



More on Refining: Distillation Curves

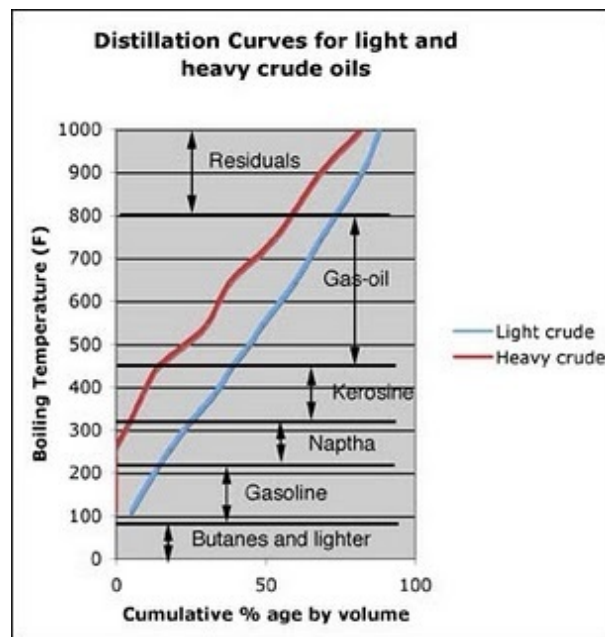
Posted by [Heading Out](#) on January 10, 2010 - 8:58am

Topic: [Supply/Production](#)

Tags: [crude oil](#), [distillate production](#), [oil refineries](#), [tech talk](#) [[list all tags](#)]

[Last week](#), I pointed out that the crude oil that comes out of the ground is not made up of a single hydrocarbon, but rather is a mix of different hydrocarbons that have to be separated. And oils from different parts of the world are formed as different [combinations of these](#), and even those from the same country have [different properties](#).

Today I would like to go a little further and talk about [distillation curves](#). And then, because the world supply is changing to [heavier crudes](#), I will go on to explain a little bit about what is involved in [cracking a crude](#). It is a little more immediately relevant than some posts given that [researchers at Purdue](#) have just come out with a suggestion for an improved refining sequence that they claim could improve efficiency by between 6% and 48% depending on how the process sequences in the refinery are re-ordered. And the crude doesn't have to come out of the ground. NIST have even tested some [made from pig manure](#), with video.

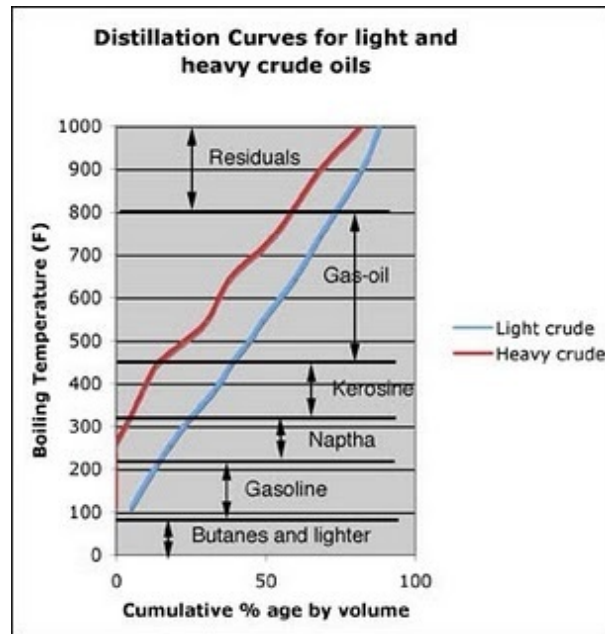


Example of two distillation curves from different types of oil

For those new to the site, this is where, on weekends, I post a small [technical talk](#) explaining some of the aspects of the fossil fuel business, so as to help understanding of some of the topics on the site. It is a very simple explanation, because of space. Those who wish to ask or expound a bit more are invited to do so through the comments.

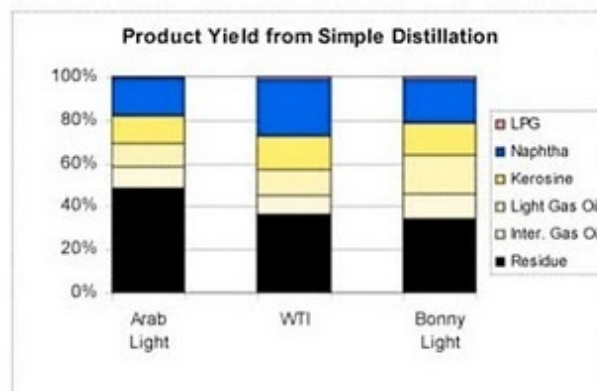
When you first get a sample of a new oil, you will gradually heat it to known temperature levels,

generally following a [standard method](#) or something [more advanced](#). As the sample is heated, the lighter fractions boil off first, and by plotting the volumes emitted within known temperature ranges, a basic sense of the make-up of that particular oil can be achieved.



