IS IT DIFFICULT TO CONTROL ABSORBER – STRIPPER COLUMNS?

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Is it difficult to control absorber – stripper columns?

The absorber – stripper configuration of figure 1 is common for gas plants, and if we are to implement APC on this gas plant it better address the control problem at hand: maximize recovery of valuable propane or propylene, subject to a C2 in propane contamination limit. Absorber – strippers work like the rectifying and stripping sections of any distillation column, but the presence of lean-oil makes it more complex. The absorber is above the stripper and its task is to preferentially absorb C3 and return it to the stripper, letting C2 through into the fuel gas system. The stripper task is to preferentially evaporate C2 into the absorber, letting C3 flow down the column to the bottom. However it is impossible to absorb C3 without some absorption of C2, and likewise it is impossible to boil C2 without evaporating some C3. That creates a large recycle of C2 and C3 between the two columns. Separation gets better with increased recycle as long as the columns do not flood, and it deteriorates quickly once flooding begins.

Feed comes in usually from an overhead accumulator of a fractionator. The liquid part of the feed, IE naphtha, serves as lean oil in the absorber. While in the fractionator overhead accumulator vapor and liquid are in equilibrium, the absorber operates at a much higher pressure, giving naphtha more absorption power. Vapor from the accumulator is compressed and partially condensed into the stripper feed drum. Absorber rich oil is also flown into the feed drum, returning the absorbed C3 with recycled C2 to be stripped. Stripper overhead vapor containing C2 and some C3 is partially condensed and also flown into the feed drum. Thus the feed drum contains a mixture of three very different streams. Feed drum vapor flows into the absorber, and liquid feeds the stripper. Often following the main absorber there is another small sponge absorber and its task is to trap the small flow of heavier LPG components in the main absorber overhead.

What's a good way to control such a configuration? Usually the stripper would have a vapor flow measurement, or we can calculate the vapor flow from heat balance. Knowledge of the vapor flow helps us maintain stripper loading below flooding constraint and avoid unreasonable recycle of C2 and C3. The manipulated variable for controlling stripper load is lean-oil flow, IE, how much of the overhead naphtha would be directed to the absorber and how much directly to the stripper feed drum.

But managing lean-oil to maintain a good stripper loading is not enough. We must also set the reboiler correctly to ensure that the stripper bottom contains but a small amount of C2, and such a control strategy must rely on an inferential model or analyzer. Typically a temperature indicator on tray 5 or so exists, and would have provided a rough inference of bottom C2 penetration, except here, looking at temperatures does not help much because heavy naphtha components distort the temperature reading. Naphtha itself does not boil in column conditions but being a diluent it increases the boiling temperatures of lighter components.

My recent February editorial [1], suggests that careful selection of inferential inputs improves the inference, even if that is a regression inference, but in this case of absorber – stripper combination I actually do not see a good way of handling the inference problem without a knowledge based model. Resorting to first principles inferential modeling I set up the problem as follows.

- Define four stripper bottom components
  - Light key component: C2
  - Heavy key component: C3
  - Intermediate heavy component: C4, mostly not volatile at column conditions except near the reboiler
  - Naphtha diluent: C5+, not volatile at column conditions

- Apply semi rigorous techniques to set up four equation to solve the four unknowns and come up with a C2 penetration inference
  1. Bottom mass balance
  2. Bottom equilibrium
  3. Section separation performance: ratio of component on tray 5 to the bottom concentration, and tray 5 mass balance.
  4. Tray 5 equilibrium

The stripper bottom stream is further separated downstream into propane, butane and naphtha, whereas C2 specification is on the propane. Hence the control variable becomes not simply the bottom C2 but the ratio of bottom C2 to bottom C3. Our ability to infer stripper C2 penetration from the semi rigorous four component model is demonstrated in figure 2. That is a four month trend of the inference of bottom C2 as concentrated in propane. The figure shows several C2 breakthroughs, which could have been avoided by operating the stripper reboiler more correctly. The agreement between model and lab is not bad, though that is not essential. What is essential is that the inference be capable of identifying C2 breakthrough events and pass it on to the controller, which in turn would increase the reboiler and/or reduce leanoil and stripper load. In the case of figure 2 that can translate into a substantial increase of FCC propylene recovery, in the order of 0.5% yield.

