

Petroleum and Process Industry Best Practices in Maintenance & Reliability

Abstract – This paper presents an overview of how safety, maintenance, and reliability are interrelated and presents some industry best practices. A framework for ensuring a holistic approach to the management of these functions is proposed.

Key words – Holistic management, Maintenance efficiency, maintenance process, reliability management

I. Background /Intro

We have all worked with managers who always ask ‘Why?’ When applied to a piece of failed equipment you might think it odd. After all, nothing runs forever and all things are bound to fail at sometime or other, right? Wrong! The simple fact is all things fail for a reason. Once you understand the reason you can make improvements to prevent that causal factor as a reason for failure, hence prolonging your reliability or meantime between failures.

Although as an operator you may make a conscious decision to run a piece of equipment to failure, this should not be your primary mode of operation. Unscheduled and unplanned failures are expensive. Additionally, they create significant safety and environmental emissions exposure. One needs to work towards a culture of predictive, proactive and planned maintenance with a focus on continuous improvement. One must always ask ‘why’ when there is a failure in a process a piece of equipment or a product. A good maintenance and reliability process must have this culture as a key element. Timing of repairs is also critical. Done too soon without proper planning could be expensive. Done too late and you run a risk of other failures shutting your unit down. High reliability does not come at a cost to maintenance spending. Indeed a lot has been published about the fact that plants with the best reliability tend to have the lowest maintenance cost.

A ‘why’ culture in maintenance also needs to involve other disciplines where appropriate. Consider the case of a maintenance engineer who showed up at a morning meeting with a show-n-tell. It was a pump seal that had failed and there was evidence of copper on the seal surface. The mechanical engineers were concerned about the impact of copper on the proper functioning of the seal. However, the chemical engineers present responded in alarm. There should be no copper in the process. Copper in this process could lead to the production of copper acetylides which are explosive. This is a significant safety issue in a hydrocarbon processing unit. The reliability alert had suddenly become a safety alert and a troubleshooting exercise was started.

This example illustrates the need for a holistic culture that brings together leadership and appropriate functional groups to the maintenance process in order to foster and promote an effective, safe and reliable workplace. Put another way, there is a need for leadership and a maintenance & reliability management system. A properly implemented holistic management

system couples maintenance, reliability and safety in a manner that reduces the overall cost of operation while continuously improving safety and reliability.

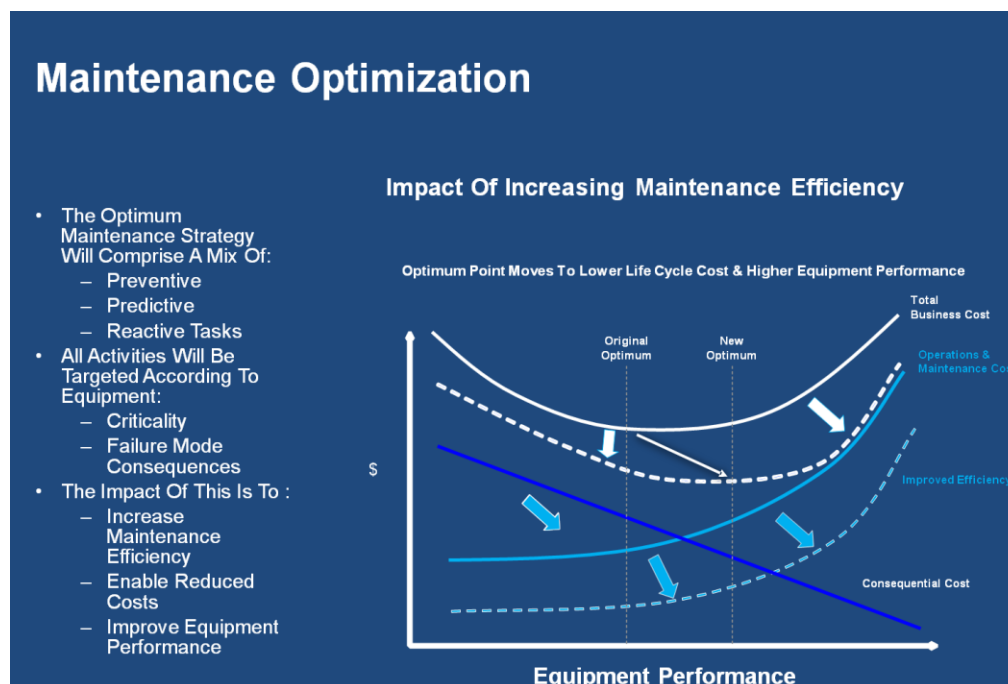
It has been our experience where our clients have realized maintenance efficiency improvements by as much as 5% of total maintenance cost. Long term time on tools improvements of up to 30% and manpower reductions of up to 6%. Correspondingly, reliability and safety performance have improved.

