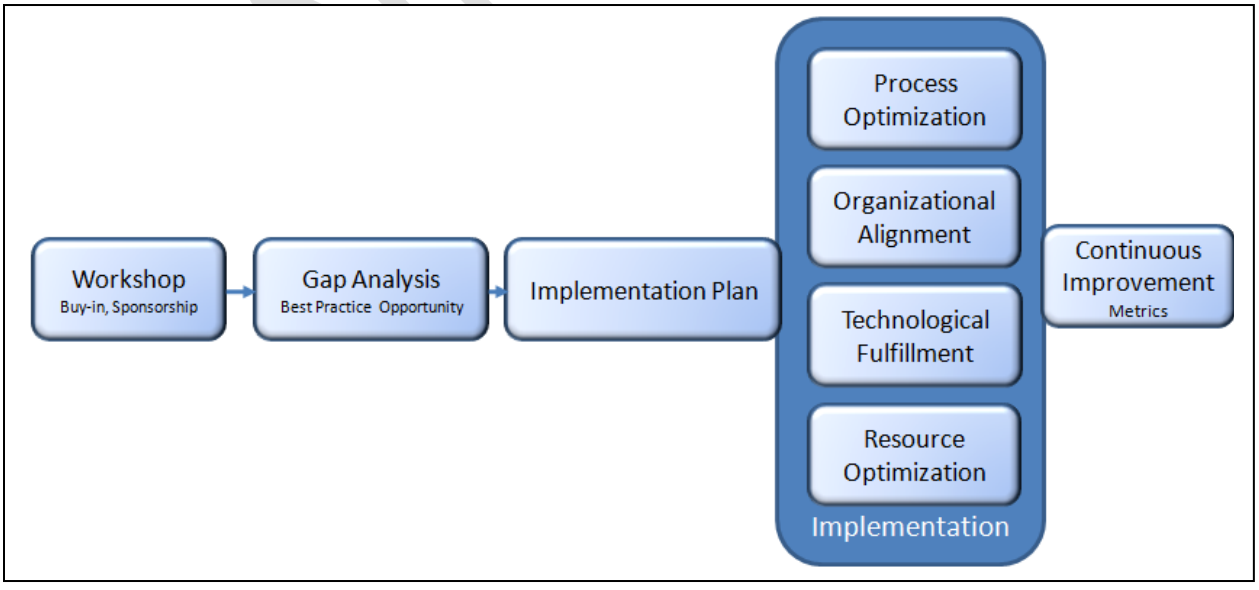
Implementation of the Maintenance Improvement Initiative

There are two aspects to implementation. First is "what" is being implemented and the second is "how" it will be implemented. As discussed below, there are four elements of "what" gets implemented. They are the processes of Reliability Basis, Condition Management, Work Management, and Continuous Improvement. However there are four parts to the process implementation. These are shown in the figure here.



The implementation must include process optimization for the attributes of the organization. Process optimization leverages existing skills and practices with the new process activities. Depending on current practice, there may be a significant shift or a minor shift in the execution of the processes. Organization alignment addresses any required changes in the organization as demanded by the new processes. An example here is the establishment of System Owners or Gatekeepers within the processes. Technological fulfillment is the start up of any technology required by the processes. This may include a new tool for reliability basis management, condition determination or condition management. It may include the work management tool, PaSTA. Resource Optimization is the implementation of those processes that assure high resource utilization and deployment. This includes the execution of best practice planning and scheduling. It includes optimized critical spares management.

If the implementation is deemed a significant change for the organization, care must be given to change management. The figure shows several extra steps to gather buy-in and sponsorship that will drive the change. Other design factors must be included in the implementation plan that directly addresses change management.

If an organization were to look to improve with a Maintenance Improvement Initiative in the four processes of PRO – reliability basis, condition management, work management, and continuous improvement, it would be done in three phases. The first phase drives to the development of an implementation plan by the organization itself that matches resources and appetite for change against the value proposition of succeeding with the change. The second phase is the implementation.

