HYDROCARBON PROCESSING®

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Utilize an optimizer to blend gasoline directly to ships

A new control system and single-blend optimization system make it possible to blend gasoline directly into tanker ships for delivery, rather than only into tanks, thereby saving millions in capital and reducing product giveaway.

The 550-acre Pembroke refinery (**FIG. 1**) has been operating since 1964. In addition to its terminal equipment, the facility has eight berths for ships and more than 100 tanks of various sizes with total capacity of 10.5 MMbbl. The complex can facilitate 10 crude ships per month.

Gasoline blending system. The refinery's gasoline blending system has a capacity of 2,000 m³/hr. The blending situation for the refinery is very complex, if for no other reason than the number of different components and grades of finished gasoline it produces. The produced gasoline must meet the different specifications for multiple markets (US, Europe, etc.). Most outgoing products go by tanker ship, with a smaller amount going by road tanker.

Refining is a highly competitive commodity industry that yields fungible products with low margins, and a refinery's blending operation can be considered its "cash register." This is the last chance to optimize the final saleable product, as well as the final opportunity to achieve as close to product specifications as possible. Any giveaway at blending—caused by shipping better-than-grade specification product—is lost revenue and cancels out the benefits from optimizing upstream unit process areas.

As illustrated in **FIG. 2,** a small reduction in giveaway yields impressive results; for a typical refinery, blend optimization could deliver millions of dollars per year in bottom-line savings. It is estimated that the industry-wide total costs of Reid vapor pressure (RVP) and octane giveaway exceed $2 B/yr in the US and several times that total worldwide. Capturing even a fraction of that opportunity can offer a strategic refining advantage.

Traditional gasoline blending methods. The original blending system in the Pembroke refinery combined set volumes of multiple gasoline component streams in a header to produce each batch of finished gasoline, which was then routed into a set of tanks. A sample was taken to the laboratory for analysis. After the results were determined, the mixture would be "touched up" to meet requirements, if necessary, and a certificate of quality/analysis would be issued. Often, the touchup of an off-spec blend caused giveaway by adding a buffer to avoid carrying out a second touchup. When the ship arrived, the blended gasoline would be pumped aboard from multiple tanks.

This method required the refinery to maintain considerable tank capacity. Tanks are costly, they require maintenance, and safety and environmental regulations require instrumentation to prevent leaking, overfilling, etc. Additionally, the tanks are never completely emptied, which represents essentially frozen assets—inventory that is never shipped but stays on the books and is taxed every year. The average tank inventory is generally considered to be captured cashflow that is not realizable until the tank is emptied or the assets sold.

Touchups, even if they result in shipped product that meets specifications exactly, are also expensive. They result in poor utilization of both equipment and human assets; they put an

FIG. 1. The Pembroke refinery in Wales has eight berths for ships and more than 100 tanks of various sizes with total capacity of 10.5 MMbbl.
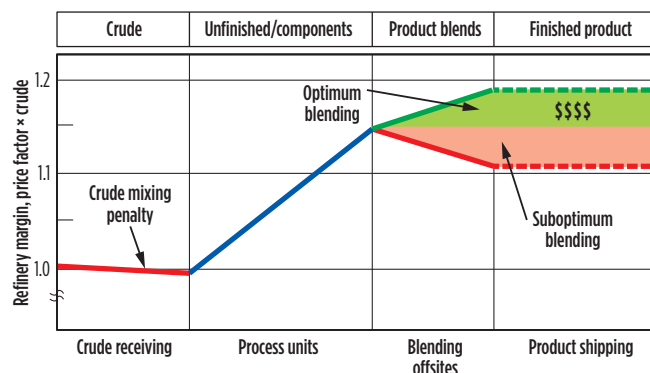

FIG. 2. Capturing even a fraction of blend optimization opportunity can present a strategic refining advantage.

extra load/cost on the lab due to the retesting required; and, if there is a problem and the blend testing comes out off-spec, then shipments are delayed and incur potential demurrage charges for holding up the ship.

In 2011, a study was undertaken to find ways to improve the blending process: a project to replace the existing blending arrangement with one that would allow the blending of gasoline directly to ship rather than solely to tankage. Such a system had the potential to save millions of dollars each year by reducing the number of tanks needed in gasoline service, as well as satisfy the key performance indicators of lower average blend giveaway and the minimization of touchup blends.

Upgrading the blending system. The refinery was already scheduled for a control system update, which would ultimately include replacing the existing, and obsolete, distributed control system (DCS). The gasoline blending optimization project was approved, and the project teams realized that it would integrate well with a new DCS system upgrade in the blending and shipping areas.

