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HOW TO KNOW IF AN

INSPECTION IS TECHNICALLY FEASIBLE

by Richard Overman

The SAE International standard for reliability-centered maintenance (RCM)[1] says an inspection[2] should be done if it is technically feasible and worth doing. The hard part is identifying when a task is technically feasible.

Under the SAE's standard, the criteria for technical feasibility of an inspection are:

1. A potential failure condition can be identified.
2. A degradation interval can be defined.
3. The degradation interval is relatively stable.
4. A task can be performed at intervals less than the degradation interval.
5. The reaction interval is long enough for predetermined action.
6. Safety, environmental and economic criteria are met.

This article primarily focuses on criteria 4 through 6. The first three criteria involve what is called the interval between potential and functional failure (P-F interval) or the degradation interval. Figure 1 is an illustration of the P-F interval. Briefly, the P-F interval is the time it takes for the failure to progress from potential failure (Point B on Figure 1) to functional failure (Point C on Figure 1). The inspection interval cannot be any longer than the P-F interval. The P-F interval can be either calculated or estimated. This article describes how to calculate the inspection interval within the P-F interval.

Criterion 4 states that the task can be performed at intervals less than the degradation interval. If the degradation interval is too short for the proposed inspection to be reasonably performed, then the inspection is not technically feasible.

Criterion 5 states that the reaction time must be long enough for a predetermined action to be taken. When an item is found to be in a potential failure condition, it must be operational until it can be repaired or replaced before it functionally fails. If the response to finding a potential failure is to shut down the item, then the inspection has provided less value. The main reason for the inspection is to give a warning so the repair can be planned and scheduled at the most opportune time to minimize loss of production. Therefore, the degradation interval and the inspection interval must be long enough for the repair to be planned and scheduled once the potential failure condition is found.

Finally, the last criterion states that safety, environmental and economic criteria are met. The first step in answering this criterion is to define the safety, environmental and economic limits. Economic limits are pretty straightforward and will be addressed later. The safety and environmental limits are more complicated. The key to the safety and environmental lim-

