

Delayed coker advanced process control at Petronas Melaka refinery

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Overview

Delayed coking is a refinery unit that is difficult to run and to control. That said, it is also one of the most profitable refinery units because it converts unwanted vacuum residue into distillates. The desire is to maximize coker feed, and APC is a lucrative application as long as it is able to increase throughput. This paper is about an APC project implemented on PETRONAS Melaka refinery coker, with the aim to

- Smooth out the periodic drum switch disturbances,
- Maximize middle distillate production
- And above all, maximize throughput.

The APC implementation work was carried out jointly by Petrocontrol and PETRONAS engineers. The project main features include

- Petrocontrol inferential modeling package GCC. This was used for product quality predictions as well as some drum condition monitoring.
- An MVPC (multi-variable predictive controller) from Honeywell (RMPCT). Two RMPCT controllers were utilized, one for the fractionator and one for the furnace.
- The controller was commissioned in December 2007, and has been operated with a controller uptime of 99.9%+.

This paper will show how the APC is structured and how it performs, demonstrating by trends that the application works very well. The post project analysis concluded that the increased throughput and reduced drum switch time created benefits of \$5 million annually.

Introduction

Delayed coking is one of the most profitable refinery units. It takes low value vacuum pitch and converts it to distillates. Why then there are not many reports of Delayed coking units employing APC (Advanced Process Control)? We only know of one recent reference [1]. The answer must be – because delayed coking is also one of the most difficult refinery units to operate and control. First, batch reactors (coke drums) are integrated, not very smoothly, into a continuous plant. And second, the unit operates at high temperatures and is prone to coking, fouling and corrosion. The number of incidents on coking units is generally higher than in other refinery units.

Figure 1 is a simplified diagram of Melaka's delayed coker. Vacuum pitch (fresh feed) is mixed with some HCGO (cracked heavy coker gasoil), heated and injected into the main fractionator bottom. Mixed feed is then heated again in the coker furnace to a high cracking temperature, and hot partially cracked feed flows from the coker furnace into coke drums, where cracking

continues. Cracked distillate vapor ascends in the coke drum and flows into the fractionator for separation. Coke remains in the drum.

Figure 2 shows the coke drums in more detail. One drum operates at a time, accumulating coke until it is almost full, and then the coke is removed. About every 15 hours, the filled coke drum is switched off for coke removal and the empty drum is connected. The drum that was just filled goes then through a cycle of steaming out, cooling, opening, coke removal, closing, steaming, pressure testing, heating, and finally re-connecting to the furnace and fractionator. Heating of cold drums creates significant disturbances because the heating is done by sending hot cracked vapor through the cold drum, depriving the fractionator of both heat and material. The main disturbance, however, comes later upon connecting the warm empty drum. Drum temperature needed for cracking is around 500 °C, but the new empty drum cannot practically be heated up to such a level. Drums are typically switched in at 400 °C, which quenches the reaction almost completely, causing a major disturbance that lasts about two hours, until the newly connected drum reaches normal operating temperature.

All and all, figure 1 presents a fairly typical delayed coker, the main exception being that there is no fractionator internal recycle of HCGO to the bottom, and instead some fuel-oil is produced to supply local demand.

At steady state operation, when the drum is at normal temperature, the APC challenge is to maximize feed and minimize fuel-oil, while controlling overhead naphtha and LCGO (light coker gasoil) products on specifications. During drum switch operation the APC goal is primarily to manage the inventory of liquid in the fractionator until the coke drum heats up and vapor supply re-established. Product specification constraints are usually inactive at that time because inventory control dictates quality giveaways. However, the economic drive for throughput maximization is still there. To compound inventory control difficulties, downstream consideration dictate some draw of LCGO at all times, and during drum switch, when LCGO is not available, APC must divert some naphtha down with LCGO to respect the low draw target.