Aside from the change management elements, the implementation plan may dictate how the reliability basis (RBO) will be constructed. Here, three basic ways can be employed. First, a team consisting of mechanical, electrical, I&C, operating, and engineering talents from the "gray beards" of the plant are trained in reliability basis techniques and given the tools to construct the basis on their own. This first way is very time consuming and takes several key individuals out of their normal responsibilities for at least one year. A second way, a combination of PRO Solutions RBO analysts and the "gray beards" work collaboratively to achieve the appropriate basis. This way the RBO is accomplished more time effectively, however these key "gray beards" must be out of their normal responsibilities for a good period of time. A third way is to have the PRO Solutions analysts use industry templates and knowledge together with gathered information from the plant to assemble the RBO with very minimal interaction with the "gray beards". Once the RBO is complete for a system, the plant experts are assembled and the reliability basis is presented to them for their challenge and

approval. This way is the fastest and most effective way to develop the basis. Also the PRO Solutions analysts understand how the basis will connect to all the processes of the plant and they assure those processes will flourish.

In answer to a question raised on the RBO process, the equipment hierarchy contained in the CMMS is used to identify the critical equipment. A failure modes and effects analysis is performed to truly define criticality. PRO Solutions has industry best practice component templates to track from failure modes to prescribed protective tasks and frequencies. These are then reflected against current practice and plant experience.

The implementation plan should assure that the condition management processes are integrated well. The reliability basis of the plant should drive the requirements of the condition management program. Technology Owners and System Owners assure that the data to information to action processes are fully linked to the demands of the reliability basis and the advocacy into the work management, outage management, and life cycle management of the plant.

The implementation plan also contains the work week management (WWM) process elements. Operations and Maintenance have highly active roles in WWM best practice processes. These processes bridge routine work management and outage management. Best practices of short range and long range work planning are employed. The work week management applies the plant's resources to the care regime and condition management of the plant assets. Therefore the metrics that are utilized as part of these work management processes will indicate the health of all processes in the plant.

Finally, the implementation plan contains the continuous improvement processes. This implementation is performed after the other processes are in place and functioning. The reliability basis is a living program. Root Cause Analysis can eliminate recurring problems. The critical metrics will indicate improvements possible in the various processes.

Maintenance Improvement Initiative

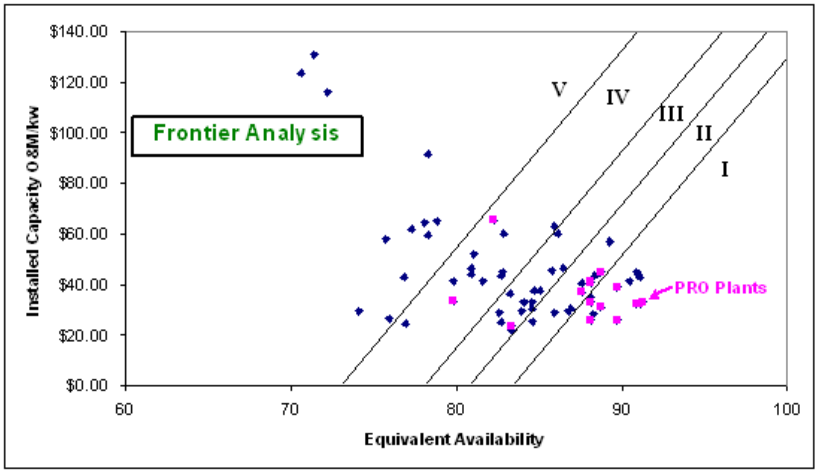
The Maintenance Improvement Initiative is directed at improving reliability while controlling costs. Its scope is not limited to the Maintenance organization at the plants nor restricted to the maintenance processes at the plants. The Initiative engages Operations and Engineering activities. It is better described as a Production Excellence Initiative. The goals and targets of the initiative are intended to drive the performance of the plants to be benchmarked at first quartile for plants of similar design. Review of the goals/targets indicates that the engineered reliability basis of the plant and the major work processes of the plant will deliver the intended results.

The intent of this paper, is to offer some input and experience to the initiative and perhaps sharpen the vision and improve the clarity on the integration of that basis and the work processes that are critical in the success of the initiative. The highest tier objectives of the Initiative is to drive lagging metrics of the plants to higher reliability through improved outage management (scope, duration, and interval) and improved critical equipment management. Together these targets result in a reduction in planned outage time, return to service times, and forced outage time while increasing plant availability. These must be accomplished within the bounds of controlled costs. Hence there will be the recognition that the integrated reliability risk of the plant must be well understood and managed so as to assure that the application of resources mitigate the maximum amount of risk with all investment.

In order to present some input and experience, the benchmark of Figure 1 will be referenced. In Figure 1, O&M cost (non-fuel) per installed KW is plotted against equivalent availability for coal fired plants greater than 500 MW unscrubbed. Study of the attributes of the top quintile plants reveals that most have (what is termed) PRO (Plant Reliability Optimization) processes in place. The population of these plants are shown in Figure 1 as the magenta points.

