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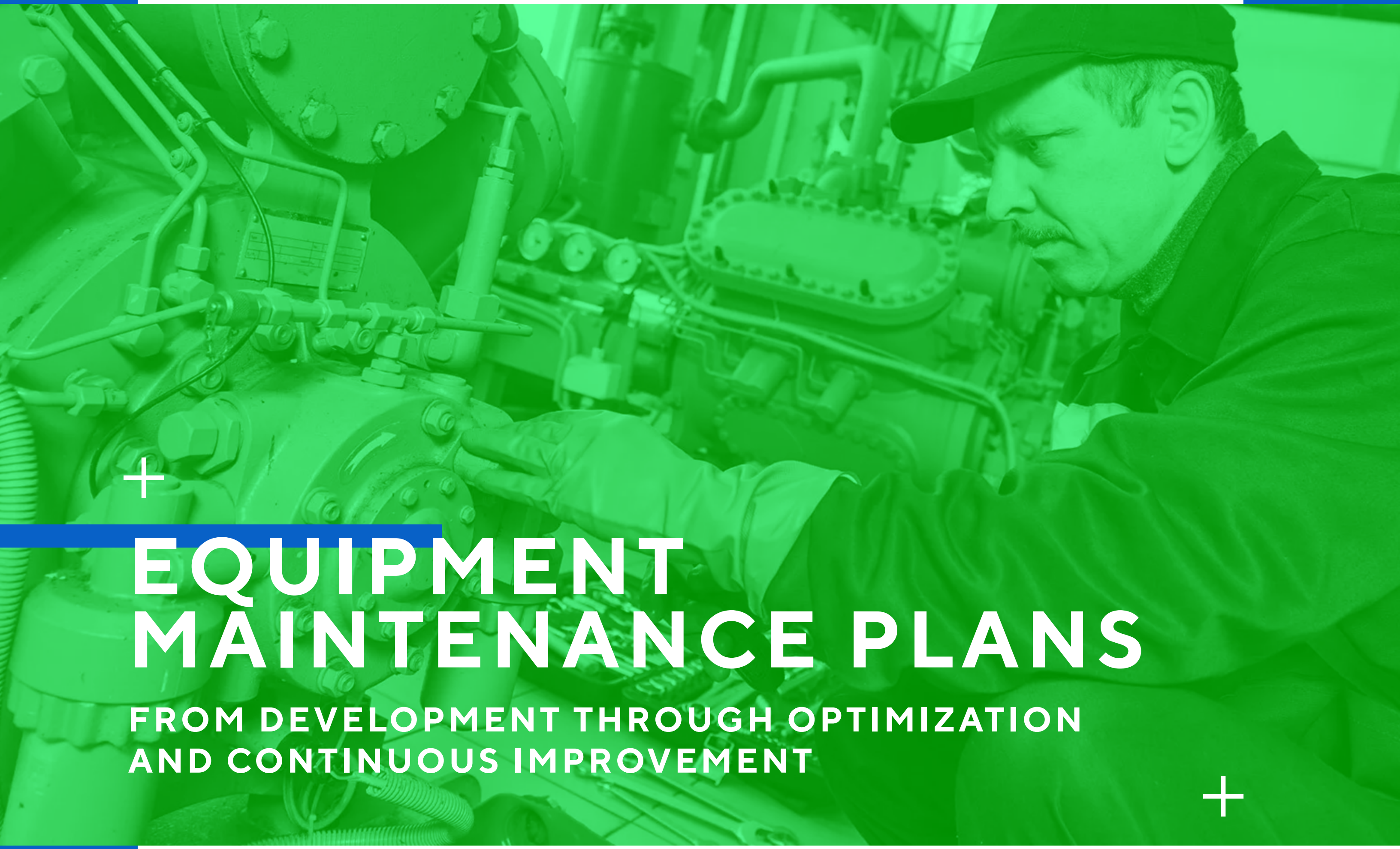

EQUIPMENT MAINTENANCE PLANS

FROM DEVELOPMENT THROUGH OPTIMIZATION AND CONTINUOUS IMPROVEMENT

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WHAT IS AN EQUIPMENT MAINTENANCE PLAN?

The Equipment Maintenance Plan, or EMP, is the document that Maintenance and Reliability Engineers use to communicate the engineered maintenance strategy to Planners and Schedulers who are responsible for developing standard maintenance procedures and scheduling work orders within the Work Execution Management process. Simply stated, an EMP is a list of the Preventive Maintenance (PM) and Predictive Maintenance (PdM) activities that an organization intends to implement on their asset base, the frequency at which they are going to be performed, who will perform them, and how long each task will take. It is an engineered maintenance strategy based on failure modes of the component parts that is intended to reduce intrusive maintenance actions while increasing equipment availability.

