Executive Summary
Opportunities exist to dramatically improve product margins by optimizing the blending of distillate products. The benefits of gasoline blending optimization are already well known. Distillate blending has the potential for large margin improvements as well. We discuss the scenarios of distillate blending and solutions for refineries that have many, if not all streams blending directly to destination tankage with little or no component storage.
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Background

The European transportation fuels market has seen a long term swing in market share from gasoline to diesel. There are two basic reasons for this: preferential tax treatment of diesel, and higher fuel efficiency of diesel engines. Refiners have reacted by increasing diesel fuel production while holding steady or reducing gasoline production. At the same time, increased availability of natural gas for home heating has produced a similar long term shift away from heating oil. Thus fuels refineries that can shift production to maximize diesel fuel are best positioned to profitably serve their markets.

In the past, European refiners concentrated on gasoline and invested in the infrastructure and automation of gasoline production. This investment included component tanks, automated control valves, pumps, blending headers, analyzers, as well as blending control and optimization applications. Blending of diesel and other middle distillate products was typically neglected in comparison to gasoline. Middle distillate fuel production is typically rundown, with few or no intermediate tanks. With the advent of very low sulphur diesel specification (10 ppm) in Europe and elsewhere, the major investments have been in distillate desulphurization, not blending.

Control and optimization technology has improved to handle multiple simultaneous blending headers with shared streams, different products and product specifications on each blend header and time-varying component qualities. A large range of product qualities can be optimized simultaneously including cetane, flash point, density, sulphur, cloud point, cold filter plugging point as well as a wide range of distillation related properties (E250, E350, T95% etc.).

The Economics

The economic benefits of middle distillate optimization can be divided into two levels.

Header Only

Header only optimization considers only the redistribution of components between the middle distillate products (heating oil, diesel fuel, and jet fuel).

Here the benefits can be obtained through a better distribution of the components such that the production of the higher value product is maximized. Scenarios have been seen where a manual blending operator solution had 200 m3/hr diesel and 350 m3/hr of heating oil being produced. The header only optimizer found an on specification solution where 300 m3/hr diesel and 250 m3/hr of heating oil were produced instead. Assuming a pricing differential of $20 USD/m3 leads to a margin improvement of $2000 USD/hr.

The header only mode assumes that the component streams are of fixed quality for a particular optimization cycle, although the qualities may change from one cycle to the next.

Upgrading Side Cuts

The production of diesel can be bracketed by two properties, T95% for the back end, and flash point for the front end. Increasing the flow of heavy components will increase the T95% property, while an increase of lighter components will decrease the flash point. The heavy components will have little impact on the flash point while the light components will have little impact on the T95%.

In most, if not all refineries, putting a rundown component directly into a finished product is preferable to passing it first through a secondary unit. For example, it is preferable to increase the naphtha proportion into kerosene which is then blended into jet fuel or diesel fuel instead of passing the naphtha through the reformer and then into the gasoline pool. This is especially interesting if gasoline is not a preferred product to begin with. The T95% must be watched carefully since it can have a limiting effect. Care as well would need to be taken with respect to secondary effects such as in the case of heavy naphtha where the hydrogen balance would need to be considered, but for small amounts this should be manageable.

Recently the spread between heavy naphtha and diesel fuel has been $350 USD/m3. If there is room in the flash point then there is an opportunity to add some more naphtha into the diesel product. Based on the above differential, 1 m3/hr of heavy naphtha into the diesel product has a value of up to $3 million USD annually.

The use of heavy components in diesel is somewhat more difficult to estimate and varies from refinery to refinery, but assuming a differential of $100 USD/m3, the benefit can be up to $1 million USD annually per m3/hr increase.
There could also be opportunities for changing the severity of intervening desulphurization units to meet the sulphur specification. It may even be possible to allow some components to be at least partially diverted around the desulphurization unit.

It should be noted that although the long term trend has been the diminished importance of heating oil, short term fluctuations as well as geographic differences still occur. These as well present an opportunity to the refiner. With the specifications of heating oil and diesel fuel being as similar as they are, it is relatively easy to shift production between the two.

In a simplified view, the production of diesel fuel (or heating oil) can be increased until a product specification limit is reached.