I have asserted here and in other editorials that while our APC industry has tended to hit every inferential problem by applying simple regression methods, those are not necessarily the best solutions, and in certain cases regression cannot work at all. The modeling knowledge exists to much improve the performance of our inferential models.

LITERATURE CITED

1. Friedman, Y. Z., “Inferential model input selection”, Hydrocarbon Processing Journal, February 2011.

Figure 1. Absorber-stripper configuration

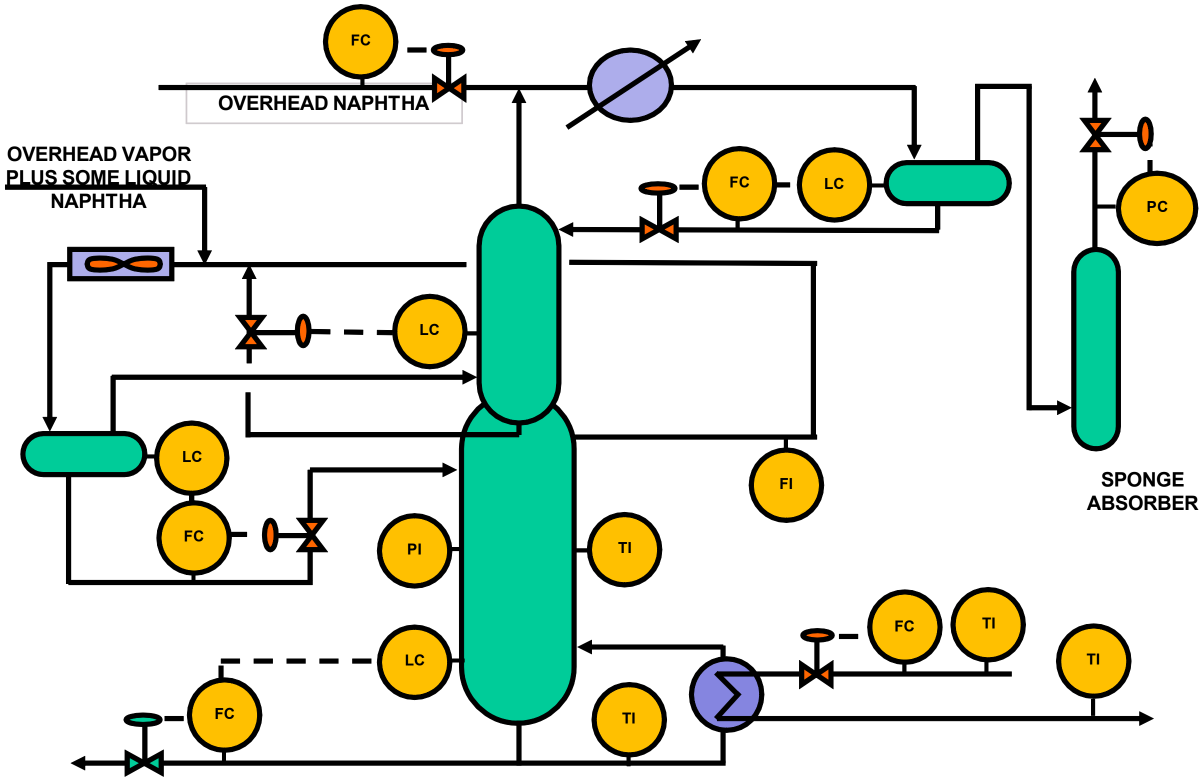

Figure 2. Absorber-stripper configuration