FAILURE ELIMINATION MADE SIMPLE

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Failure Elimination Made Simple

FRACAS, Failure Reporting, Analysis, Corrective Action System

By Ricky Smith CMRP and Bill Keeter CMRP

"Your system is perfectly designed to give you the results that you get."

- W. Edwards Deming PhD

How good is your organization at identifying failures? Sure you see failures when they occur, but can you identify when recurring failures are creating serious equipment reliability. Most companies begin applying RCA or RCFA to "high value failures" which is not wrong but I prefer not to see a failure or eliminate failures to a controllable level.

A process which can be used to control or eliminate failures is Failure Reporting Analysis and Corrective Action System (FRACAS). This is a process by which you identify the reports you require from your CMMS/EAM or a specialized Reliability Software with the objective that these reports should help eliminate, mitigate or control failures. These reports could include cost variance, Mean Time Between Failure, Mean Time Between Repair, dominant failure patterns in your operation, common threads between failures such as "lack of lubrication" due to lubricator not using known industry standards. A recent poll was conducted with 80 large companies and none of these companies were capturing the data required to understand and control equipment failures.

Answer the following questions honestly before you go any further to see if you have any problems with identifying failures and effectively eliminating or mitigating their effects on total process and asset reliability.

1. Can you identify the top 10 assets which had the most losses due to a partial or total functional failure by running a report on your maintenance software?
2. Can you identify the total losses in your organization and separate them into process and asset losses for the past 365 days?
3. Can you identify components with a common thread due to a specific failure pattern, as shown in Illustration 1?

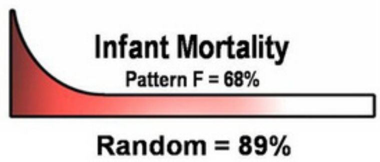


Illustration 1 – Failure Pattern from Nowlan and Heap Study

The cost of unreliability many times goes truly unknown because the causes of unreliability are many. Whether you want to point the finger at maintenance, production (operations), or engineering, each functional area plays a role in unreliability. Here are a few examples of those losses.

• Equipment Breakdown (total functional failure)

o Causes of Equipment Breakdown

No Repeatable Effective Repair, Preventive Maintenance, Lubrication, or Predictive Maintenance Procedure

No one following effective procedures

• Equipment not running to rate (partial functional failure)

o Causes of Equipment not Running to Rate

Operator not having an effective procedure to follow

Operator not trained to operate or troubleshoot equipment

Management thinking this is the best rate the equipment can operate at because of age or condition

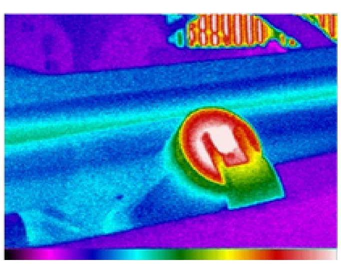
• Off-Quality Product that is identified as “first pass quality” (could be a partial or total functional failure)

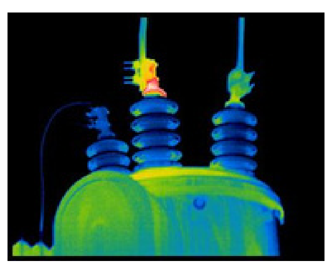
o Causes of Quality Issues

Acceptance by management that “first pass quality” is not a loss because the product can be recycled

• Premature Equipment Breakdown

o Ineffective or no commissioning procedures. We are talking about maintenance replacement of parts or equipment and engineering / contractor that fail prematurely because no one has identified if a defect is present after the equipment has been installed, repaired, serviced, etc. See Illustrations 2 and 3.





Illustrations 2 and 3 – Defect Identified

If you have ever seen equipment break down or not running to rate immediately after a shutdown you know what we are talking about.

A True Story – this probably never happened to you

• On a Thursday afternoon, an industrial facility finds itself looking at a motor in the final stages of failure.

• This motor is beyond simple repair and will cost $90k to completely rebuild.