What are the key elements of a holistic maintenance and reliability management system? One can look to some well known management systems such as the ISO standards (ISO9000, ISO14000) and the OSHA PSM (CFR1910.119) and “STAR” programs. These tend to have some common elements which also apply to the reliability and maintenance activity. We propose the following key elements for your program.

II. Management Elements

Management Leadership. As with everything, unless management sets a clear safety, maintenance and reliability vision and reinforces that vision with constant messaging and support, the organization is not going to be responsive and will devote its resources to what they see as the values of the leadership team.

Figure 1 Maintenance Optimization



This messaging should not just be limited to operations leaders but all leaders. A key marketing or sales leader reinforcing the importance of safety and reliability to the core operations work groups is very powerful. It sends a strong

Figure 2 Diagnostic process

message to the organization that these concepts are not just

important to operations, they are critical to overall business performance. One has a higher chance of sustaining excellence in performance if this expectation is cultural.

Without strong management support, entropy eventually sets in and processes will deteriorate.

There must be a culture of safety' and continuous improvement and this cannot be dictated.

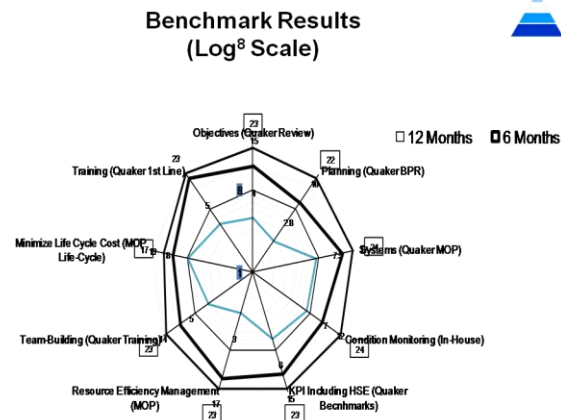
Management also requires metrics to monitor the effectiveness of processes and continuously sustain performance. Figure 1 illustrates the Quaker approach to a comprehensive short and longer term gap analysis and prioritized areas for performance improvement.

Asset Management Quaker Group Best Practice Assessment

Overall Objectives

- Align Asset Management Improvement With Business Objectives
- Discretionary Non-Discretionary
- To Identify Areas Of Best Practice And Opportunities For Improvement
- To Provide A Costed Plan With Projected ROI For Improving Maintenance Productivity And Operational Efficiency

