1. Introduction

A full-fledged APC application was implemented on a refinery Crude Distillation Unit. This included the Atmospheric Distillation column and its feed furnace, the Vacuum Distillation column and its feed furnace, the Debutaniser, and the Naphtha Splitter column. The crude oil feed was also included as control handle.

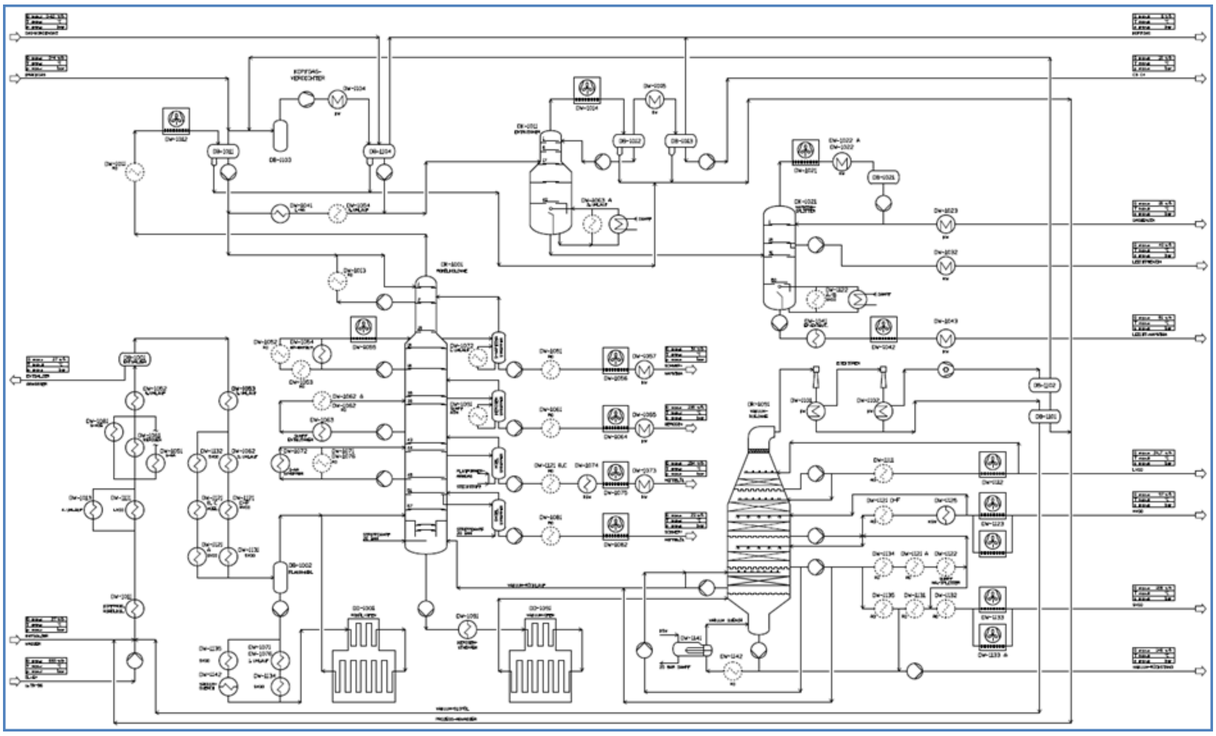

Figure 1, Plant overview

The crude oil feed is pumped through an extensive pre-heat train before reaching the flash drum. The flashed vapour from this vessel enters the Atmospheric Distillation column directly, while the bottoms liquid is first heated in a furnace.

The Atmospheric Distillation column separates the feed into the following fractions:

- Raw gasoline as top distillate
- Kerosene from a side-draw
- Medium gas-oil from a side-draw
- Heavy gas-oil from a side-draw
- Bottoms residue

The Atmospheric column bottoms residue gets pumped to another furnace to be heated, and then separated in the Vacuum Distillation column. The following fractions are obtained.

- Light vacuum gas-oil
- Medium vacuum gas-oil

- Heavy vacuum gas-oil
- Bottoms vacuum residue that is fed to the Visbreaker unit.

