Alkylation product separation control

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People do not speak much about alkylation product separation in APC. Why? Precise product separation is crucial to alkylation unit economics. Alky reactor effluent contains C5, NC4, IC4 and C3, in addition to the heavy alkylate. That mixture is separated in a column called “isostripper”, shown in Figure 1. (For simplicity of discussion we show only one isostripper version, designed for HF alkylation, although the arguments brought forth are valid for all alkylation unit product separators). Alkylate is the reactor product, iso-octane or iso-heptane to be separated as the isostripper bottom product. IC4 is one of the two main alkylation ingredients, supplied to the reactor in great excess and must be evaporated into the isostripper accumulator to be recycled to the reactor. (The other ingredient: C4 and possibly C3 olefins react fully and do not appear in the effluent).

Parafinic C3, NC4 and C5 that come in small quantities with the ingredient are inerts and must be removed. C5 ideally is removed at the bottom with alkylate. NC4 is removed as a vapor side draw, whereas C3 is removed in a downstream depropanizer, not shown in figure 1.

Isostripper operation is quite a difficult job because reactor effluent composition varies. Penetration of contaminants and ratio of alkylate C7 to C8 are determined by operation of upstream units and are not known to the alkylation operator. Responses to self inflicted disturbances of reactor IC4 to olefin ratio are also not easily formulated. The operator relies on a kind of rudimentary inference in the way of isostripper temperature profile, except the temperature profile to be kept is determined by the unknown reactor effluent composition and hence the operator is entirely in the dark. That leads to frequent mistakes that cause

- Build up of inert NC4, which penalizes octane, yield and energy efficiency
- Loss of IC4, a valuable reaction component, being purged out with inert NC4
- Flooding in the bottom section due to accumulation of C5 and incorrect bottom operating temperatures

With such large and obvious APC benefits, why the silence about alkylation unit APC?

I have come to realize that the silence occurs because reasonable inferential models would be central to any alky APC, whereas the industry generally lacks the ability to come up with quality isostripper inferences. One standard industry approach is to control the isostripper based on pressure corrected temperature (PCT), except here, since the pressure is constant this approach is no better, and in some respects worse, than the operator temperature profile approach. The second common industry approach involves regression of column temperatures against product compositions. I would qualify regression as a “better than nothing” method, which might produce low fidelity inferences in some instances, but at this level of complexity where the bottom purity model and side draw purity model are interdependent it is completely hopeless. Regression is a problematic, theoretically flawed method, which I had written against in at least half a dozen articles, see for example [1, 2], and those assessments have led to nasty public arguments, see for example [3]. After decades of being a single voice in the desert I have resigned to focus on my own inferential models the only way I know how, by use of first principles: thermodynamics and API process engineering methods.
Figure 2 is a trend of inference against lab values and it indicates what can be accomplished by the way of first principles modeling. To illustrate the point in a one page editorial we discuss only one of the important isostripper variables: IC4 in the NC4 purge sidestream. The first few weeks of this trend show not only that a correlation exists, but also how bad the operation was, losing occasionally up to 50% IC4 with the NC4 purge. At that point the plant engineer made the inference available to operators and asked them to try controlling the isostripper better. The following few weeks of the trend show dramatic process improvements, where simple manual control drove the loss of IC4 from erratic operation at average of 10% IC4 in side draw to about 2%.

Considering the substantial incentive to use inference models to improve the operation, the plant engineer had decided to apply standard DCS controllers to control
- IC4 in the side draw, manipulating the draw
- Alkylate RVP, C5 and C4 content, manipulating the reboiler
- Depropanizer C3 removal, manipulating the depropanizer reboiler
- IC4 inventory, manipulating IC4 addition to the reactor

Not APC by definition – the purist would say, where is your multi-variable controller? Correct, the multi-variable controller budget would hopefully be approved two years and a few million dollars later, and would likely make even more of an impact. The point I am trying to make is – APC is as good as the inference models it relies on. If you manage to develop good inferences then alkylation APC is lucrative.

Literature

Figure 1. Alky Isostripper configuration

Reactor effluent

#1

#20

#50

#53

#56

Main IC4 storage

IC4 from Depropanizer

IC4 recycle to reactor

IC4 + C3 to depropanizer

NC4 vapor draw

High temperature source

Alkylate
Figure 2. Alky Isostripper side draw IC4 trend