Figure 3

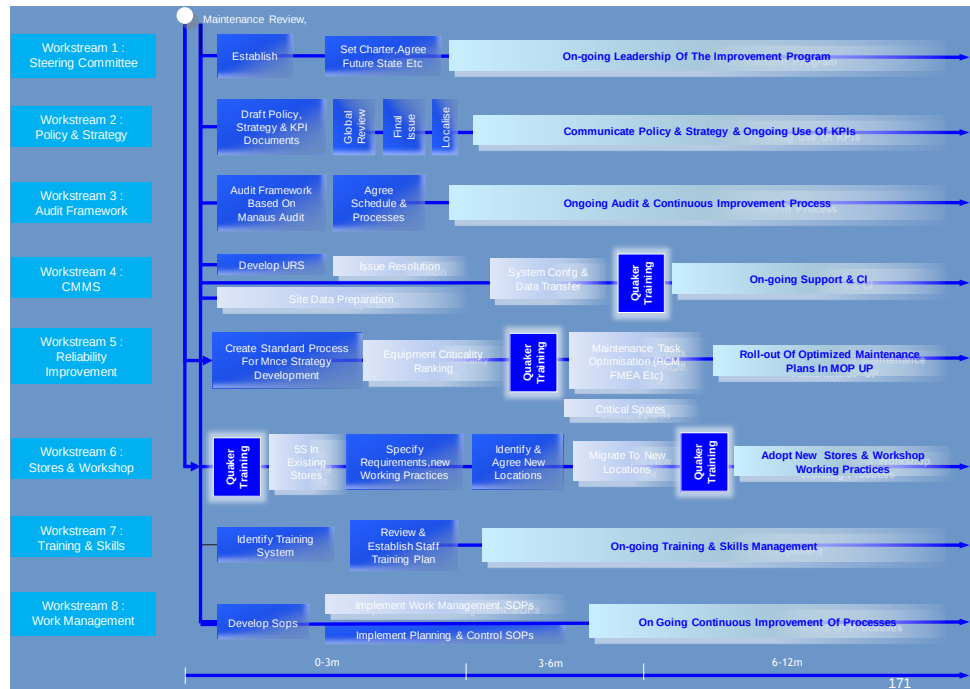


Employee Involvement Maintenance and reliability activities are not the sole responsibility of those two functional organizations. Clearly, the way a piece of equipment is repaired, started up, shut down and monitored by operations has an impact on its longevity. A car owner who has no car sympathy and makes jack rabbit starts, is hard on his or her brakes, does not check fluid levels and does not get routine oil changes is going to have more problems no matter how good a repair shop he or she has. The same holds for all your plant equipment. Operators have been known to say 'we can break a piece of equipment faster than you can fix it'. A culture needs to be created that encourages open communication and teamwork. Formalized systems such as Reliability Improvement Teams (RIT), process improvement suggestion systems, and cross functional incident investigation teams, may be used but need to be appropriately resourced and supported. Such processes are relatively common in safety programs. World class organizations have succeeded in transferring those methodologies to their maintenance and reliability programs.

Risk Identification and Management. In order to keep the failure incident rate down,

Figure3

the organization has to be transformed from one that is reactive to one that is proactive. To do this, one needs systems and processes to monitor equipment and evaluate risk. An inspection program that is risk based, calibration checks, infra-red analysis of



electrical equipment, vibration monitoring, relief valve inspection, a risk based piping inspection program, Weibull analysis of failures, effective management of change processes, a comprehensive lubrication program, an FMEA (Failure Mode and Effect Analysis) study are industry best practices, a subset of which need to be evaluated and implemented. It is more important to implement some of these processes and do them well than to implement them all and do them badly.

A reliable process is a safe process. They emit less so personnel are less likely to have occupational chemical exposure, and they have fewer sudden shutdowns that force chaotic and rushed procedures that lead to further incidents and injuries.

Properly Maintained Equipment Files Whether a documentation system is electronic or a paper system, the organization needs to be disciplined about establishing and maintaining equipment files that are accurate, complete and kept up to date. Ideally, files should include pertinent information on design, management of change, drawings, product brochures, results of failure analysis and history, and parts identification.

The assumption is sometimes made that the CMMS or ERP system will serve as a repository of parts, equipment repairs and repair history. However, not all pertinent information can be stored in such systems. Additionally when the organization migrates from one system to another (as often happens in mergers and acquisitions for example) strategic decisions are made to save cost by not migrating all the historical information to the new system and important information can be lost.

Segments of the industry are seeing significant personnel turnover. This is only going to get worse in the next several years as baby boomers exit the work force. A system that is based on the historical knowledge of individuals is bound for significant and costly incidents.

Documented Key Maintenance and Operations Processes Most sites have documented operations processes thanks to the OSHA PSM standard. Maintenance procedures on the other hand are not commonplace. A maintenance system needs to be in place that has systematic notification, prioritization, troubleshooting, engineering, planning, scheduling, execution and closure.

