Main fractionator water wash systems

When properly designed and operated, main fractionator wash water systems can remove salt with little upset. Misconceptions concerning the minimum column overhead temperature and operation when producing FCC heavy naphtha are discussed.

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Main (fractionator) column water wash systems are sometimes needed when producing heavy naphtha product to ensure the FCC feed rate and gasoline quality can be met throughout the run. Heavy naphtha product draws are used to segregate the high sulphur portion of the gasoline or to reduce the liquid load through the gas plant. This is becoming more prevalent due to the production of propylene for petrochemical feedstocks. Consequences include a lower main column overhead temperature, higher wet gas rate and reduced gas plant propylene recovery. Lowering the overhead temperature can lead to ammonium chloride deposits on the trays or in the packing. These salts must periodically be removed; otherwise, FCC capacity will be reduced.

Heavy naphtha product draws and pumparounds

Figures 1 and 2 show two heavy naphtha product draw systems. The product in Figure 1 is withdrawn from the same location as the pumparound, which is the most common arrangement. Pumparound temperature is set by the heavy naphtha product rate. As the overhead product naphtha rate decreases and the heavy naphtha product draw increases, the draw temperature drops. When cold-feed preheat or gas plant C3/C4 splitter and stripper reboiler services use the heavy naphtha pumparound heat, a reduction in the draw temperature can create problems in each of these systems. Existing exchanger surface areas or pump capacity are often insufficient to meet the required duties. It is common during revamps to have to add pump capacity and increase the exchanger surface area due to higher product draw rates.

However, in many cases, modifying the flow scheme eliminates or minimises the pumparound system investment. Heavy naphtha product can be withdrawn above the pumparound (Figure 2), allowing existing equipment to be reused without modifications. This permits a higher product draw rate without lowering the pumparound draw temperature. The internal liquid rate above the pumparound is sometimes less than the targeted heavy naphtha product yield. In these instances, it is necessary to use a dual draw system, with the majority of product yielded above the pumparound and a smaller amount from the pumparound draw tray. This maximises the pumparound temperature.

Salt formation

Localised temperatures, HCl and ammonia concentrations, and water dewpoint all contribute to salt formation. Ammonium chloride salts are deposited after condensed water has absorbed the ammonia and HCl, and subsequently the water vapourises. Water forms when localised temperatures are below the water dewpoint, which depends on the quantity of water present in the column overhead vapour and operating pressure. High concentrations of water reduce the dewpoint temperature. Water content of the overhead vapour depends on the feed nozzle atomising steam, reactor stripping steam and main column steam, with rates varying dramatically between units.

Column overhead vapour HCl and ammonia concentrations play a central role. FCC feeds containing high chlorides are mainly unhdydrotreated atmospheric and vacuum residue containing residual inorganic salts (MgCl, CaCl and NaCl) from the crude unit desalters, and purchased gas oil contaminated with seawater. As overhead vapour HCl and ammonia concentrations increase, salt forms at higher temperatures. Severely hydrotreated feeds contain small amounts of nitrogen compounds and
almost no chlorides. Therefore, overhead vapour ammonia and HCl concentrations are low. High chloride feeds generate large amounts of HCl, so the column overhead temperature may need to be as high as 265°F to avoid salt formation, whereas low chloride feeds can operate as low as 235°F without rapid salt formation.

Reflux temperature and rate influence the rate of salt deposition because they set localised temperatures. Reflux temperatures vary from 75–120°F, depending on ambient conditions and the condenser system design. Reflux rate depends on column heat balance. Overhead vapour temperature may be 240–300°F, yet the liquid temperature leaving the top tray may be only 150–180°F. High rates and cold reflux reduce the local temperature. Recognising the difference between localised liquid temperatures on the top trays and measured vapour temperatures is essential to understanding the mechanism of salt formation.

Heat is exchanged when cold reflux and hot vapour mix on the tray. Figure 3 depicts the change in liquid temperature across a one-pass tray. In this case, reflux enters at 90°F, heat (and mass) is exchanged between the vapour and liquid, and liquid leaves at 160°F. A portion of the vapour entering the top tray is condensed. Localised temperatures below the water dewpoint contribute to salt formation because the water absorbs HCl and ammonia from the vapour. Water eventually vapourises because temperatures increase as liquid flows down the column, and salt is deposited.