Figure 1

Frontier Analysis Benchmark



Other targets of the initiative are leading metrics that drive the lagging metrics of the plant. The initiative has identified the targets of achieving over 80% of executed work being planned (Schedule Compliance) and less than 20% break-in work (emergent work). These goals reflect the activity of the routine work management, maintenance processes of the plant. Those targets, with some more aggressive levels, are the aim of each PRO plant identified in Figure 1. Other targets of the Initiative focus on the outages. First are outages finishing on schedule, and second is a successful return from service from those outages. These targets, too, are the aim of each of the PRO plants identified in Figure 1. Best practice in coal fired stations for schedule compliance is 90% while emergent worked is controlled to 12% of labor hours. The most prevalent outage metric that is in place for the PRO plants is "outage readiness". This metric is created some 24 months before the outage and continues through the execution of the outage. Best practice for the outage readiness metric is 98% going into the outage. There is an almost perfect relationship between the outage readiness metric with outage completion dates, budget adherence, and return to service success.

Figure 2 presents the basic PRO process diagram.

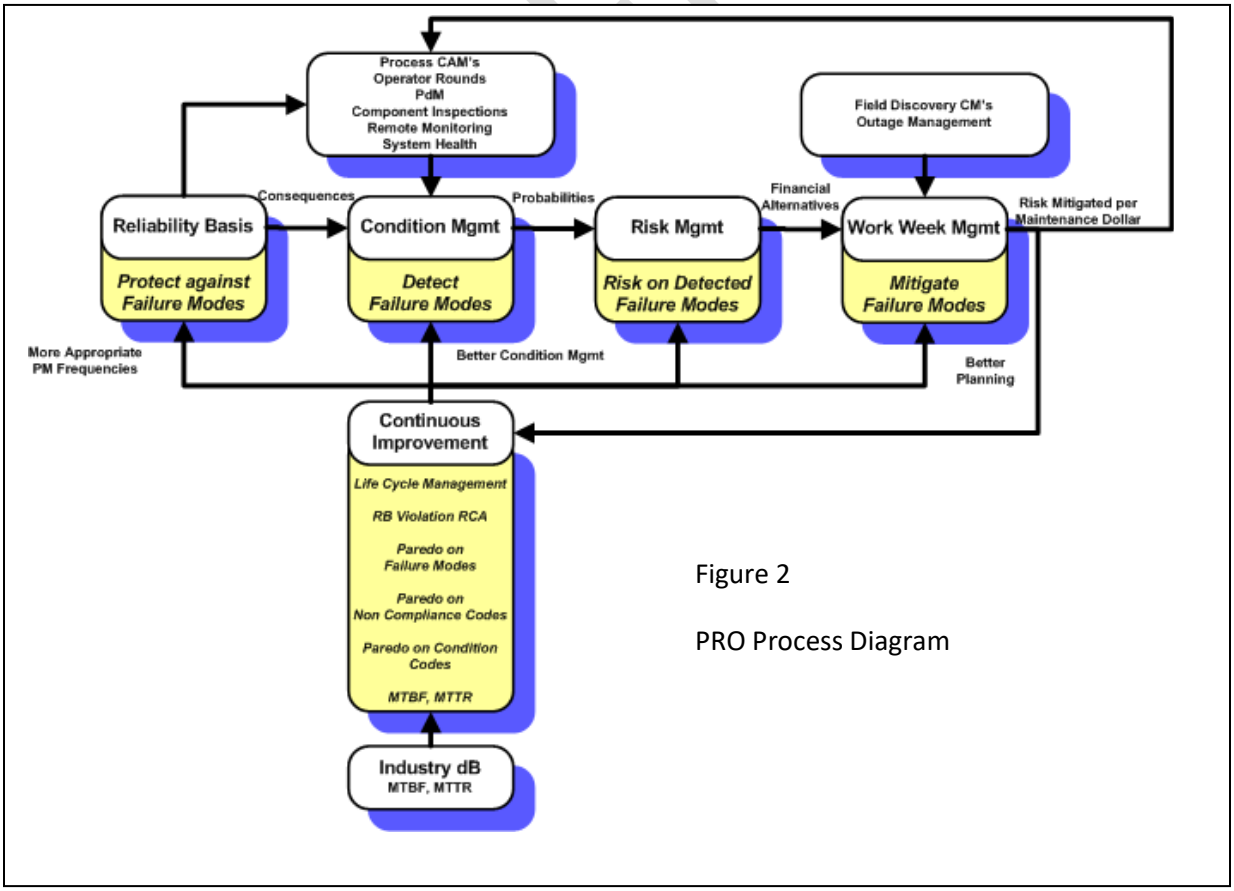


Figure 2

PRO Process Diagram

Inspection of Figure 2 and its elemental processes will reveal the success top plants have in achieving their high performance.

