"Unique Technology to characterize Shale and other Opportunity Crude Oils while optimizing Crude Operations"

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Abstract/Synopsis

The solutions provide accurate predictions of raw crude products and gives in real time, a multiple list of crude properties: TBP (True Boiling Point), Crude assays, Density API (American Petroleum Institute), Viscosity, TAN (Total Acid Number), Pour Point, Sulfur and others.

The technical crude tool is used both in:

- Upstream:

Several areas of interest regarding the use of technology in Upstream Applications:
  - Crude identification,
  - Crude characterization
  - Reservoir integrity.

- Downstream

By predicting in real time both properties of:
  - Crude Tank Farm & CDU (Crude Distillation Unit) inlet,
  - CDU Rundowns,

These solutions lead to accurate process control operations and valuable process optimization states that maximize benefits for the user.

KEY FEATURES

- A dedicated Software devoted to:
    - Laboratory applications
    - At Line & Online applications.
- Full set of Properties predicted in less than a minute
- ASTM (American Society for Testing Materials) warrantee (or equivalent) on Reproducibility and Repeatability criteria.
- This technology delivers full crude assay in less than 1 minute in lab and online applications.

MAIN BENEFITS

- Cutback on High Temperature Simulated Distillation (HTSD) or ASTM D2892 / D5236 cost and analyses time.
- Crude quality follow-up in pipe
- Better crude segregation
- Better crude blending optimization
- Tank segregation optimization
- Crude switch optimization
- Process throughput increase
- Plant capacity maximization

Two main predictions are delivered by this new technical modelling approach:

- A Full Crude Assay Property Table, including Distillation Cut Properties whatever Cut points are.
- A Fast Crude property prediction giving TBP, TAN, API Gravity, Pour Point, Viscosity @ 40°C and others.

Thanks to this modeling solution, crude composition is available within one minute.
This specific software for crude applications uses an intuitive and efficient interface that allows a simple handling of the system. All management actions, including soft/hard internal communication, alarm treatment and sampling automation, are ensured by the software to facilitate the use.

TYPICAL CRUDE APPLICATION

- Relative proportions determination of different end-member crude oils in an unknown mixture.
- Immediate crude cargo composition measurement for quality control and trading conformity checking.
- Optimal routing of crudes product during crude transportation.

Crude mixing optimization for the preparation of feeds that allow maximizing the yield of valuable products

Introduction

The nature of crude is changing and the refining industry must change with it. At one time, oil wells could be adequately characterized 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 resulting in wider feedstock variations.

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, and
- smart process control to achieve the best processing possible.

Consider the situation confronting refineries in the past. Feedstocks largely came from traditional oil wells, which were typically characterized by a crude assay that determined such important parameters as density, sulfur, salt content and volumetric yield. Usually the crude assay would change little over time, often taking years and only happening slowly as the well moved toward the end of its productive life. What's more, the crude assay of one well frequently could serve as a proxy for all other wells in a field.

As a result, refineries dealt with stable feedstocks. In many ways, this aided process optimization. Refineries and their subunits are capital intensive operations and thus not easily able to quickly adapt to changing feedstock inputs. Of course, yesterday's refineries still had to deal with variation, but the cycle of change often ran over years.

First, Analyze

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.

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 of past crude shipments that may be essential to diagnosing problems when they occur.

There are many different ways to do such an analysis (see Fig: 1). Of all the possible methods, techniques based upon light can come perhaps 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 the right spectral band to use to interrogate the incoming feedstock stream and then devising ways to interpret the data.