Control matrix structure

We have made a decision to structure the APC as two separate controllers because there is little interaction between the two controllers. The furnace RMPCT performs temperature control, pass balancing and constraint pushing. The coking furnace feed is maximized to furnace constraints, whereas the fractionator is required to handle the load, relaxing product quality targets if necessary. There is only one important point of communications between the two applications: at drum switch time the furnace outlet temperature target is temporarily stepped up to speed the recovery to normal cracking conditions.

We proceed to discuss the fractionator control structure. The key handles used are

- i) Handles for controlling naphtha and LCGO cutpoints
- ii) Pumparound duties
- iii) Pumpdown and recycles

These handles are used to control/constrain the following

- i) Naphtha and LCGO 90% inference
- ii) Pumparound flows
- iii) Pan levels

- iv) Flash zone temperatures
- v) Charge pump current

Inferential model discussion

Coker units are never at steady state. Drum switches occur every 15 hours and each switch is associated with two major disturbances: drum warm-up and drum switch. In addition to those major events, cracking conditions drift gradually as drum level increases. For a unit at steady state, a 6:00 morning sample typically yields lab results at about 09:00, at which point the operator might correct unit conditions. But when a unit is not at steady state the meaning of a sample taken at 06:00 is partially lost at 09:00. Hence, coming up with reasonable inferential models is a prerequisite to successful coker APC.

The advantage of GCC being a first principle model is that there is no frequent need to bias the model to correct it against lab reading. Not that biasing can be completely avoided, because even if the model were perfect, instruments are not ideal and their readings occasionally drift, but as compared to regression models GCC is more stable.

Figures 3 and 4 show a two months trend of ASTM 90 % point, inference versus lab data, for Naphtha, LCGO and HCGO. The predictions vary at the frequency of drum switches, and amplitudes of 15 – 20 °C. That is to be expected on a coker, where quality targets are temporarily relaxed during disturbances. Lab samples are taken at different times of the drum cycle and they also exhibit variability. These trends demonstrate how well the inferences work. The predictions have tracked the lab well and there was no need to change inferential biases during the two months period.

Monitoring of drum conditions is part of the inferential package. The following conditions are detected automatically

- Start of drum warm-up
- End of drum warm-up and start of drum switch
- Drum stripping steam going into the fractionator (affects the inferences)
- Stop of drum steam to fractionator
- End of drum switch and start of normal operation

Feed maximization

Once we succeed in controlling product qualities, the main coker APC benefit is achieved by feed maximization, and figure 5 demonstrate this achievement. The figure upon commissioning the application throughput has gone up by 5 M³/Hr, about 3%. Figure 6 shows that much of the throughput increase happened during drum switches.

Conclusions

Against the challenge of the coker being a difficult unit, with part of the unit operated in batch while the other part is continuous, plus high temperatures and many constraints and restrictions, we have demonstrated that coker APC can be made to work. Key to such success are: knowledge of the process, good quality inferences and attention to details. The Melaka coker high value APC application not only improves the unit economics but also makes operator life more comfortable, and in our opinion reducing the chance of incidents. In addition to the delayed coker knowledge within the APC team we are grateful for help from Melaka process engineering, as well as from the coker operation department. We would not recommend that anyone begin coker APC work without such support as the coker is a demanding unit, and incorrectly implemented APC is liable to damage the unit, or at least the APC team reputation.

Literature

1. Volker Haseloff, Sean G. Goodhart and Y Zak Friedman “Coker advanced process control at BP Gelsenkirchen refinery”, Hydrocarbon Processing Journal, July 2007

