Retooling APC for improved results

Raising refinery-wide awareness of the role of advanced process control delivers maximum benefit from a reinvigorated APC

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Total's Port Arthur refinery is a 174 000 b/d transportation fuels merchant facility. The site began in the 1920s as an Atlantic Refining oil terminal, shipping crude oil from the nearby Spindletop oil field to Atlantic's New Jersey refinery. The refinery was constructed later in 1936. The site has been owned and operated by Atlantic (1920s), ARCO (1938), BP (1969), Fina (1973) and Total (1999). Major processing units include two crude units (CDU), two vacuum units (VDU), isomerisation, a fluid catalytic cracker (FCC), alkylation, two gasoline hydrotreaters (GHT), three distillate hydrotreaters (DHT), a reformer (CCR) with aromatics extraction, and a delayed coker (DCU).

Beginning in the early 1990s, Port Arthur refinery installed a number of advanced process control (APC) applications, but due to lack of attention they had fallen into disuse. In early 2012, the refinery determined that APC, when treated seriously, has the potential to significantly improve profitability. The typical simple project payback for APC is less than 12 months. It may be implemented quickly (4-8 months) while the unit is running – no shutdown or mechanical modifications are required. Finally, an APC application is adjustable after commissioning to continue to maximise income under new or different operation conditions and economic scenarios.

The refinery then began a programme to reinvigorate its APC. Since then, the APC group has successfully rehabilitated existing APC applications and implemented several new applications. Presently, the APC's status is:

- Large CDU atmospheric, VDU vacuum section – fully implemented
- ULSD hydrotreater – fully implemented
- Jet hydrotreaters – sulphur control implemented
- FCC reactor, regenerator, fractionator, gas plant – fully implemented
- FCC gasoline hydrotreater – fully implemented
- CCR reactor, regenerator, stabiliser – fully implemented
- Aromatics recovery – fully implemented
- Gasoline blend optimisation – fully implemented
- DCU furnace, fractionator, gas plant – project in progress
- Small CDU atmospheric, VDU vacuum section – 2016 project
- Condensate splitter – 2016 project.

The dilemma the refinery faced is how to achieve, and continue to maintain, high APC utilisation rates with existing resource constraints. The APC group has tackled this problem by (1) separating the APC and process control organisations,[1] (2) identifying APC stakeholders[2] and (3) leveraging APC support by engaging these stakeholders in helping design, implement, steward, maintain and improve APC applications.

APC organisation

Which refinery department should house the APC team? Consider the APC engineer's skill requirements. About 80% of advanced control incentives are related to what can be termed 'on-line process engineering' or figuring out how the unit should be operated and driving it toward that objective without violating any constraints.[3] Therefore APC engineers are, or should be, skilled process engineers with a good understanding of refinery economics. On top of that, they typically possess control and process dynamics knowledge. Undoubtedly, APC engineers belong in the technical department.

Historically at Port Arthur refinery, the APC and process control (PC) people were combined into one group as a part of the technical department. That is the natural place for APC engineers, but grouping them with PC people blurred areas of responsibility, with APC engineers finding themselves responsible for DCS related tasks. To make the organisation work better, the PC engineers, who are responsible for DCS work, are in a separate group under the mechanical department.

In the new organisation, APC engineers are no longer burdened by day-to-day PC/DCS plant support demands. They are chemical engineering specialists with APC or process/APC backgrounds, focusing exclusively on implementing and maintaining APC. It also helped that the part-time APC group supervisor has a background in PC, APC, operations supervision, and planning and economics.[4]

Admittedly, there are not enough experienced resources at the site. The APC group copes with that shortage in several ways. First, the group negotiated a three-year alliance with an APC contractor. The arrangement permits single sourcing of APC projects and maintenance on a time and materials (T&M) basis. T&M allows contractor engineers to thoroughly understand issues, identify and correct underlying DCS or instrument problems.

