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Is your Predictive Maintenance Program Increasing Equipment Reliability?

Vibration Institute

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With technology and software advancements, Predictive Maintenance (PdM) programs have been greatly enhanced over the last two decades. Many Program Managers and Practitioners desire to push to the next generation of PdM, combining IIoT, Industry 4.0, Artificial Intelligence (AI), Predictive Analytics, and machine learning to their programs. However, with all this tremendous development in technology and added capabilities, most programs are still not achieving the desired results (See Figure 1). According to the annual PdM survey 2022 from Plant Services, 51% of programs are either not effective or needs improvement. Where another 26% is self-judged as just satisfactory.

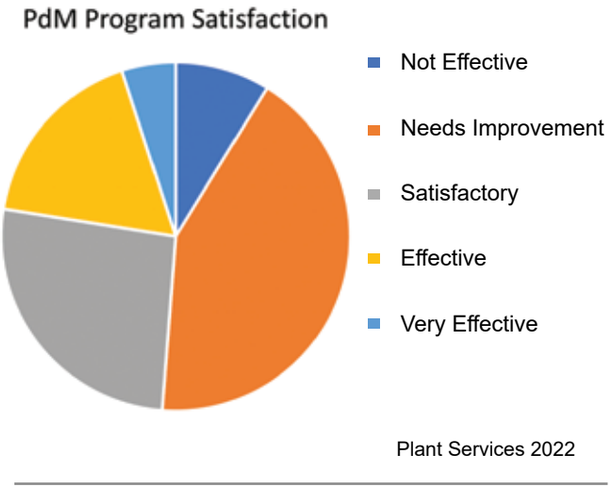


Figure 1. PdM Survey 2022

To better understand how these programs are missing the mark, we need to journey back to the beginning. Predictive Maintenance, as part of a conditioned-based maintenance (CbM) approach, is typically more effective than time-based maintenance activities for many failure modes. Corrective or intrusive actions are performed when warranted based on asset condition, not calendar or hour/run meters. PdM techniques are designed to determine the condition of in-service assets to determine when and what type of corrective action(s) should be performed.

So, if CbM strategies have been time tested and proven, why are programs falling short of expected value or return on the investment. One premise is that Predictive Maintenance is a very good tool to manage failure but not designed to improve overall reliable operations. I often ask, "Is Predictive Maintenance a reliability tool?" and almost 100% of the answer is yes. My reply, PdM is a failure management tool but was never designed to increase reliability. I don't make that statement to be argumentative but merely to open our minds to the possibility of enhancing our existing PdM program design to focus on both, failure management and improved reliability.

Many plant and facility operators are looking to increase uptime and throughput to achieve their business goals. If we define reliability as the "ability of an apparatus, machine, or system to consistently perform its intended or required function or mission, on demand and without degradation or failure", then, absence of failure is required to ensure improvements to uptime and throughput. Further, if PdM doesn't prevent failure but instead effectively manages it, then we may have the gap responsible for missing the expectations. So, while the failures

are predictable and can be effectively managed, the results are not necessarily improved reliability.

In today's environment, terms like Predictive Maintenance, Proactive Maintenance, Condition Monitoring, etc. tend to merge under the overall heading of Reliability Program. Predictive Maintenance Technicians are now called Reliability Techs, PdM Program Managers are now titled Reliability Managers. On the surface, none of this is problematic, however understanding the differences in true reliability will help align our efforts to what drives our facilities and businesses.

Failure management is absolutely a critical need for most and should be continued through your PdM and PM efforts. With early detection of impending failures, planning, scheduling, and replacement parts/material are in place to reduce maintenance time (MTTR) and to avoid unplanned downtime events, thus driving productivity gains while lowering cost.

The Traditional Program Design

(See Figure 2)

- Assets covered in the program are typically not risk or criticality based
- Data Collection Frequency is not adjusted for criticality or failure progression
- Alarm thresholds are assigned globally
- Minimal changes or enhancements are made through the program's life

