**INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR**

**Date:** 21-02-2014 FN/AN **Time:** 2 Hrs. **Full marks:** 30, **Deptt:** Agricultural and Food Engineering

**No. of Students:** 77 **MID Spring Semester Examination** **Subject No.** AG60096

**Subject Name:** Food Plant and Equipment Design **M. Tech. (FPE), IVth Yr. B. Te ch. (H) and DD (FPE), Vth yr. DD (FPE) and RS(2)**

**INSTTRUCTIONS:** Answer **ALL** questions. All questions carry equal marks. Use of Steam Table is permitted. Make reasonable assumptions with clear declaration, wherever necessary. No queries are to be entertained during examination.

1. A bulk milk cooler, whose length is six times the innermost radius, is to be designed for cooling 5kL of milk in three hours. Fresh milk has the density of 1030 kg $h^{-1}$, specific heat capacity of 3.9 kJ $kg^{-1}$ $K^{-1}$ and temperature of 35 °C. Obtain the total number of tubes of 15 mm ID and 17 mm OD with a trial value of 250, if external film coefficient is 110 W $m^{-2}$ $K^{-1}$ and the final temperature is 4 °C. Refrigerant used is R-22 and it removes 230 kJ of energy per kilogram of refrigerant. Assume ice ring diameter of 2.5 cm. Use:

$$N_{Nu} = 0.019 N_{Re}^{0.8} N_{Pr}^{0.4} \left(\frac{\rho_l}{\rho_v}\right)^{0.375} \left(\frac{\mu_v}{\mu_l}\right)^{0.075}$$

Properties of refrigerant are: Liquid density 800 kg $m^{-3}$, Vapour density 11 kg $m^{-3}$, Vapour viscosity 1.14 x $10^{-5}$ kg $m^{-1}$ $s^{-1}$, Liquid viscosity 3 x $10^{-4}$ kg $m^{-1}$ $s^{-1}$, Specific heat capacity (liquid) 1.8 kJ $kg^{-1}$ $K^{-1}$ Thermal conductivity (liquid) 8.14 x $10^{-2}$ W $m^{-1}$ $K^{-1}$. Thermal conductivities of ice and SS tube are 2.2 and 15 W $m^{-1}$ $K^{-1}$, respectively.

2. A fire tube boiler produces 2500 kg $h^{-1}$ steam at 10 bar pressure. Flue gas temperature at the entry and exit are 750 and 350 °C, respectively. Assuming there are 25 tubes of 5 cm ID, 5.2 cm OD and 6 m length, obtain the pressure drop across the length of the tubes. Specific heat capacity, thermal conductivity and coefficient of viscosity of flue gas at mean temperature are 1.1 kJ $kg^{-1}$ $K^{-1}$, 6 x $10^{-2}$ W $m^{-1}$ $K^{-1}$ and 3.6 x $10^{-5}$ kg $m^{-1}$ $s^{-1}$, respectively. Coefficient of viscosity of air is 2.14 x $10^{-5}$ kg $m^{-1}$ $s^{-1}$. Also obtain the pressure drop across the coal bed (porosity 30%), if 31.48 kg flue gas is generated from 1 kg coal. Ambient air temperature is 40 °C and fire box is 1 m x 1 m. Sphericity of coal particles is 0.8 and these have an equivalent sphere diameter of 2 cm. Use:

$$\Delta p = \frac{G^2}{\rho} \frac{L}{\varphi_s D_p} \frac{1-\varepsilon}{\varepsilon^3} \left[\frac{150}{N_{Re}} + 1.75\right], N_{Re} = \frac{\varphi_s D_p \rho v}{\mu(1-\varepsilon)}, f = \frac{0.0791}{\sqrt[4]{N_{Re}}}$$

3. In a water tube boiler the flue gas undergoes temperature drop from 950 °C to 500 °C, while heating the tubes. Emissivity of the soot which is at a temperature of 400 ° C is 0.6. Stefan-Boltzmann constant is 5.67 x $10^{-8}$ W $m^{-2}$ $K^{-4}$. Convective film coefficient is 127 W $m^{-2}$ $K^{-1}$. Obtain the total number of tubes of 5.5 cm ID and 5.8 cm OD, if the boiler is producing 10000 kg $h^{-1}$ steam at 20 bar pressure. Assume the soot and the sludge layers to be 1 and 5 mm thick with conduction factors of 1 and 0.5, respectively. Boiling film coefficient is 9000 W $m^{-2}$ $K^{-1}$ and thermal conductivity of tube material is 15 W $m^{-1}$ $K^{-1}$, specific heat capacity of flue gas is 1.145 kJ $kg^{-1}$ $K^{-1}$. The fire box is of 2m x 2m size.