Figure 1: Coker unit simplified diagram

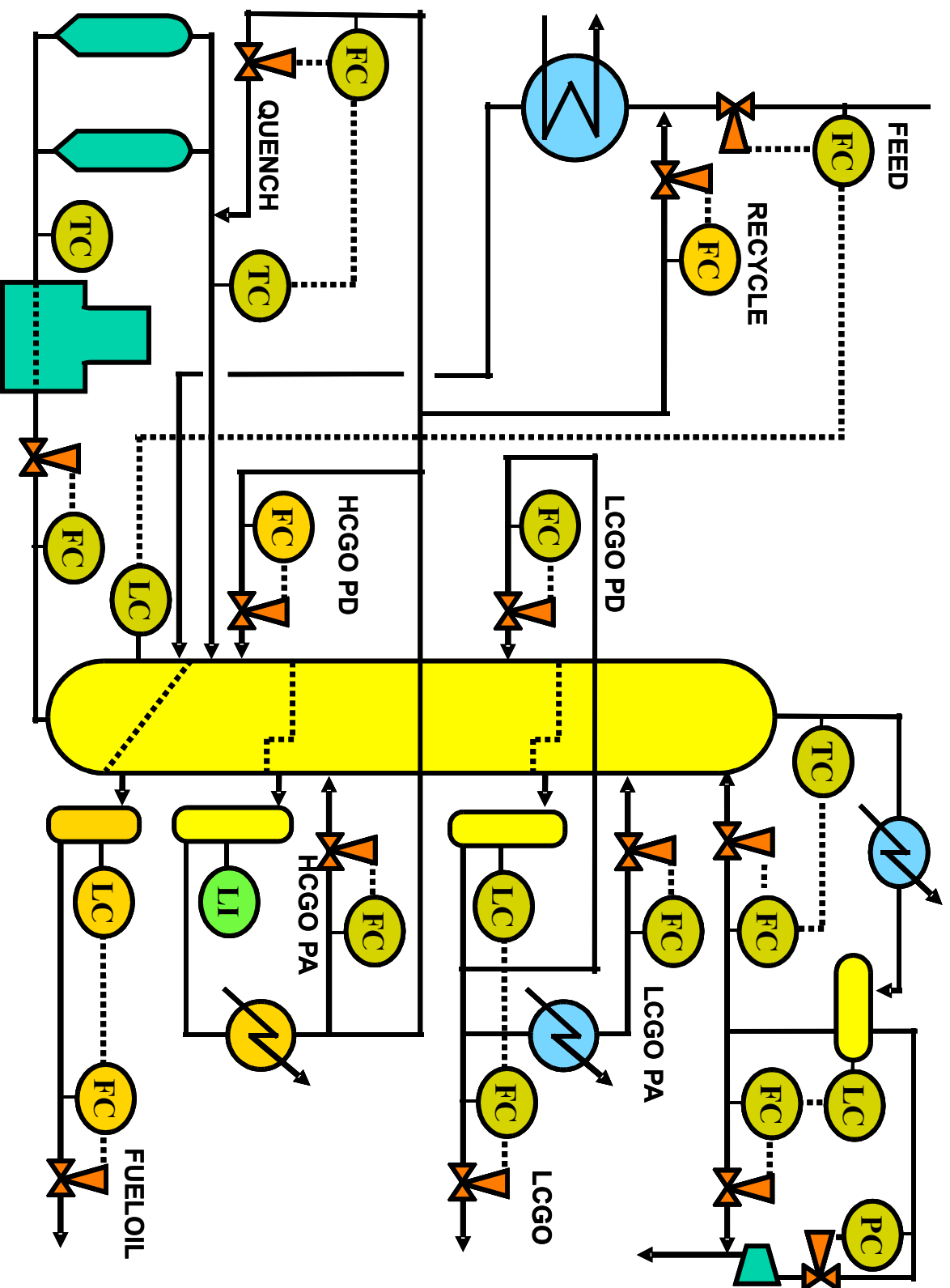


Figure 2: Coke drums configuration