• The problem is this motor is critical to a portion of the process. Losing this motor will result in losing an entire production run. Loosing this production run has a $400k implication.

• This motor needs to run until Sunday afternoon (just 4 days).

• So the plant does the only thing they can do. They take the chance and run the motor. Hoping it will last until the end of the production cycle.

• It didn’t make it. The plant lost $490k.

• From a maintenance and reliability standpoint there are 4 questions that need to be answered to learn from this situation.

• **It is these questions and the answers to these questions that fuel the continuous improvement process.**

1. **How long have we known about the defect that caused this problem?**

2. **How many opportunities have we had to deal with this issue since we learned about it?**

3. **How much would it have cost us to deal with this immediately upon learning about it?**

4. **What changes to our processes and procedures do we need to make to ensure we never again find ourselves in this position again?**

The Proactive Workflow Model - Eliminating Unreliability is a continuous improvement process much like the Proactive Work Flow Model in Illustration 4. The Proactive Workflow Model illustrates the steps required in order to move from Reactive to a Proactive Maintenance Program.

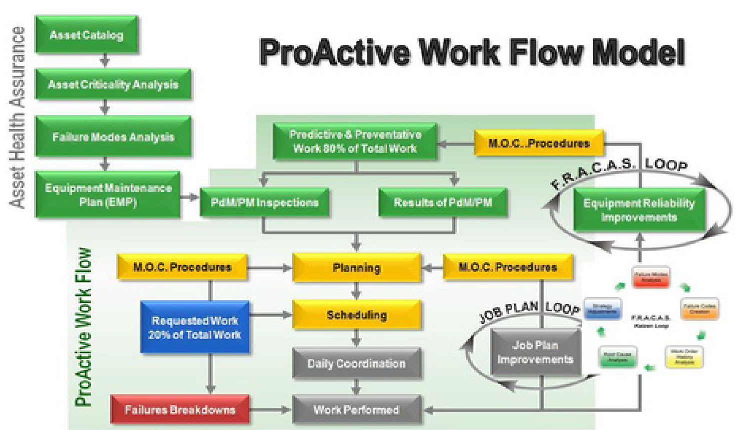


Illustration 4 – Proactive Workflow Model

What the Proactive Work Flow Model really means to your organization – Implementing The Proactive Work Flow Model is key to the eliminating failures. The built-in continuous improvement processes of Job Plan Improvement and the Failure Reporting, Analysis, and Corrective Action System (FRACAS) help ensure that maintainability and reliability are always improving. All of the steps and processes have to be implemented in a well managed and controlled fashion to get full value out of the model.

The foundational elements of Asset Health Assurance are keys because they ensure that all of the organization's assets are covered by a complete and correct Equipment Maintenance Plan (EM). These are requirements (not options) to ensure that you have a sustainable proactive workflow model.

"You cannot have continuous improvement until you have a repeatable, disciplined process"

- Unknown

The objective of the Proactive Work Flow Model is to provide discipline and repeatability to your maintenance process. The inclusion of the FRACAS provides continuous improvement for your maintenance strategies. There are fundamentals items you must have in place to insure you receive the results you expect.