Each batch of finished gasoline is made by simultaneously blending up to 21 different component streams in a header—typically 10 or fewer streams at a time, with mid-blend pump and tank changes. Each component has a flowmeter, a proportional integral derivative (PID) controller and a target ratio set by the control system. A set of online analyzers provide feedback for optimization and certification using state-of-the-art redundant sample compositors. The system can achieve up to 20 quality limits simultaneously, although the number is usually closer to five. The output of the blending system (finished gasoline) can go into tanks or directly onto a ship.

The blend optimization system used at Pembroke is comprised of a highly standardized mix of both hardware and software components. The system is built of several layers: At the bottom (just above the field devices) is the DCS; on top of the DCS is an advanced regulatory software package, which handles the ratio control functions. Above this layer is a blend optimization supervisory system (BOSS) software package. Sitting at the top of the pyramid, it processes data from analyzers,

flows, etc., and calculates a recipe that is optimal for the blend at any given moment to meet the optimization objectives. The optimized recipe from the BOSS is then fed to the regulatory software package, which calculates the appropriate flow setpoints for the individual blend component control loops. For example, it takes a 41% alkylate recipe and translates that into a setpoint for the alkylate flow control loop. It performs other regulatory level functions as well, such as starting and stopping pumps, etc. **FIG. 3** shows schematically how the different parts fit together.

Consistent data helps obtain operator acceptance. A critical success factor of the new system is the presentation of consistent views to the operator. The design and implementation of such a system must revolve around a single-screen integrated approach to minimize the different operator system interactions. All the blend regulatory controls—start/stop, routes, ramp, ratio and pacing—are handled in the DCS via commands from the blend optimizer, akin to a master/slave control relationship. The operator displays are kept to a minimum and are integrated with the DCS graphic, which helps considerably in obtaining operator acceptance of the new system.

The optimizer screen is the interface that the operators use to start and monitor the blends. This screen is typically provided on a separate interface screen, but using RDP from the DCS made it possible to display this screen within the DCS system, simplifying it for the operators and demonstrating the "single-screen integrated" approach the project team and operators wanted.

Challenges encountered. As expected, designing and implementing the new system was not without its challenges, many of which coincided with systems not always being available when needed. At the front-end engineering and design (FEED) phase, there were gaps in the system knowledge, which is often the case in projects where very old systems are in place and little or no good documentation still exists.

To in-line blend directly to a ship, a composite sampler that can take samples at required rates for the size of the blend and provide a composite of exactly what went onto the ship (it is very difficult to test the separate tanks on a ship) is required. The sample compositor takes a cross-section of the final product exiting the blend header. This can be tested in the lab and a certificate of quality/analysis can be produced.

These custom-built, redundant-sample compositors, which are a proxy for the blend tender going to the final destination (i.e. ship), must be very robust and very accurate. The reliability of such a system is critical, as any failure would result in uncertain specifications of the gasoline product loaded onto the ship. **Note:** Backup procedures are in place that allow for additional testing and sample collection, should the compositors fail to avoid any off-spec loading to the ship. Establishing the reliability of this system was a minor challenge, but in the end it proved to be extraordinarily valuable to the overall success of the project.
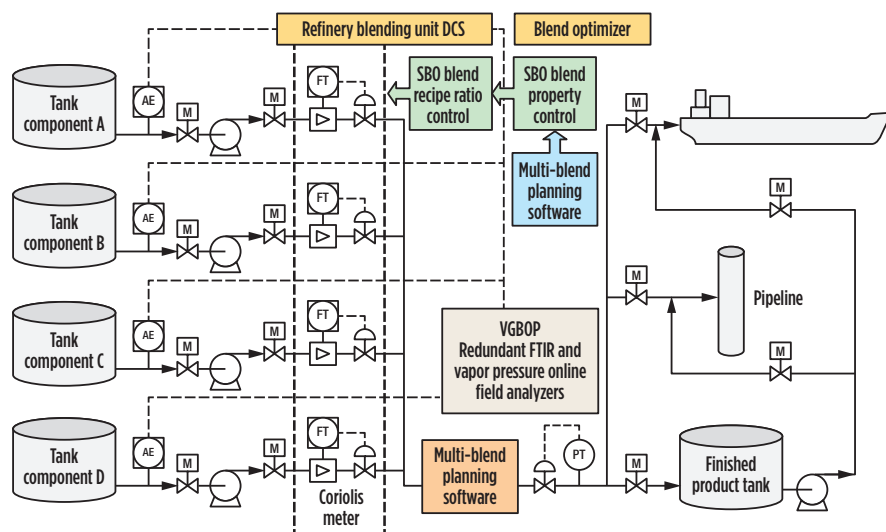

FIG. 3. A schematic drawing of the various parts that comprise a blend optimization system.