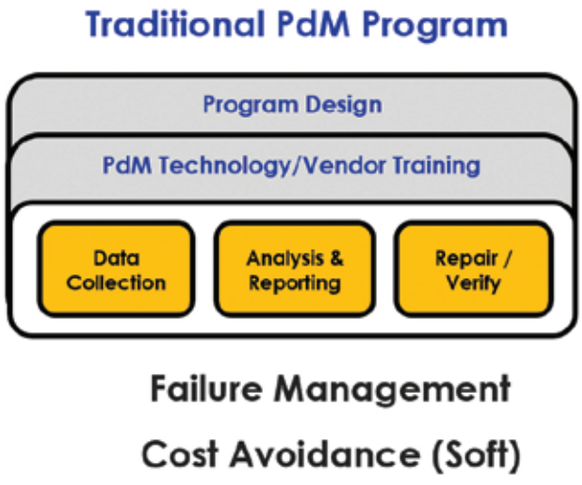


Figure 2. Traditional PdM Program

This program design is considered a "One size fits all" model from a included assets perspective. The program is setup to find failures and we celebrate them when we do. One must question this aspect of the design where finding failure is the desired outcome without linking the reduction or elimination of those same failure to the stated goals of the program.

Most traditional PdM programs focus on the functional tactics: data collection, analysis, and reporting

- Resulting in detecting and managing failures - Good
- Focus on completing tasks on a regular and timely basis.
- What gets less attention is establishing program metrics/ KPIs, ROI, or tracking other long-term successes - Improvement Opportunity

So, if the premise is true that most PdM programs are designed to effectively manage failure but not necessarily improve reliability, then adapting your PdM program design to include a focus on improved reliability is a critical, needed addition. This combined strategy and deployment is called Enhanced PdM (ePdM), whereby the program design adds focus to accomplish failure management while driving failure elimination or reliability gains.

Enhanced Predictive Maintenance

(See Figure 3)

- Combines a properly designed, installed, and managed deployment of predictive technologies with standard processes and statistical analysis to identify and eliminate most reoccurring failures at their root.
- Adds failure trending (FRACAS), bad actor triggers and root cause failure analysis (RCFA), as key components of the PdM program.
- Adds a precision maintenance effort through proper training, techniques, and tools.
- Not focused on only individual asset failures but failure patterns that affect equipment condition across all assets / types.
- Reliability gains are driven from eliminating failures rather than predicting them.

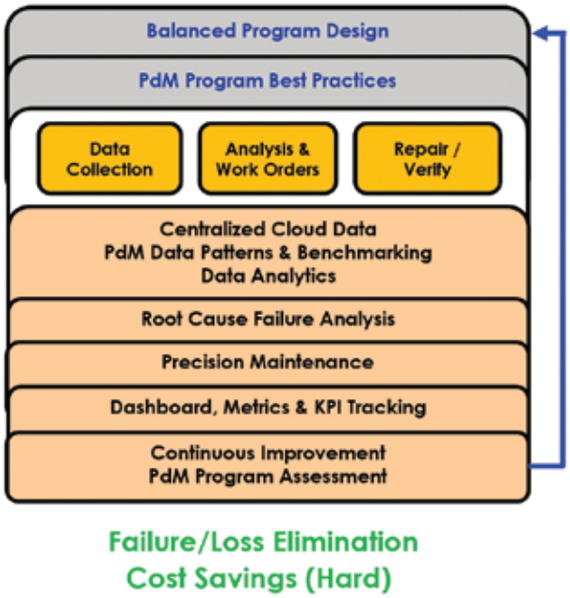


Figure 3. Enhanced PdM Design

The ePdM approach turns the focus on the desired business goal: improving reliability through failure elimination. Predictive technologies become the means to that end by leveraging data analytics and trending. In an ePdM program, success is not only measured by completing PdM tasks and identifying early failures but also achieving key KPIs and returning true reliability gains.

The following are a breakdown of key enhancements / additions in this enhanced design:

Balanced Program Design:

- Implement Asset Criticality Analysis to ensure we invest in the most critical assets and lessens our investment on least critical (not one size fits all)
- Failure Mode risk evaluation and mitigation (FMEA performed on critical assets)
- PdM technology assignment based upon failure mode and ROI
- Frequency decision based upon typical time to failure (P-F)
- Cost Justification is easily achieved with all the above items

Tracking failure data:

- The tracking is highly dependent on how PdM finds are reported and how the corrective action is initiated
- Use the CMMS to facilitate trending or an advanced PdM reporting tool
- Establish work order types (CM, PM, PdM, etc.) to filter how the work is being identified to measure the effectiveness of both PM and PdM activities
- Establish detailed failure codes and close codes in the CMMS and assign codes to each completed CM work order generated from PdM
- Proactively and routinely query the system for trending and to provide root cause analysis of reoccurring patterns. (See Figure 4)

