2.500 Desalination and Water Purification

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING

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Homework Set #4
Due 30 April 2009

Problem 1: Least heat of separation

Consider a separation system that receives heat $\dot{Q}$ from a source at temperature T_H. The system has a stream of saline feedwater entering at temperature T_0, and it rejects a stream of brine and a stream of freshwater, each at T_0. There is no work transfer over the system boundary.

Determine the least heat required to separate the freshwater from the feed. How does ths compare to the result obtained in lecture?

Problem 2: Matched system for power and water production

In lecture, we calculated the added heat required, $\dot{Q}_{\text{add}}$, for a combined power and water production system that generated power $\dot{W}_{\text{net}}$ and water $\dot{m}_d$. We also discussed, but did not calculate, the production ratio, PR $= \dot{W}_{\text{net}}/\dot{m}_d$. When the heat leaving the heat engine matches exactly the heat required for distillation, $\dot{Q}_d$, the production ratio is said to be *matched*, with a value PR* ($\dot{Q}_j = \dot{Q}_2 = 0$).

A. For the distillation section, the gained output ratio (GOR) is

$$\text{GOR} = \frac{\dot{m}_d h_{fg}}{\dot{Q}_d}$$

Determine an expression PR* in terms of GOR, h_{fg}, and temperatures.

B. If $T_H = 1000$ K, $T_s = 373$ K, and GOR = 8, determine the value of PR* in units of MW/mIgd. (Also, feel free to comment on the value of non-SI systems of measurement.)

Problem 3: Once-through Multistage Flash Desalination

A once-through multistage flash desalination plant has the following specifications.

- Feed salinity = 45,000 ppm
- Heating steam temperature = 100°C
- Feed temperature = 25°C
- Production capacity = 1 kg/s
- Brine blowdown temperature = 35°C
- Top brine temperature = 90°C
- Terminal temperature difference in the condenser = 3°C

- Number of stages, N = 30
- Boiling point elevation (taken as constant & including other losses) = 2.0°C

Determine the gained output ratio and the feed mass flow rate (in both kg/s and m^3/day).

Problem 3 is adapted from problem 6.2 in El-Dessouky, H. T., and H. M. Ettouney. *Fundamentals of Salt Water Desalination*. New York, NY: Elsevier, 2002.