Another challenge came from the limited time available for the factory acceptance test (FAT). There were delays in getting all parts of the project approved due to the compressed timescales needed to take advantage of the earlier-than-planned DCS upgrade. Consequently, this reduced the time available for the FAT. To make things worse, the system was being migrated from one that had been in place for decades. Many pages of leftover custom code needed to be identified and stripped out before the new system could be fully programmed.

Hardware problems also had to be overcome. Communications with some of the antiquated and poorly documented serial devices in the facility proved difficult. Some of the flowmeters on the blend header had little or no parts availability and documentation was sparse, making installation and tuning impossible. It was decided to replace a number of these instruments on the blender to improve long-term reliability. Custom modifications to the DCS input modules were installed to integrate these into the DCS so that future updates, tuning and maintenance would be simplified and could be carried out in-house.

Results. The new system was first used to produce optimized blends to tankage, and within weeks optimized blends were being successfully loaded directly to ship in parallel to loading from existing tanks. Several months later, the site completed its first 100% full blend to ship, a parcel of 46 Mm³ taking over 50 hours for an export cargo. All direct-to-ship blends tested to spec on shipping, and again when received at their final destination.

As discussed, one of the eight gasoline storage tanks (used previously for final product containment prior to ship loading) was removed from gasoline blending service and reallocated to another component system. This move freed up several million dollars of gasoline inventory, mitigating required upgrades and allowing tank scheduling decisions to be made on decommissioning or changing of service. Far fewer reblends are seen, and the blends are closer to spec than before, which reduces giveaway costs.

To maximize the system and manage assets effectively, a multi-discipline team was developed to monitor, maintain and improve the gasoline blender and its peripheral systems. A series of key performance indicators (KPIs) was set up, and the site began monthly tracking of the optimizer savings and performance. To date, the results have shown excellent performance, and the new system provides more flexibility for product planning and scheduling. The site has been able to maximize the value of the gasoline blender by reducing the time it takes to fill, test, certify and load multiple tanks to ship, resulting in increased system throughput and, at the same time, minimizing the cost of finished product by blending the least costly components required to make on-spec gasoline.

System troubleshooting has also become much easier. For example, the old system had four graphics for the operators to monitor pumps and controllers, whereas the new system condensed that down to one graphic. Operators can now quickly view the blend header graphics, which are more of a graphical representation of the system, and provide an overview of all running pumps, control valve positions and flowrates. A blend analyzer screen (**FIG. 4**) provides an expedited way of checking gasoline blend property value.
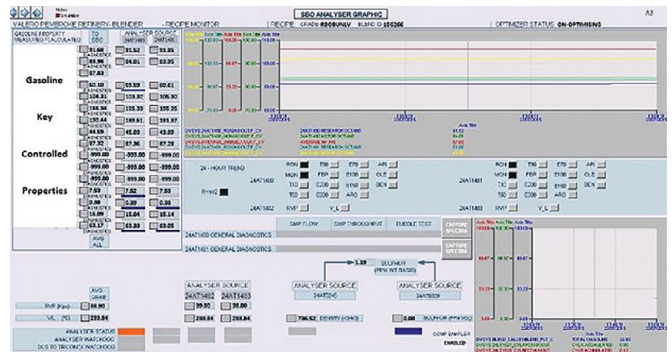

FIG. 4. A blend analyzer screen shows an overview of all running pumps, control valve positions and flowrates, providing an expedited view of gasoline blend property values.

It is much easier to see the sequential function charts executing the sequencing of the startup and shutdown with the new displays; if there is a problem, the operators can detect its origins and how to correct it. It is also useful when calibrating new turbine meters, making it possible to see exactly what K-factors have been installed and the changes needed for calibration.

Additional benefits may be considered, such as the reduction of approximately 70 Mbbl of gasoline, which reduces the onsite storage of hazardous materials, the need for operators and maintenance to work around a commissioned tank, and the environmental risks of hazardous material storage. Overall, the project team identified process improvement opportunities, delivered one-time capital benefits of several million dollars, and provided a sustainable blending optimization solution that has already contributed significant ongoing annual operational savings and is expected to continue for many years forward. **HP**

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DAVID S. SEIVER is the director of blending APC technology for Valero Energy Corp., managing the rollout of the company's single-blend optimization (SBO) program at its refineries. Mr. Seiver has over 25 years of experience in the petrochemical and industrial gas industries. Prior to coming to Valero, he specialized in gasoline and diesel SBO for ConocoPhillips at its Wood River refinery, as well as provided technical blending assistance to other sites. He has extensive expertise in APC, SBO and NIR modeling, and has two US patents in the APC field and one US patent for gasoline optimization. Mr. Seiver holds an MS degree in chemical engineering from the University of Houston.