- Notification: Failures need to be promptly reported and fully documented. A well documented work request which specifies location of the equipment, equipment number, the specific nature of the failure (not just 'pump does not work'), any initial repair attempts, etc. will go a long way towards helping the maintenance organization diagnose and plan the work.
- Risk-Based Prioritization: Each work request needs to be assigned an appropriate priority that takes into account safety or environmental emissions implications, criticality or impact on production capacity, and whether the equipment is spared and how well the spare is operating. Often this process is informal and based on "who screams loudest." Equipment criticality needs to be formal, documented and established using an agreed-upon taxonomy, and applied across the entire plant. Some plants have been successful using a "committee" approach to assigning prioritization. If the priority assigned is "emergency" or "schedule break-in" (the highest priority, the appropriate level of management review should be an established hurdle, thereby ensuring that these categories of "expensive" and "unproductive" jobs are limited.
- Root-Cause Failure Analysis: A reason for the failure needs to be determined whenever possible. This allows an appropriate repair plan that improves the MTBR. If the organization only focuses on repairing to the previous state and not engineering out potential problems, the failure frequency will not improve. The failure analysis step should also be based on equipment criticality: more critical equipment being given the most thorough root-cause failure analysis. Improvements identified should be screened for projected cost-effectiveness; including both maintenance cost reduction AND improved process availability.
- Engineering: Based on the troubleshooting activity, engineering may need to get involved to redesign the part. A change in materials of construction, process operating conditions, start up procedures, etc. may be warranted. The appropriate management of change processes have to be followed.

- Planning: (My copy was “BLANK” here. So here are some comments.) Planned work is by far more efficient than unplanned work, often by an overall cost factor of 3-4:1. Therefore if work is to be approved on an unplanned basis, the appropriate level of management approval must be established. A well planned job will address safety, process clearing and scheduling, parts availability, tools and mobile equipment, crafts required, housekeeping and turn-over. The storehouse plays an important role, ensuring that needed parts are logically bundled for individual jobs.
- Scheduling: This is determined by the priority of the repair, coordination with other crafts, coordination with other repairs in the same section of the process, turnarounds, shut downs, etc.
- Execution: There is an opportunity to feedback any problems encountered during execution so that improvements can be made in the process; were all parts available, did preceding crafts finish their part of the repair prior to other crafts showing up so there was no waiting, were there any safety issues, etc.
- Closure: (What did you have in mind here?) Proper turnover to operations must be done including not just proper safety and housekeeping practices but also appropriate management of change practices if there has been a design change. Any lessons or learnings from the job are an opportunity to upgrade the overall process.

Long-Term Equipment Reliability/Maintenance Planning and Condition Monitoring: Long-term equipment reliability plans need to be established based on equipment criticality. These plans define preventative and predictive maintenance tasks and turnaround work, leading to long-term (10-15 years), cost effective management plans that yield predictable maintenance expenditures.

“Bad Actor” Program Management: A process for identifying and tracking “Bad actors” (the equipment whose failures cost the most lost production) needs to be in place as part of the metrics review process. Additionally a system for tracking all business losses is desirable. These losses may or may not be equipment related. For example, they may involve suppliers. This data should be tracked, failures analyzed and engineering or process solutions identified and implemented. Progress in addressing bad actors should be reviewed and stewarded at appropriate management levels, regularly.

Fixed-Equipment and Piping Inspection Programs: Best in class operations have a stewardable inspection program established aimed at early detection. To make the most efficient use of resources, a risk based approach is recommended with a focus for example on bends, stress points, specification change points, etc.

Turnaround Planning and Development: Larger facilities may have a turnaround process. Those that do not certainly have shutdowns for major work, for example at product grade transitions. The turnaround discussion here, refers to both. Turnaround preparation should include well defined overall objectives (for example: Safety, T/A interval, etc.), adequate resourced teams, clear development and adhered to milestone calendar, well defined risk-based work selection and scope system, controls on late additions, project integration management, robust estimating and scheduling tools, alignment of contractor teams.

Equipment Operating Envelopes: Operating procedures and operator round sheets should define limits of equipment operations in a process unit that are monitored and corrective actions to be taken when equipment is operated beyond its limits. The PSM standard requires this from a safety perspective. A fresh look has to be taken from a reliability perspective and the limits here would be undoubtedly less than the safety limits. This would thereby minimize the potential for accelerated equipment degradation and reduce the probability of unplanned incidents.