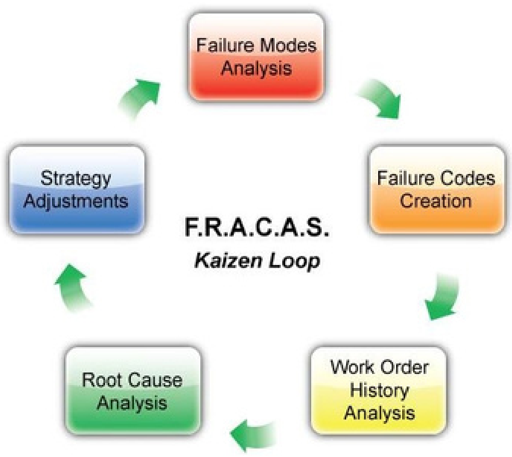


Illustration 6 – FRACAS LOOP

Think of FRACAS this way. As you have failures you use your CMMS/EAMS failure codes to record the part-defect-cause of each failure. Analyzing part-defect-cause on critical assets helps you begin to make serious improvement in your operation's reliability. Looking at the FRACAS Model above (Illustration 6) we begin with Work Order History Analysis and from this analysis we decide whether we need to apply Root Cause Analysis (RCA), Reliability-Centered Maintenance, or Failure Modes and Effect Analysis to eliminate or reduce the failures we discover. From the RCA we determine maintenance strategy adjustments needed to predict or prevent failures. Even the most thorough analysis doesn't uncover every failure mode. Performance monitoring after we make the strategy adjustments may find that new failure modes not covered by your strategy occur. You can now make a new failure code to track the new failure mode so additional failures can be tracked and managed when you review work order history. You can see this is a continuous improvement loop which never ends.

Steps to Implementing an Effective FRACAS

Let's back up a little. The foundational elements of an effective FRACAS are an effective validated equipment hierarchy, criticality analysis, failure modes analysis, and equipment maintenance plans.

FRACAS Checklist:

- ☐ Equipment Hierarchy built and validated so that similar failures on like equipment can be identified across an organization.
- ☐ Criticality Analysis is developed and validated so that equipment criticality is ranked based on Production Throughput, Asset Utilization, Cost, Environment, and Safety.
- ☐ Failure Modes Analysis is completed on all critical equipment using FMA, FMEA, or RCM.
- ☐ Equipment Maintenance Plans are developed on all critical equipment to prevent or predict a failure.

Effective Equipment Hierarchy - Asset Catalog or Equipment Hierarchy must be developed to provide the data required to manage a proactive maintenance program which includes failure reporting or FRACAS (Failure Reporting, Analysis and Corrective Action System).

In order to eliminate failures one needs to ensure this is a successful first step. Illustration 7 displays three areas of a plant with "Part – Bearing" with 27 total failures from different size electric motors ("Part" as identified on CMMS/EAM Codes drop down screen), One type "Defect – Wear" occurred 18 out of 27 failures ("Defect" as identified on CMMS/EAM Codes drop down screen), "Cause" was found to be "Inadequate Lubrication".

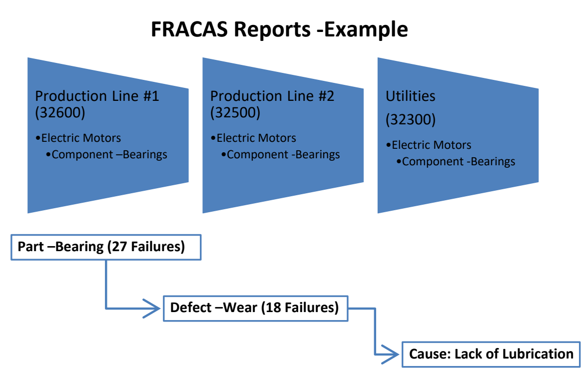


Illustration 7 – Reason for Equipment Hierarchy Validated

After a thorough analysis you will find that most failures come from a small amount of equipment. The question is "which equipment"

Now it is time to perform a Root Cause Failure Analysis on this common thread of failures. ("Cause" as identified on CMMS/EAM Codes drop down screen). Once the hierarchy is established you can find similar failures in one area of an operation or across the total operation.

Validation of the equipment hierarchy is required against the organization's established equipment hierarchy standard. We are looking for "Part" – "Defect" – "Cause". Maintenance personnel may not have the training or ability to determine the "Defect" (Predictive Maintenance Technician could identify Defect) and "Cause" can be typically identified by a maintenance technician, maintenance engineer, reliability engineer, or predictive maintenance technician.

