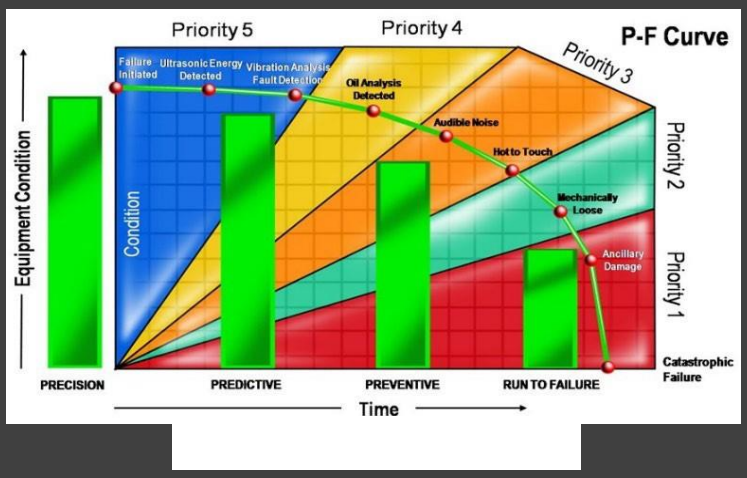
Why People Do Not Understand the P-F Curve

"CMRP Prep Document"



The intent of the P-F Curve **(Figure 1)** is to illustrate how equipment fails and how early detection of a failure provides time to plan and schedule the replacement or restoration of a failing part without interruption to production **(Figure 2)**. Another way to explain this is that the P-F Curve represents the gradual loss of function.

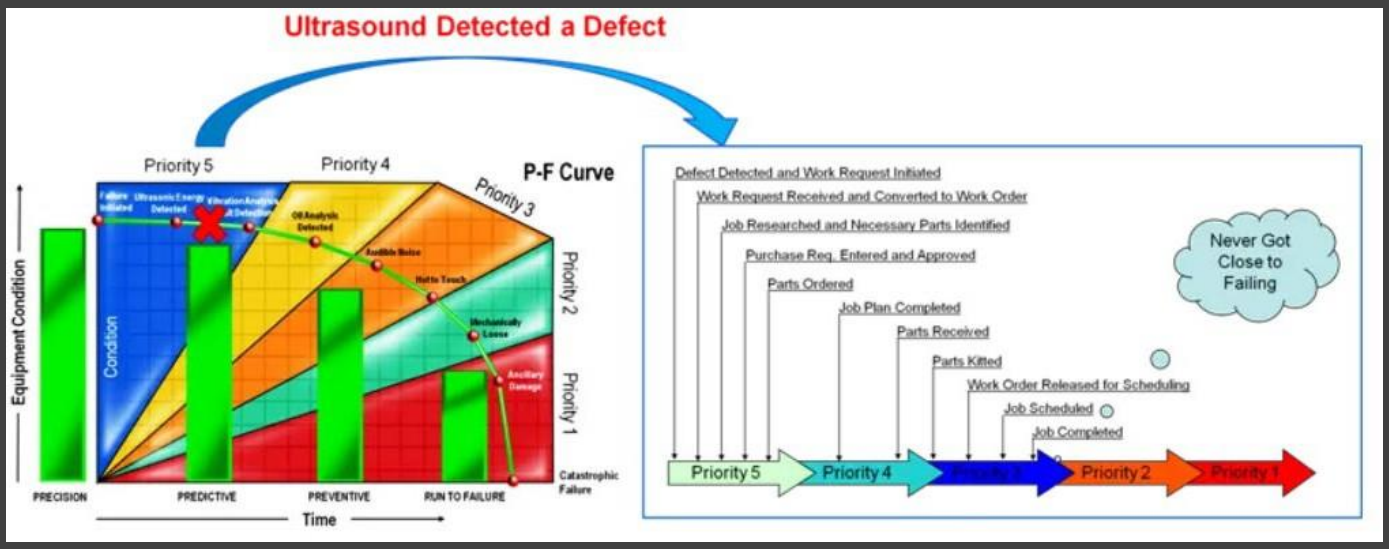


Figure 2: Planning and Scheduling and the PF Curve

The Basics of the P-F Curve (need to know for the CMRP Exam)

When talking about the P-F Curve, we must go back to the *Reliability-Centered Maintenance* report[1] by Nowlan and Heap of United Airlines that was sponsored by the U.S. Department of Defense. This report was approved for public release on December 29, 1978. The Department of Defense's objective in sponsoring the development of this document was for it to serve as a guide for managing reliability on a wide range of equipment.

In the Nowlan and Heap study, they stated the following:

1. There are essentially only four types of tasks in a scheduled maintenance program. Mechanics can be asked to:
    - Inspect an item to detect a potential failure.
    - Rework an item before a maximum permissible age is exceeded.
    - Discard an item before a maximum permissible age is exceeded.
    - Inspect an item to find failures that have already occurred but were not evident to the equipment operating crew.

