BABY BREAK IT DOWN, PART 2 - REFINERIES' OPTIONS FOR DEALING WITH EXTRAORDINARY TIMES

May 6, 2020

The COVID-19-induced social isolation and subsequent economic slowdown have caused major drops in U.S. refined products consumption, especially gasoline and jet fuel, which have experienced declines of as much as 44% and 70%, respectively, relative to similar periods in 2019. Diesel fuel consumption has been off as much as 20% on the same basis, and given that COVID is a global crisis, product exports have also fallen. As a result, U.S. refinery utilization has dropped to less than 70% for the last few weeks, the lowest levels since September 2008 during Hurricane Ike. All this presents refiners with two challenges: (1) reduced total demand; and (2) the disproportionate decline in gasoline and jet fuel. Each refinery is configured differently and has a varying degree of flexibility to react to these challenges. Today, we discuss what refiners can do to adjust operations and product yields, and examine the point at which some refineries might be forced to shut down completely.

As discussed in Part 1 of this blog series, refineries are doing everything they can to reduce their overall output, minimize their gasoline and jet fuel production in particular, and enter what you might call "max diesel mode." There are four levers that a refinery can use to deal with the current situation: (1) adjust its operating conditions, (2) alter its crude slate, (3) ratchet down its utilization rate, and (4) shut down the entire facility. To gain a better understanding of a refinery's ability to adjust its refined-product output in response to shifting markets, we also discussed the basics of how a refinery breaks down crude oil into component parts or fractions, beginning with atmospheric distillation and continuing with vacuum distillation.

Generally speaking, a refinery's objective is to break down heavier, more dense components that have larger hydrocarbon molecules into lighter, less dense components that have smaller hydrocarbon molecules. Each refinery has a set of equipment and processes that is used to break down either crude itself or particular crude fractions into component parts — the more sophisticated the refinery, the more breaking down that goes on. Once the breakdown is complete, refineries treat, reconstitute and/or blend these component parts together to make refined products to meet consumer demand. The refinery's objective is to yield the most valuable mix of refined products possible from a given crude input.

Next, we discuss in some detail what refinery operators can do in response to the extraordinary market conditions they now face.

Operating Conditions

What does it mean to adjust operating conditions? This essentially involves adjusting the "cut points" for products — the "cut point" is the temperature break between one fraction, such as diesel, and another fraction, such as jet fuel — and potentially adjusting the operating severity of units. For example, refineries have some, albeit limited, ability to tune a crude distillation unit to produce more or less of certain products. In a crude distillation unit, crude oil is boiled and divided into products based on boiling points. Each product has a different "boiling range," and in some cases, those ranges overlap slightly (Figure 1). For example, jet fuel and diesel are two crude oil distillation products whose boiling ranges are close to each other and can slightly overlap. Given the current market situation, unit operation can be adjusted to shift some jet fuel into diesel to maximize diesel production and minimize jet fuel production. Similarly, the crude distillation unit can be adjusted to shift production between naphtha (which, in U.S. refineries, is further processed to make gasoline) and jet fuel. There are limitations on how far this can be pushed, based on finished product specifications, such as the initial boiling point, end boiling point and flash point. Other refining processes, such as fluid catalytic cracking (FCC) and hydrocracking, also have the capability to adjust the balance between gasoline, jet fuel and diesel production, within limits.

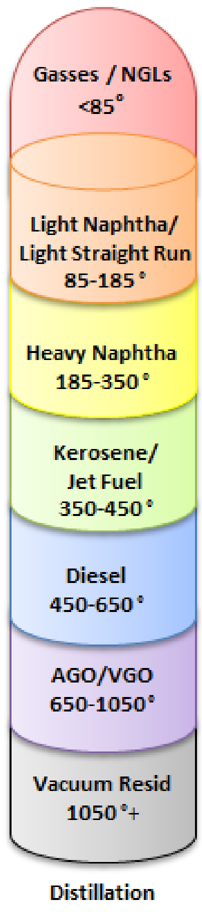

Figure 1: Crude Oil Distillation Ranges. Source: RBN

Crude Slates

Most refineries also have the ability to buy different grades of crude oil within the limits of the refinery configuration and design. Crude oils vary widely in their composition, including their API gravity and sulfur content. For any given refinery configuration, some crudes will yield more diesel fuel and less gasoline than other crude oils. For example, Figure 2 shows the estimated yields of different products from a grouping of crude oils that would all be considered in the "light sweet" range. We've highlighted in the red boxes the materials that would typically be considered gasoline-range products, such as naphtha, light straight run (LSR) and light ends. In the current environment, crude oils such as