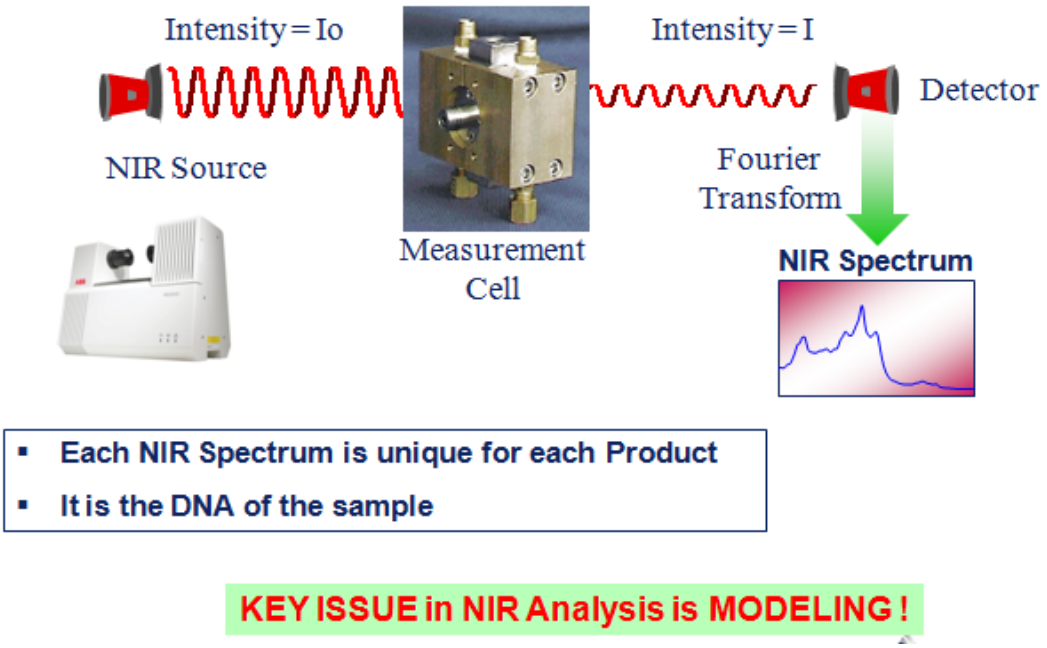

Figure 1: Typical NIR spectra collection

Researchers at large global oil companies have devoted years to investigating the feasibility of using light in the near infrared (NIR), a spectral region that runs from the edge of the visible at 700 nanometers out to about 2500 nanometers. This is well below the thermal IR (Infrared), which is 5000 nanometers and on up and 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 nanometers 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. It is demonstrated on the picture below (see Fig: 2), where residual absorbance is well seen in this graph after 5.000 cm^{-1} with one axis (X) being the wave number (cm^{-1}) and the other (Y) being a relative reading (absorbencies).

The result of absorption in this NIR band is a spectral signature. Such a signature can identify specific hydrocarbons as clearly as fingerprints do people.

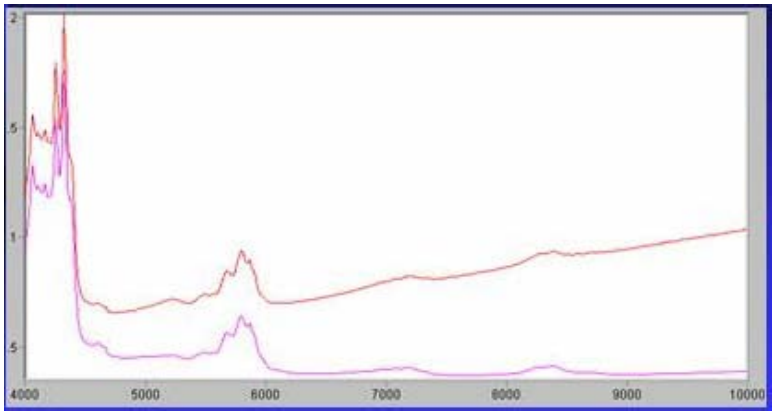

Figure 2: NIR spectra typical shape

Correctly classifying and analyzing hydrocarbons is a multistep process. It is done through this unique technology (TOPNIR) based on NIR technique and which is the sole source to perform Crude analysis by NIR. Indeed, the instrument takes firstly spectral data from a sample of unknown composition. This is then compared to the results from a library of samples with a known makeup. The product is something like a scatter plot (see Fig: 3), with one axis being the wavelength and the other being a relative reading. Visually, this would group various grades of crude into different clusters as shown below.

