Three steps to successful processing of shale and other opportunity feedstocks

Careful blending of incoming feedstocks makes it possible to create an input stream to the refinery that is a better match than any crude source on its own

PATRICK TRUESDALE *Emerson Process Management*
DIDIER LAMBERT *Topnir Systems s.a.s.*

The nature of crude is changing and the refining industry must change with it. At one time, oil wells could be adequately characterised by a crude assay that would change only slowly with time. Thus, refineries could count on fairly stable feedstock.

That is no longer the case, with the arrival of shale oil and other opportunity crudes driving wider feedstock variability. Dealing with this situation requires three components:

- An ability to do accurate, on-the-fly, rapid analysis
- The capability to adjust feedstock blending as needed
- Smart process control to achieve the best possible processing.

Changing assay parameters

Consider the previous situation confronting refineries. Feedstocks largely came from traditional oil wells typically characterised by crude assays determining important parameters such as density, sulphur, salt content and volumetric yield. The crude assay would usually change little over time, often measured in years and only happening slowly as the well moved toward the end of its productive life. What is more, one well's crude assay could frequently serve as a proxy for all other wells within the field. Consequently, refineries dealt with stable feedstocks. In many ways, this aided process optimisation. Refineries consist of many process units operating on a fully integrated basis, which, as a whole, pose challenges in quickly adapting to changing feedstock. Of course, yesterday's refineries still had to deal with variation, but the cycle of change often ran over years.

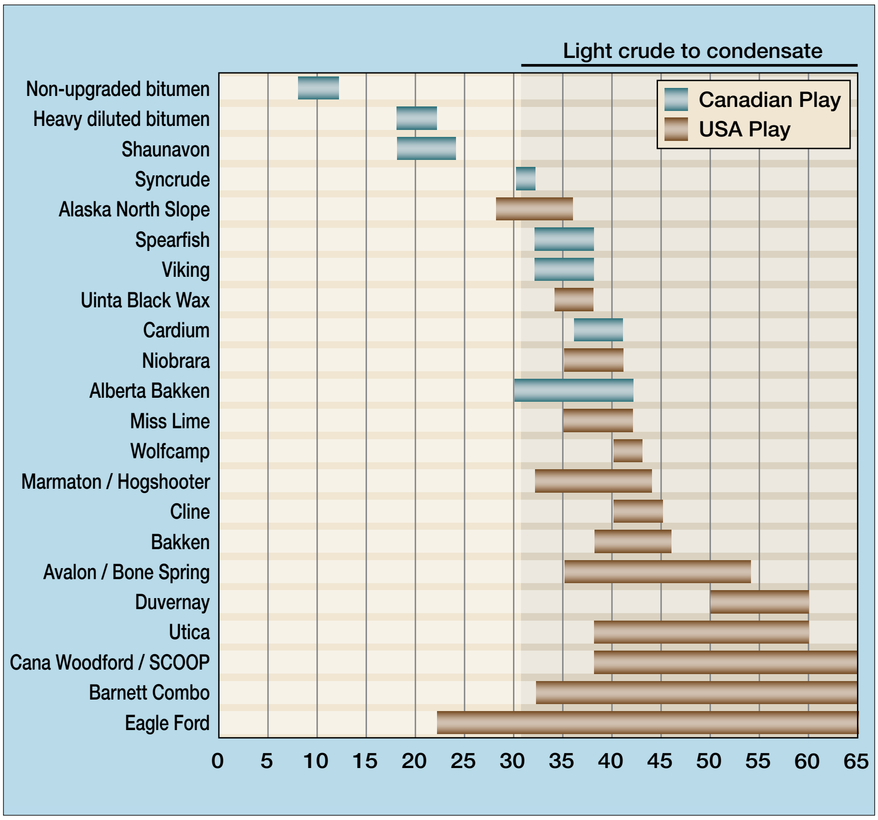

Figure 1 Properties of various US and Canadian crude sources *Source: Platts*

Now look at the world confronting refineries today, as illustrated by the accompanying chart of properties (see **Figure 1**) of various US and Canadian crude sources. Examine the last entry, that of Eagle Ford. In 2009, this source accounted for only 50 000 bpd. A year ago, thanks to hydraulic fracturing and horizontal drilling, that figure climbed to 1.1 million bpd, a more than 20-fold increase. Understandably, this feedstock source has become more prominent. Thanks in part to this surging production, the US has vaulted into the position of being the world's leading fossil fuel provider. Yet, crude produced from the Eagle Ford has the most variation of any of the 22 sources listed. The percentage of light crude to condensate lies between a low of about 20 and a high of 65%. Thus, it can require very different processing, depending upon where along the spectrum a particular batch of crude lies. However, other sources also exhibit large variations in important parameters.