2. Two of the four maintenance tasks defined in the report were related to the detection of a hidden failure or a potential failure. So, for all four of these types, if there is a gradual loss of function, the P-F Curve is representative of the failure mode. One value then of the P-F Curve is to help equipment owners understand that with the right type of inspection method, the failure mode can be detected very early. Detecting the failure mode early and then acting on that information has tremendous value to the organization. (Hopefully, the intent of the P-F Curve and the value it brings to optimizing equipment reliability is now becoming clearer.)
3. There are a few definitions that will help anyone better understand the P-F Curve and its value to both the maintenance function and equipment reliability. Many maintenance reliability professionals fail to truly understand what the P-F Curve represents because the definitions of the following words are unknown to them. They may have heard of a term or word, but they do not understand its true definition.
    - **A functional failure** is the inability of an item (or the equipment containing it) to meet a specified performance standard. In other words, a functional failure also includes the inability of an item to function at the level of performance that has been specified as satisfactory. This definition thus implies that functional failure is an identifiable and measurable condition, a concept that changes the way we inspect machines.
    - **A potential failure** is an identifiable condition that indicates a functional failure is imminent.

    The ability to identify either a functional or a potential failure thus depends on three factors:

    1. **Clear definitions of the functions** of an item and how they relate to the equipment or operating context in which the item is to be used.
    2. **A clear definition of the conditions that constitute** a functional failure in each case; and
    3. **A clear definition of the conditions** that indicate that a failure is about to occur.

4. Eighty-nine percent of failures are random in nature. This means they can occur anytime; it does not mean they occur without assignable cause. Figure 3 is a graphic representation of the dominant failure patterns identified in the Nowlan and Heap study. As you can see, 89% of failures occur randomly. Therefore, the failure rate and occurrence of these failure modes could not be improved by the imposition of a periodic replacement strategy based on time or throughput.

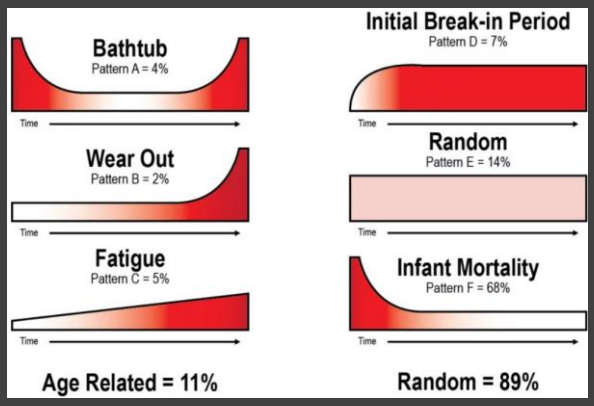


Figure 3 – Graphical Representation of Dominant Failure Patterns

So, why do most maintenance organizations manage equipment reliability with time-based preventive maintenance (PM) programs? Nowlan and Heap noticed this issue in the 1960s and here is what they had to say about time-based and not condition-based inspections.

*…**The chief focus has been on anticipating the age at which things were likely to fail, rather than on how they fail and the consequences of such failures. As a result, there has been insufficient attention to the failure process itself, and even less attention to the question of precisely what constitutes a failure.***

Proactive vs. Reactive Work and the P-F Curve

Many times, I find people who understand the basics of the P-F Curve, but they are uncertain about how it relates to their maintenance organization and equipment reliability strategies. This question is tied to the number one question I receive all the time, which is: "What maintenance work is considered proactive and what is reactive?" Let's first define what proactive work is.

The term proactive, with respect to maintenance, can be defined as *acting before the necessity of the situation demands it or acting before the cost of doing so increases*. So, proactive is not a binary condition of either on or off, it is a continuum. Some decisions and actions are more proactive than others. As such, one way to define proactive work is to say it is *work that has been identified in advance* (at the minimum, it is scheduled one week in advance).

Therefore, all other work that has not been identified in advance is reactive work. It should be noted that the earlier the work is performed, the more proactive it is. If the equipment operator waits too long, even though the machine has not catastrophically failed, the proactive value of the act of maintenance drops exponentially as it gets closer and closer to the point of failure. In that case, the label "proactive" would be more symbolic and not truly the preferred strategy as the value of early detection was lost due to waiting too long to act.

The P-F Curve and Its Relationship to Work Type

Let's look at how the P-F Curve mentality manifests itself in the work distribution of an organization. The definitions provided here, and the work distribution percentages represent the best practice with respect to embracing a proactive maintenance mindset.

The different work types for proactive and reactive maintenance are defined below and the relationship of each type of work to the P-F Curve is shown in Figure 4.

