Department of Chemical Engineering IIT Delhi

CHL 735 Design of Separation Processes Term : Jan. 2007

Max. 50 points
Time 2 hr. 2.5.2007

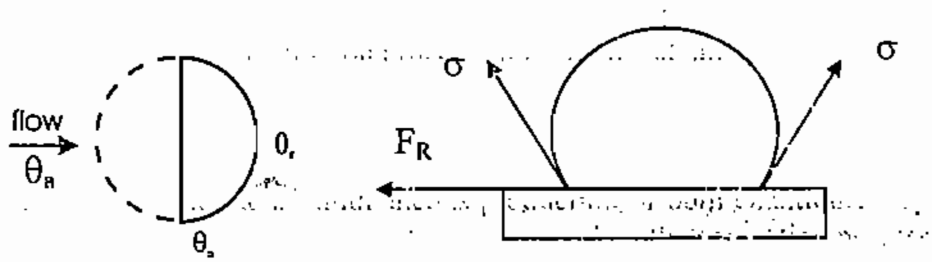
Major

Answer should be brief and to the point.
Maintain the continuity of the parts of each question

1.(a) What is moving bed DPA process? What is the significance of break through curve in adsorption?
(b) If bed utilization is low in an adsorption column how it can be improved?
(c) Find out cross over ration of a system with $X_i = 0.1$ and $Y_i = 0.01$;What would be the choice of adsorption cycle and why?
(d) What are the advantages of wheel based adsorption process?
(e) How would you choose regeneration cycle in adsorption - discuss?

[5x3 = 15]

2. Show that for circular contact area of a spherical drop attached to a solid substrate in the form of spherical cap, the retentive force acting opposite to the direction flow, $FR = (4/\pi)\,\sigma R\,[\cos\theta_r + (\pi/2-1)\cos\theta_a]$. Assume, in the rear part of the contact area, the dynamic contact angle changes (shown in fig below) from θ_a to θ_r linearly.



Top view: circular contact area

Side view: drop attached to solid substrate

(b) What would be required o/w interfacial tension for the detachment of an oily-soil droplet of 0.05 micro litre size from fabric surface during the soaking period in water containing surfactants. Assume, density of oil is 930 kg/m^3 and the θ_c =120°.
[6 + 6 =12]

3. (a) State briefly the process selection criteria you would apply for separation of any given mixture of compounds.
(b) Give example of a reactive distillation process and state its advantage.
(c) Mention situations when distillation can not be employed?
[4+3+5=12]

4. (a) Describe how quasi continuous simultaneous production of both enantiomers by preferential crystallization can be achieved. Give phase diagram to explain the separation process.
(b) Read the attached sheet on 'Increasing capacity of a stretched-to-limit C_2 splitter' and answer the following questions. (i) What are the differences in terms of product purity and capacity between the first mentioned solution and the one which is implemented (leaving aside the cost factor)? (ii) What is the role of feed condenser and how it is reducing the load on rectifying section? Design a dual flow tray. [5+ 2+2+2 = 11]

Nevertheless, it was decided to go ahead with the operation, realizing there was little to lose. The cost of a new charge of reactor catalyst was negligible compared to the cost of either the flared C_4 make or a plant shutdown.

A shutdown would be required whether the operation failed or was not carried out at all, while success would have avoided the need to shut down or flare.

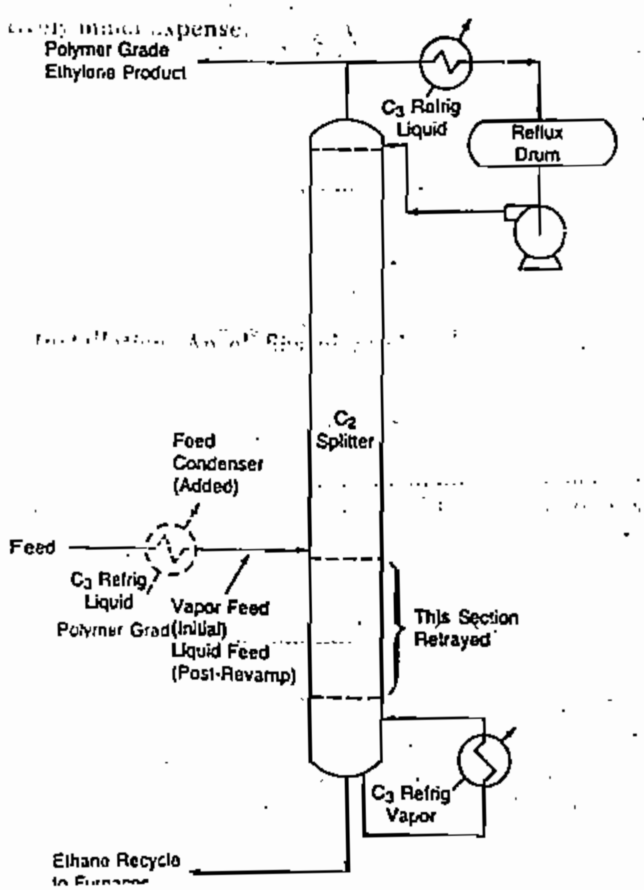
Cure. Prior to bypassing the lower feed, the upstream plant was trimmed in order to minimize the butadiene in that stream. This reduced the concentration of butadiene to about 2-3 percent, giving about 1-2 percent butadiene in the hydrogenation reactor feed.

