Why do people not understand the P-F Curve? At a recent maintenance function, I asked 70 maintenance and reliability professionals how many of them had heard of the P-F Curve and only about 10% stated they had. From that 10%, only 1% felt like they truly understood it. This was shocking to me. I assumed everyone had heard about the P-F Curve and its intent.

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 (see Figure 2) with most failures. Another way to say this is that the P-F Curve represents the gradual loss of function.
The Basics of the P-F Curve

When talking about the P-F Curve, we must go back to the Reliability-Centered Maintenance report by Nowlan and Heap of United Airlines that was sponsored by the US 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 this article I do not speak about all the information in the Nowlan and Heap report. This article is focused on the majority of maintenance organizations who are not in proactive maintenance and do not fully understand the value and impact of Predictive Maintenance)

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.
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.)

2. 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 and reliability professionals fail to truly understand what the P-F Curve represents because the definitions of the words shown below 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. Another way to say it is that 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:

- 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
- A clear definition of the conditions that constitute a functional failure in each case; and
- A clear definition of the conditions that indicate that a failure is about to occur.

3. 89% of failures are random in nature. This means they can occur anytime, it does not mean that 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. A few people disagree with the 89% of failures are random however when one thinks about all the variation maintenance induced to equipment reliability one changes their thinking. The causes of this variation in equipment reliability comes from many sources, ineffective PM and CM procedures, maintenance person “fixing” the equipment the way they think is right without regard to specifications and standards, PM compliance is wide along with PM procedures which are executed even though failures continue, etc., etc. If an organization has the data to determine what percentage of failures are random, great. Most companies cannot obtain this type of failure data and thus one must make their conclusions based on facts.
Illustration 3: Failure Patterns

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

...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 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 that I receive all of 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 then 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 that it is work that has been identified in advance (at the minimum, it is scheduled one week in advance); thus, all other work that has not been identified in advance must be “reactive work”. It should be noted that the earlier the work is performed, the more proactive it is and that 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 we get 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 take a look now 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:

**PM (Preventive Maintenance)** – Replenish (lubricate), Quantitative Inspections, Restoration, and Replacement. PM work can be accomplished before “P” (example: lubricating an electric motor) or after “P” when looking for the beginning of a failure (example: inspecting a hydraulic system for leaks). Typically, PM inspections are assigned a Priority 3 with respect to scheduling the inspection activities.

**PdM (Predictive Maintenance/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 typically scheduled as Priority 3 work as well (15% of labor hours).

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

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

**Requested Work** – Requested work is 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% of the total maintenance labor hours.
In Figure 5, (shown below) 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.

**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.