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Turnarounds: Strategic Opportunities to Improve

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To be successful, both capital projects and turnarounds need to be planned and implemented as one event.

Turnarounds in continuously operating process plants, such as petroleum refineries, are complicated and costly events, and each day of downtime translates to lost revenue. Mitigating the risk of cost and schedule overruns is vital to competitiveness and profitability. Turnaround teams are tasked with coordinating a limited workforce in a constrained time period and must also ensure maintenance crews are safely working on only the assets that need attention. Missing a required maintenance service or doing unnecessary work could extend the turnaround schedule and increase the probability of an unscheduled shutdown after the turnaround.

The traditional view of turnarounds is that they are just maintenance events. In reality, turnarounds extend far beyond maintenance and can have significant impacts on capital and operating budgets that can determine profitability for the manufacturer. These planned shutdown events are strategic opportunities for processing facilities to improve operational efficiency, reliability, and safety. Operating plants that are not improving are falling behind their competitors. A turnaround is the planned shutdown opportunity to implement a capital improvement project *(1)*.

Traditionally, capital projects and turnarounds are treated as two separate events led by different project managers and, many times, executed by different contractors. Because the two events are not coordinated, the performance of such turnarounds is subpar. Ever-changing regulations and the increasing abundance of discounted opportunity crudes have driven refiners to take on larger capital projects. At the same time, teams are pressured to reduce the duration of the turnaround. Thus, turnarounds are becoming more complex because so many activities must be coordinated safely in a limited timeframe. Unfortunately, these added activities and the increased number of workers onsite often result in budget and schedule overruns, as well as a higher probability of a safety incident.

Traditional approaches and current trends

Ineffective turnaround planning can cause a turnaround to go significantly over budget and over schedule. Table 1 shows the top 10 reasons for turnaround failure *(2)*. The inability to integrate a capital project within a turnaround is one of the top reasons, behind only unrealistic targets for turnaround success. An example of an unrealistic target is to plan a turnaround duration that is shorter than the critical-path work.

At many continuous processing facilities, capital projects are traditionally considered a separate event from

the turnaround, even when both are carried out at the same time. Surprisingly, capital projects often require more labor hours than are required for the turnaround *(3)*. The planning of the turnaround and the capital project must be coordinated so that the right equipment, materials, and personnel can get where they need to go at the right time, and so that the work for the turnaround does not interfere with the capital project and vice versa. For example, if scaffolding needed for a turnaround will block access required to perform the capital project upgrade, that needs to be communicated in advance. Or, if only one crane is available or can fit around the process unit, it would need to be shared between the turnaround and the capital project (Figure 1). Separating the planning for the two events creates misalignment between the turnaround team and the project team.

Many times, the turnaround and the capital project have different contractors and contracts. The capital project may have a lump-sum turnkey (LSTK) contract (*i.e.,* a fixed payment amount for the delivery of a defined scope of work) and the turnaround contract may be based on time and materials. Many turnaround managers would agree that the time-and-materials contract carries the highest risk for the processing facility. However, manufacturers can still implement cost controls in the form of negotiated labor rates, maximum labor hours, material markup, and a maximum total cost. A LSTK contract is typically not implemented for turnarounds because of the high probability of discovery work — *i.e.,* work that was unknown or only suspected during project planning that is discovered when equipment or piping is opened during shutdown. Thus, a time-and-materials contract is required for turnarounds primarily because of the discovery work uncovered during a turnaround, despite best efforts to plan the work. Discovery work tends to be the largest contributor to scope growth *(4)*.

As shown in Table 1, scope growth is a main contributor to cost and schedule overruns. There are three main types of work scope:

Table 1. The top 10 reasons for turnaround failure *(2)*.

10. Quality issues at startup
9. Improper management of contractor resources
8. Significant scope growth
7. Delayed decontamination and unit handover
6. Lack of resources for optimum preparation
5. Incomplete adherence to turnaround work processes
4. Inadequate/incapable execution organization
3. Ineffective turnaround strategy and/or turnaround teams
2. Inability to integrate with capital projects
1. Unrealistic targets for turnaround success

- known scope (planned)
- anticipated scope (can be planned)
- discovery scope (unknown).