Asset Criticality Analysis – Everyone says they have identified their critical equipment. Equipment criticality, in many cases, could change based on how upset people are about an equipment problem or people are confused about what consequences associate to failure and the probability it will occur if we manage equipment reliability effectively

The purpose Asset Criticality Analysis is to identify which equipment has the most serious potential consequences on business performance, 'if it fails'? Consequences on the business include;

Production Throughput or Equipment / Facility Utilization

Cost due to lost or reduced output

Environmental Issues

Safety Issues

Other

The resulting Equipment Criticality Number is used to prioritize resources performing maintenance work. The Intercept Ranking Model illustrates this process (Illustration 8). On the "Y" axis you see the asset criticality is listed from none to high. I like using a scale of 0-1000 because all assets are not necessarily equal. Using the Intercept line which struck down the middle a planner or scheduler can define which job should be planned or scheduled first or at least get close to the best answer because management has already be involved in determining the most critical asset and the equipment has told you (on the "X" axis) which one has the highest defect severity (in the worst condition).

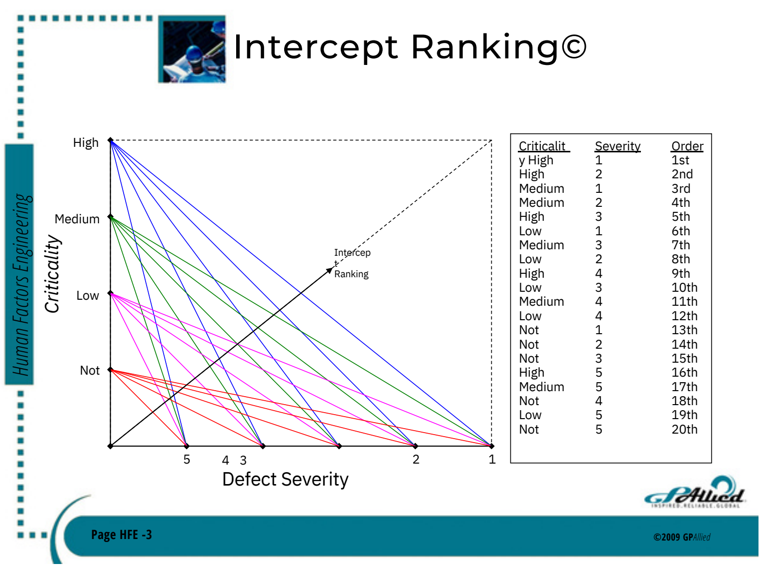
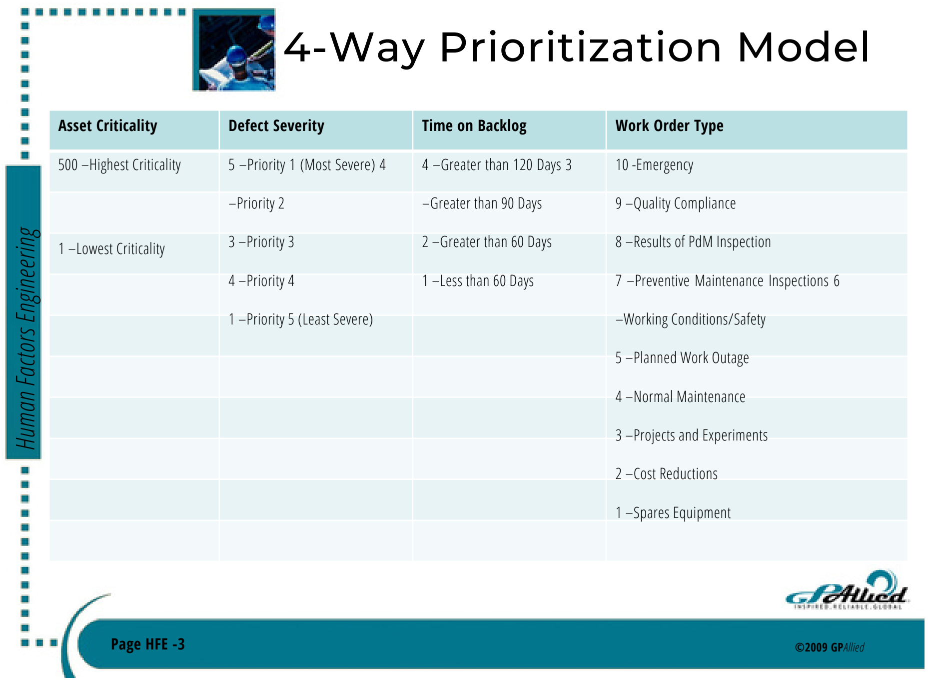


