Gas Chromatography Analysis Speeds LPG Distillation

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This article describes the efficiency improvements that have resulted from automating the analytical instrumentation in the liquefied petroleum gas (LPG) columns at the Tamoil refinery in Collombey, Switzerland.

Since the 1960s, the Tamoil SA refinery in the Western part of Switzerland has been processing crude oil and semi-finished products, which arrive by pipeline from Genoa, Italy, into a wide range of finished products including gasoline, diesel and aviation fuel, various types of heating oil and liquid gas – both as both fuel for vehicles and as raw material for the petrochemical industry. The current capacity of the refinery amounts to approximately 2.5 million tons per year or 7200 tons per day, representing about one-fifth of Switzerland's total fuel demand. In the course of the last 15 years this site, which employs more than 200 workers, has continually been modernised and expanded in order to cater for changed market requirements and to further improve production efficiency, particularly in the area of energy consumption.

LPG distillation

At approximately only three percent, liquefied petroleum gas (LPG) constitutes a relatively small share of the production of the refinery in Collombey. Nevertheless, this light fraction, which consists mostly of saturated hydrocarbons with three and four carbon atoms (i.e. propane and butane), has substantial significance for the process control of the entire refinery. That is because of the fact that these low boiling-point components are used in different ways:

- On the one hand, they are sold as fuel for gas-powered vehicles. Because the higher boiling-point fractions of the LPG (C5+ fraction) can be sold more profitably in gasoline while at the same time the maximum permitted concentration of the C5+ fraction in liquid gas for vehicles is limited, Tamoil limits this fraction's share in LPG to a maximum of 2.5%.
- On the other hand, the C4 proportion of the LPG is added in the blending process to the gasoline in different quantities depending on the season and according to the fuel specifications. In summer, the proportion can only be relatively small - the internal specification lies within less than 1%, so that the vapour pressure of the fuel does not exceed the maximum permissible 60 kPa, as opposed to the winter, when this limit is 90 kPa and accordingly a higher C4 proportion of up to 25% gives an economic advantage in so far as the respective octane number requirements are to be brought into alignment with it.

LPG is essentially separated in Collombey in three places in the production process (Fig.1): during the naphtha stabilisation, during the reforming stabilisation after the catalytic reforming, and after the hydro-treatment of the light gas oil. The heavy fraction of the latter separation is fed back into the atmospheric distillation, so that an extensive separation of the LPG has direct energy savings and thus economic benefits as the amount of recirculated mixture decreases.

Optimal LPG separation is further complicated by the fact that its proportion and composition are also subject to fluctuations. These fluctuations arise firstly from the differing quality of the crude oil, secondly from different ambient temperatures (during daytime and night-time, for example) and thirdly from different hydro treatment assets. In total, more than 400 m^3 of liquid gas are produced per day in Collombey.

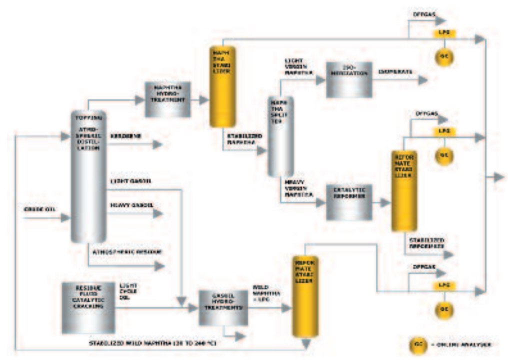

Figure 1: Simplified representation of the material flow in the Collombey refinery

Faster analysis leads to better separation

The demand for a more efficient operating mode for the separating columns can only be fulfilled if more precise information can be obtained about the composition of the light fraction: something that previously involved evaporation samples in the laboratory. More significantly, however, it needs measurement values to be available at a substantially higher frequency than is possible with manual sampling followed by laboratory analysis: a process that previously allowed not more than two analyses per day to be made for each column. In addition, only the products of naphtha stabilisation can be analysed using the evaporation procedure because the other product flows contain dissolved hydrogen sulphide, meaning that laboratory analysis can only be carried out under substantial safety conditions.

At the beginning of the instrumentation project, it was therefore important to select a state-of-the-art, robust and - on the basis of the total cost of ownership - attractive solution for the LPG analysis. Between the two concepts considered first: namely, NIR spectroscopy and the process gas chromatography (GC) - the decision fell in favour of the GC solution in initial discussions with Yokogawa, a company which was also finally selected as the system partner. The main factor that counted against an NIR solution was that it could only be used without problems in a homogeneous liquid phase. Since with a liquid/gas mixture close to its boiling-point curve, the occurrence of vapour bubbles has always to be taken into account, the reliability of this alternative appeared to be endangered right from the beginning.

Furthermore, an NIR concentration determination of hydrocarbons with rather similar chemical and spectroscopic properties initially requires extensive preparatory work, such as the development and adaptation of a reliable analysis model that must be specifically provided for the individual separation problem. These aspects would have certainly delayed the implementation of an appropriate solution, as well as increasing the costs.

Measuring close to the process

Crucial to the successful implementation of a GC process analysis in the separating columns was an analysis which could be performed as close to real time as possible, i.e. an almost delay-free sampling and a short analysis time in order to reflect the situation in the process immediately. This can be achieved most economically when the analysers are positioned in direct proximity to the columns. Feeding the product to a centrally positioned analyser shelter would involve long stainless-steel pipes and correspondingly high flow rates in order to obtain close to real-time results. In addition, there is also the danger of condensation, which would lead to analysis errors.

Furthermore, because of the lage drop in pressure over the long sampling lines, it would be difficult to feed the product back into the process. It would therefore have to be fed back into the flare, which would entail unnecessarily high product losses. It is much easier to install an analysis unit with sample evaporator and sample conditioning system just a few metres away from the column.