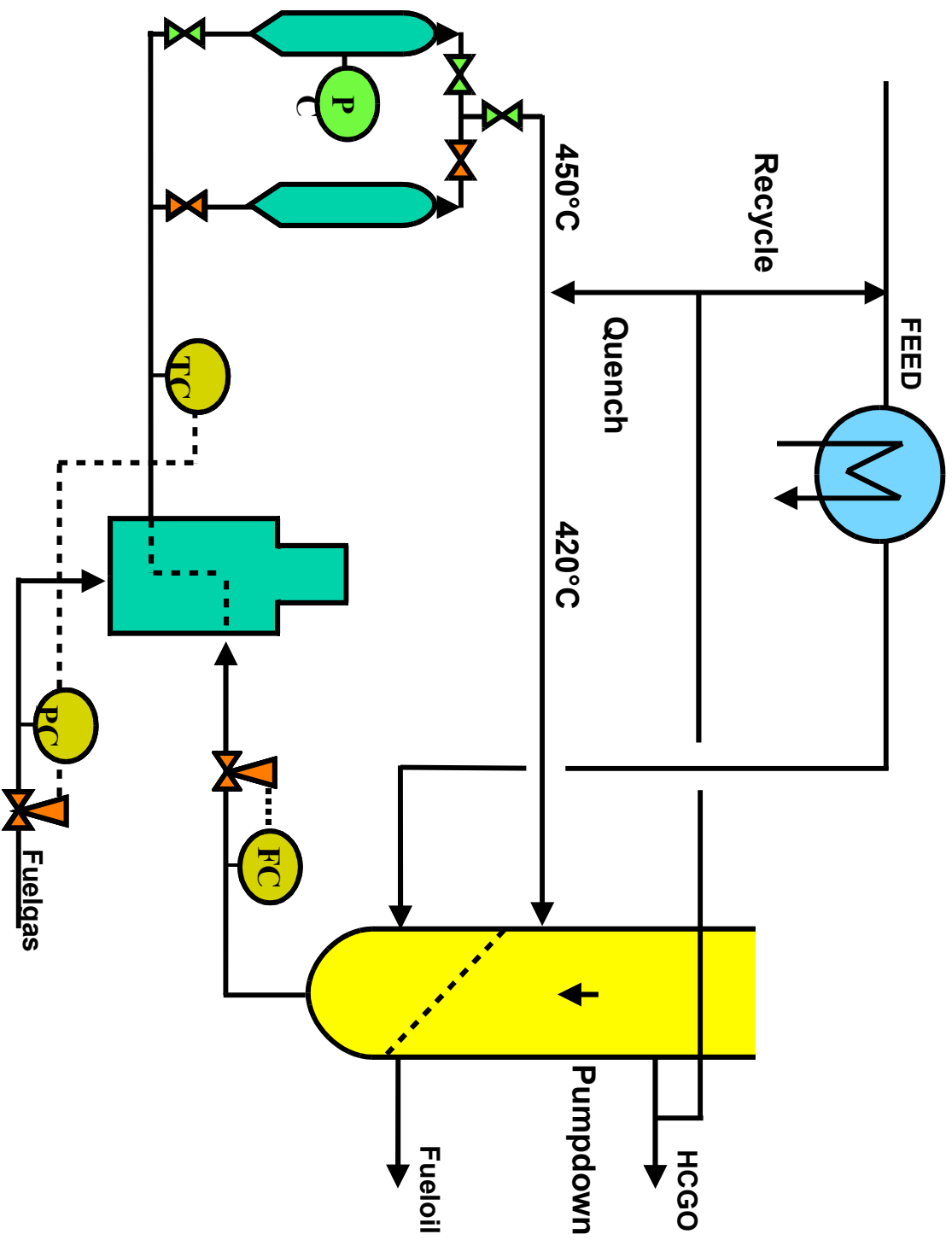


Figure 3: Naphtha 90% point inference (NAP90_M) versus lab (NAP90_L)