In addition to APC contractor personnel, the group began using expert corporate (central engineering) APC resources. Corporate level effort is in the order of 4-5 visits per year, about 10 days per visit. A corporate APC specialist stewards the contractor's activities for technical consistency and reasonable man-hour expenditures. Further, the group has learned to leverage APC engineers by using engineering interns for more basic work.

APC engineer time allocation for ongoing support

The refinery wants to keep its APC engineers fully loaded, but not overloaded. Each APC engineer is responsible for several applications. He/she is to keep the applications dynamically stable and economically correct. What does it take and how many applications can an APC engineer support?

The following workload numbers are taken from a 2010 paper.[5] To keep a single large APC application running to maximise profits, the APC engineer must:

- **Understand unit economics and planner intentions** It is assumed that the engineer is already familiar with the APC structure and the process. The understanding of how this unit should operate as a part of the bigger planning picture would take in the order of two hours per week.
- **Configure APC applications to comply with the daily operational plan** Operational plans can be seasonal, but they may contain unusual elements in response to unforeseen refinery or market conditions. Sometimes it takes considerable effort to reconfigure APC to comply with the plan. On average, this effort is estimated at 4-6 hours per week
- **Monitor and adjust inferential models** These are a critical part of almost any control application in the sense that reliable inferences ensure that APC has the information needed to control product qualities. On the other hand, inferential models rely on process measurements that can occasionally be erroneous. APC engineers should spend time monitoring and making sure inferential models are in good health, and that should take in the order of 2-4 hours per week.

The conclusion of that 2010 paper was that a good APC engineer can successfully steward four large APC applications, 5-6 with outside help. The refinery's experience tends to support this conclusion. For example, a recent responsibility transfer to a new APC engineer included 18 separate 'in-process' follow-up issues for a single established APC application. This application had been in service since 2013. This example demonstrates the complexity and on-going support required to properly maintain APC performance and its continuing relevance to changing economics and constraints.

Interactions with stakeholders

Once APC is designed and implemented, what is the difference between a beautiful mathematical exercise and a control program that optimises the unit against constraints? The difference is that productive APC applications have targets that reflect the real capability of equipment as well as the economics of the day.

To make the latter happen, the APC group solicits the assistance of 'stakeholders', that is people whose job is to make a process unit run better, functionally and economically. Other than APC engineers, primary stakeholders are:

- Console operators and process supervisors who know how to drive the unit in all possible scenarios, relying on mental cause and effect models
- Process engineers who study the process at steady state and perform troubleshooting and test runs. In Port Arthur refinery, they have been given a charter to "…understand and monitor APC applications on their units as they do any other piece of equipment."
- Planners who know current plant economics and define the daily plan and operating focus for maximum profitability

Secondary or supporting stakeholders are people needed to support APC, though not on a continuous basis:

- **Laboratory:** APC applications rely on inferential models, which estimate product properties from unit measurements. Those are validated against laboratory values. Laboratory support is often needed during calibration or troubleshooting of those models
- **On-stream analyser (OSA) technicians:** well functioning on-stream analysers, even if not in closed loop, give the operator assurance that while APC moves the unit to optimise it, products are kept on specifications. Poorly functioning on-stream analysers or discrepancies between OSA and laboratory analyses destroy operator confidence and end up reducing APC service factor
- **Process control and instrument groups:** the DCS control layer below APC must be correctly configured and tuned for APC to work. That includes not only process controllers but also sensors and final control elements. Sensors are used as inputs for inferential calculations and sometimes for economic calculations
- Last but not least, management is an important stakeholder and the APC group is constantly searching for ways to educate management and obtain their support.

APC engineers provide the 'glue' that brings stakeholders together to achieve and maintain improved APC profitability. They coordinate with stakeholders, help them understand the synergy between their goals and APC, and use their help in setting APC targets. The APC group's most successful educational venue is a series of quarterly stakeholder meetings, discussing how APC works in specific units.