Training. To run a safe and effective organization, all employees must be properly trained to execute their assignments. Again, as a result of the OSHA PSM standard, most plants generally have a process for operator training. In most cases, this formalized program does not extend to the rest of the organization. Engineers are on their own for their professional development and today's lean organization means that often they do not have the right mentors to technically develop them along the way. Maintenance technicians typically have no formalized ongoing training. Typically maintenance is outsourced. It is thus up to that contractor to maintain skill levels and certifications. However, narrow margins give the contracting company little incentive to have a very rigorous training program.

In some countries such as Germany, there are well established apprentice programs for incoming technicians that are very comprehensive.

Incident reporting, Investigation and corrective action. Incidents that result in or could have resulted in a reliability event need to be investigated and corrective action taken. The purpose of incident investigation is prevention. There are many tools available for this including traditional six sigma tools and other licensed investigation methodologies. The important point here is these techniques should lead to a clear root cause. Knowing a root cause, one or two recommendations can then be made to prevent further occurrences. Most organizations become overwhelmed with recommendations from various investigations, particularly from safety events and safety hazard analysis. It is helpful if the site can minimize the number of recommendations generated from each event to a critical one or two. A management risk matrix can be effectively applied to ensure that recommendations which are approved yield a desired and meaningful reduction in risk at an acceptable cost. A priority should be

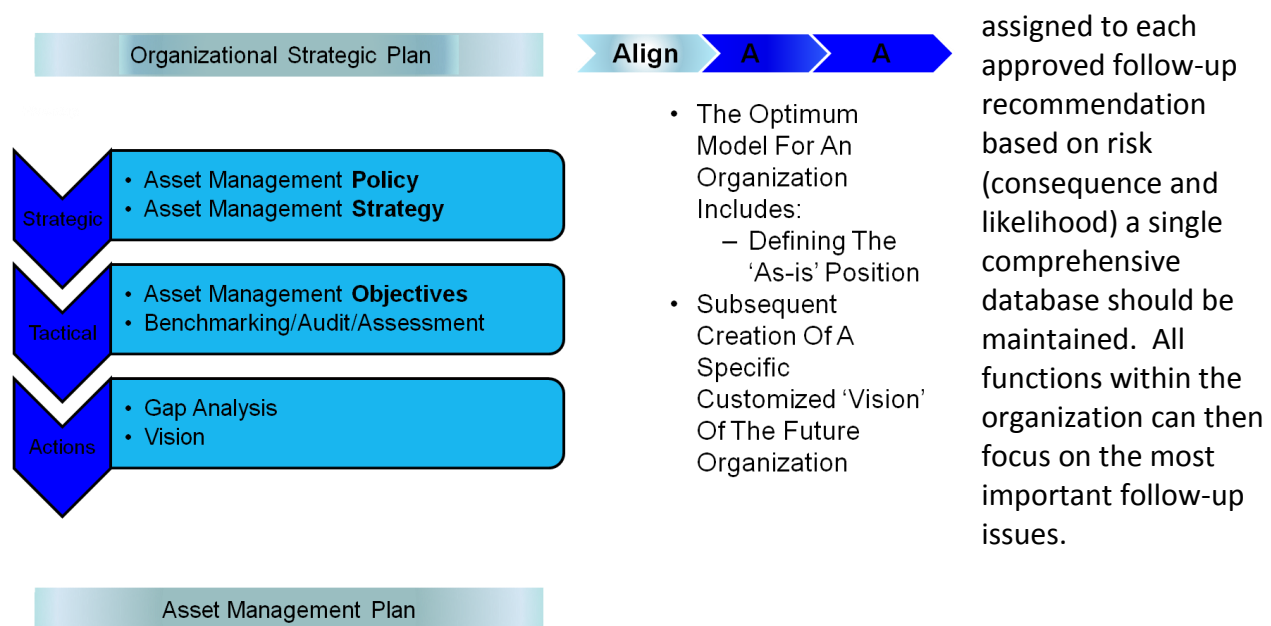


Figure 4 Strategic Plan

III. Maintenance Improvement Sustainability Elements

Goals need to be set that align with the vision. Appropriate metrics that allow tracking of performance, rate of improvement, and the strategic review of those metrics has to be institutionalized. Within each organization and at each level within that organization, a handful of measures within the control of that individual or function have to be defined. This keeps the organization from being overwhelmed with a lot of data. Measurements such as pump mean-time between repairs, tracking monthly or quarterly progress of preventative maintenance or inspection programs, planned v. "break-in" work, etc. are traditional and effective KPIs. But it is also important to establish documented taxonomy for these KPIs, and to establish a regular schedule for senior management review of progress. These meetings can also be used

effectively by management to track and evaluate the rate of progress in a given area, and subsequently adjust resources as needed.