Two more pieces of information complete the picture. The first is that one Eagle Ford cargo may

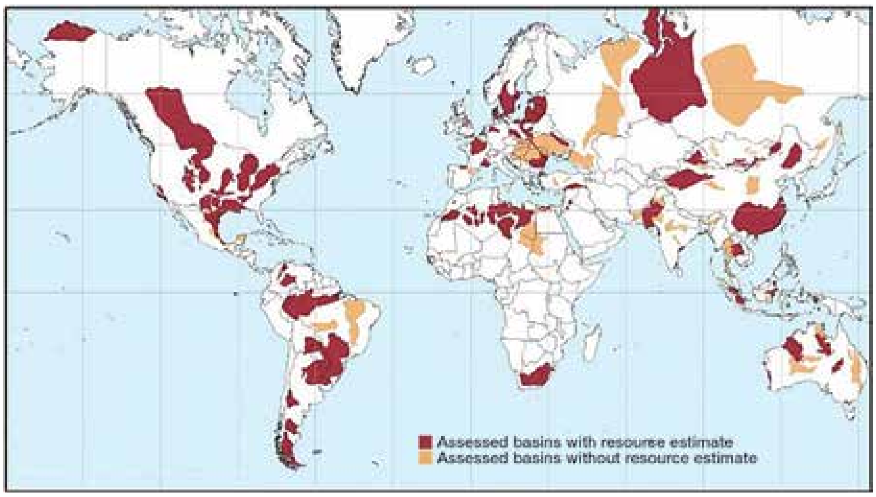

Figure 2 Basins with assessed shale oil and shale gas formations *Source: EIA*

differ radically in characteristics from another, even though both bear the same name. So, the type of crude assay that has been valuable in the past is no longer as useful because assays that were once good for many years, if not decades, may no longer hold from one well to another, or from one well to itself a few months hence. Second, for those who want to dismiss this as mainly an Eagle Ford or US problem, realise that other areas around the world are also considered strong hydraulic fracturing candidates. For example, Argentina's Vaca Muerta basin is thought to be similar to the richest drilling areas in the US, and there are also plays in Australia, China and Poland, as shown in the US Energy Information Administration (EIA) developed **Figure 2**.

In general, such opportunity crudes offer discounted pricing and are increasingly abundant as compared to traditional sources. However, they vary in properties and so may not match a refinery's design and configuration. Dealing with the situation involves three steps: developing the right analysis capabilities and then using the data thus generated to adjust the blend and the process to create the optimum solution.

Analyse

Having a sufficiently advanced analysis capability is critical. Ideally, this analysis will be capable of rapidly discriminating between different types of crude, thereby providing information about distinguishing characteristics. Such data can then serve as the source for any plan to deal with incoming feedstock. More importantly, the analysis must also capture data about crude properties in general. Often, the engineering and operations team at a refinery may not know exactly what will cause problems with heat exchangers, distillation columns and other components of a crude processing unit. Casting as wide an analysis net as practical can provide some protection against such unknowns.

The analysis data can be used to produce a history of properties for past crude shipments that may be essential to diagnosing problems when they occur. There are many different ways to do such an analysis. Of all the possible methods, techniques based upon light can perhaps come closest to the ideal of a fast, cost-effective and highly discriminating analysis method. All matter interacts with electromagnetic radiation, but the nature of that interaction depends upon the material and the wavelength of the radiation. So, developing a light-based method involves finding and applying the correct spectral band to 'interrogate' the incoming feedstock stream, and then devising ways to interpret the data.

Researchers at large global oil companies have devoted years to investigating the feasibility of using light in the near infrared, a spectral region that runs from the edge of the visible at 700 nanometres (nm) out to about 2500 nm. This is well below the thermal IR, which is 5000 nm and on up, which is where objects can be detected by the heat they generate.

The reason why the near-IR has attracted interest as an analysis tool is that chemical bonds absorb such light. This is particularly true for the varying hydrocarbon bonds found in crude, with the region running from 2000 to 2500 nm being among the best possible choices because it is far enough from the visible to be free of any absorption effects related to the light that can be seen with the naked eye. The result of absorption in this near-IR band is a spectral signature. Such a signature can identify specific hydrocarbons as clearly as fingerprints can identify people.

Correctly classifying hydrocarbons is a multi-step process. First, the instrument takes spectral data from a sample of unknown composition. This is then compared to the results from a library of samples with a known make-up. The product is something like a scatter plot, with one axis being the wavelength and the other being a relative reading. Visually, this would group various grades of crude into different clusters.

In the ideal world, there would be plenty of data points to easily place an unknown into the proper classification. In the real world, refinery managers cannot wait too long for an analysis to be complete. At the same time, they cannot afford to have an analysis be wrong, since that may actually be worse than not knowing anything at all.