Louisiana Light Sweet (LLS) that yield more diesel (violet bar segments) and less gasoline-range products will have a higher economic value to refiners. So even within a common quality range of crude oils, refiners will value streams with higher yields of diesel at a premium to those that produce more gasoline and will make their feedstock acquisitions accordingly.

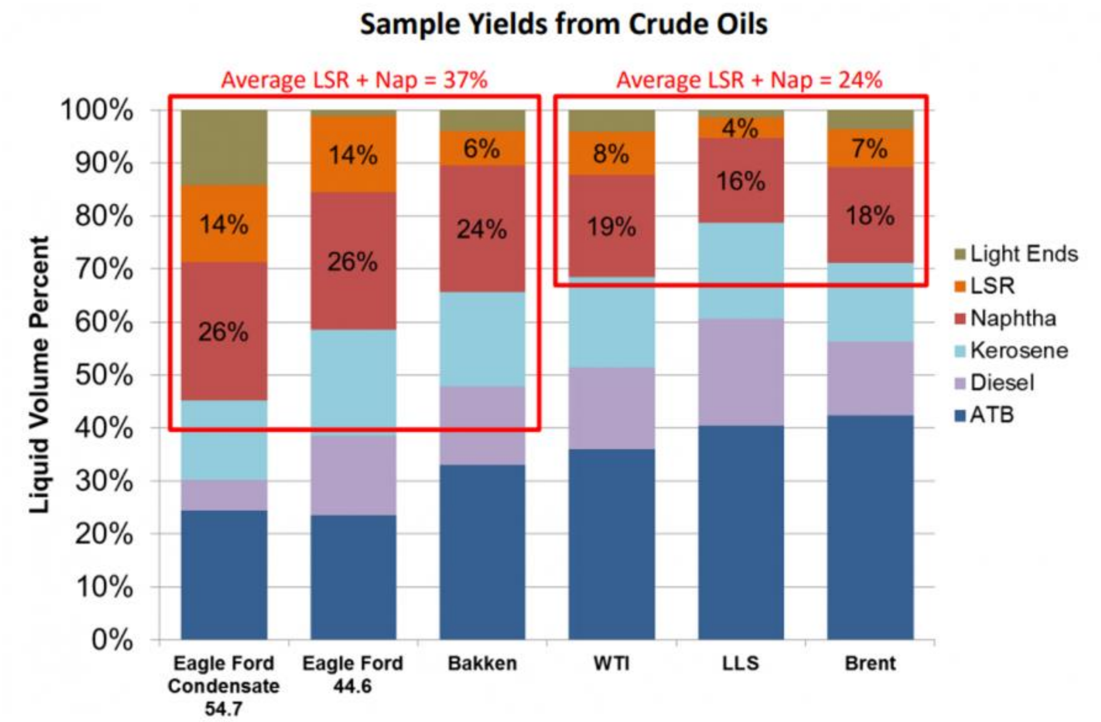

Figure 2. Sample Yields from Light Sweet Crude Oils. Source: Baker & O'Brien

Utilization Rates

Next, we'll dive into the heart of the problem, namely that, even with the adjustments made to shift product yields, U.S. refiners are still producing too much fuel overall (see How Much More Can I Take). With the dramatic decline in worldwide petroleum product consumption, refiners have had no choice but to reduce throughput. This is driven by economics and physical containment of products (i.e. storage). Generally, refineries have the ability to reduce their crude processing rates to around 65% to 75% of their nameplate capacity. This minimum rate is typically referred to as "turndown."