An EMP should only include interval-based inspections designed to identify a failure mode, and interval-based activities designed prevent a failure mode or address statutory or regulatory requirements. A complete EMP includes the following elements:

- The failure mode being addressed;
- The PM and PdM activities;
- The frequency of execution for each activity;
- The assigned resource (by title, not by name);
- The required labor hours to complete each task by both labor hours and clock hours; and
- The required equipment downtime duration, if any.

An EMP can be created for a specific piece of equipment, as is commonly done when performing an RCM analysis, or for a general equipment type, such as centrifugal pumps or AC motors. When creating an EMP, it is important to first decide how the EMP will be used and if the strategy will be applicable to other areas or equipment within the overall facility or enterprise.

CLEANING UP EXISTING EQUIPMENT MAINTENANCE PLANS

Before a comprehensive EMP can be developed, any existing EMPs should be cleaned up. This cleanup process provides the organization with several benefits and begins with a Preventive Maintenance Evaluation (PME).

Performing a PME on an existing maintenance strategy allows for the non-value-added tasks to be removed from the PM program and either deleted entirely or reassigned to more appropriate personnel. It also calls out which PM tasks need to be kept and which ones need to be reengineered in terms of wording and formatting to create a more quantitative, repeatable procedure.

A PME can be done one of two ways. A sample PME can be done at the beginning of a reliability improvement initiative to build some momentum around the types of changes possible and start to define the size of the changes that could happen. This is typically performed on 200-300 PM tasks that are deemed to be representative of the entire PM program. The PM tasks should be selected from across 20-25 different equipment types in the plant and from a combination of monthly, quarterly, and annual PM tasks.

Secondly, a full PME can be done. This is typically performed on the entire PM library, towards the middle of a reliability improvement initiative. This is done to calculate precisely how many craft resources will be freed up and how many PM tasks need to be reengineered into the proper format.

The organization does not have to implement the results of the PME right away. The output of the study should follow a staged implementation, as outlined below.

1. **All tasks deemed "Non-Value Added":** These tasks can and should be deleted from the program immediately. This will not be detrimental to the equipment's performance because the tasks, by definition, hold no value. This is an excellent time to begin reengineering the tasks that need to be made more qualitative and repeatable.
2. **All tasks deemed "Non-Value Added: Reassign to Operator Care":** These tasks do not require a skilled maintenance craft person to be successfully completed. These tasks should only be assigned to the individual operator(s) after the proper task procedure has been created and the operator has been task qualified to both the written procedure and the physical procedure. This step gets the operator(s) more intimately involved with the maintenance of the equipment and provides another line of defense against equipment failures.
3. **All tasks deemed "Non-Value Added: Reassign to Lube Route":** Lubrication tasks require a significant amount of training to be performed correctly. Contamination control and sound lubrication fundamentals are broad topics and should be accounted for in the design of the procedure. These tasks, like the operator care tasks, should only be assigned to the individual lube technician after the proper task procedure has been created and the lube technician has been task qualified to both the written procedure and the physical procedure.
4. **All tasks deemed "Reassign to PdM":** Parallel to the PME process, the PdM improvement process should be taking shape (more on that later) and it should be time to relieve the PM program of all tasks that were previously deemed "Reassign to PdM". This should only be performed after the PdM program is up and running, and like all these steps, can be done department by department as the technicians are ready to increase their coverage.

PM Task Action Recommendation	# of Tasks	% of Tasks	Man-Hours Represented
Non-Value Added (Delete)	1,640	8.2%	6,661
Reassign to Operator Care	1,380	6.9%	5,605
Reassign to Lube Route	2,856	14.3%	11,600
Replace with PdM	6,437	32.2%	28,222
Reengineer	5,200	26.0%	26,221
No Modifications Required	2,487	12.4%	8,987
TOTALS	**20,000**	**100%**	**87,296**

Figure 1: Sample Preventive Maintenance Evaluation (PME)

THREE-TIERED APPROACH TO EQUIPMENT MAINTENANCE PLANS

Allied Reliability Group uses a unique three-tiered method to develop EMPs, which ends with the EMP being optimized to achieve maximum benefits.

The final EMP is the marriage of the plans generated from the Asset Health Matrix (Tier 1), RCM activities (Tier 2), and optimization (Tier 3). It is designed to provide long-term asset health assurance by combating the system's inherent and operating context failure modes.

