P.J. Walton, BP Oil, UK, and C.J. Swart, Invensys Performance Solutions, The Netherlands, describe an integrated approach to gasoline blending at refineries.

The boss of blending

The operational benefits resulting from the implementation of an integrated gasoline blending operation are reaped in the areas of offline blend planning and scheduling, together with online optimisation control up to the final product certification. The savings achieved by implementing such a system are quantifiable, and as the technology applied is readily available, can be captured by all refineries.

In addition to these benefits, the planning and scheduling of gasoline blending is also an important aspect of operations. It has been recognised by the interaction of monthly refinery planning tools with the offline functionality of blend optimisation and supervisory software (BOSS), as offered by Invensys.

Online blending analysers at the blend header are used for feedback control and product certification, which necessitates consideration of the relevant organisational aspects of the operations, analyser technicians, and laboratory departments.

This article discusses the Invensys concept for gasoline blending at refineries, and provides operational results of systems implemented over the last 15 years. More than 50 refinery blending systems have been installed using BOSS, and of these more than 94% are still operational.

Interaction planning/scheduling and online optimisation

Each refinery makes use of an LP based monthly planning system, which balances crude supply and product demand on a monthly basis. Imbalances remaining after crude optimisation are compensated for by the purchase of additional gasoline products or components. These components are known as marginal gasoline components, as they are commercially available, and therefore have a market value. These component prices, together with the final product values, are important drivers for optimisation.

Within this monthly plan, a schedule of the individual gasoline blends has to be created, taking into account the delivery (lifting) time of gasoline batches; the availability of the component volume; the component tank capacities; and the limitations of the blending operations.

Different offline medium term planning and scheduling tools are available, but they do not fulfil all the needs of the refineries. The available tools do not use live data and, hence, are not accurate enough. Nor do they take into account operational constraints, such as blend flow loop restrictions, pumping constraints and analyser instrument ranges. It also requires a major engineering effort to keep these tools up to date.

At the same time, it is necessary to optimise the allocation of the available components in such a way that the gasoline is produced at minimum cost, whilst it remains within the operational constraints of component inventory and blending equipment limitations.

The offline BOSS from Invensys does not present these drawbacks. Product deliveries (blend schedule) are used as input. Based on this product delivery schedule, the current component inventories and the component production, equipment constraints and quality projections, the offline BOSS defines the optimum scenario for production of the gasoline blends.

Figure 1 is an example of one of the BOSS offline human interfaces. Resulting component inventory behaviour is represented. It clearly shows that during the blends (green line), the component (brown line) is used from the component tank. During the different blends, the component volume remains within the capacity of the tank's minimum and maximum dips. At the same time, the different blend recipes are designed to optimise the finished product to be on specification at the lowest cost using the available components.

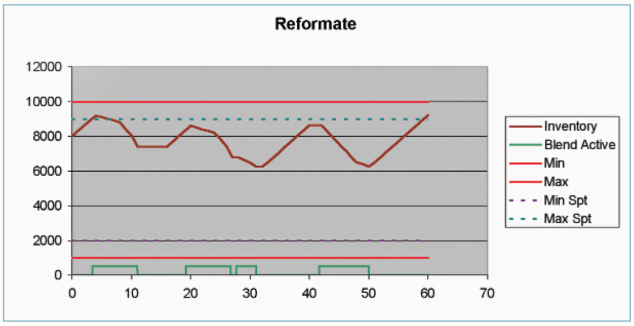
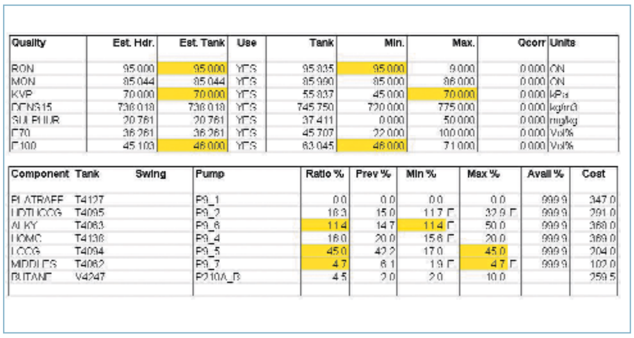


Figure 1. BOSS offline human interface.

The recipes for individual blends are communicated to the operational department. As will be discussed later, the online BOSS optimises within the constraints of these blend instructions. The control space available for optimisation is created as a result of deviations from the predicted quality and quantity of the blend components.