The most frequent stakeholder interaction occurs when setting daily APC targets. It is sometimes a challenge to translate planning desires into operating modes and APC targets. The daily operations meeting is where meaningful discussions take place about the economics of the day versus unit constraints, and realistic limits reflecting soft and hard constraints. A soft constraint is a situation that cannot be tolerated at steady state, but can be somewhat exceeded during a transient, for example a product quality target. A hard constraint is a situation that might cause equipment damage if exceeded, even for a short duration.

Cultivate relations with console operators[6]

The APC group provides formal APC training to console operators as a part of requalification, but that is not enough. If there is a single factor that is the key to success it is the acceptance of APC by console operators, and before that can happen the APC engineer must demonstrate process, economics and APC skills.[7] He/she can make mistakes, but not many, and those must be quickly corrected. Once the APC engineer's competence is established, console operators would lend themselves to be coached, and should be coached so that they fully understand the application. The final stage of such coaching comes when operators take ownership and begin setting APC targets and limits. He/she has to be an active participant in the daily discussions of how to adapt the APC application to operating plan targets. Successful APC engineers maximise their time at the operating console rather than in their offices. While operators have deep knowledge of unit behaviour, they lack chemical engineering education and benefit from follow-up one-on-one, ad-hoc mini-training sessions at the console (see **Figure 1**).

Stakeholder training and documentation

The APC group provides computer based training (CBT) as a self-paced introduction to model based control. The training package has seven modules meant for different stakeholders (operators, process engineers and management).