Root Cause Failure Analysis:

- Traditional PdM programs continue to find the same failure repeatedly
- Once a bad actor or reoccurring failure pattern is identified through proactive data analytics, driving to the root cause if key for failure elimination or mitigation
- Formalize definitions for a bad actor compared to a reoccurring failure
- Enhanced programs are focused on using historical pareto analysis and RCFA to drive elimination (See Figure 5)

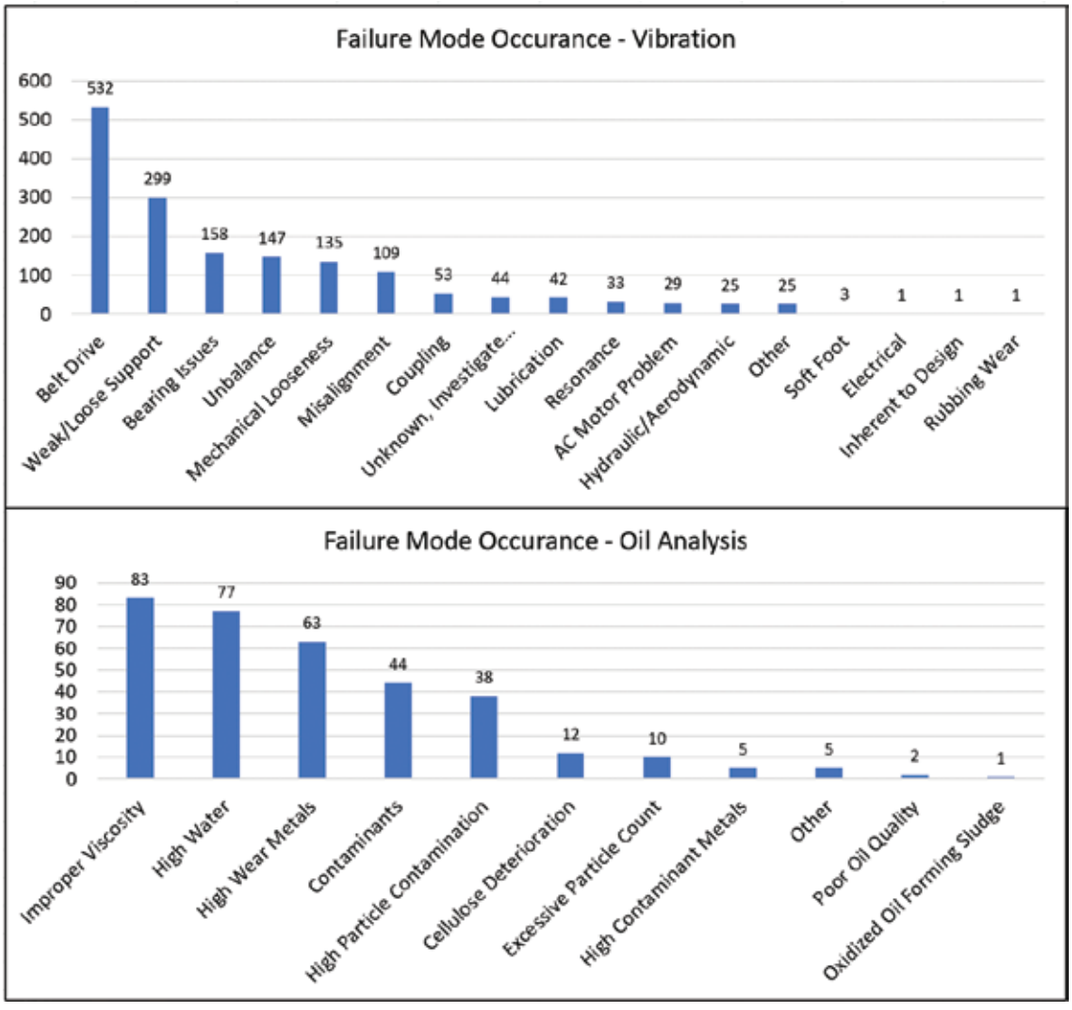


Figure 4. Failure Trending

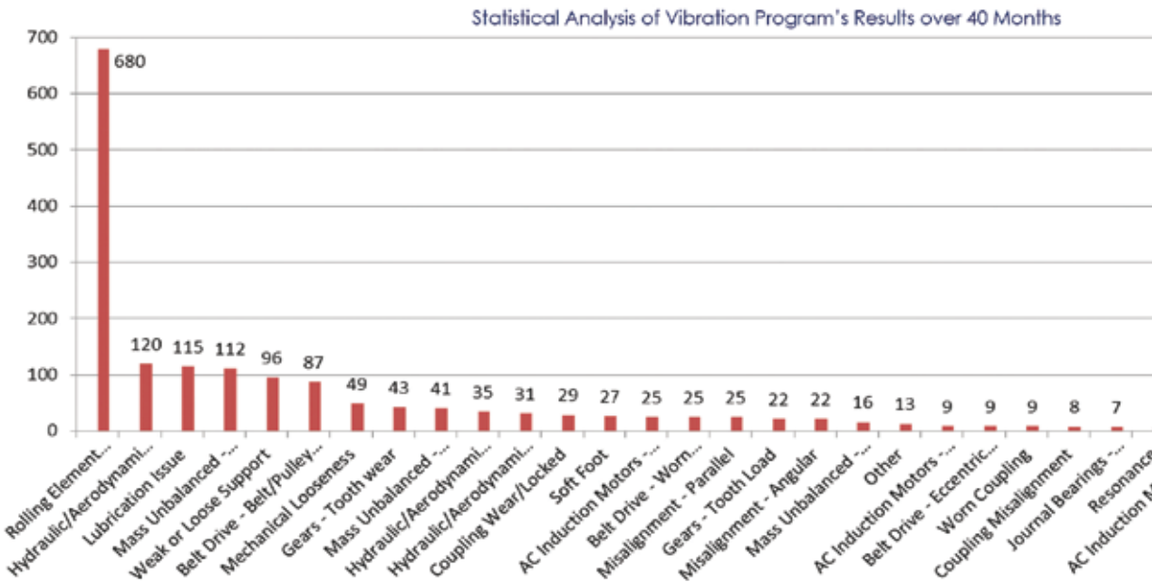


Figure 5. Statistical Analysis of Vibration Program's Results over 40 Months

The example data in Figure 5, shows a vibration program over a 40-month period, where predictive finds were categorized and tracked for approximately 2000 rotating assets. A root cause analysis was performed on the top failure, breaking down the 680 identified failures into four primary categories based upon work order histories and failure timing. (See figure 6)

Addressing the largest segment of the analysis, installation issues, focused precision training on the proper removal and replacement of rolling element bearings. (See Figure 7)