Illustration 8 – Intercept Model

The only other two factors I would add in determining which job to plan or schedule would be based on work order type (PM, CM, CBM, Rebuild, etc) plus time on back. Illustration 9 shows the 4-Way Prioritization Model for planning and scheduling.

Identify what equipment is most likely to negatively impact business performance because it both matters a lot when it fails and it fails too often. The resulting Relative Risk Number is used to identify candidate assets for reliability improvement.

A consistent definition for equipment criticality needs to be adopted and validated in order to ensure the right work is completed at the right time. This is the key to the elimination of failures.



Asset Criticality	Defect Severity	Time on Backlog	Work Order Type
500 –Highest Criticality	5 –Priority 1 (Most Severe) 4	4 –Greater than 120 Days 3	10 -Emergency
	–Priority 2	–Greater than 90 Days	9 –Quality Compliance
1 –Lowest Criticality	3 –Priority 3	2 –Greater than 60 Days	8 –Results of PdM Inspection
	4 –Priority 4	1 –Less than 60 Days	7 –Preventive Maintenance Inspections 6
	1 –Priority 5 (Least Severe)		–Working Conditions/Safety
			5 –Planned Work Outage
			4 –Normal Maintenance
			3 –Projects and Experiments
			2 –Cost Reductions
			1 –Spares Equipment

Illustration 9 – “4 Way Prioritization Model”

Identification of Failure Modes

The goal of most maintenance strategies is to prevent or predict equipment failures. Equipment failures are typically caused by the catastrophic failure of an individual part. These parts develop defects, and those defects when left alone lead to the ultimate catastrophic failure of the part. The defects are in turn caused by “something”. Eliminating that “something” (cause) will eliminate the failure.

Definition of a Failure Mode

“How something fails”

Example of a Failure Mode

“Wear”

- Cause of Wear:

“Inadequate Lubrication”

The primary goal of an effective Preventive (PM) program is to eliminate the cause and prevent the failure from occurring.

The primary goal of a Predictive Maintenance (PdM) or Condition Based Monitoring (CBM) Program is to detect the defects and manage the potential failures before they become catastrophic failures.

In addition, many program tasks are designed to maintain regulatory compliance. Many companies have PM programs however many of the tasks in them do not address specific failure modes.

For example: An electric motor with roller bearings has specific failure modes which can be prevented with lubrication. The failure mode is "wear" caused by "Inadequate Lubrication". The next question may be why you had Inadequate Lubrication. The Inadequate Lubrication could be identified as a result of result of no lubrication standard being established for bearings. In other words someone gives the bearing "x" amount of shots of grease even though no one knows the exact amount to prevent the bearing from failure.

The best way to identify failure modes is to use a facilitated process. Put together a small

team consisting of people knowledgeable about the equipment, train them thoroughly on the concept of part-defect-cause, and go through the basic equipment types in your facility such as centrifugal pumps, piston pumps, gearboxes, motors, etc.. You will find that a relatively small number of failure codes will cover lots of failure modes in your facility. The failure modes developed during this exercise can later become the basis for the failure modes, effects, and criticality analysis that takes place during Reliability-Centered Maintenance (RCM) projects. In this book we are going to focus on failure mode identification as an output of a strong continuous improvement process called FRACAS (Failure Reporting, Analysis and Corrective Action System) See Illustration 10 below.

If in a period of one year the dominant failure mode is "wear" for bearings caused by

Inadequate Lubrication then one can change or develop a standard, provide training and thus eliminate a large amount of failures.