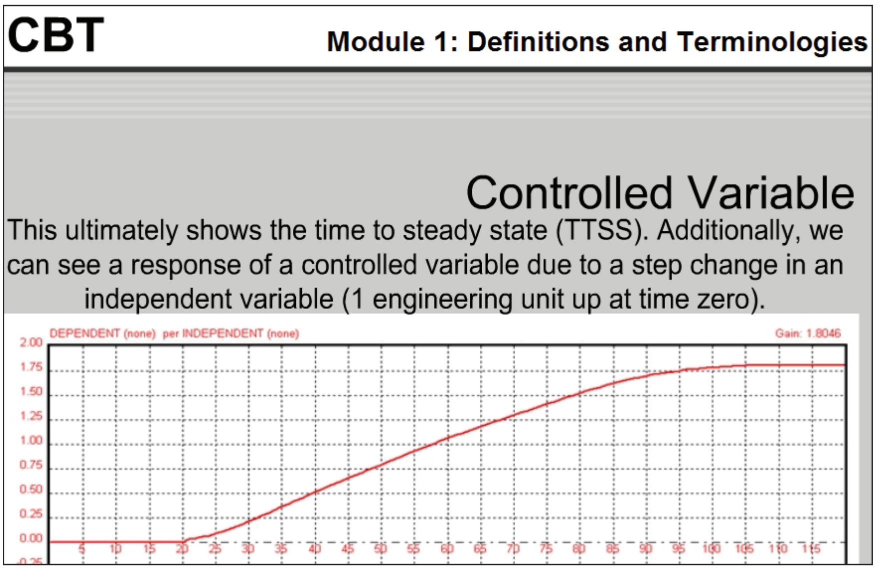

Figure 1 Operators benefit from mini-training sessions at the console

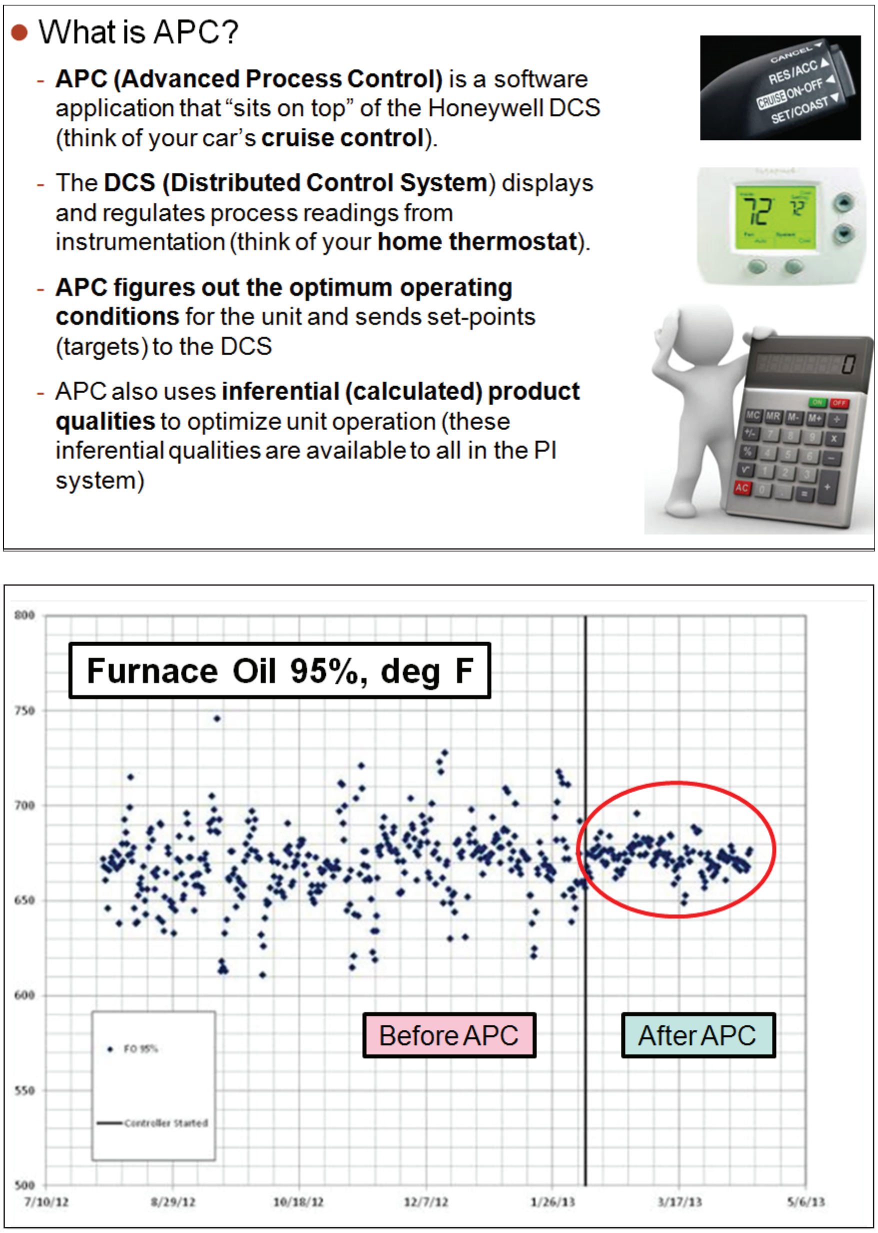

Figure 2 Slides from a non-technical, high-level presentation given to all salaried personnel