**The Problem**

**Model Overview**

A classic optimization scenario considers the component qualities as “fixed” for the course of an optimization run. The component qualities may change over the course of the blend but the optimizer considers the qualities as fixed for the current snapshot of the blend. The solution is thus a set of flow rates of the components that meets the specification either at the header or at the end of the blend in the destination tank. In the latter case the initial destination tank heel is taken into account.

In a rundown blending scenario with multiple units and little or no intermediate component tanks, the number of classic degrees of freedom is limited. One way to increase the degrees of freedom is to add the component rundown flow rate or the component qualities as manipulated variables. This can be done by developing simple correlations that predict the change in flowrate and properties of components based on incremental changes in the cutpoints. When optimal cutpoints are determined they can be published to operators as set points for the upstream unit operations. Thus we steer the upstream units to produce better blending components but leave it to the controls on those units to attain them.

The solution must be aware of intermediate residence times as well as the flow-quality correlation for the component flows. Any intermediate desulphurization units need to be modeled since some cracking occurs and outlet qualities are changed, the distillation may be shifted slightly to the heavier end and the density will be slightly heavier. This however is dependent on the type and configuration of the desulphurization unit as well as the feedstock properties.

Figure 1 shows a typical scenario.
For a refinery that has low diesel component tank storage capacity and is mostly rundown, typically blend planning is indicative and not as detailed as is seen in gasoline planning where the component storage is more abundant. That is, in gasoline blending detailed recipe plans are generated while in distillate blending the plans are cursory of the form, “please fill tank 123 in the next 2 days then swing to Tank 222”. Recipes are not detailed and the control room operators tend to be left to use their own judgment. This leads to operators “tuning” the blends to the best of their abilities based on watching online analyzers and the occasional lab sample. Thus the operators will create blending recipes that work but may not be optimal. The product mix they blend in interacting blending scenarios such as in figure 1 may also not be optimal. As previously discussed, the price differential between heating oil and diesel fuel may be on the order of $20 USD/m3, but to be on the safe side the operators may blend an excess of heating oil because that is a “safe” recipe from their perspective. There is likely a better scenario where more diesel is produced and less heating oil with the correspondent improvement in margin.

The Solution
The Optimization Problem can be divided into two parts.

Header Only
The first part is the classic header only optimization model. Here the component flows directly at the header are considered and their associated degrees of freedom. For components that do not have multiple destinations, say a Hydrogen Desulphurization Unit (HDS) direct rundown to the diesel header only with no segregation, the flow will be considered as a wild or uncontrolled flow. For a flow that may be sent to multiple blending headers or has a segregation destination, this stream may then be considered as a fully controlled flow.
The qualities of the components in this header only mode are considered fixed for this optimization run.

**Full Network**

In the second part of the optimization where the full model of the entire network is considered, the header is of course included but as well the component rundowns themselves and the quality/flow correlations of the properties are included. In this part, the optimal solution for the entire network is considered. That is, the qualities of the components are adjusted within the specified limits.

The unit operator with the support of the unit APC can determine the maximum and minimum achievable qualities of the rundown components. These min-max limits are then passed as constraints to the full network optimization. This allows the range to be large or perhaps none at all. These min-max limits can also vary from full network optimization cycle to cycle.

For example: the CDU gasoil side cut T95% low high limits may be specified as 350C-380C, with the current flow rate of 50 m3/hr and a T95% at 355C. The model states that for every increase in T95% an extra 0.5 m3/hr of gasoil can be expected. Thus the optimizer can adjust the T95% set point for gasoil. Even an increase of 1 degree centigrade of the final product T95% point closer to the specification can bring significant benefits.

In the full network it has been found that relatively simple correlations can be sufficient to achieve significant results, such as a linear relationship between rundown quality and flow rate. As long as the allowed range is reasonably limited over a known range then the correlations can be considered reliable. Unit APC implementations typically have quality estimations as part of the installation. These quality estimations can also be leveraged by the network optimization.

**The Approach**

**The Requirements**

To allow for a full network solution as described above several factors need to be present:

1. Flow metering;
2. Online Analyzers on the blending headers;
3. Online analyzers or dependable quality estimators at the unit rundown;
4. Direct rundowns from units that have a reliable APC application;
5. Defined quality flow correlations for the controllable rundown;
6. Defined HDS property shifts (for HDS included in the model);
7. Interconnected blend headers, headers that share rundown components.