The liquid gas flow from the process is first connected by a small-volume fast loop to the sample evaporator. The gas then flows a short distance to the heated sample conditioning system, and is finally fed to the gas chromatograph. This minimal fast loop concept has several advantages, including the near real-time access to precise information about the process, coupled with simple and robust installation.

Figure 2: The Yokogawa Model GC 1000 Mark II process gas chromatograph

The sophisticated GC analyser (Fig.2) offers an important advantage, especially for decentralised use: it does not need air conditioning, but only heating and ventilation. The equipment, furnished with a packed column and a thermal conductivity detector, works on the back-flush principle in order (depending on the exact requirements of the process) to determine in the shortest possible time the most crucial parameter: in this case, the C5+ proportion in the LPG. To this end, as complete as possible separation of the C3 and C4 components is carried out before back flushing. The comparison with suitable test mixtures then permits the quantitative determination of the total of the higher boiling-point components. Moderate fluctuations in the composition of the C5+ fraction have little effect on the accuracy of the measurements because of the very similar thermal conductivities of the hydrocarbons involved.

These analysis units were installed on all three LPG columns. The exact position as well as the individual arrangement of the sample supply was done in consultation with the system partner and one of its authorised local installation partners. The installation of the sampling equipment and the analyser cabinets was carried out as part of a planned plant shutdown in summer 2007, and the measuring points were gradually put into operation in August and September 2007. No difficulties arose, and the systems have worked very reliably from the start.

Integrated monitoring and maintenance concept

Although the individual measuring points in the plant are separated by several hundred metres from one another, they can be simply and easily controlled and supervised from a central analyser server (Fig.3). Here the current status of each measuring point is shown at any time. In addition, detailed status reports can be called up, chromatograms displayed and calibration procedures initiated and monitored. In winter - especially in bad weather - this is an important advantage. Only the replacement of empty feed gas bottles and calibration media now has to be carried out on the analyser cabinets themselves.

The maintenance network uses a special data concept in which the maintenance information from the three analysers is first fed to two separate stations

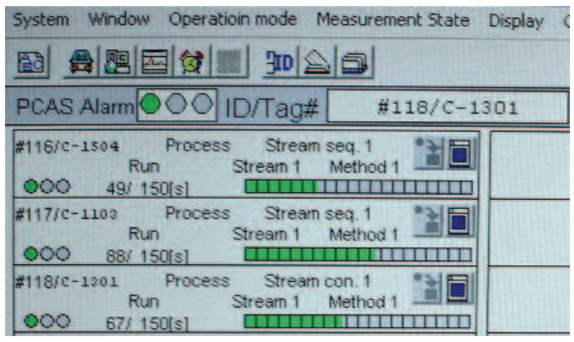

Figure 3: Top-level functional overview of the three GC analysis systems in Collombey

connected via the Tamoil intranet (Fig.4), so that data exchange over the intranet closes the information loop. Because of the relatively large distances between the analysers and the maintenance stations (approximately 150 m each), it was decided to use fibre-optic data communications. Using the intranet in this way saved the substantial costs of a several hundred metres long glass fibre connecting directly to the measuring point.

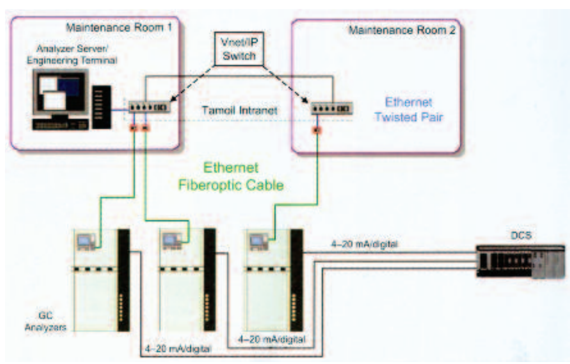

Figure 4: Integrated transmission concept for maintenance information for the process GCs at the LPG columns

Closed-loop control for more efficiency

The crucial objective of the automation of the LPG column analysis was to significantly increase the efficiency of the process. Within a few months of start-up, it was clear that this expectation was confirmed. With the automated system, an accurate measured value is available for the C5+ concentration at each of the measuring points every 150 seconds - around the clock. These values form a substantially more reliable and more precise basis for the subsequent statistical computations for the characterisation of the distillation process, and have resulted in a substantial increase in quality. It is now possible to react automatically with a total delay of barely 15 minutes by adjusting the column feed and other distillation parameters to changes in the composition of the LPG fraction.

The new analysis equipment has proven to be particularly successfully in the column, which is downstream of the hydro-treatment stage. Here the LPG fraction contains a considerable amount of C3 hydrocarbons, such as propane, and the efficiency of the separation has now been increased to the extent that between 1.5 and 2 m^3/h more LPG is produced than before the installation of the process analysis equipment. Among other things, the quantity of 'off' gas is also reduced. The sales value of the additionally product, as well as the energy savings from the reduced feedback into the atmospheric distillation - contribute to a substantial overall saving.

Summary

The project for the analytical upgrade of the LPG columns at the Tamoil refinery in Collombey with Yokogawa's process GCs has been a complete success. Clear responsibilities and short response times led to the fact that barely a year separated the first tender and commissioning. The choice of a worldwide experienced system supplier, who was responsible for the project from the design of an optimally suitable solution to the planning, engineering, installation and start-up up to the training of the workers, has proved itself to be an optimal solution for Tamoil. This is particularly important because the project required a high level of process understanding and therefore needed a competent project manager. In this way, potential additional workload for the refinery personnel has been avoided.

All systems have functioned since start-up without problems and have fully met expectations. This also applies for the connection to the distributed control system and the monitoring of the analysers by means of fibre-optic data communications.