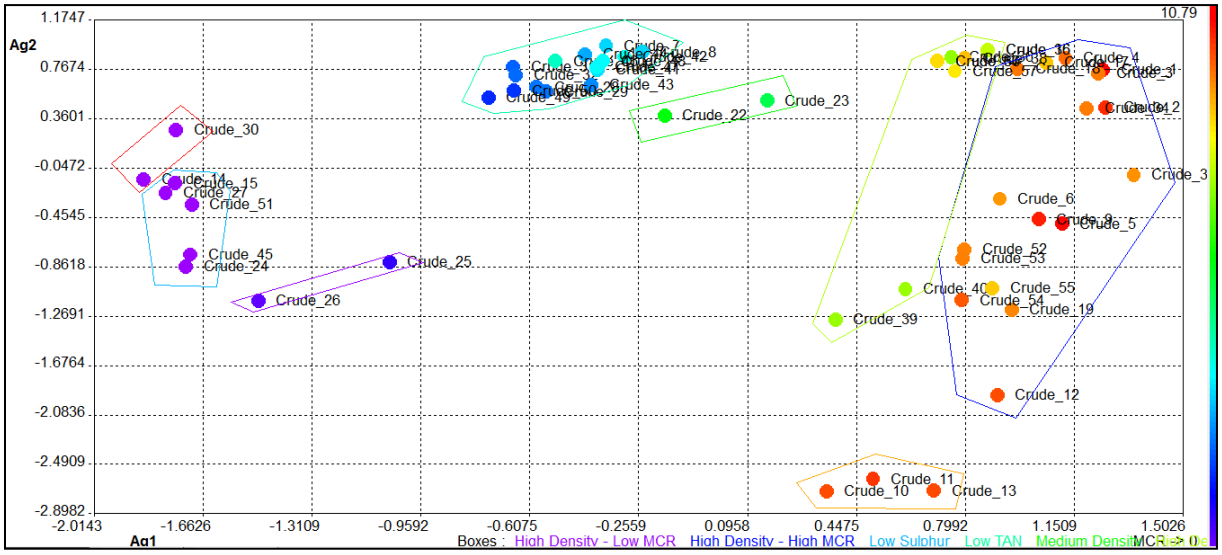

Figure 3: Topological crude oil clusters

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, another unique feature of this technology. 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 (see Fig: 4).

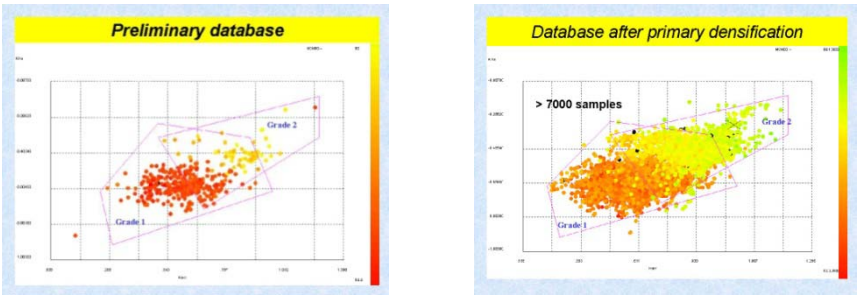

Figure 4: Samples scatter plots before and after densification process

After completion of densification process, calculation can be carried out. Our calculation approach is based on topology, works through pattern recognition and databank densification. It does not use linear model for a set of properties which require one model per property. The software instantly delivers all the properties required for a given application. Moreover, it offers the possibility of extrapolation from the initial calibration range.

Then, to do a prediction, this new calculation tool will position the new sample in the database and will identify all the samples, the neighbours, located up to a certain distance (see Fig: 5). Having identified all the neighbours, Topnir will then use the properties of the neighbours to calculate the properties of the new sample. It is immediate, fast and accurate. Indeed, this calculation keeps the coherence in terms of chemistry between all the properties, as everything is linked to the overall spectra.