The first elemental process is the reliability basis (Figure 3) of the plant. This engineered basis is the care regime for the critical equipment of the plant. It utilizes RCM analytical process, but streamlines the effort with industry best practices and templates. The FMEA performed in the reliability basis identifies the failure modes active and incipient in the critical components and establishes best practice to protect against those failure modes. This analysis results in clarity on the consequences of those failure modes on the critical equipment and on the plant and corporation.

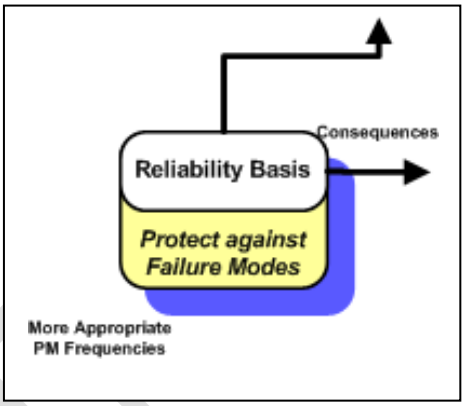


Figure 3 The Reliability Basis

The reliability basis results with two types of PM's to protect the critical equipment. First are the direct PM's performed on the equipment to assure its successful performance such as lubrication tasks. The second are PM's requiring data to be collected. For most Reliability Basis, these PM's are the majority. Therefore the Condition Management Process (Figure 4) of Data to Information to Action becomes critical to the success of the plant. Condition Management ultimately detects the presence of the failure mode and determines the likelihood or probabilities associated with the failure actually occurring.

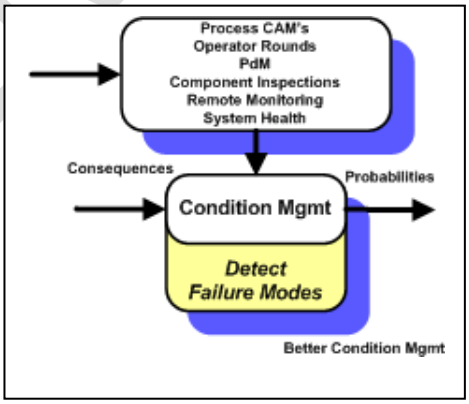


Figure 4 Condition Management

Contained in the Condition Management Program are PM's such as: on-line process Component Analytical Methodologies (CAM's), Operator Rounds, Predictive Maintenance Rounds, Component Inspections, Remote Monitoring expert systems, System Health Management.

Once the conditions of the critical equipment has been determined, knowledge of the active critical component failure modes is known. The consequences of those failure modes is known from the Reliability Basis and the likelihood or probabilities of those failure modes is known from the condition management. Since Risk is consequence times probability, those

organizations that have good Reliability Basis and Condition Management have the prerequisites for employing good Risk Management process (Figure 5).

Risk must be managed to achieve the targets set forth in the Maintenance Improvement Initiative. Each expenditure of resource ought to have an optimized reduction of risk at the plant. Therefore, risk being mitigated from work tasks represent an ultimate way to scope work such as in outages and work week management. Since consequences include MWH lost, risk can be integrated across all critical components to determine anticipated plant availability factors after outage capital and expense investment is made.

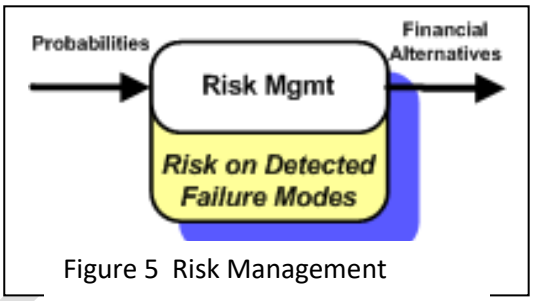


Figure 5 Risk Management

Once condition data has been converted into good information for the plant to use, then actions are recommended usually via the work management system. The work management system is in place to apply the plant's resources to reduce the cumulative risk within the plant allowing operations to optimize production at the plant.