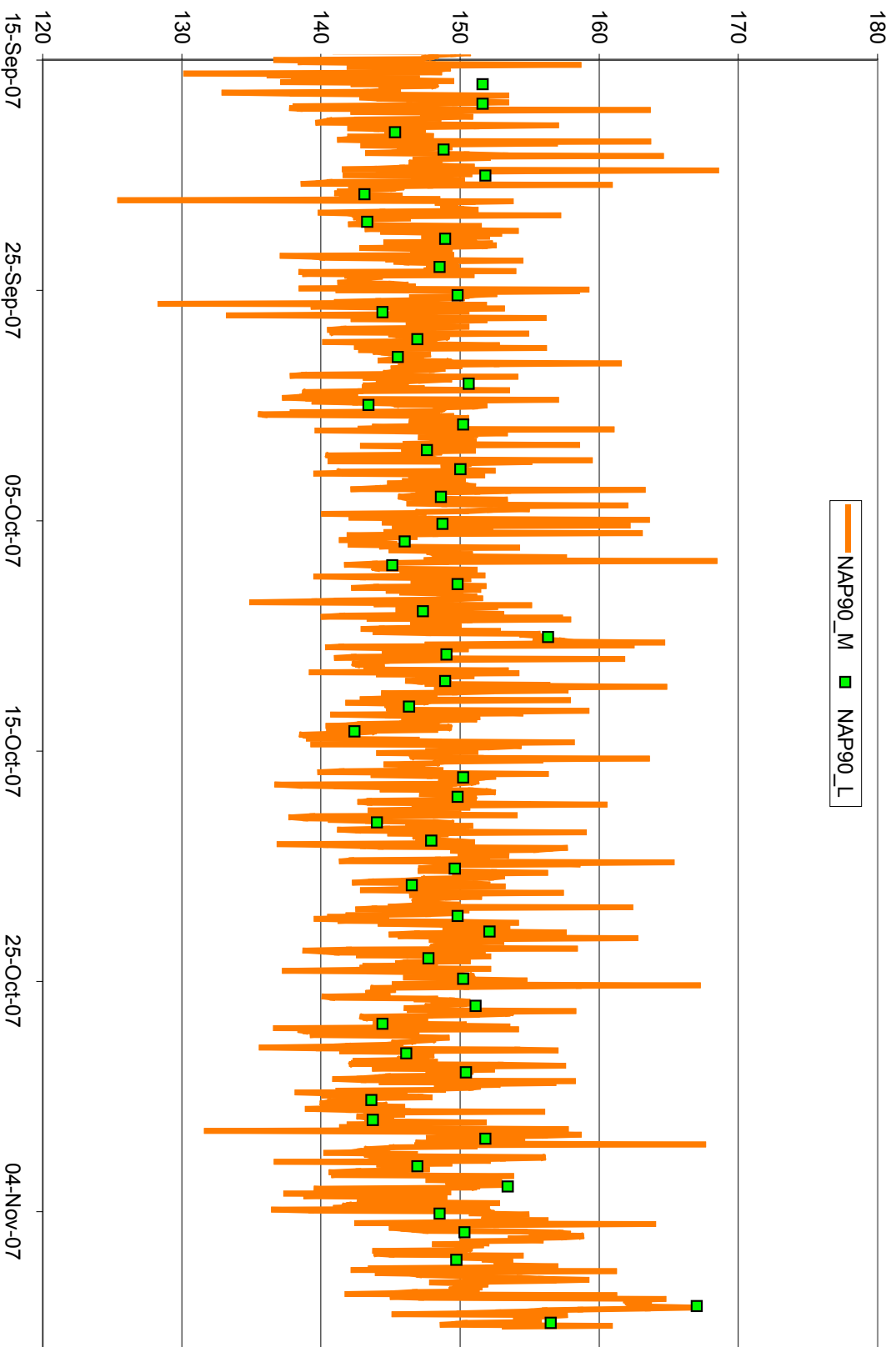


Figure 4: LCGO 90% point inference (LCG90_M) versus lab (LCG90_L)