**The Project**

A project can directly consider the full network right from the beginning; however it may be beneficial to first implement a header only optimization such as one using Honeywell's Open Blend Property Control (OpenBPC). For refineries that are not consistently producing the optimal product mix based on existing production this can bring immediate and significant benefit.

A further study to simulate the full middle distillate network can then be undertaken to determine and justify any further investment in metering and online analyzers. The study can also determine whether benefits can be expected in the full network optimization and to quantify them. This can then in turn be used to justify a further expansion of the OpenBPC application to include the Manufacturing Modeling and Solving System (MMSS) network optimizer option.

**OpenBPC Optimizer**

OpenBPC uses a nonlinear optimizer that executes at every control interval to adjust the blend recipe based on analyzer feedback. The problem statement for the optimizer is contained in the recipe information. Basic blending objectives include property control, minimum cost, minimum giveaway, and minimum distance (deviation from the scheduler's original recipe or from high or low component limits).

OpenBPC executes blend optimization in multiple sequential stages, with each stage optimizing for one of these objectives. Each succeeding stage preserves the optimum blend recipe achieved in the previous stage, while using any remaining degrees of freedom to optimize for an additional objective. OpenBPC delivers the following objective combinations:
• Property control and minimum giveaway
• Property control and minimum cost
• Property control, minimum cost, and minimum giveaway
• Property control, minimum giveaway, and minimum cost
• Property control and minimum distance.

MMSS Plug-in for OpenBPC Optimizer
Manufacturing Modeling and Solving System (MMSS) is a plug-in to OpenBPC that allows for a full network optimization of a product pool such as a distillate pool.

MMSS uses the network definition in OpenBPC. The network is designed to model the real site configuration and utilize the appropriate stream qualities and flows as degrees of freedom. A quality of a flow that has an analyzer and flow meter and is possible to adjust can be determined to be a degree of freedom.

Tank volume inventories of buffer tanks can be assigned targets as well. Buffer tank levels may need to be kept between a minimum and maximum level, they may also be targeted towards specific level.

Intervening units such as HDS can have maximum and minimum expected charge rates. These are modeled in the MMSS system through the OpenBPC user interface.

MMSS is scheduled independently of the standard OpenBPC header only optimization. There is a separate blend report for MMSS but is linked to the standard report for cross referencing purposes.

The results of each optimization run are available inside of OpenBPC where they may be passed directly to the unit APC or reported in an advisory fashion.

Who Can Benefit From This Approach?
Although any refinery with a proportion of rundown blending can benefit, the more rundown streams available for control (i.e. APC configured) the higher the potential benefit. Some refineries operate in highly regulated fuels markets. These refineries may also benefit since there may be opportunities to improve thin or even non-existent margins through the upgrading of low value side cuts to higher value blended products.

Refineries that have a small number of rundowns and a corresponding higher proportion of component tanks may also benefit, if the rundowns can be adjusted.

Since the benefit is realized through added flexibility, the refinery should have the capability to market any added production, whether this added production is through upgrading of the side cuts, or through re-distribution of production quantities.

The benefits are not limited to the middle distillate pool; a gasoline blending system with a similar constellation may also have realizable benefits.

Glossary

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>APC</td>
<td>Advanced process control- applications such as Honeywell’s Profit controller (RMPCT)</td>
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<td>CDU</td>
<td>Crude Distillation Unit</td>
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<td>CFPF</td>
<td>Cold Filter Plugging Point. A cold temperature diesel property</td>
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<td>FAME</td>
<td>Fatty Acid methyl Ester. A plant derived diesel blending component</td>
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<tr>
<td>HC</td>
<td>Hydrocracker Unit</td>
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<tr>
<td>HDS</td>
<td>Hydrogen Desulphurization Unit</td>
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<tr>
<td>Kero</td>
<td>Kerosene</td>
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Distillate Blending Optimization

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<tr>
<th>MMSS</th>
<th>Manufacturing Modeling and Solving System- Modeling tool for a full network optimization</th>
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<tr>
<td>OpenBPC</td>
<td>Open Blend Property Control, Honeywell’s blending optimization application, designed for multiple platforms.</td>
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<tr>
<td>SR Kero</td>
<td>Straight Run Kerosene</td>
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<tr>
<td>VDU</td>
<td>Vacuum Distillation Unit</td>
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<td>Vis Breaker</td>
<td>Viscosity Breaker Unit</td>
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