22.313 THERMAL-HYDRAULICS IN NUCLEAR POWER TECHNOLOGY

Tuesday, March 29th, 2005, 1:00 – 2:30 p.m.

OPEN BOOK MID-TERM QUIZ 1.5 HOURS

Problem 1 (20%) – Calculation of Flow Quality from Void Fraction Measurements

By means of X-ray imaging techniques an MIT graduate student is able to measure the void fraction in the downcomer of an experimental apparatus designed to study steam carryunder at 7.0 MPa. This student has taken course 22.313, so she is also able to calculate the relative velocity, $v_b=v_\ell-v_v$, from a Re-Eo-M diagram for bubbly flow. Does the student miss any information needed to calculate the flow quality in the dowcomer? (*Note:* in answering this question, do not assume that a carryunder correlation is available)

If so, what information is missing?

If not, write a set of equations that would allow the student to calculate the flow quality given only the void fraction, the relative velocity and, of course, the properties of steam and water at 7.0 MPa.

Problem 2 (30%) – Pressure Drop in Accelerating Single-Phase Flow

Consider upflow in a vertical section of the PWR primary system piping.

i) Write the time-dependent mass and momentum conservation equations for this system, assuming that the water coolant can be treated as perfectly incompressible. (15%)

ii) Now consider a transient during which the mass flux within the tube increases linearly with time, while the inlet pressure is held constant. Using the momentum equation, demonstrate that the pressure at the outlet decreases during this transient. (15%)

Problem 3 (50%) – Sizing of a Turbulent-Deposition Air/Water Separator

An engineering company is designing an air-conditioning system for a large building. An important component is the moisture separator that removes small water droplets from the conditioned air. The separator is of the turbulent-deposition type, and consists of a single horizontal tube. The deposited liquid is drained at the tube outlet (Figure 1). The separator processes an air/water mixture with mass flow rate of 0.42 kg/s and flow quality of 95%. The physical properties of water and air at the temperature and pressure of interest are reported in Table 1.

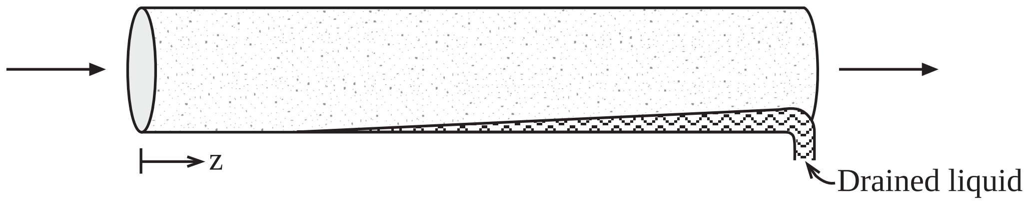

Figure 1. Schematic of the air/water separator.

i) For the effective performance of the separator, it is essential to prevent re-entrainment of the deposited liquid. Using the Ishii-Mishima correlation for the onset of entrainment, calculate the diameter of the separator that guarantees a 30% margin to re-entrainment. (15%)

ii) Using the McCoy-Hanratty correlation for droplet deposition in turbulent flow, calculate the length of the separator required to reduce the moisture content of the air by 50%. (30%)

iii) What is the separation efficiency of the separator? (5%)

Assumptions

- The water droplets move homogeneously with the air.
- The liquid film on the wall is thin.

Simplified versions of the Ishii-Mishima and McCoy-Hanratty correlations are given below for your convenience:

$$j_{v,e} = \frac{\sigma}{\mu_\ell}\sqrt{\frac{\rho_\ell}{\rho_v}} \cdot N_\mu^{0.8} \qquad \text{with} \quad N_\mu \equiv \frac{\mu_\ell}{\sqrt{\rho_\ell \sigma \sqrt{\frac{\sigma}{g(\rho_\ell - \rho_v)}}}} \qquad \text{(Ishii-Mishima)}$$

$$K = 0.03 \cdot j_v^{0.9} \left(\frac{\mu_v}{\rho_v D} \right)^{0.1} \qquad \text{(McCoy-Hanratty)}$$

Table 1. Properties of water and air at room temperature and atmospheric pressure.

Parameter	**Value**
Water	
ρ_ℓ	1,000 kg/m^3
μ_ℓ	0.001 Pa·s
σ	0.07 N/m
Air	
ρ_v	1.2 kg/m^3
μ_v	1.7×10^{-5} Pa·s