TIER #1 – STANDARDIZE

Allied Reliability Group's Asset Health Matrix (AHM) tool utilizes the most common failure modes in asset components to identify which PdM technologies could apply to the asset. Similarly, a brief description of what Quantitative Preventive Maintenance (QPM) inspections tasks could be performed to identify a given defect or failure mode is also provided. This tool also identifies tasks that could be performed by task-qualified operators, sometimes referred to as "Basic Care".

The AHM tool utilizes asset criticality to determine maintenance strategy. Using benchmark data, each technology is assigned percent coverage models to populate an Asset Versus Technology Matrix. A complete, granular Criticality Analysis is vital. The accuracy of the resulting EMP is directly proportional to the ability of the Criticality Analysis to differentiate one asset from another.

TIER #2 – CUSTOMIZE

Using the asset criticality ranking index, the top 5-20% of the equipment receives a complete Reliability Centered Maintenance (RCM) Analysis. Allied Reliability Group utilizes Targeted RCM, a fully SAE JA1011 compliant RCM Analysis methodology that accomplishes rapid results. The output of the Targeted RCM process is a complete maintenance strategy, from condition monitoring tasks to plans surrounding the run-to-failure components. The Targeted RCM process is very effectively used to analyze both systemic and operating envelope problems that manifest themselves as component-level defects.

TIER #3 – OPTIMIZE

Once the EMP is developed and some failure history is collected, it can then be optimized. EMP optimization is accomplished using powerful statistical software that incorporates the FMECA library developed with Targeted RCM together with the failure data from your plant's assets to produce an optimized maintenance strategy. Changes to the maintenance strategy can then be analyzed to understand the overall impact on the system and decisions made in the best financial interest of the company.

EMP optimization is accomplished through a detailed analysis of the failure rates of the plant equipment. The software model uses Weibull statistics and Monte Carlo Simulation routines to calculate the optimum maintenance strategy, failure mode by failure mode, over the entire life cycle of the asset. The optimum task frequency is calculated by accounting for the cost of downtime, the cost of repair, and the cost of the inspections and the Life Cycle Cost (LCC) of operating and maintaining the machine can be calculated.

The process uses local knowledge, maintenance history, and inspection results to develop models based on RCM principles. Failure effects can be assessed in terms of dollar impact, safety/environmental risk, and operational criticality. These models are used to evaluate, compare, and optimize maintenance and inspection strategies over the entire life cycle of the machine.

As with all computer modeling processes, the quality of the data in the model determines the quality of the results. Fortunately, most organizations have enough data to determine the parameters required for the model. Once built, models can be easily updated and refined as parameters change. To generate results that provide a definitive comparison of alternatives, all parameters in the modeling process need to be brought back to a common unit. Simply put, the only way to demonstrate the benefit of any maintenance policy is to compare alternatives in terms of dollars or reduction in business risk. Sometimes the lowest cost alternative does not provide the required reduction in safety, environmental, or operational risk. In those cases, the goal is to find the lowest cost alternative that will achieve the required reduction.

The reality is that maintenance tasks should be determined or optimized based on many more parameters, including:

- Cost of failure
- Risk of injury or death
- Risk of environmental releases
- Risk of business shutdown
- Cost of corrective maintenance
- Cost of inspections
- Cost of on-condition alarms
- Cost of replacement parts
- Cost of labor
- Cost of delays associated with unpredicted failures
- Equipment failure characteristics
- System redundancies

Many organizations have followed an RCM type approach for their maintenance activities and have generated effective maintenance policies directed towards the identified modes of failure. The next step in the optimization process is to quantify the maintenance strategy decisions and apply real life parameters to an entire system model so that asset life costing and predictions can be performed.

In several cases, organizations have generated what they believed to be their optimum policies, but because they could not substantiate these, they had trouble applying the decisions to real life. Generally, these decisions are made, but the results are not clearly understood or checked. The optimized model should assist with these decisions and allow the user to understand the consequences.

BENEFITS OF AN OPTIMIZED EMP

Utilizing this three-tiered approach to EMP development and optimization creates an environment where EMPs can be developed more rapidly than they previously were. The addition of Weibull Analysis and LCC Analysis ensures that the maintenance strategy is optimized to produce the most favorable results possible. Full application of the optimized EMPs ensures very high levels of system reliability and availability, at the lowest Total Cost of Ownership.