There are competing demands on the resources of the plant. There are the PM's to execute. There are condition directed repairs to execute. There are emergent repair activities to execute. There are capital improvements to be made. The plant has limited resources and must use those resources efficiently to achieve a lot and effectively to maximize risk mitigation. Within work week management (Figure 6), excellent planning and scheduling creates that high efficiency and effectiveness. Numerous process metrics are in place for high performing organizations. One of the key investment opportunities to mitigate risk is the planned outage. An outage must be constructed on fine Project Management principles. Outage preparation, including complete contingency planning, is necessary to achieve full success in the outage. Outage preparation is measured thorough an Outage Readiness metric constructed from status of material, complete planning, all departments and contractors integrated and prepared, etc.

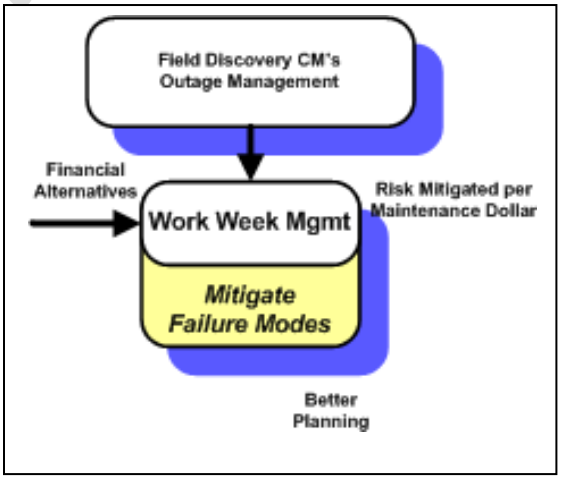


Figure 6 Work Week Management

Work Week Management maintains a proactive culture in the organization when, in fact, the natural state of the organization is reactive – react and repair components after they fail.

The final set of processes contained in the asset management program, PRO, are the Continuous Improvement processes (Figure 7). In order to continue to advance success towards the achievements of the organizational targets, processes must be in place and integrated with the routine operations and maintenance work processes. The experience gained from operating experience must be learned and when appropriate effect change in those O&M processes. The Reliability Basis is a living program and must be managed. Reliability Basis Violations must not be tolerated. Condition Management is an ever learning utilization of expert technologies. Work Week Management is the utilization of plant resources – both labor and material – and learning feedback is necessary to assure resources are used efficiently and effectively. Root cause analysis is performed to manage recurring failure situations, however, the organization must not wait for failures to learn. Metrics must be put in place to create the ability to learn from all of the PRO processes. Key to the metrics is the comprehensive nature exposing the gaps within the PRO processes before any failures take place. These metrics ought to be designed and implemented for the organization as application consistency must be in place in order to learn from other plants and the industry as a whole. The feedback improvement opportunities will improve the Reliability Basis of the plant, the Condition Management of the plant, the Risk Management of the plant, and the Work Week Management planning and scheduling of the plant.

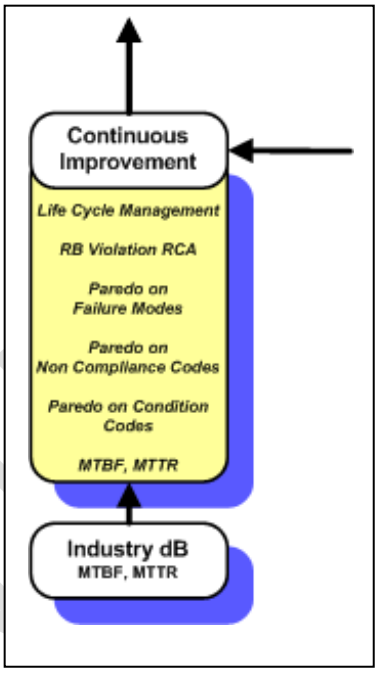


Figure 7 Continuous Improvement

Connection Between PRO Processes and Maintenance Improvement Initiative

1. Outage Optimization – Clearly outage optimization focuses on outage duration (scope, schedule, budget), outage interval, and outage return to service excellence. First, achieving schedule and budget is driven by discipline to the best practice outage process which “outage readiness” is measured from at least 24 months out through the outage. The connection from the initiative is in the processes of PRO work week management. The scope of the outage ought to be driven by solid risk management principles – Critical Component life management, critical component current risk levels and outage

task risk mitigation. The intervals between outages are driven by proactive critical component damage mechanism management. Some plants are moving outage intervals out 3 years with corresponding reductions in EFOR. Not surprisingly, the return to service success factors are closely linked to the outage readiness factors. Detailed planning and scheduling associated with outage preparation and the anticipated contingencies will result in higher return to service success factors. The connection from the initiative is comprehensive. Risk accuracy is driven by the reliability basis work and the condition management processes. Best practice planning and scheduling come from work week management.