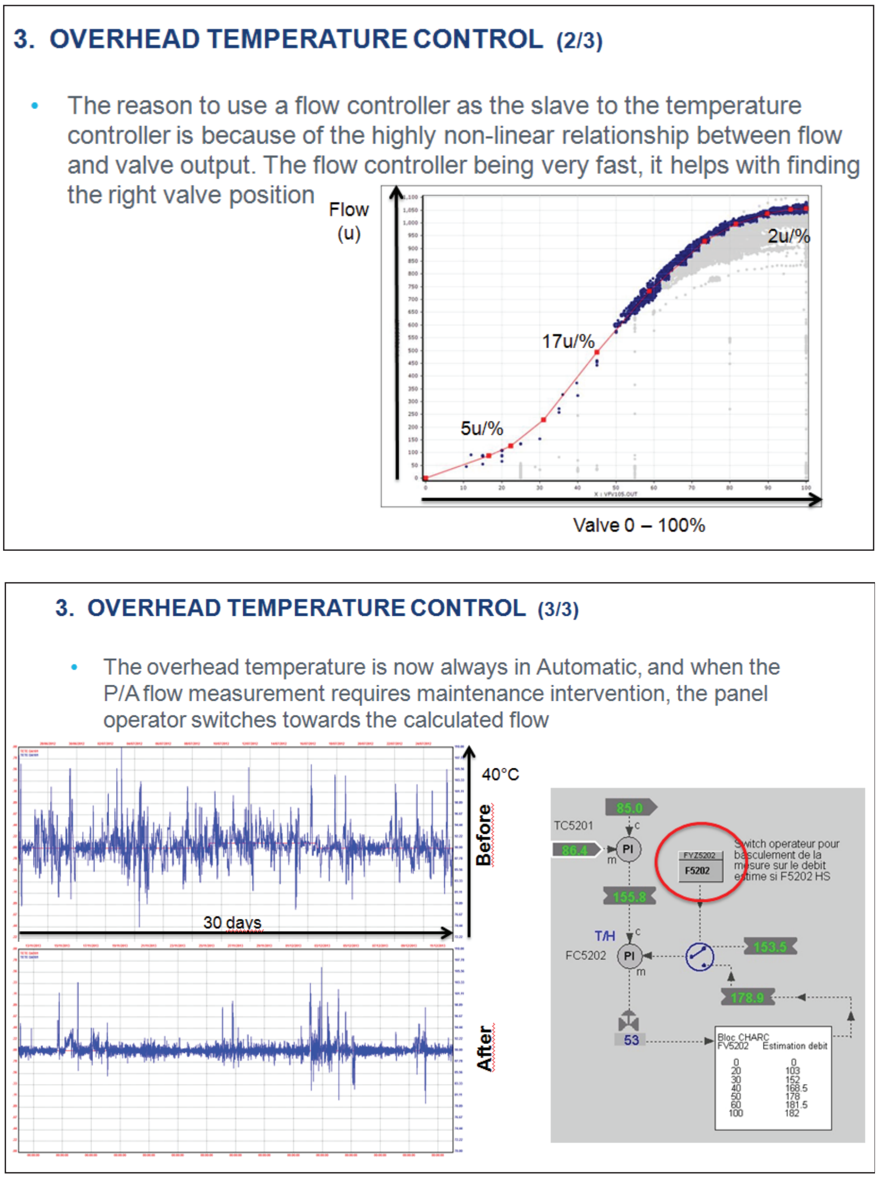

Figure 3 Slides from a presentation for process engineers and operation supervisors

A 'web-viewer' is also available on the business network. Stakeholders can see the status of all model based APC, including on-off status, targets, constraints, and limits.

To further the group's visibility, a non-technical, high-level presentation was created and given to all salaried personnel, an audience of about 120. This presentation explains DCS, APC, inferential models and refinery optimisation in simple terms, and it shows examples of how throughputs are being driven up and how product qualities are kept at targets. Typical slides from this presentation are shown in **Figure 2**.

For communication with technical management, there is a presentation for process engineers and operation supervisors, an audience of about 20. Slides from that presentation are shown in **Figure 3**.

The latest tutorial is on inferential properties. Furthermore, the APC group keeps a frequently updated website containing:

- A one-page APC summary per application
- A post-audit report for each APC application
- All lunch-and-learn tutorials
- A monthly high-level report. This is a summary report, distributed to about 50 people. It contains KPIs, instrument/DCS issues, and the latest APC project status. An example KPI diagram is shown in **Figure 4**.

More detailed website technical information, actually aimed at internal APC group use, includes pretest, operator[8] and engineer documentation, and a strategic APC plan for the facility.