According to a study by AP Networks *(4)*, the average scope growth during a low- to medium-complexity turnaround due to discovery work is approximately 9%. For high-complexity turnarounds, the scope of a project can grow by 12% during the turnaround period (or 6% for top-quartile performers) due to discovery work.

Since discovery work is unknown until you open an asset or piping for repairs or inspection, it can be detrimental to the overall success of a turnaround if significant work is unexpectedly required. A part of this unknown is insufficient asset monitoring and predictive analytics to assess the rate of asset degradation over time. Older refineries were typically built with the minimal amount of instrumentation required to operate the plant safely. Unlike new facilities, these refineries typically do not perform continuous asset



▲ **Figure 1.** The work schedule of turnarounds and capital projects must be synchronized. For example, if only one crane can fit in the workspace, it must be shared between maintenance and capital project activities.

Higher margins typically do not come from premium-priced products. Higher margins come from operating the processing facility better than the competition.

health monitoring. As a result, turnaround teams are forced to use insufficient asset health data and rely more on risk matrix calculations (which take into account the severity and probability of a specific hazard) and time-based maintenance to determine scope. When the plant is shut down during turnaround, unexpected discovery work can put additional strain on the resources scheduled and available for the turnaround work.

The production of tight oils in the U.S. has increased significantly over the past few years, and the global petroleum refining industry has started to process more "discounted," or opportunity, crude oils, including tight oils as well as heavier and more-sour crudes and crudes with a high total acid number (TAN) *(5)*. As a result of processing these higher-acidity crudes, piping metallurgy upgrades and replacement of corroded pipe has recently been the critical path in determining the duration of a turnaround. The traditional critical path for a turnaround is catalyst reloads, maintenance of large rotating equipment (critical compressors), or a capital improvement project.

In addition to piping upgrades, refiners are also investing in meeting new clean fuels regulations and upcoming flare and relief-valve monitoring requirements. Beyond these mandatory changes, refiners are installing digital technologies to utilize process and asset health data in a new way to avoid abnormal operation and minimize unscheduled shutdowns *(6)*. With all these investments to improve the facility and comply with new standards, the refinery typically needs to be shut down to safely implement the upgrades and improvements. A scheduled turnaround provides a window of opportunity to make these upgrades. In the past few years, refiners have seen higher margins and have used these additional funds for capital improvement projects.

All industries are challenged with finding a skilled workforce to conduct the maintenance and/or upgrade work within the time allotted. Manufacturers do not want to extend the duration of a turnaround and they will often reduce the scope to accommodate the available resources. In addition, manufacturers do not want inexperienced workers learning on the job during a time-compressed and stressful activity like a turnaround. They prefer having access to certified and experienced workers to ensure the job is done correctly the first time. The Construction Industry Institute (CII) has shown that a certified industrial craft workforce tends to be safer, more productive, and less absent — all valued qualities for resources working in a turnaround. In addition to shortages of skilled resources, low unemployment in this field in the U.S. creates even more pressure to reduce turnaround scope.

Best practices

The top-quartile performing plants are leveraging availability-focused spending and sustainable best practices aimed at continual improvement *(7)*. The payoffs for this focus on performance improvement are lower operating expenses and higher margins. Higher margins typically do not come from premium-priced products (*e.g.,* gasoline is a fungible commodity); rather, higher margins come from operating the processing facility better than the competition.

A best practice is to manage capital projects within a turnaround as one event, thus having the capital project issued for construction (IFC) documents completed before the turnaround scope freeze date. Many refiners have turnaround scope freeze dates 9–12 months in advance of the turnaround, and extend this date to 16–18 months when a significant capital project is integrated with the turnaround. The freeze date may seem to be a long time before the actual turnaround, but this provides sufficient time for proper planning of resources and for obtaining spare parts or asset replacements that have long lead times.

It can be very costly to add work to a frozen scope. Therefore, some companies will not add work to a frozen scope unless its return on investment (ROI) is two or three times the ROI that would normally be required to justify being part of the turnaround scope.