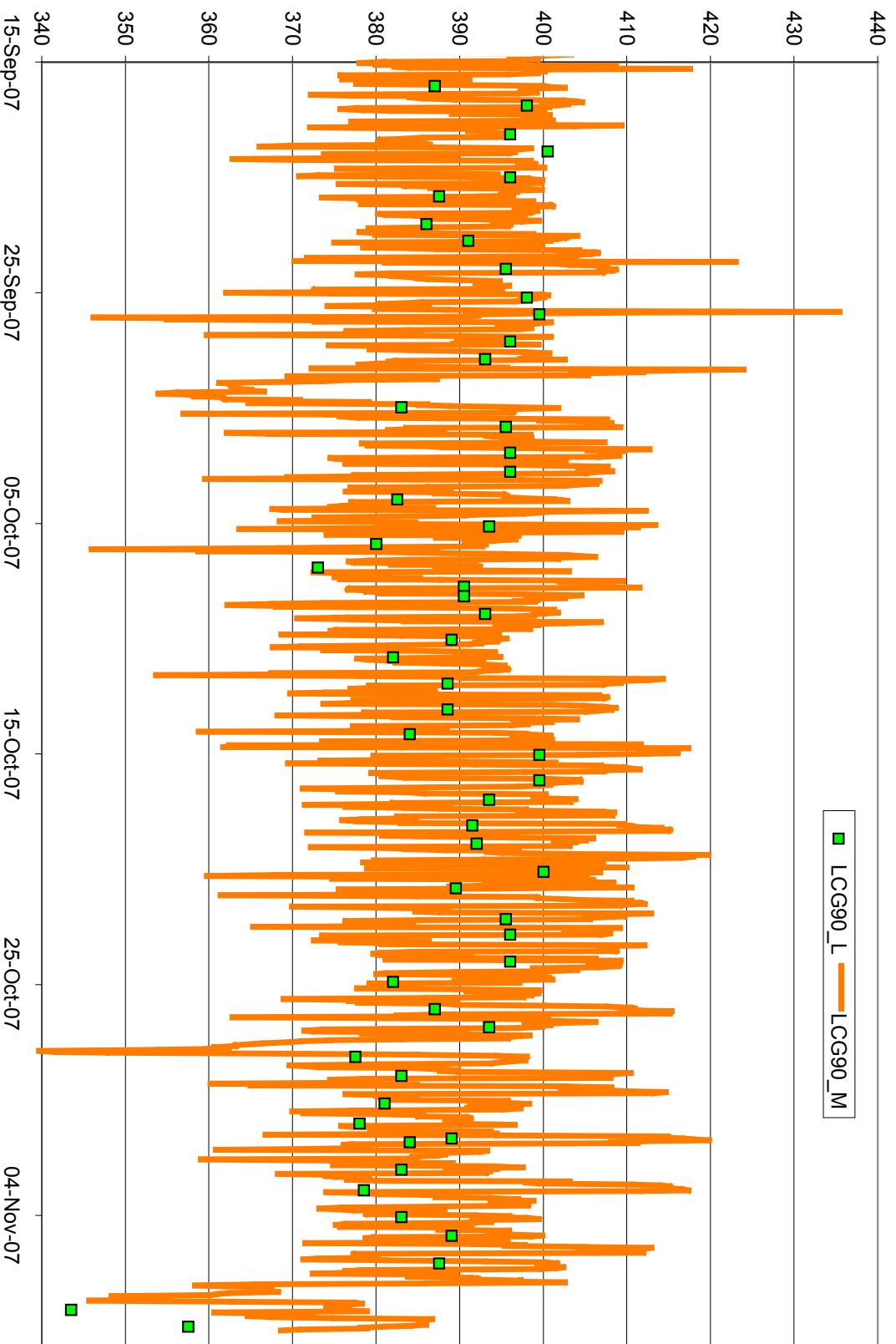


Figure 5: Coker fresh feed flow before and after commissioning of APC