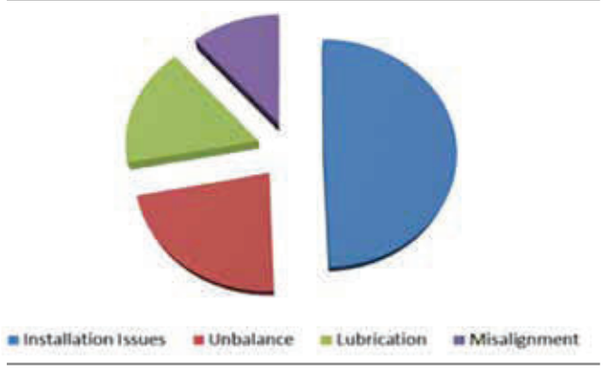


Figure 6. Root Cause Analysis

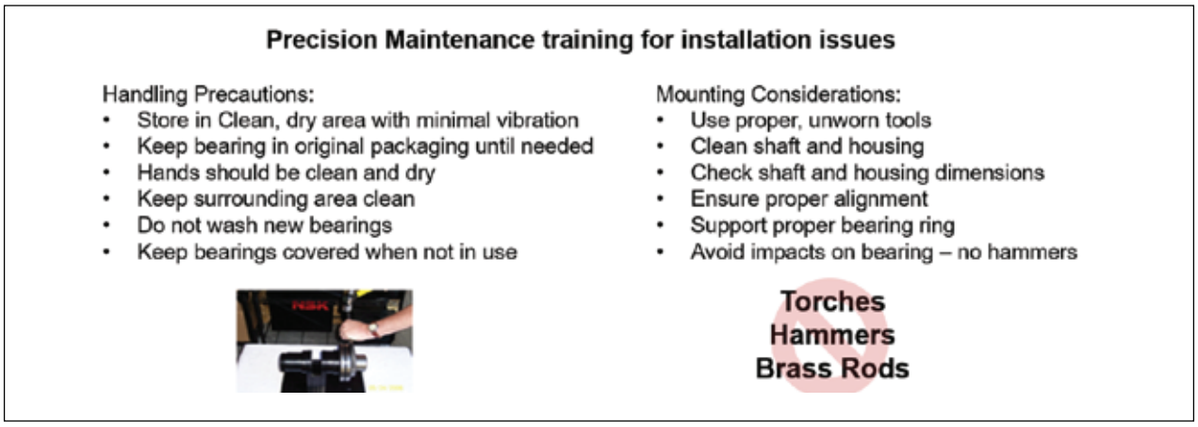


Figure 7. Handling Precautions and Mounting Considerations

Through this training and equipping the maintenance personnel with proper tools and the time to perform the work precisely, year over year improvements were seen. (See Figure 8)

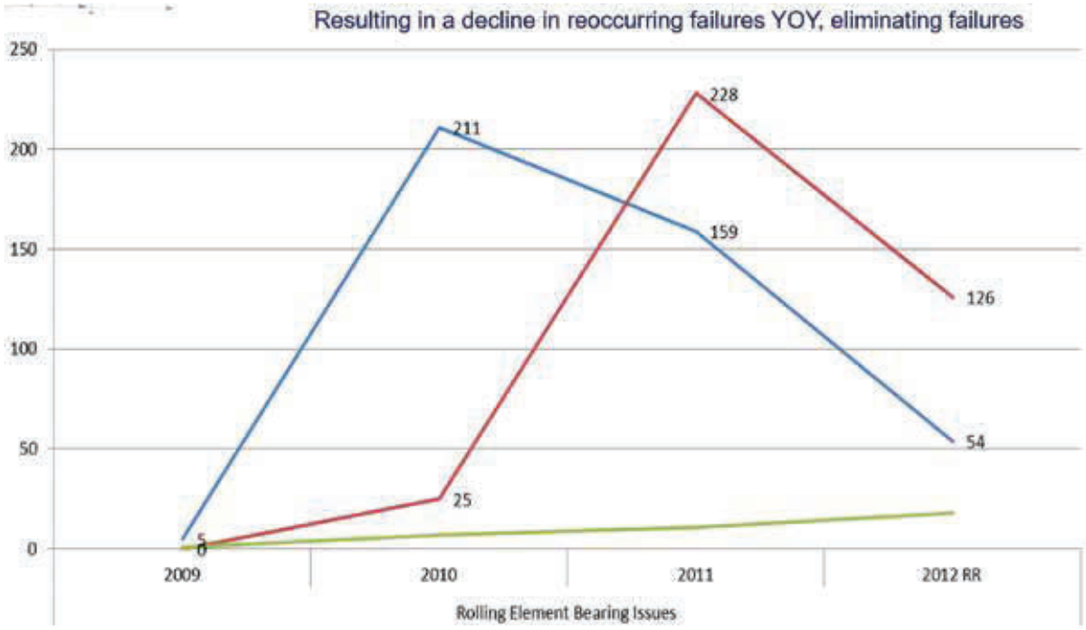
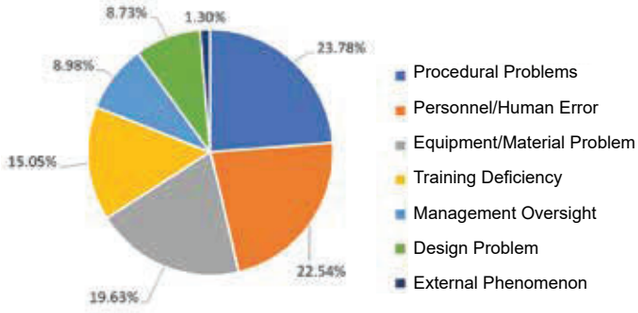


Figure 8. Failure Patterns & Elimination Strategy Trends

Focusing on the failure patterns and an elimination strategy, drives the rate of recurrence down. The trends exhibited in Figure 8 would have not shown improvements year over year if we did not get to the root cause and apply a corrective initiative. In fact, doing nothing, you could statistically predict having similar failure counts each subsequent year. The reduction or elimination of those failures adds true reliability to the process.