A set of roles and responsibilities for each department or level with target goals for metrics works well for periodic performance reviews. A process for recognizing and rewarding the right behaviors and results reinforces the key values of the leadership.

Effective IT systems are instrumental in achieving sustained maintenance improvements. Well maintained databases with macros to generate required metrics with minimal human input or data manipulation are very desirable. A good Contract Maintenance Management System (CMMS) is also a requirement. Some CMMS applications include:

- Planning (Quaker MOP UP® /Turner® / Maximo®) Unit rate built-up work plan
- Scheduling (Primavera® / Quaker MOP UP®)
- Execution (In-house SAP® /Tiger® / Quaker MOP UP®)

Since no single software is able to meet all maintenance and reliability needs, invariably, several tools are needed and so integration of the tool set is important. One may have SAP® for financial reporting, Primavera® for scheduling, Meridium® for asset performance tracking, etc. The degree of integration of these systems varies as a function of company, site, processes and legacy systems. Companies tend to use the same or similar processes and management systems infrastructure to manage routine maintenance, turnarounds, projects and contracts.

In terms of supplier management, for both materials and maintenance craft resources, we have found that site level Maintenance & Operations MUST be involved in the contracting / bid process to ensure accuracy and consistency. Although the 'right' CMMS system can significantly help in meeting maintenance and reliability objectives it must be emphasized that a CMMS system alone will not improve performance. IT systems will only support the changes in culture, attitudes, process and competencies.

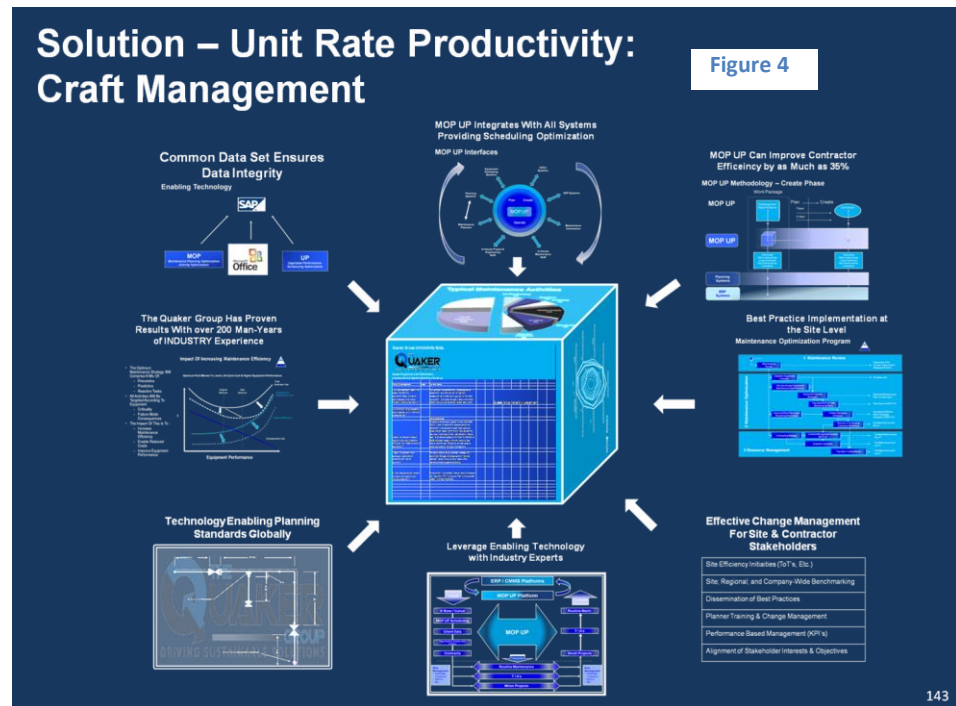
Contractors: Site contractor management and performance are critical to the overall performance in all HSE, business and operating metrics. It is imperative that contractor performance and objectives are aligned with the site overall business and operating objectives. This is becoming more critical and site and corporate resourcing strategies move increasingly toward outsourcing models as a strategic tool to manage and optimize organizational efficiencies. Historically, site level routine maintenance contracting formats have been lump sum turnkey; where the contractor is given discreet projects to implement on a stand-alone basis. This has led to competing stakeholder objectives as flat fee lump sum contracts incent a contractor to maximize contractor revenue and margin for each job. The trend has been toward integration of contractor resources with company resources, planning, processes and