The group considers its efforts successful in that its high visibility prompts management to ask questions. And with management showing interest, APC coordination meetings have become well attended, and APC has become an important tool for implementing planning decisions.

Benefits of a systematic approach

The refinery has consistently experienced APC application uptimes of 90+%. Stakeholders understand APC concepts and are motivated. They feel a part of the APC team. Operations supervisors and planners are quick to ask why an application is turned off. APC-critical DCS or instrument repairs are given a high priority. Within the group, every stakeholder suggestion or complaint is considered seriously and is responded to immediately, or at least a problem is acknowledge and a temporary way to work around it is found.

Summary of an APC programme philosophy

- Maintain the programme's high visibility
- Provide frequent interaction at the appropriate conceptual/technical level
- Seek stakeholder input
- Provide stakeholder training
- Hold stakeholders accountable
- Update APC application limits to reflect current operations
- Challenge/coach console operators on how best to configure APC applications to achieve operating targets
- Make APC utilisation an expectation across the organisation.

Things to consider

- "Match management's APC ambition to the number and quality of people they are willing to dedicate to the effort"[9]
- Choose a group supervisor with broad plant experience: control, operations and plant economics. A part-time supervisor is acceptable
- Deal with DCS/instrument

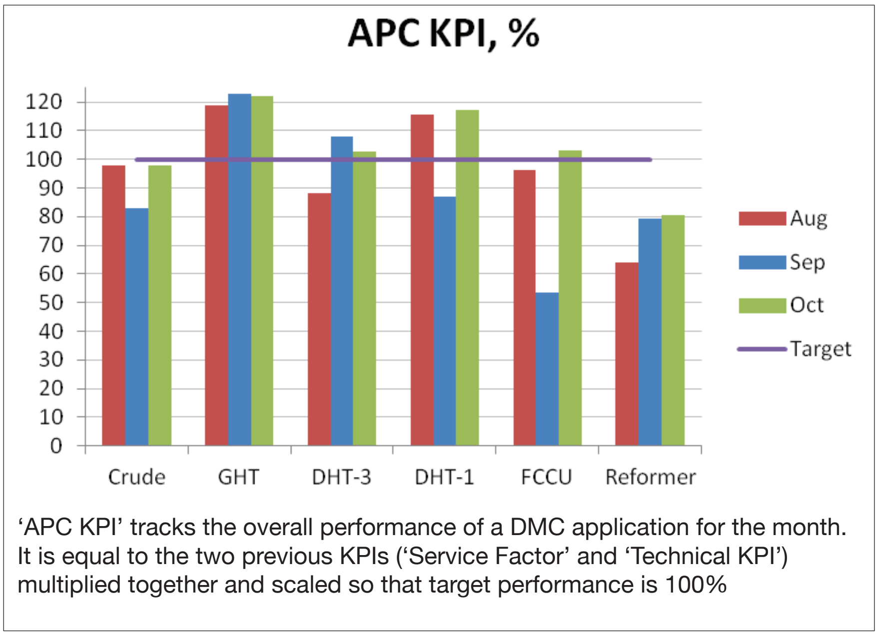

Figure 4 KPI diagram from a monthly summary report

problems before beginning APC
- Partner with a proven APC contractor
- Focus APC engineering efforts on implementing and maintaining successful applications
- Involve console operators, process supervisors and process engineer in all aspects of APC development and usage.

Potential call-outs

- Management must match their APC ambition to the number and quality of people the refinery is willing to dedicate to the effort
- Process engineers must understand and monitor APC applications on their units as they do any other piece of equipment
- Successful APC engineers spend their time at the operating console rather than in their office
- If there is a single factor that is the key to success it is the acceptance of APC by console operators, and before that can happen the APC engineer must demonstrate process, economics and APC skills
- About 80% of advanced control incentives are related to what can be termed 'on-line process engineering' or figuring out how the unit should be operated and driving it toward that objective without violating any constraints.

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