ENCH 445 – Separation Processes -- Problem Set 5

In a chemical plant that produces styrene from ethylbenzene, a certain liquid stream has a flow rate of 25 moles/s and a composition that is 13% (mole/mole) benzene, 18% toluene, 23% ethylbenzene, and 46% styrene. The system of two distillation columns shown below is used to separate this starting material into a stream that is mainly a mixture of benzene and toluene, a stream containing mainly ethylbenzene which will be recycled to a reactor, and a stream containing the final styrene product. In the first column shown below 98% of the toluene present in the column feed is to be recovered in the top product and 98% of the ethylbenzene present in the column feed is to be recovered in the bottom product. In the second column shown below 98% of the ethylbenzene present in the column feed is to be recovered in the top product and 98% of the styrene in the column feed is to be recovered in the bottom product.

Determine optimal designs for the two columns described above and shown below. Your designs should include the total number of plates in each column, the location of the feed plate, and the height of each column. Assume in your designs that the pressure in the columns and for the starting material is 1 atm, that the starting material is saturated liquid at its boiling point, that the two columns contain sieve trays that each provide one equilibrium stage, and that each column incorporates a partial reboiler and a total condenser. Confirm that your designs incorporate the optimal location of the feed plate in each column by changing the location of the feed plate (while keeping the total number of plates and the separation specification fixed) and showing that the reflux rate (and therefore the energy cost) increases regardless of whether the feed plate is moved higher or lower in the column. Also confirm that the heights of the two columns are reasonable. Use any reasonable assumptions and "rules of thumb" that are necessary, and also use either COCO/ChemSep or Aspen to perform detailed numerical simulations where warranted in order to achieve an accurate design. Also use COCO/ChemSep or Aspen to plot the liquid phase composition and temperature profiles inside the two columns. Present your results in the form of a short report that explains your reasoning and results.