2. Critical Spares – the reliability basis analysis includes the critical spare determination. This analysis is a risk factor calculation based on numerous inputs. These many inputs will determine the need for strategic, critical spares, but also modular spares.
3. System Ownership – one of the key elements of PRO is the role of system owner. This person is engaged in and owns the reliability basis for their system. This person owns the conditions within their system per the condition management processes of PRO. The person becomes an advocate for their system within the work week management processes. And finally, the system owner owns the continuous improvement on his system and those processes that lie underneath.
4. The interest in refining the Plant PM Programs with the focus on intervals engages the PM Optimization element of PRO's reliability basis.
5. The initiative intends to audit the processes to assure best practice. The PRO processes encourage auditing on a bi-annual basis. The maintenance excellence matrix with its categories, elements, sub elements, and attributes is a good way to perform this periodic audit.
6. The initiative includes a bill of materials for critical equipment and is developed as the reliability basis is implemented into the CMMS system.
7. Incorporating failure analysis into the continuous improvement is keystone in the PRO continuous improvement process. PRO processes intend to manage those failure modes or damage mechanisms and run them to a zero occurrence. This is measured by MTBF, MTTR, and MTTI.

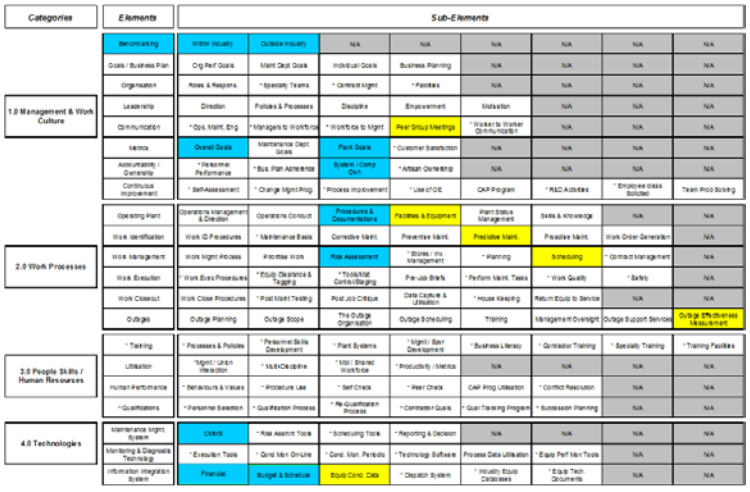


Figure 8 Maintenance Excellence Matrix

8. Incorporating Safety and Environmental data onto the work orders for pre-job briefings is part of the best practice planning and scheduling of work week management.

Recommendation and proposal

1. Initiate an Outage Optimization program setting out the disciplined process of advance outage management including outage duration and outage interval optimization. These contain outage tools, process, and metrics for best practice outage management. The tool PaSTA automates this optimization. We did this at one plant and achieved world records of continuous operation for coal fired plants – over 1000 days of continuous operation. Institute Risk Evaluation and Prioritization (REaP) to assure maximum risk mitigation with the investments being made into the assets during outages. PRO Solutions is qualified to lead outage optimization.
2. Initiate a Reliability Basis program identifying the truly critical equipment of the plant and the associated care regime for that critical equipment. Assure that the failure modes, and active and passive damage mechanisms, are identified and proactively managed. Assure the frequencies of PM's are in accordance with the risk tolerance of the plant. As part of this effort, assure critical spares are strategically identified per the risk tolerance of the corporation. Assure that the bill of materials of those critical equipment are identified when implemented in the CMMS. PRO Solution's tool OPEX is a fully integrated system – an IIoT - achieving all elements of reliability basis, condition management, and risk management, including failure modes management, critical spares, outage task risk mitigation, etc.
3. Institute a SMET program – (Subject Matter Expert Technician) – a streamlined system ownership with the roles of owning the reliability basis, owning critical equipment conditions, advocating system conditions with work management, and owning the continuous improvement of system performance.
4. Institute PRO Solutions' maintenance excellence matrix for periodic audits of process execution and results.
5. Implement PRO Solutions' PaSTA immediately to control the processes of routine work and outage work to assure the effective and efficient utilization of resources and implement the full metrics of PaSTA process measurements. Include in the planning and scheduling effort the safety and environmental data onto the work orders for the supervisors' pre-job briefings.