When we identify a failure that is found through PdM repeatedly, we need to ask one simple question, "why do we have this same problem over and over?" Many times, the results can be traced back to improper procedures, improper training, or lack of proper tools. On occasion, it can be attributed to human error but those type of errors may not typically exhibit traceable patterns. (See Figure 9). This survey shows approximately two-thirds of issues that go wrong in a facility are related to human deficiencies (Procedural problems. Personnel/human error and training deficiencies). Another 19.6% shows equipment or material problems which would typically be found through PdM activities.

Understanding the lack of proper precision maintenance techniques and its effects on reoccurring failures may help us get to an expedited root cause. Driving the justification to implement precision maintenance and the time to proper apply those techniques can reduce many failure patterns. If we look at the top four issues found in Figure 6, Installation, Balance,



Machinery Lubrication, Survey 2010

Readership survey of "What goes wrong in the factory" based upon the general failure cause categories outlined in the U.S. DEO's root cause analysis standard (DOE-NE-1004-92). **The reply shows that equipment is to blame in less than 20 percent of the occurrences. Nearly 80 percent of what goes wrong can be attributed to people issues. Problems with procedures and training (combined) are responsible for nearly 40 percent.** Personnel/human error constituted a little more that 22 percent of the vote.

Figure 9. General Failure Causes

Alignment, and Lubrication, each can be tremendously impacted by applying a precision approach to those assets and components. Ultimately, we want to effectively drive to the proactive domain illustrated in Figure 10 below.

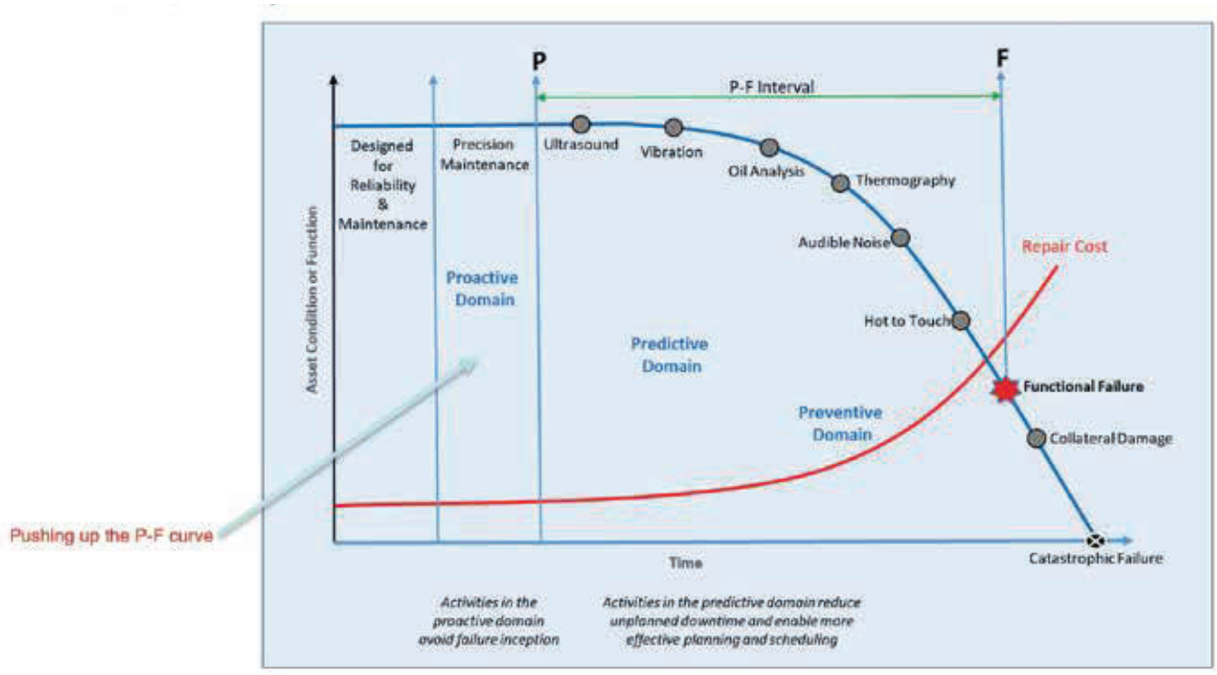


Figure 10. PF Curve

Performance Management - Dashboard, Metrics and KPIs:

- The adage is true here - "You can't manage what you don't measure" Drucker
- PdM goals must be aligned with overall business objects
- Add a focus on improved reliability
- PdM and work history results are the fuel for reoccurring failure pattern tracking
- Program compliance goals are important, however, eliminating failure patterns drives reliable operations

Continuous Improvement

- It is doubtful that any program design hits a perfect mark right out of the gate.
- Be prepared to continuously challenge the design and program outcome to align with the needs of the business
- Perform a routine program assessment every year or so to ensure the program's strength and weaknesses are identified putting corrective actions and improvement initiatives in place (See Figure 11)

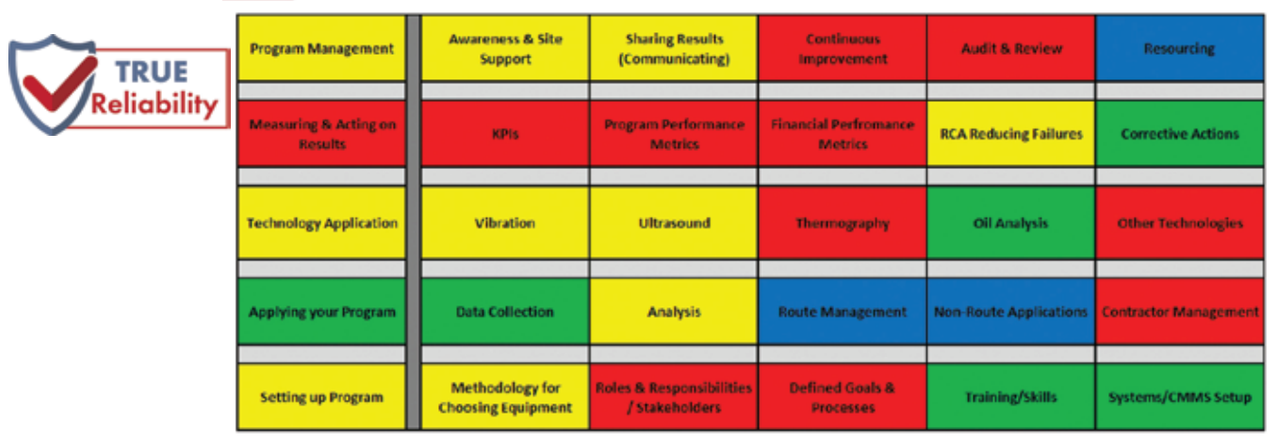


Figure 11. Assessment Results Dashboard

A program that does not focus on the reoccurring patterns, typically never leave the failure management mode, and will limit improvements in overall reliability. By adding this critical enhancement to an existing program will ultimately reduce the number of problems found through predictive maintenance. The reduction of potential "finds" from the program seems counter to the traditional program's goals. Essentially eliminating failures seemingly works the PdM program out of business but delivers added value to the overall operations. However, eliminating failures to zero just won't happen, but adjusting the PdM coverage / frequency may be a result of reducing the number of overall failures year over year. This reduction may be considered a good thing to most and a bad thing to others, but we must push on to add value to the organization. The bottom line is the gap in expectations from the Plant Services PdM survey may be a direct reflection of this mismatch set of priorities.

The benefits of adding thee Enhanced PdM approach to your existing program:

- Creates additional value to the PdM investments
- Focuses on your organizations value stream or business objectives
- Key goals - failure elimination and overall reliability improvements
- Leverage statistical data you already collect and analyze to a failure mode
- Increases planning & maintenance productivity
- Improves quality
- Improves safety
- Increases throughput / reduces downtime / MTBF
- Reduces emergency work
- Reduces PM events
- Reduces troubleshooting time / decreases MTTR

ePdM will also help facilities prepare for new approaches like IIoT, AI, machine learning and predictive analytics by focusing on four key areas; doing the right things for the right reasons (design or optimization of new or existing programs), managing to set standards, processes, and procedures to achieve KPIs and stated goals, delivering high-quality analysis, reporting and statistical trending, identifying reoccurring failure modes and applying RCFA techniques for corrective actions.

Start with your organization's business objective and ensuring all the predictive maintenance efforts have a direct impact on those goals.

1. Assess where your program falls within the maturity matrix (See Figure 12).

2. Developing an initiative or plan to enhance your existing effort to push up the program's maturity.

3. Develop a data driven approach to measuring value that has a direct line of sight to facility's goals.

4. Finally, many facilities have pieces described in the Enhanced PdM approach, but they are typically managed in silos. Incorporate all these individual efforts into a coordinated effort, breaking down the silos and use the predictive analytics from the program to make all initiatives more effective.