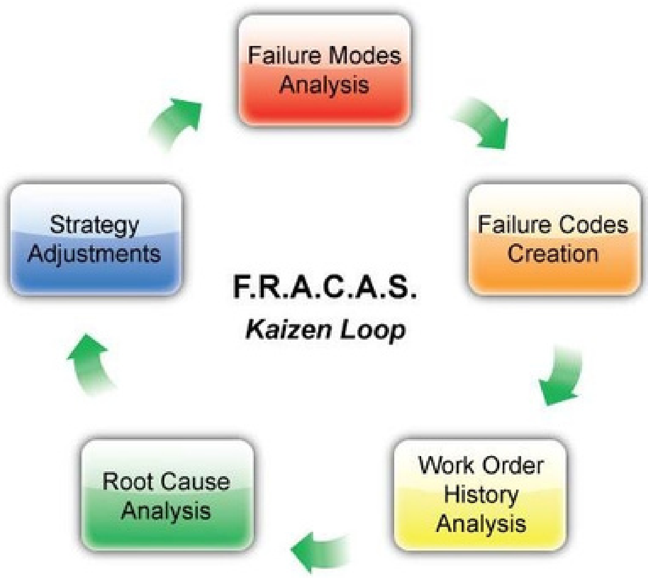


Illustration 10 – FRACAS Model

The problem is most companies do not have the data to identify a major problem on multiple assets (No data in equals no effective failure reports out). It isn't the motor that fails; it fails because of a specific part's failure mode which resulted in catastrophic damage to the motor unless the defect was identified early enough in the failure mode.

Maintenance Strategy

The maintenance strategy is a result from a Failure Modes and Effect Analysis, Reliability Centered Maintenance or as a result of failure data from your CMMS/EAM.

Elimination Strategy: The best way to eradicate this deadly waste is get a better understanding of the true nature of the equipment's failure patterns and adjust the *Maintenance Strategy* to match.
- Andy Page CMRP

So what is a maintenance strategy? Let's break down the two words;

Maintenance is to Maintain or keep in an existing condition, to keep, preserve, protect

Strategy is development of a prescriptive plan toward a specific goal

A Maintenance Strategy is a prescriptive plan to keep, preserve, or protect even though one specific type of maintenance strategy is "run to failure" (RTF). However, RTF is only used based on thorough analysis identifying it as the best solution for specific equipment to optimize reliability at optimal cost. Less invasive is preferred to more invasive. This is one of the fundamental concepts of any well-defined maintenance strategy. Specific maintenance strategies are designed to mitigate the consequences of each failure mode. As a result, maintenance is viewed as a reliability function instead of a repair function. Saying this means Predictive Maintenance or Condition Monitoring is the best solution because it is mainly noninvasive.

Knowing that both systemic problems and operating envelope problems produce the same type of defects, a maintenance strategy that merely attempts to discover the defects and correct them will never be able to reach a proactive state. Technicians will be too busy fixing the symptoms of problems instead of addressing the root cause. To reach a truly proactive state, the root cause of the defects will need to be identified and eliminated. Maintenance strategies that accomplish this are able to achieve a step change in performance and achieve incredible cost savings. Maintenance strategies that do not attempt to address the root cause of defects will continue to see lackluster results and struggle with financial performance.

A Maintenance Strategy involves all elements to aim that prescriptive plan toward a common goal.

Key parts of a maintenance strategy include Preventive and Predictive Maintenance based on a solid Failure Mode Elimination Strategy, Maintenance Planning consisting of repeatable procedures, work scheduled based in equipment criticality, work executed using precision techniques, proper commissioning of equipment when a new part or equipment is installed, and quality control using Predictive Maintenance Technologies to ensure no defects are present after this event occurs. The very last part of your maintenance strategy is FRACAS, (Failure Reporting, Analysis, and Corrective Action System) because it drives the continuous improvement portion of this strategy.