Example of two distillation curves from different types of oil

For example, if one looks at the blue line in the above graph, this shows a typical light oil composition. It might well yield, on passing through the first distillation column of a refinery, the sort of separation that I showed in the plot last time.



Distillation products from light oils (Source EIA)

However, as is slowly becoming apparent, we are seeing less of these light oils on the market, and increasingly the world is having to accept a greater proportion of heavier crudes. To understand the difference that this makes, consider the red line in the above graph.

You can see that there is no fraction boiled off until the temperature has passed 250 deg. This means that, in its untreated state, there is **no natural gasoline** in the oil. Likely it was too close to the surface and those fractions evaporated away over the millennia (as is the case with the heavy oils in Alberta for example, though this example is from somewhere else). So how do we change this mix into something more useful?

The answer, not only for this crude, but also for the heavier fractions of the light crude, since in both cases we would like to end up with about 45% gasoline, requires that we crack (or split) the higher carbon molecules into lighter or lower carbon ones. For example say we have a molecule of Cetane (16 carbon and 34 hydrogen atoms or $C_{16}H_{34}$). If we heat this to a high enough temperature, then we can break it down into some Octane (C_8H_{18}), some Hexane (C_6H_{12}) and some Ethylene (C_2H_4). But, obviously, what we would like to do is to control what it is that we break these heavier molecules into, and how much of each we produce.

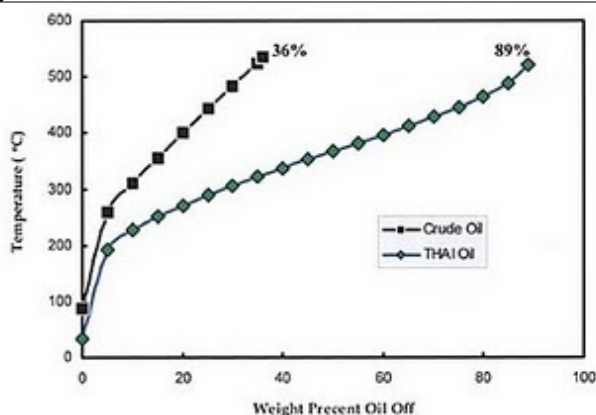
And so we get into the world of [Cracking Oil](#). After the crude oil has been separated into the different fractions, the gas-oil fraction is then fed to a second heating process, where the fluid is brought back up to a high temperature (perhaps around 735 deg C 1400 deg F) and mixed with a finely powdered catalyst (hence the "cat"). Steam is also added to help with the movement of the mix, and the combined mix is fed up a pipe (called a riser) into a tank. As it flows up and into the tank, the gas-oil breaks down into the lower carbon molecules. This happens very quickly, so that by the time the mix is in the tank, the heavy molecules have broken down, and so can be drawn off.

However the catalyst has first to be removed, which happens by passing the flow through cyclones that spin the flow and separate the heavy catalyst, which is collected and fed down a pipe back to be reclaimed and re-used. It needs to be processed since, in part, the process is not perfect and carbon will be deposited on the particles of catalyst, blocking its action. (The carbon can be burned off - providing some of the heat for the process.) The catalyst can then be re-used. One operation might use the catalyst at a flow rate of some [55 tons/minute](#).

The hydrocarbons that flow out of the cracking process are then separated into different fractions. Depending on the season, more gasoline or distillate might be desired, but the process might yield about 8% coke, 55% gasoline, and 12% light gas oil with about 10% of the flow being a sufficiently heavy product that it is sent back to be run through the process again. Light gas oil becomes diesel and furnace fuel oil. The lighter gas products are usually sent to [alkylation](#), or [reforming](#), where the lighter molecules can be combined to give products that can be [blended into a gasoline](#) or another desired product.

Different crudes have different mixes of hydrocarbons, and will need different sizes of processing sections that convert these different fractions to usable and desirable products. Refineries usually have been built to handle only a given range of crudes, and thus have to be considerably modified if that mix should change.

Sometimes the crude can be even heavier. The sands in Alberta contain an oil which is more conventionally called a bitumen, since it has less volatile material than the heavy oil example I used. That oil must therefore go through an additional step to produce the lighter synthetic oil that can then be distilled and cracked more conventionally. Some of the new processes involved in mining and processing the ore are described in a pdf file by [Herron](#). It also includes the distillation curves for the original crude and that obtained when the THAI process is used.



Distillation curves from the Athabasca Oil Sands (after Herron)

There are also contaminants such as sulfur that can be found in the oil. If the content is higher than 2.5%, then the oil is called "sour". This sulfur must be removed. While at one time sulphur was used as fuel in the refinery, that has been stopped, and now the sulfur is recovered. Recovering contaminants requires a treatment circuit that must be installed if the mix to the refinery changes.

This is part of an ongoing weekend series on technical aspects of oil and natural gas production, among other things. As ever, if my explanation is not clear, or if there is disagreement, then please feel free to post, and I will try and respond.



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