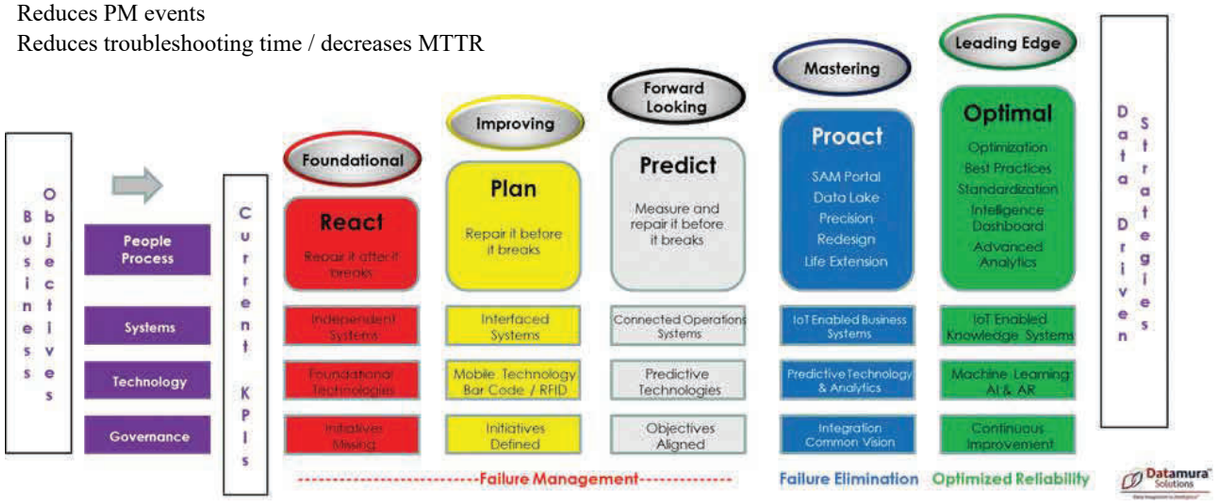


Figure 12 - Asset Performance Management Maturity Framework

feature article

In Summary, Enhanced Predictive Maintenance combines the time proven PdM / condition monitoring approach with Risk Based Asset Performance Management's "best practices" to achieve superior results quickly. Combining traditional PdM program results with advanced trending and analytics, provides a means to move from failure management to failure elimination thus turning cost avoidances into true cost savings. The goal, where possible, is to detect and eliminate failure patterns at their root, reducing the reoccurring failures to create true long-term reliability, maximizing return on investment. In addition, leveraging advances in technology, condition monitoring devices and cloud-based software, will allow for a unique platform to manage and improve operational and asset productivity across the enterprise asset base.

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editor's note

I selected Mr. John Pucillo's paper titled "Is Your Predictive Maintenance Program Increasing Equipment Reliability?" after hearing him present it at a Georgia Chapter Vibration Institute Meeting. I found his topic relevant and insightful for those of us in predictive maintenance. Two of my takeaways from John's paper are as follows:

1) Predictive maintenance if performed well allows us to manage machinery failures in an orderly and scheduled fashion. While this function alone has great value and saves a tremendous amount of money and heartache to a facility, it alone doesn't improve the reliability of the equipment being monitored.

2) To improve the reliability of equipment we must reduce or eliminate equipment failures from happening in the first place.

The path to improving equipment reliability involves first changing the way we think about maintenance. For example, when thru predictive maintenance we successfully identify a defective bearing on a critical machine and have it changed during a scheduled outage – great! Let's now take the next step forward by asking the question why did this bearing fail in the first place? Has it failed in the past? If so when? Are there any similar machines in the plant having similar failures that could represent a repeating pattern? Are their similar machines in the plant having no documented bearing failures? Can we learn something from the absence of failures here? Placing increased emphasis on properly documenting our work and including at least an annual review of each plant area to identify "bad actors" both by total maintenance cost as well as number of failures constitutes another "step forward". Ensuring our maintenance personnel are trained in "precision maintenance" techniques designed to eliminate or at least minimize the most common causes of equipment failure is another clear "step forward".

I hope you enjoyed reading his excellent paper as much as I have.

Barry T. Cease
Technical Editor
Vibrations Magazine