If the crude distillation unit rate is reduced much below the 65%-to-75% level, operations can become erratic to the point that the distillation tower operation and product separation becomes difficult to control, resulting in "off-spec" product. In addition, the facility has critical equipment, such as pumps that transfer fluids into, through and out of the refinery. Pumps are designed to move liquids within a range, or a band, of flow rates. Not only is there a maximum flow rate that a pump can deliver, there is also a minimum flow that it can effectively handle. When a pump gets to a point below its design minimum flow rate, an unstable and undesirable condition called "cavitation" may occur. Cavitation is similar to a car accelerating so quickly from a stop that its tires can't establish traction with the road, which can result in spinning of its wheels, and, subsequently, uncontrolled vibration. As is the case with a car, when the pump reaches that low flow point where it is "spinning its wheels" or "cavitating," it will begin to vibrate, and in extreme cases, it can completely destroy internal parts of the pump.

So the turndown rate is the minimum rate at which typical refineries can safely run all units. For the most part, refineries can adjust their utilization to the turndown rate without requiring any significant changes in the operation other than a commensurate reduction in rates for the downstream units, such as the FCC, hydrotreaters, reformers, hydrocrackers and alkylation units. Remember, as of the Energy Information Administration's Weekly Report on May 6, 2020, U.S. refineries were at a roughly 71% utilization rate (see Figure 3), which is a slight improvement from the previous week, but still means we are probably at or very near the minimum turndown limitations without seeing an increasing number of refinery shutdowns.

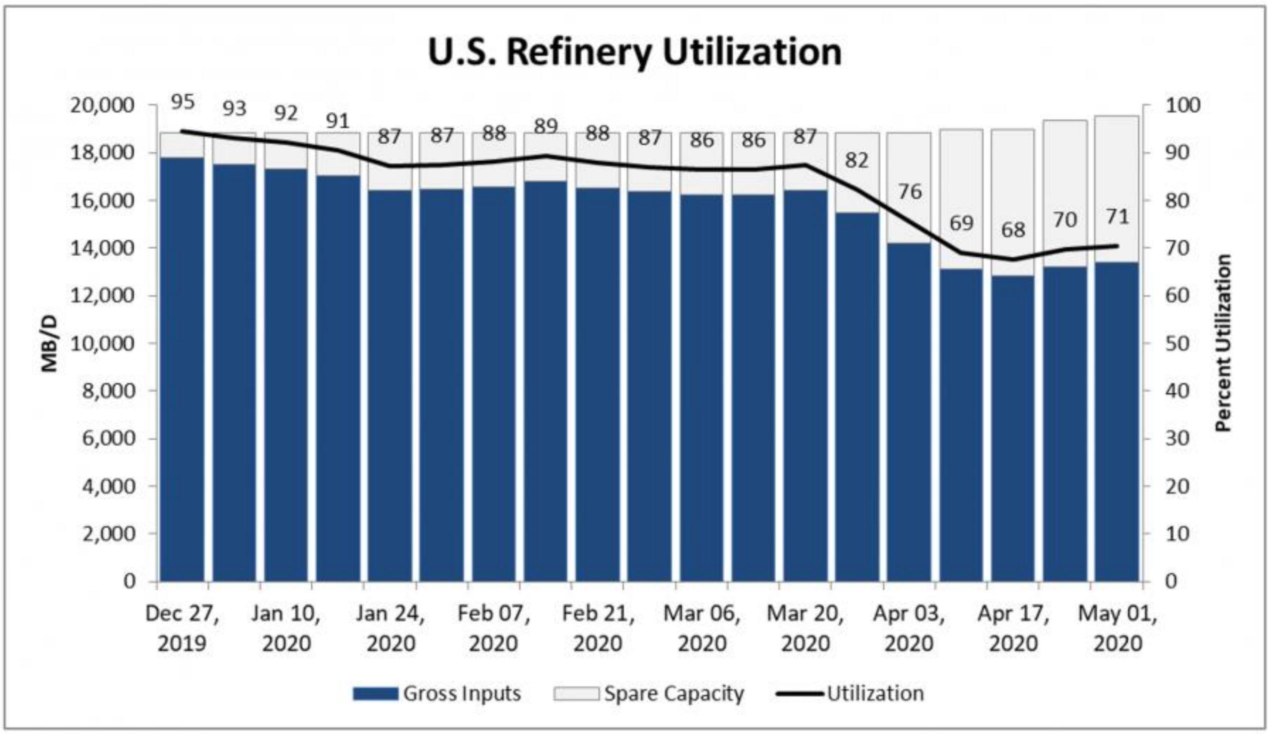

Figure 3. U.S. Refinery Utilization in Early 2020. Source: EIA

Shutdowns

When the options above have been exhausted — and if there are no physical, economic, or strategic justifications to continue to run — part of the refinery or the entire refinery may need to be shut down. Some refineries have more than one train (two crude units, two FCCs, etc.), which offers more flexibility in positioning units to shut down.