Failure Reporting: Failure reporting can come as in many forms. The key is to have a disciplined plan to review failure reports on a specific time period and develop action to eliminate failure.

Failure Report Examples (all included as part of your *FRACAS Continuous Improvement and Defect Elimination Process*):

1. Asset Health or Percent of Assets with No Identifiable Defect reported by maintenance management to plant and production management on a monthly basis at least. An asset that has an identifiable defect is said to be in a condition RED. An asset that does not have an identifiable defect is said to be in condition GREEN. That is it. It is that simple. There are no other "but ifs", "what if" or "if then". If there is an identifiable defect the asset is in condition RED. If there is no identifiable defect, it is GREEN. The percentage of machines that are in condition GREEN is the Asset Health (as a percentage) for that plant or area.

Defect:	an abnormality in a part which leads to equipment or asset failure if not corrected in time.

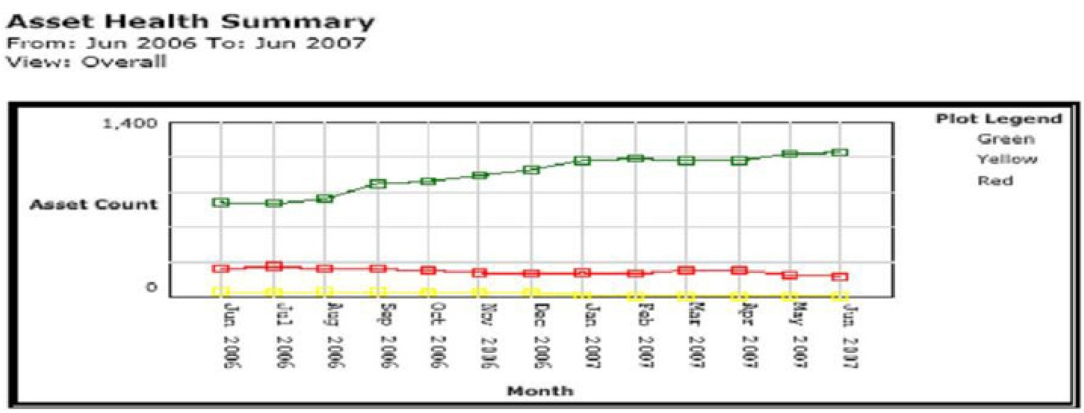


Illustration 11 – Percent of Assets with No Identifiable Defect

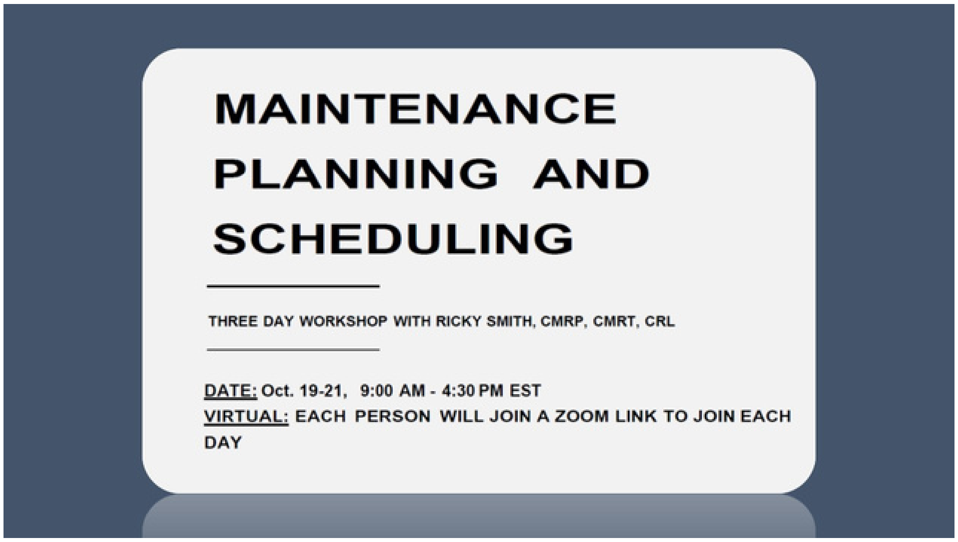
Example: the plant has 1,000 pieces of equipment. Of that number, 750 of them have no identifiable defects. The plant is said to have 75% Asset Health. There is an interesting aspect about Asset Health. Once this change is underway, Asset Health, as a metric, becomes what most maintenance managers and plant managers have wanted for a long time — a leading indicator of maintenance costs and business risk.

