentals and Practice*, MEDRC & Water Research Center Sultan Qaboos University, Oman

M.A. Darwish, Ammar Alsairafi, (2004), *Technical comparison between TVC/MED and MSF*, Desalination **170**, Elsevier, pp. 223-239.

M.A. Darwish, Hassan K. Abdulrahim, (2008), *Feed water arrangements in a multi-effect desalting system*, Desalination **228**, Elsevier, pp. 30-54.

M.A. Darwish, N. Al-Najem, N. Lior, (2006), *Towards Sustainable Energy in Seawater Desalting in the Gulf Area*, Tenth International Water Technology Conference, Alexandria, Egypt, pp. 655-684.

M.A. Darwish, S. Alotaibi, S. Alfahad, (2008), *On the reduction energy and its cost in Kuwait*, Desalination **220**, Elsevier, pp. 483-495.

Mohamed A. Dawoud, (2005), *The role of desalination in augmentation of water supply in GCC countries*, Desalination **186**, Elsevier, pp. 187-198.

Mohamed Al-bahou, Zamzam Al-Rakaf, Hassan Zaki, Hisham Ettouney, (2007), *Desalination experience in Kuwait*, Desalination **204**, Elsevier, pp. 403-415.

Nabil M. Abdel-Jabbar, Hazim Mohameed Qiblawey, Farouq S. Mjalli, Hisham Ettouney, (2007), *Simulation of large capacity MSF brine circulation plants*, Desalination **204**, Elsevier, pp. 501-514.

Rautenbach R and Arzt B (1983) Waste heat utilization of large diesel engines by thermocompression and low temperature multiple effect evaporation. *Desalination* 44, 121-128.

Rautenbach R and Arzt B (1985a) Gas turbine waste heat utilization for distillation. *Desalination* 52, 105-122.

Rautenbach R and Arzt B (1985b) The development of high-performance distillation plants. *Desalination* 56, 261-275.

Rautenbach R and Gebel J (1987) Studies on the behaviour of high performance multiple effect stack processes. *Desalination* 65, 75-85.

Rautenbach R and Gebel J (1989) On the concentration of RO-brines by seeded horizontal tube falling film evaporation (HTFE). *Desalination* 76, 107-119.

Rautenbach R and Widua J (1995) Application of seeding to horizontal-tube film evaporators as scale prevention method. *IDA World Congress on Desalination and Water Sciences* (Proceedings of the IDA World Congress, Abu Dhabi, 1995), Vol. 3, pp. 559-574. Abu Dhabi: Abu Dhabi Printing and Publishing Co.

Roberton Borsani, Silvio Rebagliati (2005), *Fundamentals and costing of MSF desalination plants and comparison with other technologies*, Desalination **182**, Elsevier, pp. 29-37.

Standiford F C and Sinek J L (1961) Stop scale in seawater evaporators. *Chem. Eng. Progress* 57(1), 58.

Takada M (1976) Multi effect stack type distilling plant. (Proceedings of the Fifth International Symposium on Fresh Water from the Sea), Vol. 2, pp. 325-333.

Takada M and Drake J C (1983) Application of improvement high-performance evaporator. *Desalination* 45, 3-12.

Tusel G F, Rautenbach R and Widua J (1994) Seawater desalination plant, Sirte, - an example of an advanced MSF design. *Desalination* 96, 379-396.

Wassner L (1985) Eindampfung von Gemischen und Lösungen in einem Fallfilmapparat. *Chem. Ing. Tech.* 57, 11.

Water and Electricity Department WED Abu Dhabi, UAE (1986) Research and Development on Solar Energy Desalination Project Final Report.

Widua J (1995) Application of Seeding to Horizontal-tube Film Evaporators as Scale Prevention Method. Düsseldorf Fortschritt Dericht 410 REIHE 3 VDI Verlag, Germany.

Y.M. El-Sayed, (2001), *Designing desalination systems for higher productivity*, Desalination **134**, Elsevier, pp. 129-158