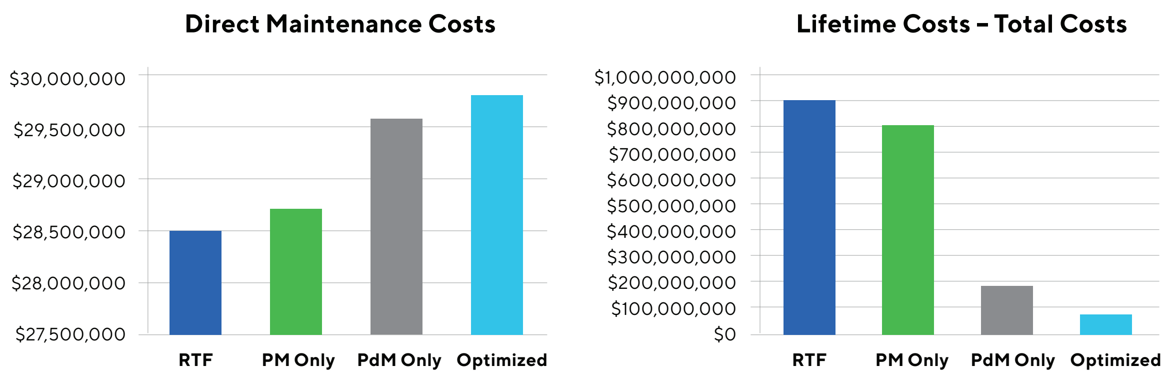

Figure 2: Value of an Optimized EMP

Additionally, the result of the EMP optimization process is a balanced PM/PdM approach, with qualitative, repeatable PMs that target specific failure modes. By removing PMs that are non-value added, time is freed up, and reassigning intrusive PMs to PdM means more availability of equipment and less opportunity for infant mortality. Further, operators will become more involved by reassigning tasks to "Operator Care" and lubrication practices will improve by reassigning to "Lube Route".

Additional Benefits:

- Reduced downtime
- Jobs are consistent regardless of who performs the tasks
- More meaningful work (failure mode based) is generated
- True manpower needs are identified, eliminating guess work
- Relationships between maintenance and production are strengthened
- Craftsmen have more time for proactive work
- Quick returns based on criticality index are achieved

CONTINUOUS IMPROVEMENT: FAILURE REPORTING, ANALYSIS, AND CORRECTIVE ACTION SYSTEM

Once the EMP is developed, optimized, and implemented, continuous improvement to the strategy should take place. This is referred to as a Failure Reporting, Analysis, and Corrective Action System (FRACAS). An easy way to think of FRACAS is as a loop, as shown in Figure 3.

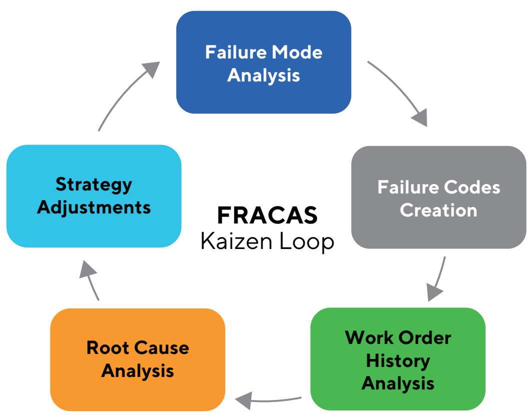

Figure 3: FRACAS Loop

Failure Mode Analysis: This step represents the entire EMP analysis and all the known failure modes that are expected to occur.

Failure Codes Creation: The failure codes in a CMMS should match very closely to, if not exactly, the failure modes listed in the failure modes library.

Work Order History Analysis: One of the roles of the Reliability Engineer is to periodically analyze the failures that have occurred in the plant and compare those failures to the failure modes library. Do the failures that have occurred match up with the failures that were expected? If not, why not? Best Practice is for the Reliability Engineer to perform this analysis monthly.

Root Cause Analysis: When the failures that have occurred do not match the expected failures, there is room for improvement. Methodologies like RCA provide an opportunity to analyze these situations and devise an adjustment to the current strategies.

Strategy Adjustments: Modifications to the EMP, or even to the asset management plan to compensate for operational changes, are warranted after the RCA has been completed.

Failure Modes Analysis: After the cycle has been completed, the failure modes library should be updated. For example:

- New failure modes
- New failure finding tasks
- New PM/PdM tasks
- Different task frequencies

Now the failure modes library is complete and the cycle is ready to begin again. The process never ends, which is why the failure modes library and the EMP are referred to as "living documents". As you learn more about the way the equipment fails, the strategy gets updated and improved.

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Allied Reliability's production and asset management experts are committed to optimizing equipment, processes, and people. Our experts work with you for best outcomes.

Understanding how critical asset failures impact the environment, production, financials, and safety enables us to deliver the right monitoring, analytics, decision making and maintenance plans.

We bring unique asset management content along with best practices, advanced tools, and proven methodologies to help customers move forward in their Digital Transformation journey to deliver enhanced performance.

Contact us for more information about our offerings in:

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- PM Evaluation
- Asset Health Matrix
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