Some units have the ability to send their product streams back to their feed tank, which is then circulated back into the unit. This is referred to as "total internal circulation" and would only occur if the unit is having temporary operating issues or if there is not enough feed from an upstream unit. If rates are reduced to a point that a unit needs to be bypassed or placed on total internal circulation, the best course of action is to shut down the unit, unless there is a very near-term plan to increase crude rates within a day or two. A bypassed or circulating unit is not producing sellable product, yet it is still utilizing electricity, and, in some cases, natural gas, treating chemical and personnel. If it is expected that the unit will be offline for a while, it is typically more economical to shut it down. Ultimately, the extent of the closure depends on the duration of reduced product demand.

Once the decision is made to shut down a unit or the entire refinery, the operating company needs to determine to what extent to take the shutdown activities, which is dependent on the expected duration of closure. If it is anticipated that the downtime will only last a few weeks to a few months, refinery units can be shut in for a relatively low expense. The procedure would be similar to that of a shutdown for a refinery turnaround or maintenance outage, but at much less expense than if the equipment is opened and entered (depending on the type of unit, that can mean people physically going inside to pull exchanger bundles, remove trays and the like). After safely ceasing operations of the units, a low-pressure nitrogen blanket can be injected into the system to prevent oxygen from entering the inside of the equipment and piping, which would cause corrosion.

When short-term solutions aren't enough, refiners must consider longer-term and therefore more costly options. For longer-term closures, refinery process units can be shut down, purged of all products, and cleaned with steam, condensate or other cleaning solutions. Units such as crude distillation units and vacuum units, gas plants and cokers that do not contain particulate catalyst are much easier to shut down and clean out. Process units, such as FCCs, hydrocrackers, reformers, hydrotreaters and sulfur recovery units, have a considerable amount of catalyst that either needs to be removed from the unit during the shutdown process or manually removed after the unit is shut down. In some cases, the catalyst can remain in the unit if the unit is carefully shut down and then properly prepared and managed. Some catalysts will need to be flushed out during a shutdown and then regenerated. (Regeneration means the controlled introduction of oxygen to remove carbon from the catalyst to restore its effectiveness.) After the regeneration process, the catalyst can remain in the reactor for extended periods and protected with a low-pressure nitrogen blanket, again to prevent exposure to undesired atmospheric oxygen. All of this adds to the refiner's expense and can complicate the resumption of operations.

In addition to process units, there are support units, such as boilers that provide the plant with some of the refinery's steam and condensate, and there are air compressors that provide plant or utility air and instrument air. In a situation where the plant is expected to be idled for a few months or less, most of these support processes would remain in service because instruments are still needed so the operators can continue to monitor the system levels, pressure and temperature, even if just periodically. The steam and condensate system remains online in standby mode because the start-up process can be considerably longer if the process starts with a cold steam system.

There are also tank farm operations that do not typically need special attention other than routine visual monitoring, unless, as mentioned above, you have asphalt, atmospheric tower bottoms etc., that require steam to keep the tank contents from solidifying. Bullet and sphere tanks that contain high vapor-pressure products, such as propane and butane, will need ongoing pressure monitoring.

So far, two refineries in the U.S. have been completely shut down in response to COVID-related demand destruction: Marathon Petroleum's 161-Mb/d Martinez refinery in northern California and 26-Mb/d Gallup refinery in New Mexico. However, most, if not all, U.S. refineries have reduced crude rates and others have shut down specific units such as FCCs. Given the gap between refined-product supply and demand and the high storage levels for major refined products, low utilization will likely stay for a little while longer and it is possible that other U.S. refineries could join the ranks of the shut-down in the coming weeks.

Note: The article was authored by David Huffman of Baker & O'Brien and published on RBN Energy's Daily Energy Post on May 6, 2020.

"Baby Break It Down" was written by Mick Jagger and Keith Richards and appears as the 13th song on The Rolling Stones' 22nd American studio album, Voodoo Lounge.