The Atmospheric column raw gasoline distillate is pumped to a Debutaniser column, where a lighter LPG fraction is removed, and then separated in the Naphtha Splitter column into a light gasoline fraction, a medium gasoline side-draw, and a light naphtha product.

The new APC application is performing very well and satisfies the following objectives:

- Maximize recovery of HVGO from vacuum residue,
- Maximize recovery of LVGO from HVGO, on 95% point specification,
- Maximize recovery of MGO from LVGO, on 95% point specification,
- Maximize recovery of kerosene from MGO and light naphtha, prioritizing control of the LN 95% point, and the kerosene flash point, above the kerosene 95% point,
- Maximize feed against various throughput constraints,
- Maximize light gasoline at the expense of LPG,
- Control a light naphtha tank balance.

2. Challenges

The main challenge faced by the APC application is the regular crude oil change, often as frequently as three days apart. The product quality estimators used as controlled variables in the application can only fully compensate for these changes in feed quality by a bias update from laboratory analysis.

These frequent feed quality changes also make it very difficult to calculate the real benefits achieved by the APC application, as a different potential yield of the range of distillation products are to be obtained from different crude oils.

3. Results

With the APC commissioning date of 10 June 2013 taken as reference point, a comparison of the data was made one year before, to that of one year after. Firstly, laboratory analyses before and after commissioning have been averaged.

Secondly, the quality specification targets were averaged and compared. The “before” data used limits set up in the old Honeywell Profit controller in the case of the light naphtha 95% point, the kerosene 95% point, and the MGO 95% point. For the LVGO 95% point, the set point of a previous base-layer quality controller was used. The “after” data used the limits and targets set up in the new APC application.

Thirdly, the deviation between the laboratory values and the quality targets was compared. A reduction in these deviations meant that running closer to specification created the ability to maximize these product yields.

In the case of the kerosene flash point, which was operator controlled before, the low limit never changed and the entire reduction in this quality could be claimed as an APC benefit. The same applies to the HVGO 95% point. The operator controlled this quality between wide limits which did not change, and the entire increase in quality could be claimed as an APC benefit.

Below are the quality target changes before and after APC commissioning, next to the change in average deviation between the lab values and those targets.

Product	Target before (degC)	Target after (degC)	Change in deviation from target
LN 95%	147	143.6	-0.34
Kero 95%	241.27	249.68	0.47
MGO 95%	363.3	366.2	-0.29
LVGO 95%	366.65	371.67	-0.63

Below are the absolute quality changes for the kerosene flash point and the HVGO 95% point, before and after APC commissioning. The entire quality change is claimed as an APC benefit.

Product	Quality before (degC)	Quality after (degC)	Control limit (degC)
Kero flash	57.56	56.48	56 low limit unchanged.
HVGO 95%	578.74	585.3	No high limit. Optimization low limit currently 580.

Using these quality changes and imposing them as target values on the LP solution of the APC application controller model, within set limits on the manipulated and controlled variables, result in the following changes in product yields.

Product	**Change in mass (t/h)**	**Price ($/t)**	**Value change ($/h)**
Raw gasoline distillate	-0.694	788	-546.99
Kerosene	-0.503	845	-424.89
MGO	3.139	795	2495.97
Atmospheric residue	-1.942		
LVGO	-0.978	769	-751.89
HVGO	5.053	636	3213.83
Vacuum residue	-6.018	443	-2665.97
Fuel gas Atmospheric furnace	0.0506	470	-23.78
Fuel gas Vacuum furnace	0.1	470	-47
			1249.27
			10 943 633 $/a

These product yield changes were achieved by an increase in Atmospheric furnace outlet temperature (FOT) of 0.81 degrees Celsius, and in Vacuum furnace outlet temperature (FOT) of 3.93 degrees Celsius. The top temperature of the Atmospheric Distillation column was reduced by 0.23 degrees Celsius. Furthermore, these results were based on a fixed feed rate of 900 m3/h.

