Temperature points on main fractionators

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Main fractionators are those distillation columns that handle wide boiling curve feeds, cutting that feed into several products. Almost every major refinery unit has such a column, IE, crude, vacuum, FCC, coker, hydrocracker, visbreaker units. All have similar design features, though some are easier to operate than others, and "easier to operate" translates to more optimal operation and fewer incidents. From my APC (advanced process control) and inferential control perspective, units that are easier to operate naturally lend themselves to better inferential modeling and better APC. This editorial attempts to highlight the differences, and it concludes that a small investment in instrumentation can substantially improve main fractionator performance.

To fit the space we cover only one typical style of main fractionator design, shown in figure 1. Hot partially vaporized feed enters the flash zone at a fairly low elevation. the vapor portion includes all distillate products plus some additional evaporated material called overflash. Below the flash zone is a steam stripping section for stripping absorbed distillates off the bottom residue product. Above the flash zone, vapor is condensed in stages by cooling circuits called pumparounds, and side streams are proportionally drawn, stripped by steam in side strippers and become middle distillate products: kerosene, diesel and heavy diesel. In the style of figure 1 the draws are partial draws, meaning – the excess internal reflux not drawn out flows down the column. For simplicity figure 1 does not show stripping steam, but it shows all other control handles: pressure control, top temperature controller, used primarily for control of top distillate 90% point, side product flow controllers for control of side product 90% points, and pumparound flows to ensure reasonable internal reflux throughout the column.

What this control structure misses is the fact that the operator does not in general knows the content of middle distillates in the feed, and hence has no clue as to how to set pumparounds or side draws. Here lies the difficulty of operating main fractionators. If too much side products are taken, they would go off specification. Worse yet, the section of column immediately above the flash zone can run dry, with too little overflash, resulting in contamination of heavy diesel by entrainment. On the other hand, if side draws do not take all of the middle distillate material available there are economic penalties. At steady state operation that is merely an inconvenience, forcing the operator to rely heavily on lab tests, but upon disturbances, such as crude switches, coke drum switches, operational mode changes, etc, the operator is in the dark and has to rely on instrument readings. The danger of contaminating the lowest side draw makes overflash perhaps the single most important control variable, only that most important variable is unmeasured. Of the attempts to measure overflash by orifice meters the rate of success stands at about 10%.

Temperature and pressure indicators typically available on main fractionators are shown in figure 1 in pink. Cooling circuits usually have enough temperature points to permit calculation of heat duties. Most fractionator also have draw and flash zone temperature indicators. You would think at first sight that such a set would give operators enough data to handle unit during disturbances, but actually draw temperatures are not good inferences of side product quality. First, draw temperatures are bubble points, IE, they are not so much related to the product 90% point, but rather to the initial boiling point. Second, these draws are saturated with light materials, which skew the interpretation of
temperature reading. Temperatures are also measured downstream, after the light material is stripped, except stripper bottom temperatures are affected by steam conditions and cannot be relied on. As for pumparound heat duty calculations, those might be useful for engineers but they do not provide the operator with inference of product qualities. To use these available indicators in a productive way one needs to employ an inference package connecting all of this information together and digesting it into product quality inferences. That implies the implementation of APC, and even then, being in the business of inferential modeling has taught me that model repeatability improves if it does not have to rely on draw temperatures.

Temperature points that in my opinion could help the operator handle fractionator disturbances are located in the vapor space of trays immediately below the draws, and are shown in figure 1 in orange. These are dew point indicators with much cleaner interpretation. Dew points are reasonable inferences of the 90% points we are trying to control, and as opposed to bubble points are less influenced by light material flowing across the tray. Especially the one orange temperature point below heavy diesel is of much value. In addition to this temperature being a rudimentary inference of heavy diesel 90% point, the temperature difference between flash zone and vapor below heavy diesel is an inference of overflash, and being able to control overflash is mandatory for good operation during disturbance.

Actually some process designers do recognize the value of temperatures placed in the vapor space below the draw, except they associate that value only with a total draw tray configuration, shown in figure 2. Total draw configurations are in vogue for some fractionators, most notably vacuum units, and of course they do have the added value of internal reflux being directly measured, as opposed to inferred. What this editorial suggests is that even if your unit has a partial draw tray configuration, installing temperature points just below draw trays is a good investment, especially if one follows with an inferential package that improves the interpretation of these measurements.
Figure 1. Wide cut fractionator structure
Figure 2. Total draw tray configuration