Application and advantages of online blend optimisation

BOSS uses online and real time multi variable (N)LP based profit optimisation techniques. The online and real time function of BOSS calculates and sets the optimum component ratios every 3 - 6 mins. It ensures the maximum economic



Quality	Est. Hdr.	Est. Tank	Use	Tank	Min.	Max.	Qcorr	Units
RON	95.000	95.000	YES	95.835	95.000	9.000	0.000	ON
MON	85.044	85.044	YES	85.990	85.000	86.000	0.000	ON
RVP	70.000	70.000	YES	55.837	45.000	70.000	0.000	kPa
DENS15	738.018	738.018	YES	745.750	720.000	775.000	0.000	kg/m3
SULPHUR	20.761	20.761	YES	37.411	0.000	50.000	0.000	mg/kg
E70	36.261	36.261	YES	45.707	22.000	100.000	0.000	Vol%
E100	45.103	46.000	YES	63.045	46.000	71.000	0.000	Vol%

Component	Tank	Swing	Pump	Ratio %	Prev %	Min %	Max %	Avail %	Cost
PLATRAFF	T4127		P9_1	0.0	0.0	0.0	0.0	999.9	347.0
HDTLCCG	T4095		P9_2	18.3	15.0	11.7	32.9	999.9	291.0
ALKY	T4063		P9_6	11.4	14.7	11.4	50.0	999.9	368.0
HOMC	T4138		P9_4	18.0	20.0	15.6	20.0	999.9	369.0
LCCG	T4094		P9_5	45.0	42.2	17.0	45.0	999.9	204.0
MIDDLES	T4062		P9_7	4.7	6.1	1.9	4.7	999.9	102.0
BUTANE	V4247		P210A_B	4.5	2.0	2.0	10.0		259.5

Figure 2. BOSS overview display, indicating active constraints.

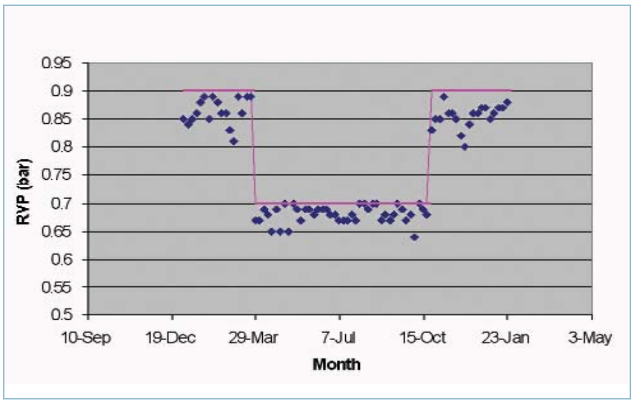


Figure 3. Gasoline blending without BOSS.

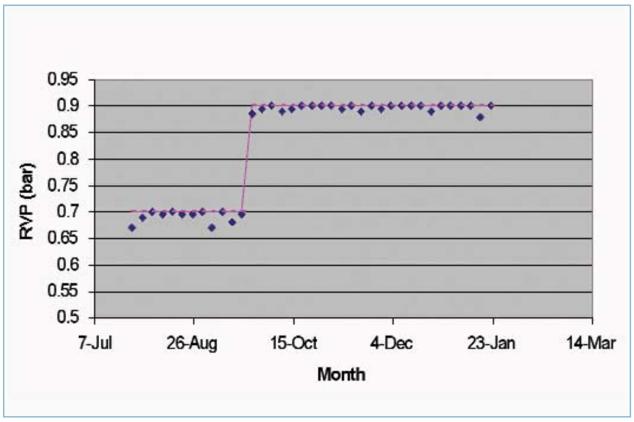


Figure 4. Gasoline blending with BOSS.

use of the given components, within the given component availability, quality, equipment, and process constraints.

During the blending operation, the online validated analyser measurements are used to update the blending model and for quality integration of the blended product. This integrated quality measurement, together with the original tank heel quality, is used to determine the quality of the blended product and to update the blend header qualities required to meet the product specifications. An operator configurable control strategy is available to smooth tank heel correction.

Using this control approach, the blending process is directed into an operational environment, where it hits the economically attractive operational constraints.

The number of components used also defines the number of constraints reached. In the case of six components, six degrees of freedom are available. These degrees can be consumed by the following constraints:

- Total blend flowrate, which is often a given.
- First quality constraint (minimum octane; RON or MON).
- Second quality constraint (maximum sulfur; 50 ppm).
- Third quality constraint (maximum RVP or VLI).
- Minimum or maximum blend loop (or a fourth quality constraint).
- Minimum or maximum component availability (or a fifth quality constraint).

Figure 2 is part of the BOSS overview display, indicating the constraints that are active.

By using the offline BOSS in combination with the online package, the third quality constraint will always be achieved, whilst even a fourth quality constraint can be achieved with sufficient component availability.

Without the combination of inline blending with quality control/online optimisation, three quality constraints can never be hit simultaneously.