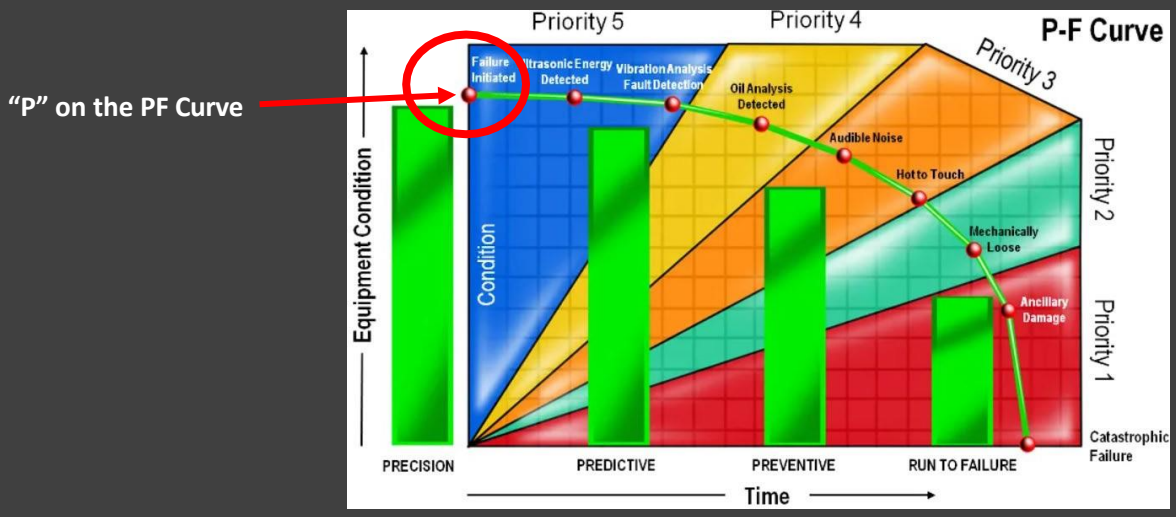


Figure 4 – PF Curve and Work Types

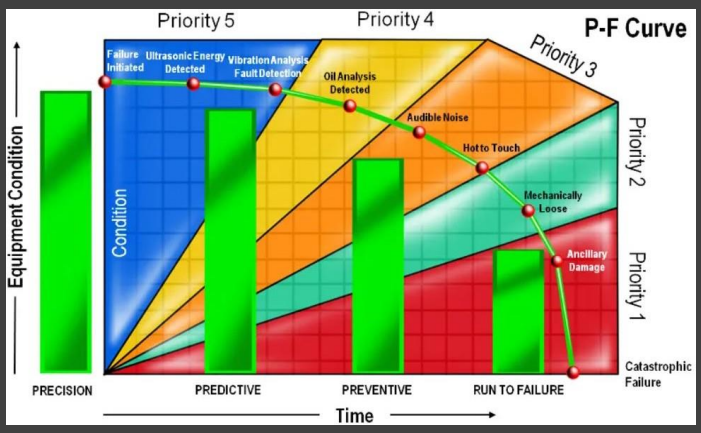
Preventive Maintenance (PM) – Replenish (lubricate), quantitative inspections, restoration, and replacement. PM work can be accomplished before "P" (e.g., lubricating an electric motor) or after "P" when looking for the beginning of a failure (e.g., inspecting a hydraulic system for leaks). Typically, PM inspections are assigned a Priority 3 with respect to scheduling the inspection activities.

Predictive Maintenance (PdM)/Condition Monitoring – Through the use of specific tools to identify the presence of a failure mode, we can plan and schedule the work early enough before a total functional failure occurs. Examples include vibration analysis, infrared analysis, thermography, passive ultrasound, motor circuit analysis, lubricant analysis and several others. These inspection activities are also typically scheduled as Priority 3 work (15% of labor hours).

Corrective Preventive Maintenance (CPM) – Most of the work identified through preventive maintenance should be completed proactively and constitute 15 percent of the total maintenance labor hours.

Corrective Predictive Maintenance (C-PdM) – Most of the work identified through PdM inspections should have corrective action taken in Priority 4 or 5 and represent 35 percent of the total maintenance labor hours.

Requested Work – Work that comes from sources other than PM and PdM inspections. Examples of requested work include emergency work, improvement ideas, the results of root cause or reliability centered maintenance analyses and safety inspections. This work should comprise no more than 20 percent of the total maintenance labor hours.



In Figure 5, Work Priority Distribution, a *typical week* is laid out in a simple matrix that shows the relationship of work distribution, defect severity (work priority) and work category type.

	PM (15%) Inspection/Preventive	PdM (15%) Inspection	Results of PM (15%) Corrective	Results of PdM (35%) Corrective	Requested Work (20%)
Priority 1 *(Emergent)* Within 24 hours)					5%
Priority 2 *(Emergent)* Within 2 days					5%
Priority 3 *(Routine)* Within 1 week	15%	15%	5%	10%	5%
Priority 4 *(Proactive)* Future Work			5%	15%	3%
Priority 5 *(Proactive)* Future Work			5%	10%	2%

Figure 5: Work Priority Distribution

Conclusion

When everyone understands the P-F Curve and how it works in a proactive organization, life is less stressful, costs are down, reliability is up, and life is good. I hope this article explained the P-F Curve to you in a fashion that helps you be successful!

References

1. Nowlan, F.S., Heap, H. Reliability-Centered Maintenance. San Francisco: United Airlines: 1978. http://www.barringer1.com/mil_files/AD-A066579.pdf

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