Chemcial Engineering 140 **November 21, 2007**

Midterm #3

From Felder and Rousseau*

In the final stage of the manufacturing process for a solid organic product, the product is cleaned with liquid toluene and then dried in a process whose flowchart is shown below.

The wet product enters the dryer at a rate of 300 lb_m/h containing 0.200 lb_m toluene/lb_m dry solids. A stream of nitrogen at 200°F, 1.2 atm, and containing a small amount of toluene vapor also enters the dryer. (A higher temperature would cause the product to soften and degrade.) Heat is transferred in the dryer from the gas to the wet solids, causing most of the toluene to evaporate. The final product contains 0.020 lb_m toluene/lb_m dry solids. Gas leaves the dryer at 150 °F and 1.2 atm with a relative saturation of 70% and passes through a water-cooled condenser. Gas and liquid streams leave the condenser in equilibrium at 90°F and 1 atm. The gas is reheated to 200°F and reenters the dryer.

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Figure 1: Flow chart for final stage of manufacturing process

Note: vapor pressures of toluene are attached in Figure 2. Relative saturation is equivalent to relative humidity but for fluids other than water.

*Adapted from Professional Engineering Examinations, Vol. 1 (1965-1971), National Council of Engineering Examiners, p. 60

(30)	Briefly explain this process in your own words. In your explanation, include the purpose of the condenser and the nitrogen reheater and a likely reason that nitrogen rather than air is used as the recirculating gas. What do you suppose happens to the liquid toluene leaving the condenser?
(25)	Calculate the compositions (component mole fractions) of the gas streams entering and leaving the dryer.

(30)	Calculate the circulation rate of dry nitrogen (lb_m/h).
(20)	Calculate the volumetric flow rate of gas entering the dryer at the stated conditions (ft^3/h).
(25)	Find the highest temperature at which the condenser can operate.
(25)	A rule of thumb is that heat exchange requires at least 15°F driving force. Hence, the inlet stream to the reheater is set at 215°F. At what pressure and quality is the inlet steam to the reheater? What is the temperature of the exiting steam condensate from the reheater?
(25)	What might be done to reduce the N_2 circulation rate?