One way out of this bind that is being pursued by instrument makers is through a process called densification. This is based on interpolation between a sparse set of data points to create a much denser data cloud. Consequently, the accuracy of analysis can be significantly improved without having to sacrifice speed. Doing densification properly demands deep expertise in the how and why of spectral blending.

Blending

Using analysis to determine crude characteristics is only part of the solution. The second and third steps involve acting on the information.

In the ideal world, such action would be easy. Distillation columns, heat exchangers and the remaining components of a crude processing unit would be infinitely and rapidly adaptable to the incoming feedstock, thereby ensuring the best possible outcome. Unfortunately, refineries operate in the real world. Consequently, there are some constraints on how they can be configured. However, the range of possible solutions can be expanded because there are two sides to this optimisation puzzle. On the one hand, there is the refinery and its capabilities. On the other, there is the feedstock. It is the mismatch between the two that is the problem and, as has been discussed earlier, today's feedstock has more variability than ever. So, by carefully blending incoming feedstocks, it may be possible to create an input stream to the refinery that is a better match than any crude source may be on its own.

What would an ideal blending solution look like? It would be responsive and react in real-time to input from analysers characterising incoming crude. It would have algorithms built into it that would give the optimum ratio of different feedstocks for a given situation. More importantly, the best crude oil blend would vary, depending upon refinery configuration and the desired fuel target to maximise during favourable market conditions. At one time, it might be gasoline. In another case, it might be either ultra-low sulphur diesel (ULSD) or jet aviation fuel, Jet A1. Lubricants and asphalts are another class of products that might be part of the decision matrix.

Projects in Europe and Americas using an analyser-driven blending system have shown that it is possible to determine such important properties of crude as its true boiling point (TBP) in less than a minute. In turn, this enables blending adjustments that result in benefits running into millions of dollars.

Scheduling in such a blending scheme will be improved by having visibility into incoming crude characteristics as soon as possible. That implies that analysis should be done as soon as feasible in the supply chain.

Speaking of the supply chain, disturbances happen. A crude shipment may be delayed, for instance, and a refinery will then run with what is in the tank because it costs too much for a facility to shut down and sit idle while waiting for a shipment to show up. Even in this case, though, knowing the characteristics of what is on hand can be used to minimise the disturbance of a crude switch. For instance, automatically making set-point changes in a fractionator via advanced process control may help smooth out any supply hiccups.

Refinery process control should be nimble to cope with changes in operational targets and feedstocks

Taking action: smart refining

The last item brings up an important point: process control. Actual situations will necessarily have some unevenness in feedstock properties. Therefore, the third and final part of the ideal solution involves implementing intelligent refining solutions. For instance, it is not only changes in feedstock that can impact the distillation process that is at the core of refinery operations. Changes in the weather can also push distillation column operation out of optimum.

One way to avoid going out of spec as a result of feedstock, weather or other changes is to over-purify, leading to wasted energy and lower product yield. A better solution is to use advanced process control technology to automatically adjust distillation column parameters to optimal targets without violating constraints. Doing so will reduce product quality variation and off-spec production while minimising energy consumption per unit of feed. It will also increase recovery of more valuable products and column throughput. In the context of a world where feedstocks are more variable, this will mean that blending operations will have more leeway. This is because the blended feedstock can have a wider range of characteristics, yet the refinery will still be able to produce the required product blend.

This distillation process control also has to be dynamic. After all, it is not only the feedstocks that are changing over time. The output goal is also changing. The possible targets include reduced energy consumption or production at maximum capacity, just to name two. It may be necessary in the first case to minimise purification, while in the second the requirement may be to continuously operate a distillation train at the most limiting overall constraint. Thus, refinery process control should be nimble so as to cope with changes in operational targets and feedstocks.

Real-time analysis

The world of crude is changing due to the appearance of significant supplies of shale oil and other highly variable feedstock. In addition to becoming increasingly abundant as compared to traditional feedstock, these opportunity crudes may be discounted and so cannot be ignored. Because their properties are so variable, an old-style crude assay does not make sense. Hence, the need is for real-time analysis to provide the data for *ad-hoc* blending of crude supplies and intelligent process control. Together these can make a solution.

Given the reality of the world refineries face today, it is important that such optimisation solutions be implemented. It is also important that when this is done, it must be backed by deep expertise, as this is the best way to successfully handle a complex and changing situation.

Patrick Truesdale is Principal Solutions Consultant, PlantWeb Solutions Group, Emerson Process Management, Houston, Texas.
Email: Patrick.truesdale@emerson.com
Didier Lambert is President, Topnir Systems s.a.s, Paris, France.
Email: didier.lambert@topnir.com