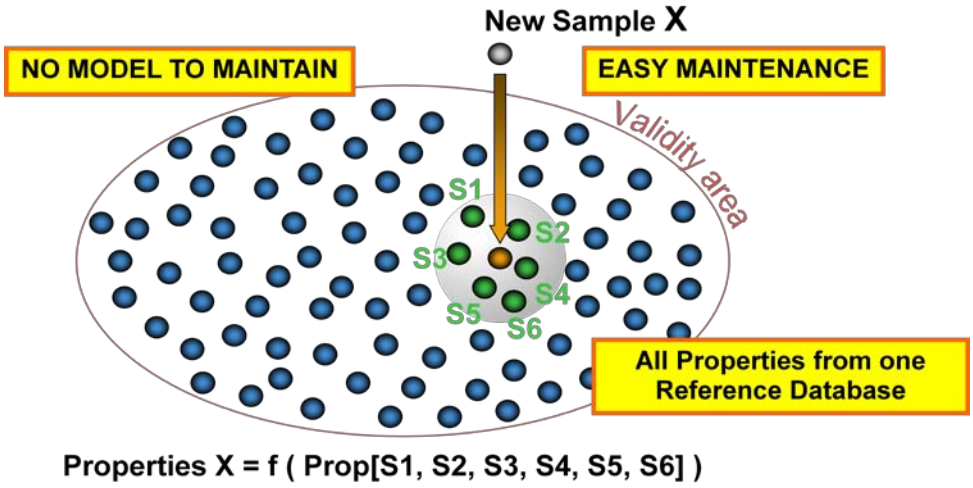

Figure 5: Topological calculation process

Regarding Crude Oil analyses, this calculation approach delivers, off-line and on-line, in less than one minute, the Crude Assay results under two standard formats:

- A Fast Crude analysis giving TBP (True Boiling Point) distillation curve (see Figure 6), TAN, Sulphur, API Gravity, Pour Pt, Viscosity @ 40°C and others.

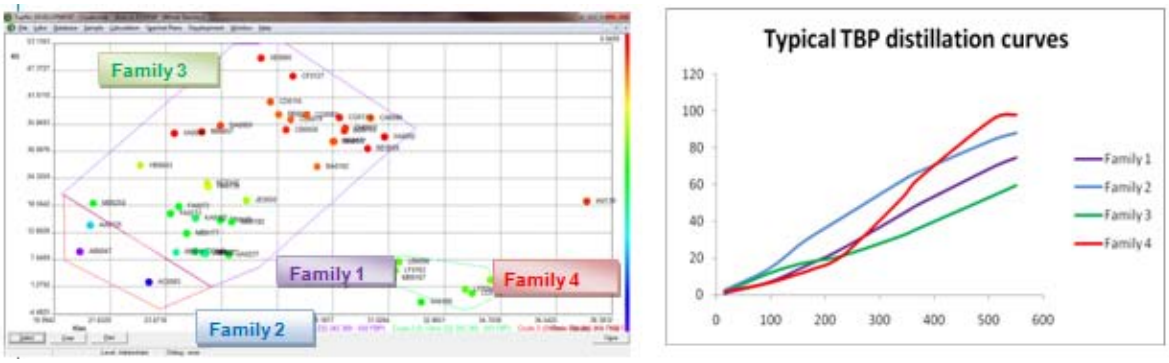

Figure 6: Typical TBP distillation curves for different Crudes oil families

- A Full Crude Assay Property Table including Distillation Cut Properties.

This unique Crude solution addresses several operation sectors.

For Upstream, it can be:

- Reservoir integrity,
- Crude identification,
- Commingled Oils for end-members quantification,
- Transportation,
- Crude characterization.

Regarding Downstream, applications are:

- Crude Tank Farm for Tank allocation,
- Crude Blending,
- CDU Process Control with Crude feed and Rundown on-line analysis.

To summarize, TOPNIR Crude analysis can be used for (see Fig: 7):

- Relative proportions determination of different end-member crude oils in an unknown mixture.