Many people assume that the turnaround manager determines the scope and has overall ownership for a turnaround. However, in many refineries the operations team is typically in charge of managing the turnaround. Although it may seem advantageous to have both the capital project and turnaround being managed by the operations team, the main priority of the operations team is to minimize duration of the turnaround. They are generally more willing to cut back scope to make the turnaround as short as possible, and can more easily justify cutting maintenance work from a turnaround if current asset health information is not available during the scope-defining phase.

Best practices utilize current asset health trends (beyond a single data point) and technical risk analysis (*e.g.,* failure modes and effects analysis [FMEA]) to take emotion out of deferred maintenance decision-making. Reliability engineers should advise the turnaround team after taking into account risk analysis calculations and asset health information.

Monitoring asset health trends ensures only the assets that need attention during a turnaround are part of the scope, and provides confidence that an asset requiring attention was not missed if the overall scope was reduced. When used with analytics, asset health trends can mitigate some of the

discovery work once the turnaround begins.

It should be noted that not all assets have online monitoring with predictive analytics; these are potential candidates for future investments to embrace the current digital transformation taking place in manufacturing (*e.g.,* big data, industrial internet of things, Industry 4.0, etc.). These monitoring capabilities assist with maintenance decisions based on asset condition (rather than time-based) for an upcoming turnaround, and also continue to provide value during operation to indicate abnormal performance or imminent failure, thereby improving overall availability and profitability for the plant.

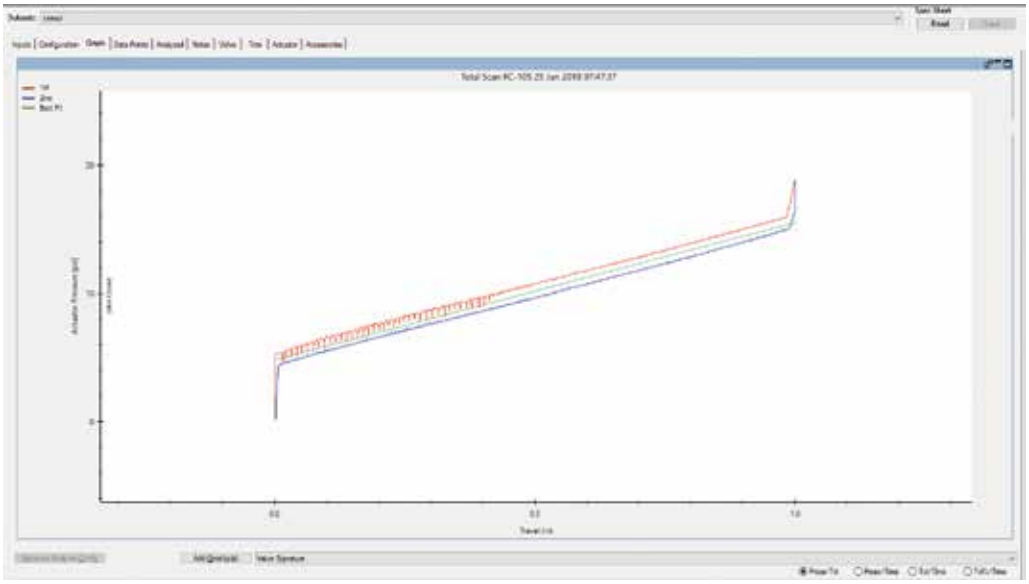
Online asset health data from sensors has been available for decades, but a transformation is now taking place because wireless sensors have lower cost and are faster to install than their wired counterparts. At many process plants, wireless sensors provide additional insights into asset health that enable new and better ways to integrate work processes and improve the timeliness and accuracy of decisions, including for turnarounds and deferred maintenance. This awareness allows plants to reduce turnaround scope with confidence and lower maintenance costs while reducing unscheduled downtime. Improved plant availability reduces the amount of time workers spend in dangerous transition periods (startup and shutdown), which reduces the probability of a safety or environmental incident.

For example, using smart positioners on control valves provides diagnostic capabilities that can significantly reduce the amount of control valve maintenance required during a turnaround (Figure 2). Smart positioner functions use about 10% of the microprocessor's capabilities, which leaves most of the electronics available for diagnostics that can provide insight into the valve's performance *(8)*. One refiner used diagnostics technology to minimize the number of control valves repaired during three maintenance turnarounds. By selecting only the control valves that needed attention, it saved hundreds of man-hours, and ensured there was no delay getting back into production due to required valve maintenance during the turnaround *(9)*.