Distribution curves of the deviation from target values, before and after APC commissioning, are shown below for the LN 95% point, kerosene 95% point, MGO 95% point and the LVGO 95% point. The absolute value (lab analyses) for the kerosene flash point and the HVGO 95% point are shown.

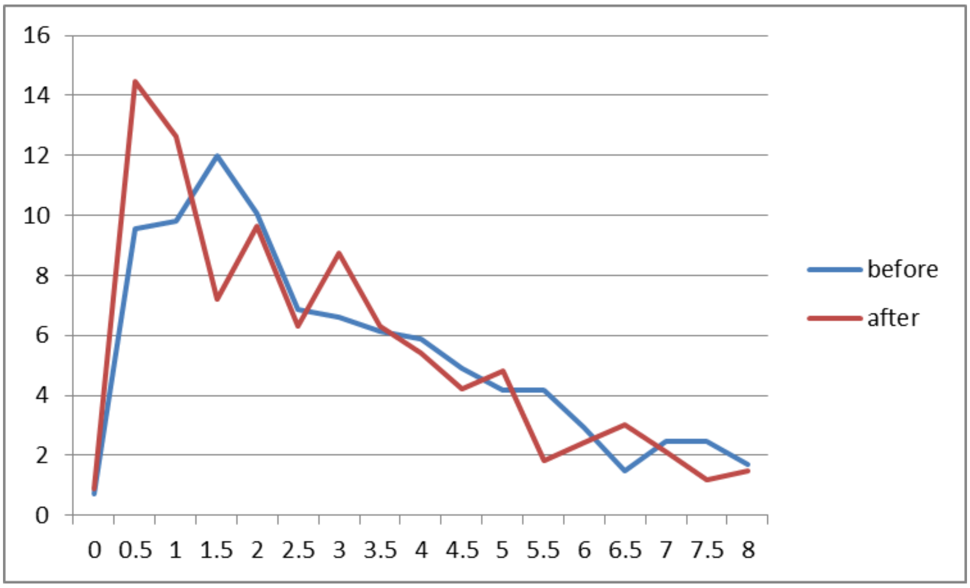

Figure 2, LN 95% point deviation from low limit distribution curve

The average deviation from target value was reduced by 0.34 degC.

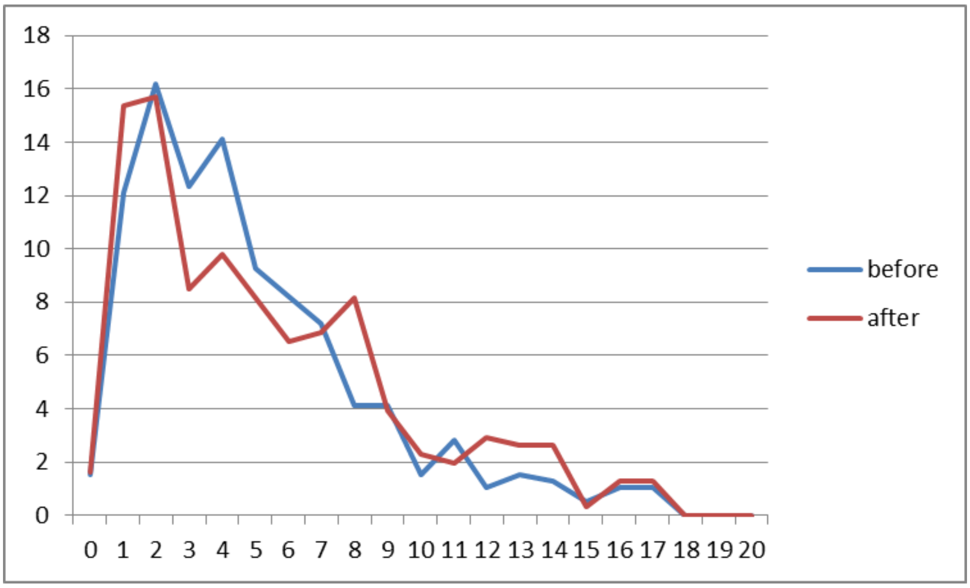

Figure 3, Kerosene 95% point deviation from high limit distribution curve

The average deviation from target value was increased by 0.47 degC in this case.