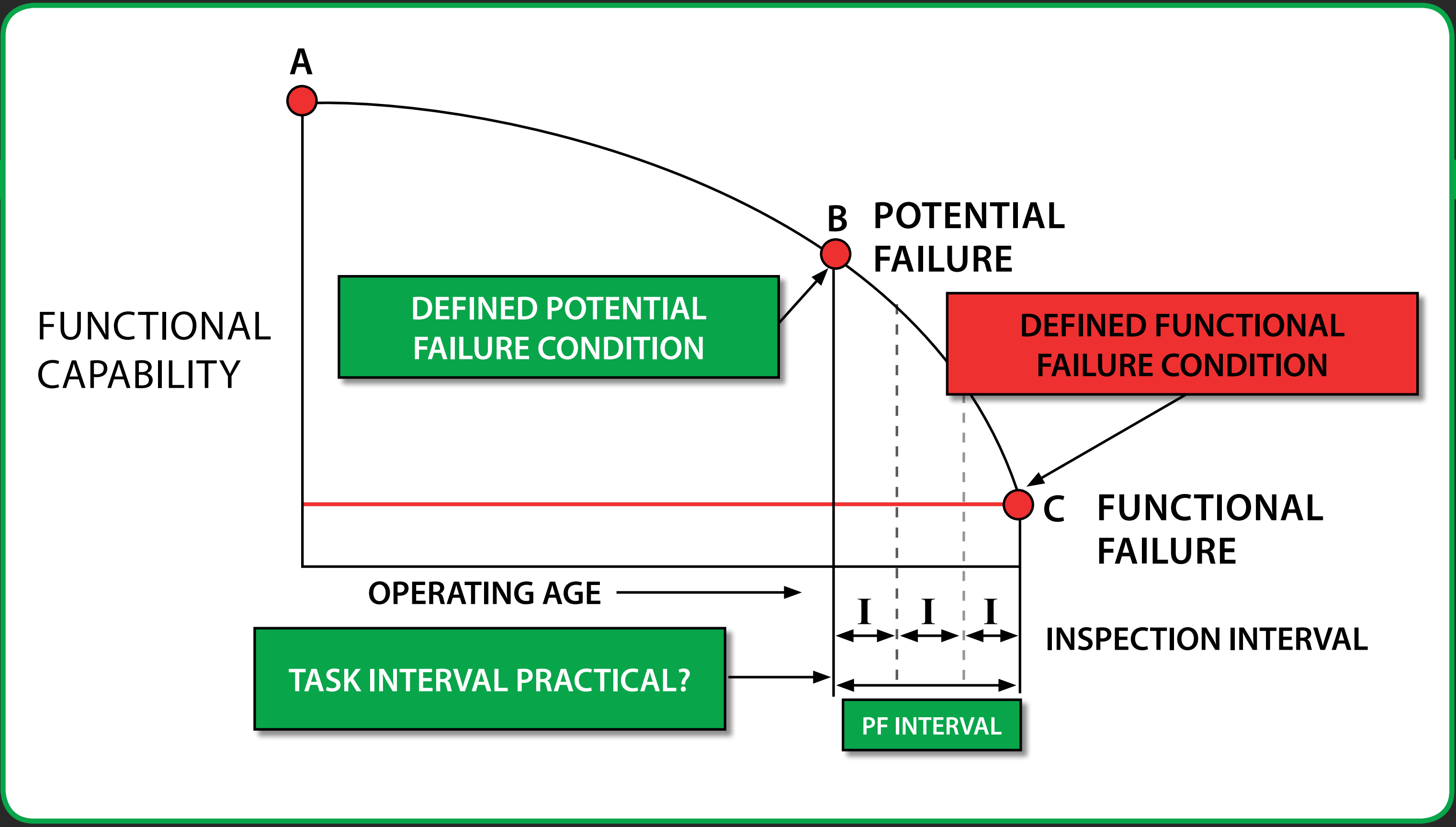

Figure 1: P-F interval

its is identifying the tolerable probability of allowing a functional failure (P_{tol}). This is difficult because management's first response is that no failure is tolerable. Unfortunately, reducing the probability of failure to zero is impossible. Therefore, a practicable probability must be identified. Some industries have standard probabilities that can be applied. Other industries do not. At any rate, corporate management must specify a P_{tol}. The second piece of information needed is the probability that a potential failure will be found by one inspection, assuming the potential failure exists. This is identified by the Greek letter theta (Θ). This will depend on how easy it is to find the potential failure condition and the skill of the people performing the inspection.

Let's say, for the sake of illustration, that P_{tol} is one in a million (1×10^{-6}) and that Θ is 0.9. In this case, the probability of missing an existing potential failure condition with one inspection is $1-\Theta$ or 0.1 (1-0.9). So, there is a 10 percent chance a potential failure condition will go undetected the first time. The second time the inspection is performed, there is also a 10 percent chance the potential failure will be missed. However, the chance the potential failure will be missed both times is 0.1 x 0.1 or 0.01. This also can be written as $(0.1)^2$. If the potential failure is missed, the item will continue down the degradation curve toward functional failure. Therefore, the probability of functional failure, or the probability of actual failure (P_{act}) after two inspections is 0.01. It can be shown that P_{act} is equal to $(1-\Theta)^n$, where *n* is the number of inspections. Now, if you set P_{tol} equal to P_{act}, you come up with this equation:

$$P_{tol} = (1-\Theta)^n.$$

Solving for *n* in the next equation gives you the number of inspections that must be performed within the degradation interval to reduce the probability of failure to the tolerable level.

$$n = \ln(P_{tol})/\ln(1-\Theta)$$

Finally, the inspection interval (I) is the degradation interval (D) divided by *n*, as shown in this equation:

$$I=D/n.$$

It must be understood that the use of mathematics here can imply a level of precision that does not exist. Recall that the degradation interval is an estimate and theta is an estimate. While you make the best estimate possible, these estimates must be conservative in nature. It is also important to understand that this method assumes that a potential failure exists every time the inspection is performed. This is not always the case, but assuming the potential failure always exists is an additional level of conservatism.

Some practitioners have taken the view that if nothing is found after performing a task a certain number of times, the inspection interval can be lengthened. Such a view must be avoided, as it demonstrates a fundamental lack of understanding the degradation interval. Let's say, for example, the degradation interval is six months and the inspection interval is quarterly (three months). This means there are two inspections within the degradation interval. Now, let's say the view taken is that if no potential failure is found after four inspections, the inspection interval can be doubled. So, if no potential failure condition is found after performing the inspection for a year, the inspection interval is increased to six months. At this point, there is now one inspection within the degradation interval. If a potential failure is not found during two more years of inspections, the inspection interval is increased to annually. Now, the item can go into a potential failure condition and go to functional failure between inspections, and the actual probability of failure is greater than one.

Moving on to failures with economic consequences, in these cases, for the task to be cost-effective, the cost of the functional failure (C_{ff}) must be greater than the cost of the scheduled maintenance task (C_{sm}) plus the cost of repairing the potential failure (C_{pf}). This is illustrated by:

$$C_{ff} > C_{sm} + C_{pf}.$$

It can be shown that the value for *n* (the number of inspections within the degradation interval) to satisfy this equation is calculated by the next equation (the derivation of the equation is beyond the scope of this article). All the terms in this equation have been previously defined, except $MTBF_{nsm}$, which is the mean time between failures, assuming no scheduled maintenance is in place, and P-F is the degradation interval.

$$N = \left[\frac{\ln\left(\dfrac{(-MTBF_{nsm})CSM}{P-F} \Big/ (CFF - CPF)\ln(1-\Theta) \right)}{\ln(1-\Theta)} \right]$$

Using this equation, if the value for *n* is greater than one, the inspection is cost-effective and the inspection interval is calculated using the I=D/n equation. If the value of *n* is between zero and one, the task is not cost-effective, but if there are other considerations that would argue for having the task, *n* can be assumed to be one and the inspection interval would be the same as the degradation interval. Do not use the I=D/n equation if *n* is between zero and one, as this would make the inspection interval longer than the degradation interval. If the value of *n* is negative, the task is not cost-effective at any interval.

Conclusion

To be a useful task, an inspection must be able to detect a potential failure condition with enough warning to be able to do something about it before functional failure occurs. It also must be able to reduce the probability of failure to a tolerable level or be cost-effective on its own. This is the essence of the technically feasible question.

Endnotes

1. SAE JA1011- Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes, 1999.
2. An inspection task is known by many synonyms: Predictive Maintenance, On-Condition task, condition based maintenance, etc. For this article, an inspection is any task (using technology or human senses) that is performed to determine if an item is showing indications of failure but has not yet functionally failed.

Richard Overman, *CMRP, CRL, has over 30 years of experience in working with companies and facilities to improve their organization, as well as their equipment maintenance and reliability. He is an expert in process design, FMECA, RCM, lifecycle cost analysis, and other aspects of equipment maintenance and reliability. Richard is the author of Reliability Centered Asset Management (www.reliabilityweb.com/books).*
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