At one major refinery in Germany, the improvement on hitting the second or third quality constraint has resulted in significant savings following the installation of the online BOSS. In Figure 3, the RVP giveaway is indicated before the BOSS was installed, whilst Figure 4 shows the RVP giveaway after the installation. It clearly shows that the RVP quality constraint has been achieved for every blend since the online blending tools were commissioned. The resulting RVP giveaway reduction of more then 0.015 bar has resulted in additional butane consumption, which has provided a profit increase of more than US$ 2 million/yr.

A traditional multi variable controller is not able to achieve these results, as the model error prevents it from approaching the quality constraint.

For certain refineries, the light distillate blending operation (gasolines, naphthas) has more than one blender. In these situations, BOSS is applied in the pool blending mode. Online, the component allocation is optimised between the two active blends. This application enables more control, resulting in additional savings. This strategy has been implemented at two refineries.

In addition to the requirement to apply the aforementioned optimisation and control strategy, it is the refineries' experience that operator (user) friendliness is essential for successful acceptance of the application. This alone results in a utilisation time of the application as proved by BOSS.

Blend header analyser and its application for certification

The software controls quality constraints that are economically attractive. Therefore, it is important that these quality constraints are the true, without any additional safety margins. In general, the blending analysers in the blend header are only used for feedback control, whilst the traditional laboratory analyses of a tank sample from the top, middle and bottom are used to determine whether the product is on specification and certified to be delivered to the customer.

Variation exists in the laboratory, as well as in the blend analyser measurement techniques and standards. To ensure that blends are not off specification as a result of these variations, a tolerance is added to the product specifications. A tolerance is also added to cover variation resulting from sampling.

Several European refineries have recognised that this additional tolerance could be avoided by using the integrated blend header analyser as the certification criteria. This has major implications for different work processes in place (including the laboratory, analyser maintenance, and blend operation processes).

Successful implementation of blend analyser certification procedures requires the following operational procedures to be in place:

- The laboratory is responsible for the calibration of the blend analysers (analyser technicians are reporting to the laboratory).
- The laboratory authority signs the product certificate based on the print out, showing the validated utilisation of the analyser during the blending of the product and the final integrated tank quality.
- Top, middle and bottom samples are still taken and stored in the warehouse for claims. No analyses are performed on these samples unless claims have arrived.
- No blends are made when the analyser is not cleared/calibrated by the laboratory
- Blends are stopped if the analyser fails a tolerance check.

One of the major steps to be taken is to demonstrate that the integrated analyser reading is much more reliable than the single laboratory analysis of a tank sample. From a theoretical point of view, this is easy to understand, as the analyser takes many more samples. In addition, quality variation is less, due to more consistent sampling for online analysers than with manual sampling. However, convincing the operational staff involved can be difficult.

In order to demonstrate the reliability of online analysers, Invensys has developed a software tool that supports the calibration of the blend header analysers. This tool, called analyser maintenance and data acquisition software (AMADAS), automatically generates analyser control charts (Figure 5). These are essential tools for the provision of a reliable and accurate analyser.

The analyser control chart displays the deviation between the analyser reading and laboratory analyses of the same sample (or the standard sample). Together with the statistical parameters, it is essential for demonstrating the favourable reliability of the blend header analyser.

The implementation of the analyser based certification of the blended product (described above) brings significant additional margin improvement to the blending process in addition to the margin improvement resulting from the implementation of BOSS with laboratory/tank analyses. In the case of a 200 000 bpd refinery, the margin of improvement resulting from analyser based certification can be as much as US$ 2 million/yr.

Real time optimisation of blend component qualities

After implementing the gasoline blending tool with analyser product certification, only the optimisation of the component qualities is left as an optimisation parameter.

The offline BOSS evaluates the economical influence of changes in gasoline component qualities and quantities. This functionality makes use of the market prices for the product and components (TAME, MTBE, butane, etc). The LP within the offline BOSS generates the marginal values of the changes in component qualities and quantities. These values are available for process unit optimisation software, which produce components for the gasoline pool.

Using the Invensys Romeo optimisation software, a high fidelity real time model can be made of the operation of the units producing gasoline components (e.g. the reformer). With the marginal component values from the BOSS model, the operation of the reformer can be optimised based on the value of reformate in the gasoline pool.

Optimal operational settings are generated for reformer operations on an hourly basis. A multivariable controller (such as Connoisseur from Invensys) applies the optimal settings to the reformer process as calculated by the Romeo optimiser.

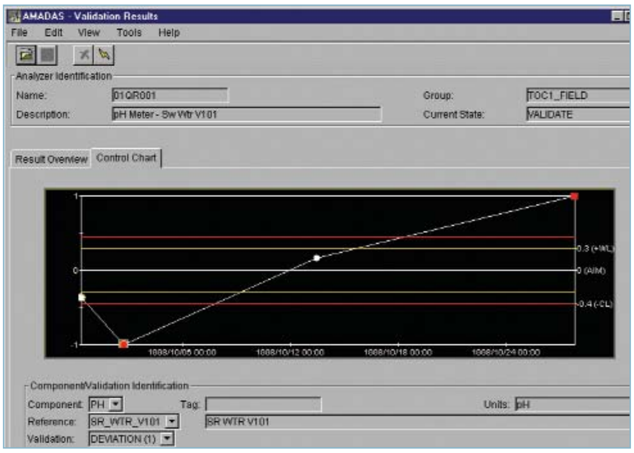


Figure 5. Analyser control chart.