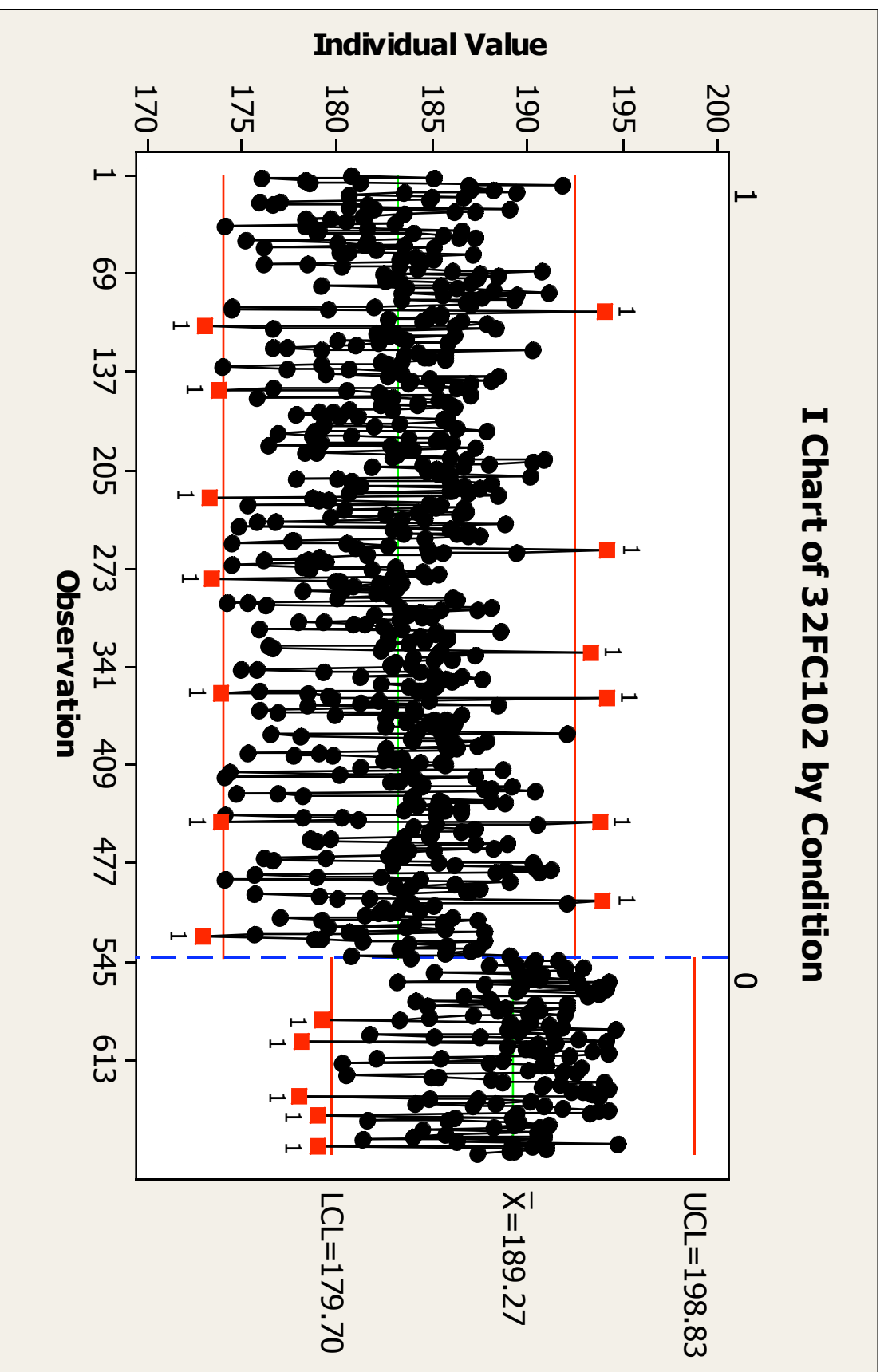


Figure 6: Fresh feed flow during drum switches