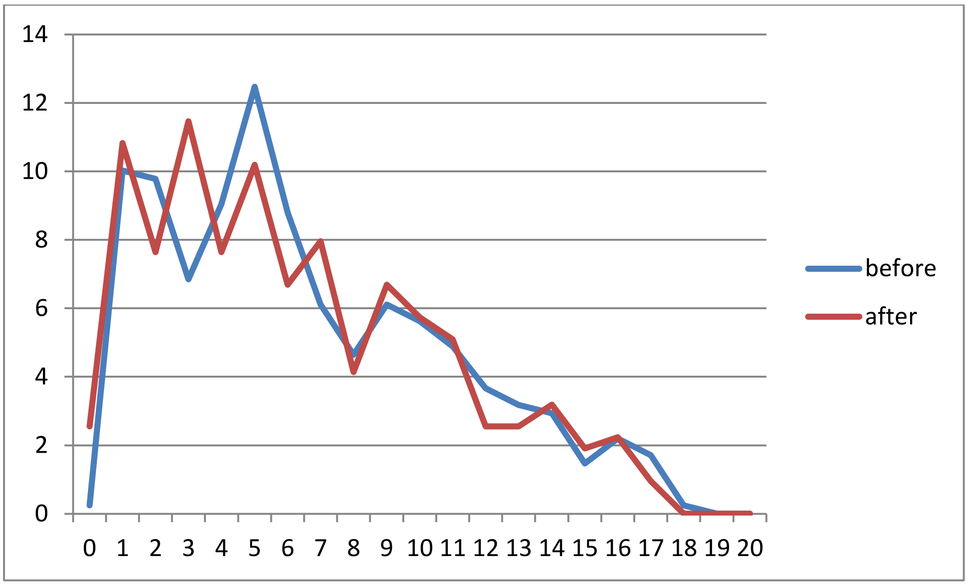

Figure 4, MGO 95% point deviation from high limit distribution curve

The average deviation from target value was reduced by 0.29 degC.

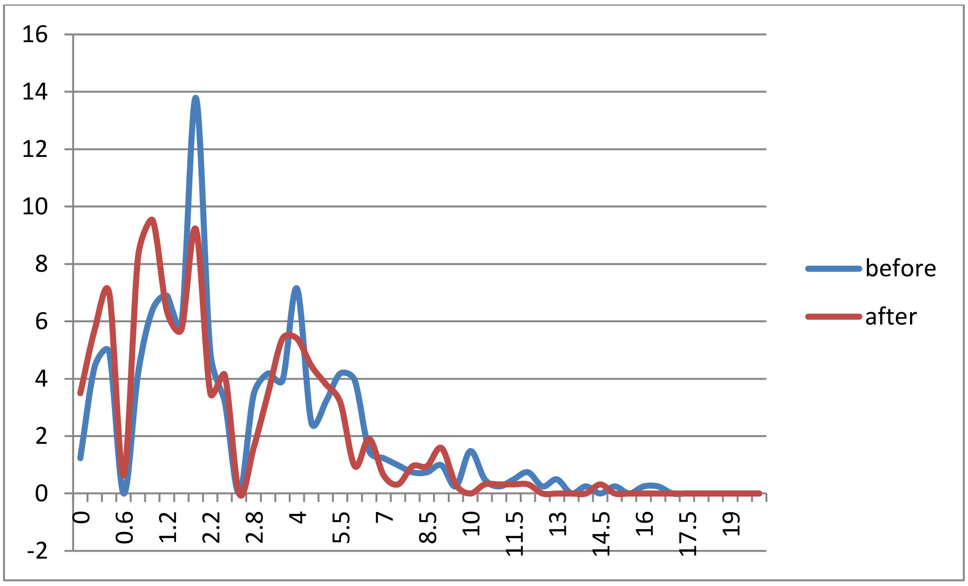

Figure 5, LVGO 95% point deviation from target distribution curve

The average deviation from target value was decreased by 0.63 degC.