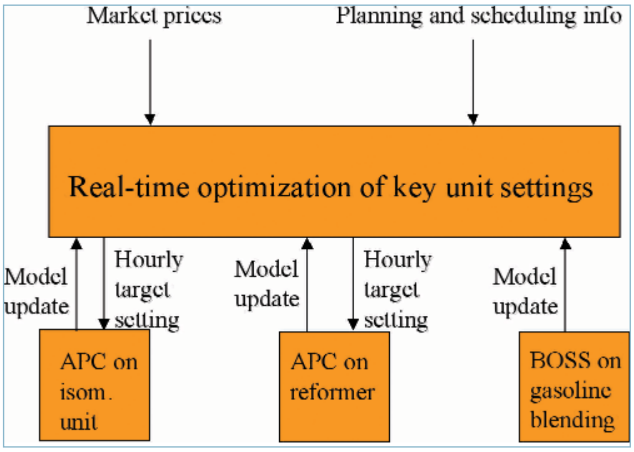


Figure 6. Real time optimisation of key unit settings.

The only major disturbances that can jeopardise the predictions of the optimal settings for the reformer are changes in the feed quality to the reformer. A major operational influence is, for example, the ratio of the paraffins/aromatics in the feed.

In order to correct the model for this influence, Invensys can apply an online magnetic resonsonance analyser (MRA) on the feed to the reformer to correct for 'up front' feed changes. The reformer unit is controlled in such a way that the reformate produced is of a consistent and optimal quality for the gasoline pool.

Figure 6 provides an overview of the real time optimisation architecture as discussed. The applied technology can also be used for optimisation of other units, such as isomerisation units.

Project execution approach

Successful implementation of the integrated gasoline blending system requires a solid project execution. The separate stages should be implemented in the correct order to ensure the participation of the different organisations within the refinery.

First, the basic control layer has to be in place. The ratio blending has to be implemented, and the interface to the tank gauging and laboratory must be available. Then the blend header analyser needs to be installed, which includes:

- Key product quality analysers (including the 50 ppm sulfur analyser).
- A reliable analyser sampling system.
- Maintenance procedures.
- Organisational structure (analyser is managed by the laboratory).

With the blend header analysers operational, BOSS can be commissioned. At the same time, it is important to establish communication between the planning/scheduling engineer using the offline software, and the operation's boardmen using it online.

This communication requires initially frequent evaluation (every two weeks) to ensure that maximum flexibility is provided from planning, as well as from operational points of view. Maximum flexibility provides maximum optimisation possibilities, and therefore maximum savings.

Once experience has been gained with the analyser rather than with the laboratory, it is a natural step to eliminate the quality safety margins resulting from the laboratory analyses used for product certification. In order to use the integrated blend header analyser readings for product certification, the final step is to implement the analyser certification process.

Sustained performance of the blending operation

In order to maintain a high level of blending performance (and thereby obtain the expected benefits), it is essential to define ownership for the gasoline blending solution. It is often owned by the 'advanced application' group within the refinery. They provide the ongoing support for the application, and provide the necessary training for the users (such as the planning and operational staff).

The owner of the blending solutions plays the key role of linking the groups together for gasoline blending. In the case of BOSS, the effort required in support of the application is relatively low. This is as a result of the user friendliness and the configuration flexibility offered by changing the service of the tanks, the addition of blend qualities, blend analysers, etc.

In addition, remote support is available for the owner of gasoline application from the offsite centre of excellence, where helpdesk support as well as remote login capabilities are provided if needed.

Effectively, the 'advanced control' group (or equivalent owners) provide the link with the gasoline blending tool (BOSS) for all users onsite. Without these key people, the benefits of such a tool slowly disappear, and the original project fails after initial success.

Conclusion

With more then 30 gasoline blending systems operational at refineries, Invensys has proved that savings of more than US$ 4 million/yr can be achieved by implementing the integrated gasoline blending system for a 200 000 bpd refinery.

A user friendly software solution is needed for online blend optimisation, as this provides the necessary acceptance of the operational staff. It is essential that all elements are implemented, including the offline planning/scheduling tool and the analyser based product certification. The proof that analyser readings are more reliable than laboratory results is essential.

It should finally be mentioned that the implementation of an integrated gasoline blending project is ideally carried out in the stages identified.

This implementation approach, together with the Invensys solution, can result in low risk capital investment with high return on capital employed.