**Column overhead temperature**

Column overhead temperature is set by operating pressure, the amount of water and overhead naphtha product endpoint. A question often asked is “What is the maximum percentage of FCC gasoline that can be withdrawn as heavy naphtha?” The answer depends on the rate of salt deposition that is tolerable. If the rate of salt laydown is high, there needs to be an effective way to remove it; otherwise, the tray will plug, eventually causing flooding.

Refiners yielding 20% or more of the gasoline as heavy naphtha will likely have high rates of salt deposition unless the feed has no chlorides. Those main columns that have operated problem-free for years at 215°F or lower have well-designed water draw trays and good operating procedures. One refiner has been operating at below 190°F for several years (Figure 4), but continuously withdraws water during normal operation. Hence, salts never build up on the trays. Yet, it is essential that all free water be withdrawn; otherwise, water containing HCl and ammonia will flow down the tower. This is difficult to remove when it deposits below the water draw tray.

**Normal operations**

During normal operation, the targeted heavy naphtha product rate is set by controlling the overhead temperature. Lowering the overhead temperature produces more heavy naphtha product with localised temperatures low enough to condense water even during normal operation. Ideally, this water is withdrawn continuously to minimise the amount of salt deposited. When the column is designed with a proper water draw one or two trays below the top tray, it is possible to continuously remove free water.

Operating with a continuous draw is quite simple. Draw rate is set high enough to ensure hydrocarbon is always present. This is done by sampling the draw stream and visually checking for hydrocarbons. Since there is little water present, this stream will be more than 90% hydrocarbon. This ensures water is removed without having to install an interface detector on the main column. Even though the draw stream contains 90% hydrocarbon or more, it will be less than 10 gallons per minute for most units. This stream can be cooled and routed to the main column overhead receiver, where the oil and water are separated. The rate is so low that it does not materially change the sulphur content in the main column overhead product stream.

**Water washing: abnormal operations**

Water washing will cause significant upsets if the system is poorly designed, process routing is incorrect or the procedure is not done properly. During the water washing procedure, water and oil will be withdrawn from the column at 150–190°F. If this stream is routed directly to the main column overhead receiver without cooling, it will flash, generating a higher wet gas compressor load. During water washing, this stream needs to be piped upstream of the overhead condensers (Figure 5).

Proper operating procedures are essential, because water washing forces an abnormal operation on the main column. First, the column overhead temperature must be reduced, and then sufficient water added to the reflux so water is present on the water draw tray. Water draw tray temperatures need to be low enough so that sufficient water is present to remove the salt. When the water draw tray product is routed to the main column condensers, the main column overhead receiver temperature...
and overhead product naphtha remain relatively constant, minimising gas plant upsets.

**Water wash system design**

Four main features of a functional water wash system are:

- Correct water draw tray location
- Proper routing of oil and water
- Proper water draw tray design
- Good operating procedures.

In one instance, the overhead temperature ran continuously at 175°F, which was below the water dewpoint. Yet, the water draw tray was located only two trays below the top. Reflux was just 75°F during the winter; therefore, its temperature increased to only 185°F on the water draw tray (Figure 6). At times, operating temperatures below the water draw were below the water dewpoint. In this instance, the water draw tray should have been located at least three trays below the top of the column to ensure the tray below the water draw operated above the water dew point. The water draw tray should typically be located one to two trays below the top of the column, but in a few cases, as noted in this article, it needs to be lower. In all cases, it must be seal-welded to ensure all the water is removed.

The water draw tray design needs to provide sufficient residence time to separate the oil and water. The downcomers from the tray above the water draw and those feeding the tray below need to be oriented correctly (Figure 7). Low residence time or improper downcomer orientations will allow free water to flow below the water draw. In some cases, it is necessary to make the trays and water draw from a dual alloy stainless to avoid corrosion.

Operating procedures are important. During normal operation, there is only a small amount of water and mostly oil. When water washing, the flow increases significantly, so the piping system must be large enough to handle the full flow rate.

**Conclusions**

What is the maximum heavy naphtha draw and minimum main column overhead temperature? Truly, there is no minimum temperature as long as the unit has facilities to remove the salts, metallurgy to deal with potential corrosion and is run with proper operating procedures. Since most main columns have no water draw, few engineers have experience of them, so they are often viewed as unnecessary. Yet, without an effective water wash system, the overhead temperature must be high so that the rate of ammonium chloride deposition is very low. A main column with a high reflux rate, cold reflux and high concentrations of chlorides and ammonia will need a very high temperature. Often, this high temperature means producing little or no heavy naphtha.

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