**Homework-5 (Due on 7th May, 2020)**

1. In a counter-current flow heat exchanger the hot stream is cooled from 120 to 30 oC while the cold stream is being heated from 20 to 60 oC. If the same exchanger were operated with parallel flow, what would be the exit temperatures of the two streams? It may be assumed that properties are not sensitive to temperature.
2. Obtain the area required to heat mineral oil from 20 to 50 oC at a rate of 0.6 L/min in a double pipe exchanger. The inner pipe has a diameter of 1 cm and the outer pipe has diameter 2 cm. Pressurized water at 100 oC is available as heating fluid. The mineral oil has the following properties which are reasonably constant over the temperature range mentioned: *Cp*=2000 J/Kg. K; *k*=0.147 W/m. K and the viscosity may be obtained from any reliable source. Use countercurrent flow.
3. Toluene is being condensed at 230 oF on the outside of a ¾ in OD 16 BWG copper condenser tubes through which cooling water is flowing at an average temperature of 80 oF. Individual heat transfer coefficients are 3970 (water side) and 2840 W/m2 K (toluene) respectively. Estimate the wall temperature by including and excluding the pipe wall resistance.
4. Gas oil (Cp=0.625 Btu/lb oF, µ=0.7 cp, k=0.069 Btu/(hr. ft2 (oF/ft)) at 480 oF is available to heat midcontinent crude (Cp=0.55 Btu/lb oF) at 150,000 lb/hr from 170 oF to 285 oF. This will be achieved by using a 1-2 exchanger where the gas oil will be fed to the shell side and the crude in the tube side. The gas oil should be cooled to 300 oF. The exchanger has the following details: Shell ID: 25 inches, Tube Bundle: 252 nos 1 inch OD BWG tubes 16 ft long and arranged in on 1.25 inch square pitch. Bafffles are spaced 10 inch apart. Assume properties are not sensitive to temperature. Viscosity correction due to wall temperature difference is not required.
   1. Calculate the shell side equivalent diameter and mass velocity.
   2. Estimate the shell side heat transfer coefficient
   3. If the tube side heat transfer coefficient is 160 Btu/hr ft2 oF, determine the overall heat transfer coefficient.
   4. Determine if the exchanger is suitable for the purpose.
5. A triple effect standard evaporator, each effect of which has 140 m2 of heating surface, is to be used to concentrate a solution from 4% solids to 35% solid. The solution has negligible boiling point elevation. Forward feed is to be used. Steam is available at 120 oC and the vacuum in the last effect corresponds to a boiling temperature of 40 oC. The overall coefficients (in W/m2 oC) are: 2950 in I, 2670 in II and 1360 in III. All specific heats may be taken as 4200 J/kg K. Radiation and other heat losses are negligible. Condensate leave as saturated liquid. The feed enters at 90 oC. Calculate a) The kgs of 4% liquor that can be concentrated per hour and b) The steam consumption in kg/hr.