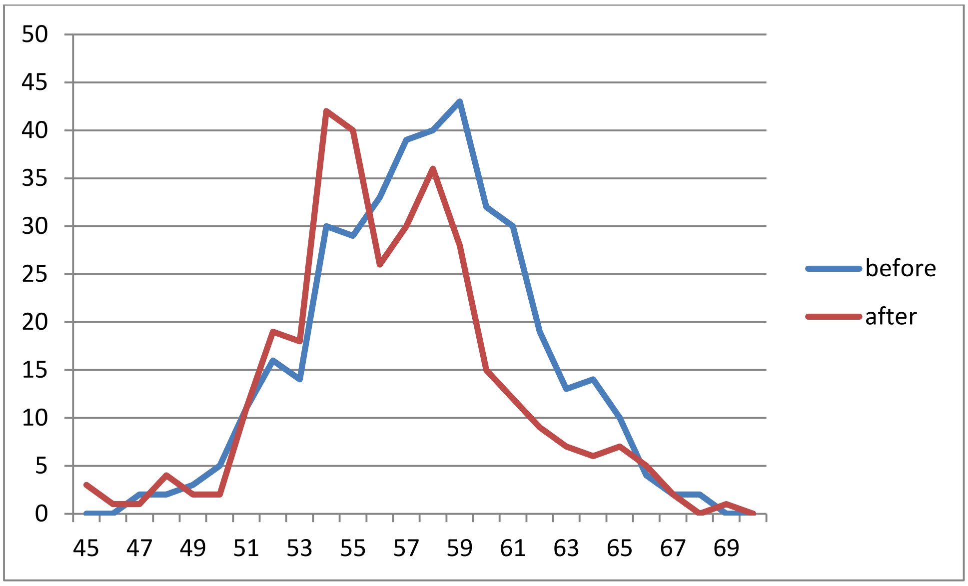

Figure 6, Kero flash point lab value

The average absolute lab value was decreased by 1.08 degC.

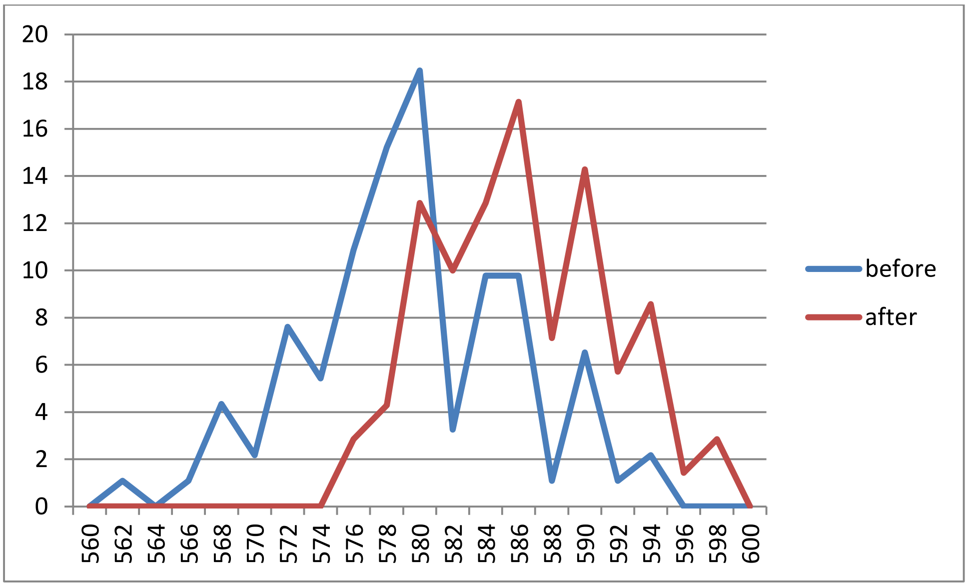

Figure 7, HVGO 95% point lab value

The average absolute lab value was increased by 6.56 degC.

4. Conclusion

The MPC solution has shown excellent results with respect to optimizing product specifications, even during crude switches. The improved yield on the most valuable products has been audited post-commissioning, and has resulted in annual savings for the customer in excess of **10.9 MM US$**