2. *Mean Time Between Failures and Mean Time Between Repairs* reported by maintenance or reliability engineers on a monthly basis on the top 5-20% of critical equipment. The report to management should include recommendations to improve both metrics and should be measured and posted on a line graph for all to see.

3. *Cost Variance by area of the plant* reported by maintenance and production supervisor area of responsibility. Cost variance must be reported to maintenance and production management on a monthly basis. The report should not be acceptable without a known cause of the variance and a plan to bring it in compliance.

4. *Most Frequent Part-Defect-Cause Report* is reported monthly by maintenance or reliability engineers. If you do not have maintenance or reliability engineers, you may need to appoint a couple of your best maintenance technicians as "Reliability Engineering" Technicians even if unofficially and train them to be a key player in this failure elimination process. This one report can identify common failure threads within your operation which when resolved can make a quick impact to failure elimination.

There are many more reports however there is not enough room in this article to detail them all. If you have questions send Ricky an email at rsmith@worldclassmaintenance.org or Bill by sending them an email at bkeeter49@gmail.com



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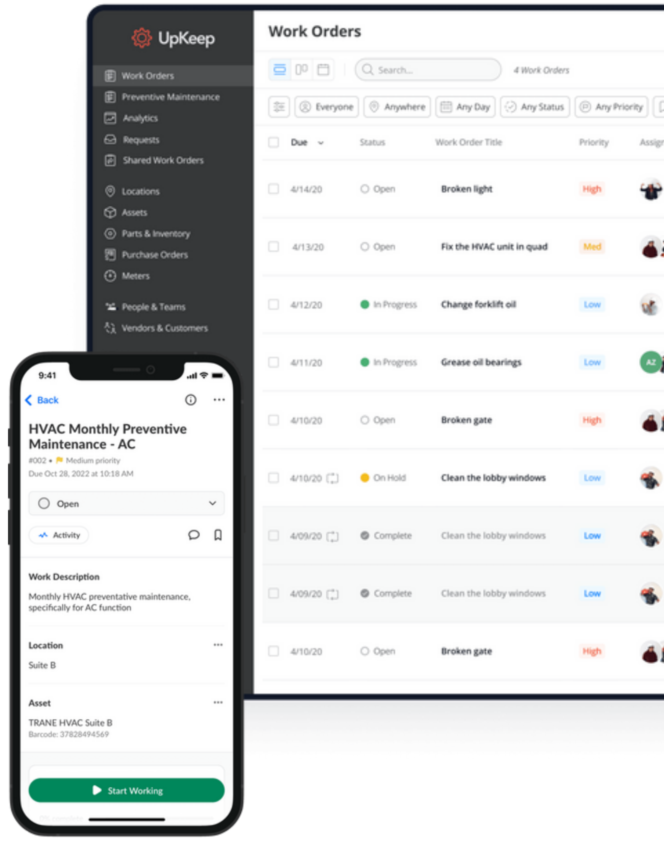

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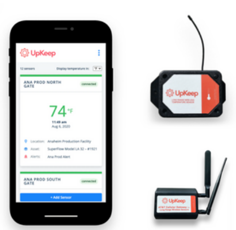
With nearly 340 different machines in our work environment, it's an impossible task to manually assign and track PM's. With UpKeep we can schedule regular maintenance without overlapping tasks with other critical jobs."

★★★★★ **Paul D, Health and Safety Coordinator**



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