Another best practice is to consider replacing or upgrading equipment rather than repairing equipment during a turnaround. Many times, refiners are willing to spend days or weeks repairing equipment, which can extend the turnaround duration and contributes to a lower plant availability. With the high margins refiners have experienced over the past few years, they have been more willing to shorten the turnaround duration by replacing equipment like control valves rather than taking the additional downtime to repair these assets.

This strategy does not make sense for all assets, especially expensive and critical assets like large compressors. In addition, the shortened duration while margins are good can only be used short-term. Some assets will require maintenance that cannot be deferred until the next planned turnaround, and inspections may need to be carried out for legal and/or insurance compliance.

Processing facilities have a core competency to operate the plant while monitoring catalyst activity and providing asset maintenance. However, having early access (before the scope freeze date) to additional knowledge and experience in areas outside a manufacturer's competency can be beneficial to the success of a turnaround. For example, the automation solutions provider that manufactures the control valves and transmitters will have intimate knowledge of the engineering and design of the equipment and expected degradation through embedded diagnostic capabilities. A refiner can use the automation provider's experience,



▶ **Figure 2.** A valve signature indicates the integrity of the valve body and the actuator. The red line represents the recorded travel as output pressure increases until the valve is 100% open. The blue line is the recorded travel once the positioner releases the pressure and the valve travels to the closed position. The green line is the best-fit line. The distance between the green line and red or blue lines can be used to calculate valve friction. Valve signatures should be recorded when the valve is brand new so that future valve signatures can be overlaid to check for changes *(8)*.

expertise, and asset diagnostics to provide additional insight into the health of an asset and whether maintenance can be deferred. Automation providers have engineered the equipment for the application, thus the OEM parts will provide the required reliability and performance compared to a non-standard copy.

Effective teams communicate during the planning phase. Communication and leadership are required to ensure safe work, since anywhere from 500 to 2,500 additional workers could be onsite for the turnaround (and capital project, if it is also part of the scope). Safety is the number one priority for a turnaround and capital project integrated within a turnaround. During a turnaround, the entire plant may not be shut down — there may be some operating systems next to the unit(s) shutdown for turnaround. Therefore, there is an extreme need for good communication, hot-work permitting, and overall awareness that a live plant is close by.

There are two key times during a turnaround with higher risk of a safety incident: at the start of the turnaround, because workers are unfamiliar with the environment and there may be nearby processes still in operation that can pose a hazard, and at the end of the turnaround, when workers are fatigued from long hours and they anticipate the turnaround completion is near. It is vital that communication remains strong to ensure everyone is aware of others' work nearby and the importance of safety.

When a turnaround is completed, it is important that all teams, including contractor leadership, provide a lessons learned and post-turnaround discussion about possible ways to improve the process for the next turnaround. Turnarounds can happen once every three to five years, so having good documentation on best practices and potential mishaps can provide the next team a good start for a successful turnaround. This post-turnaround discussion should be important to contractors as well to ensure they deliver on expectations and re-establish working relations for future turnarounds.

Final thoughts

Advances in automation and wireless sensors have enabled processing facilities to quickly and easily invest in additional process and asset health measurements. Having access to online and trending asset health data allows for condition-based maintenance decisions for an upcoming turnaround. Basing deferred maintenance decisions on this information along with standard risk matrix evaluations is an effective way to ensure that the scope involves only assets requiring work and that no asset requiring work is missed — which ultimately leads to improved availability and profitability.

To stay competitive and comply with ongoing regulations, manufacturers need to continuously improve. A turnaround provides scheduled downtime to implement a capital improvement project. Turnarounds are already challenging, with many resources working on multiple assets in a fixed duration of time, and adding capital projects only increases the complexity and risk for budget and schedule overruns. Recent trends have also shown that the capital project may actually require more labor hours than the turnaround, thus emphasizing the point that both activities need to be coordinated as one event. CEP

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