- Immediate crude cargo composition measurement for quality control and trading conformity checking.
- Optimal routing of crudes product during crude transportation.
- Crude mixing optimization for the preparation of feeds that allow maximizing the yield of valuable products

Figure 7:

Taking Action, 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 rest 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 optimization puzzle. On one hand there is the refinery and its capabilities. On the other 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 careful 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 analyzers characterizing incoming crude. It would have algorithms built in to it that would give the optimum ratio of different feedstocks for a given situation. Importantly, the best crude oil blend would vary depending upon refinery configuration and the desired fuel target to maximize during favorable market conditions. At one time it might be gasoline. In another case it might be either ultra-low sulfur diesel 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 analyzer-driven blending system have shown that it is possible to determine such important properties of crude as its True Boiling Point in less than a minute. In turn, this enables blending adjustments that result in benefits that run into the 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 in can be used to minimize 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.

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 minimizing energy consumption per unit of feed. It also will 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 minimize 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.

Conclusion

As has been shown, 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 (see Fig: 9) to provide the data for ad-hoc blending of crude supplies and intelligent process control. Together these can make a solution.

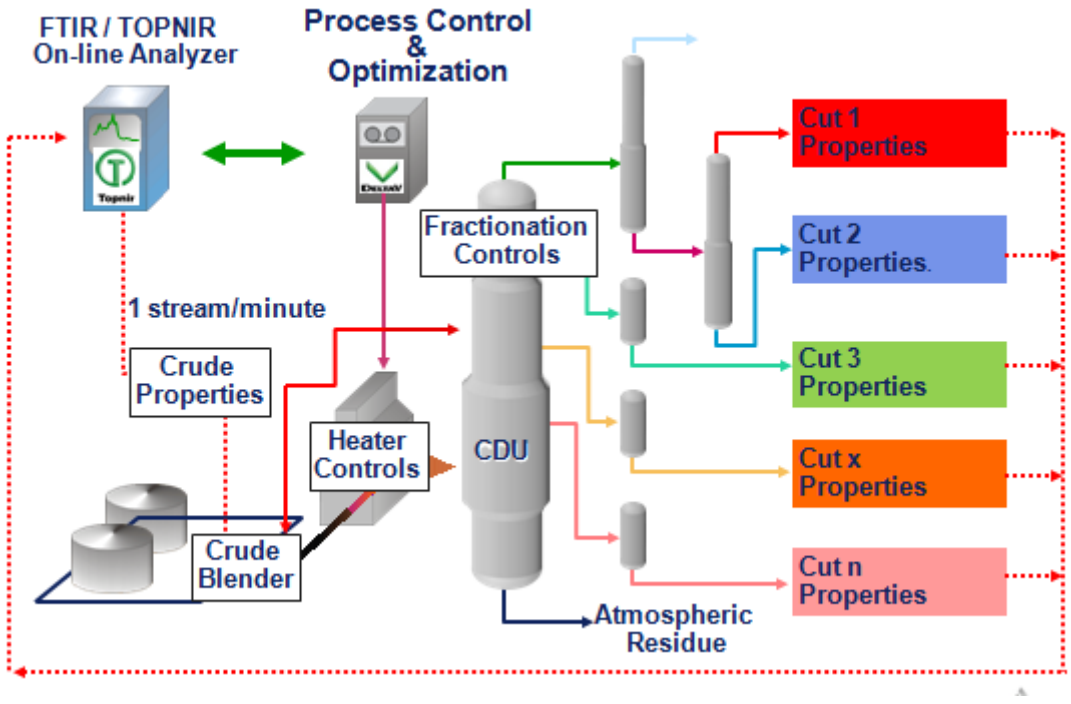

Figure 9:

Given the reality of the world refineries face today, it is important that such optimization solution 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.

The impact of Topnir analysis on Crude operations can be seen as follows:

- Crude quality follow-up in pipe
- Better crude identification and segregation

- Better crude blending optimization
- Tank segregation optimization
- Crude switch optimization
- Process throughput increase with Plant capacity maximization

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