management systems. These competing stakeholder objectives have led to inefficiencies for both contractor and site company maintenance performance. The Quaker Maintenance Optimization Planning and Upgrade Program (MOP UP) Contractor Management System involves a site unit rate contract creation

and management process that utilizes proprietary craft activity factors to plan and measure maintenance performance. This MOP UP program provides for a standardized site, regional and corporate level bid and contract management process. Included in the unit rate contract is a memorandum of understanding whereby the contractor is incented to outperform the benchmarked work package, but to complete the work faster, more safely and with less material cost. We have found this approach has led: (1) to maintenance efficiency improvements of up to a 30% increase in time-on-tools; (2) significant reductions in safety incidents; (3) better alignment between contractor and company business and operating processes; and (4) a common platform to align contractor and company longer term objectives in this and tangential functional areas.

The success of our program is a direct result of our proprietary unit rate activity database that has been developed over many years, specifically for the process and extraction industries. These credible first principal activity factors have been the key factors in transparent contractor pricing with “Open Book” negotiated margins and performance incentives. Implicit in contractor performance metrics are explicit milestones for improvement, e.g., safety, time on tools, planning accuracy, scheduling effectiveness, etc. The Quaker MOP UP® enables plan versus actual KPI’s linked with legacy systems for KPI management. These management systems have driven significant maintenance efficiency improvements in a sustainable manner.

Conclusion An effective maintenance process successfully integrates safety, reliability improvement, process simplification and improvement, and contractor management in a





continuous improvement cycle. It right sizes existing best practices for its culture, size and resource availability and focuses on doing those very well. Vital information is well documented and readily available and leadership takes a keen interest in reviewing performance and setting goals.



Authors

Dr. Charles Becht IV is the President of Becht Engineering and is a recognized authority in pressure vessels, piping, expansion joints, and elevated temperature design. He is a member and former Chairman of the American Society of Mechanical Engineers (ASME) Post Construction Committee, founding and current Chairman of the Subcommittee on Repair and Testing (of pressure equipment), Chairman of the B31.3, Process Piping Code Committee and is a member of seven additional ASME and ASTM codes and standards committees. Dr. Becht received a PhD from Memorial University in Mechanical Engineering, a Master of Science degree from Stanford University in Structural Engineering and his B.S.C.E. from Union College, New York. He is a licensed professional engineer in sixteen states and provinces.

Larry Lester is a Partner in the Energy practice of The Quaker Group based in its worldwide Houston HQ's. He specializes in Maintenance improvement strategies and Organizational Leadership concepts. He is also experienced in the area of Engineering and Project Management. Larry has more than 30 years of experience working as a Engineer, Supervisor, Manager and Maintenance Advisor for ExxonMobil Refining and Chemical facilities. He has a BS in electrical engineering from Prairie View University and an MS electrical engineering from Stanford University.

Chris Tagoe is a Partner in the Energy practice of The Quaker Group based in its worldwide Houston HQ's. He has over 26 years in the chemical industry. He specializes in Operational Excellence concepts within the manufacturing space. His broad experience includes senior leadership positions in manufacturing, engineering, IT and HS&E. He has a BS in Chemical Engineering from The University of Massachusetts (Lowell) and an MS in Chemical Engineering from Northeastern University. He is a registered Professional Engineer in the state of Texas.

Gene Stangel is a Senior Engineering Advisor for Becht Engineering. He has over 35 years of experience in the refining industry with Exxon and Valero Energy as an engineer, operations supervisor, environmental manager, rotating equipment reliability manager, and retired as a maintenance director. He joined Becht Engineering 3 years ago and has provided reliability consulting to a variety of clients in the machinery and management systems areas. Gene has a BS in Civil Engineering from St. Martin's University and an MS in Civil Engineering from Stanford University.