Bypassing the lower feed unloaded the column, and the C_4 make achieved its purity specs. The greater quantity of butadiene in the feed did not disable the catalyst, although it shortened its life to an extent that one additional catalyst charge was required. This was considered a relatively minor expense.

One surprising side-effect of this operation was a great reduction in overall steam consumption, which resulted from unloading the debutanizer. The steam savings achieved in the following six-month period (to the next scheduled shutdown) was alone more than sufficient to pay for the new catalyst charge.

INCREASING CAPACITY OF A STRETCHED-TO-THE-LIMIT C_2 SPLITTER

Installation. An olefins plant C_2 splitter (Figure 8). Feed to the column was a vapor ethylene/ethane mixture with minor quantities of other components. Top product was polymer-grade ethylene, while bottom product was ethane, which was recycled to the plant's cracking furnaces as a cracking feedstock. The main requirement of the column was to produce on-spec ethylene. There was an economic incentive to minimize the amount of ethylene in the column bottom stream, but in this case the bottom flow rate was small and minimizing the loss of ethylene to that stream was not critical. The rectifying section of the column contained about 3-4 times as many trays as the stripping section.



Problem. Following previous revamps, the plant was operated at 135 percent of its intial design capacity. Field experience indicated that at this rate, the C_2 splitter operated right at its hydraulic capacity limit, both in the top and bottom sections. This was confirmed by calculation.

The plant capacity was to be further raised to 150 percent of its original capacity, the C_2 splitter being one of the major bottlenecks. Since downtime and lost capacity were extremely costly, the proposed solution had to positively assure that the desired capacity increase would be achieved, and that ethylene purity would be maintained. A preliminary revamp study concluded that replacing the column internals alone could not positively assure that both these objectives would be simultaneously met. The only solution that appeared capable of positively achieving both objectives was to add a 40-tray section in series with the existing column, which would enable reflux and reboil to be reduced and allow for greater throughput. This solutinn required large capital expenditure, and had a negative impact on the payout of the planned revamp.

Solution. The idea that solved the problem with relatively little expense is shown on Figure 8. A feed condenser was added, which lowered the vapor and liquid loads in the rectifying section sufficiently to ensure this section was capable of processing the increased throughput. This, however, considerably loaded up the bottom section of the column. To accommodate the greater loads, the sieve trays in the bottom section were replaced by dual flow trays (i.e., sieve trays without downcomers). This type of tray is capable of achieving significantly greater capacity than a normal sieve tray, often at the penalty of a slightly lower efficiency and a somewhat lower turndown. The loss in efficiency, however, only occurred in the small stripping section, and could be tolerated, since it did not affect the purity of the ethylene product.

Post Mortem. The revamped column (Figure 8) achieved 150 percent of its initial design capacity while producing on-spec ethylene product. Ethylene losses in the bottom stream increased from about 1 percent to 1.8 percent, which represented a minor economic loss, especially when one considers the small bottoms flow rate.

WATER IN A REFLUXED GAS PLANT DEETHANIZER

Installation. A gas plant refluxed deethanizer (Figure 9). Feed to the column was rich absorption oil saturated with absorbed gas components (C_1 to gasoline). Reflux was condensed using C_3 refrigeration and entered the column at −30°F.

Problem. At upredictable time intervals, a slug of water would empty out either from the top or from the bottom of the column. Emptying out from the top appeared to occur by massive vaporization of water, which carried over the fluids above the point of vaporization and out of the top rapidly. Some absorption oil, water, and gasoline were found in equipment downstream of the reflux drum following emptying out from the top. Emptying out of the bottom appeared to take place by a massive slug of fluids. This slug caused a large increase in feed to a downstream depropanizer, resulting in a major upset in the column train downstream.

Cause. Trace quantities of water absorbed in the ab-