22.313J, 2.59J, 10.536J THERMAL-HYDRAULICS IN POWER TECHNOLOGY

Homework Set 3

Steam Separation in a PWR U-tube Steam Generators

The schematic of a PWR U-tube Steam Generator (SG) is shown in Figure 1. Saturated steam at 5.7 MPa and 11% quality is generated in the U-tube bundle region. The majority of the liquid is removed in the steam separator. The residual liquid is removed in the steam dryer. The steam flow rate to the turbine is 456 kg/s. The properties of steam and water at 5.7 MPa are reported in Table 1.

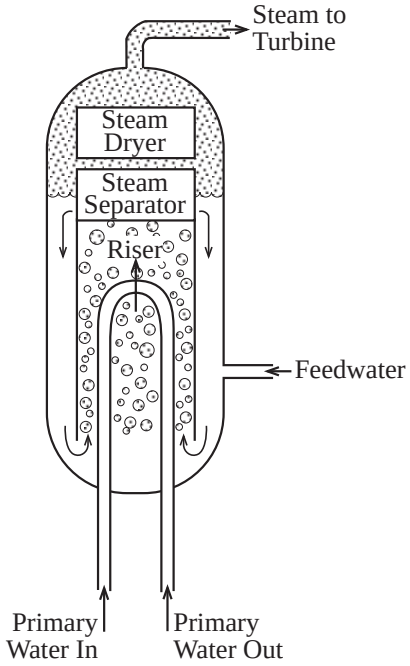

Figure 1. U-tube Steam Generator

Steam Separator

You are to consider a steam separator design based on gravity separation.

i) Calculate the minimum height of the region above the free liquid surface that minimizes carryover. (Hint: the riser has a flow area of 7.07 m^2, and is partitioned, so that its equivalent diameter is 0.2 m)

ii) Calculate the separation efficiency of the gravity separator. (Hint: ignore the effect of steam carryunder)

iii) Estimate the maximum diameter of the entrained droplets. (Hint: use a value of 22 for the critical Weber number)

iv) Gravity separators are not actually used in PWR steam generators. Cyclone separators are used instead. Why?

Steam Dryer

Now consider a steam dryer design of the chevron type. The height of the chevrons is 1 m, the spacing is 15 mm, wave amplitude is 12.5 mm, the wavelength is 50 mm and the length is 100 mm (= 2 wavelengths).

v) Calculate the minimum number of chevrons required to obtain a 20% margin to liquid re-entrainment in the dryer. (Hint: use Figure 2 to calculate the breakthrough velocity for the dryer)

vi) Calculate the separation efficiency of the dryer, assuming a flat distribution for the diameter of the entrained droplets.

vii) Repeat 'vi' for chevrons of same height, spacing and wave amplitude, but 86 mm wavelength and 172 mm length (= 2 wavelengths). Which design would you choose?

Table 1. Properties of saturated water at 5.7 MPa.

Parameter	Value
ρ_f	764 kg/m^3
ρ_g	29 kg/m^3
h_f	1,196 kJ/kg
h_g	2,788 kJ/kg
$C_{p,f}$	5.2 kJ/(kg°C)
$C_{p,g}$	4.7 kJ/(kg°C)
μ_f	1.0×10^{-4} Pa·s
μ_g	1.8×10^{-5} Pa·s
k_f	0.59 W/(m°C)
k_g	0.06 W/(m°C)
σ	0.021 N/m

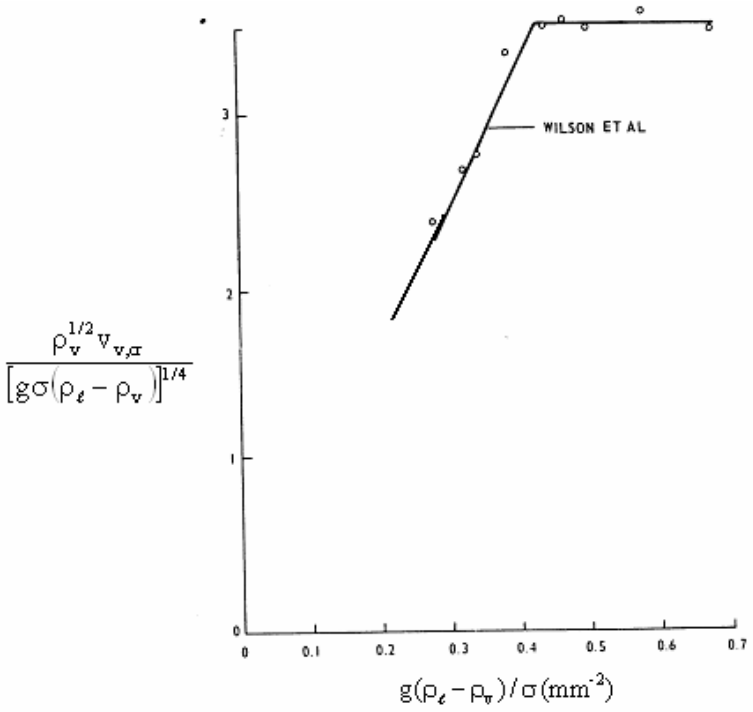

Figure 2. Breakthrough velocity in chevron separators.