TARGETED RCM

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WHAT IS TARGETED RCM AND WHY IS IT IMPORTANT?

Targeted RCM is a fully SAE JA1011-12 compliant Reliability Centered Maintenance (RCM) analysis methodology that incorporates the use of one or two facilitators who focus on small portions of the plant to accomplish rapid results.

It is a team-based approach designed to answer the seven basic RCM questions to produce a maintenance strategy with the goal of achieving the inherent reliability in any system.

1. What are the functions and associated performance standards of the asset in the present operating context? (Function)
2. In what ways does it fail to fulfill its functions? (Functional Failure)
3. What causes each functional failure? (Failure Mode)
4. What happens when each failure occurs? (Failure Effects)
5. Why does the failure matter? (Failure Consequences)
6. What can be done to predict or prevent each failure? (Task Selection)
7. What should be done if a suitable task cannot be found? (Redesign/No Scheduled Maintenance)

The output of the Targeted RCM process is a complete maintenance strategy, from condition monitoring tasks all the way to plans to surround the Run-to-Failure (RTF) components. The Targeted RCM process is very effectively used to analyze systemic problems and operating envelope problems that manifest themselves as component level defects.

THE 5 MAJOR STEPS OF THE TARGETED RCM PROCESS

1. **UpFront Tasks** – Set up the RCM facilitators and the team for success.
2. **Probability and Consequence** – This is where we will build the groundwork for understanding the importance of each individual failure mode and developing sound methods to prioritize RCM tasks.
3. **Functions and Functional Failures** – The roadmap to successful RCM analysis. World class companies understand the importance of addressing maintenance at the functional failure level.
4. **FMECA** – The heart and soul of RCM. This is where the work is done: identifying failure modes, describing failure effects, and developing tasks.
5. **FollowUp Tasks** – Designed to help the team quickly move forward and drive the implementation of the RCM tasks. Followup is just as important as the analysis itself, and like everything else, it has a process that must be followed.

These 5 major process steps and their associated steps are shown in figure 1.

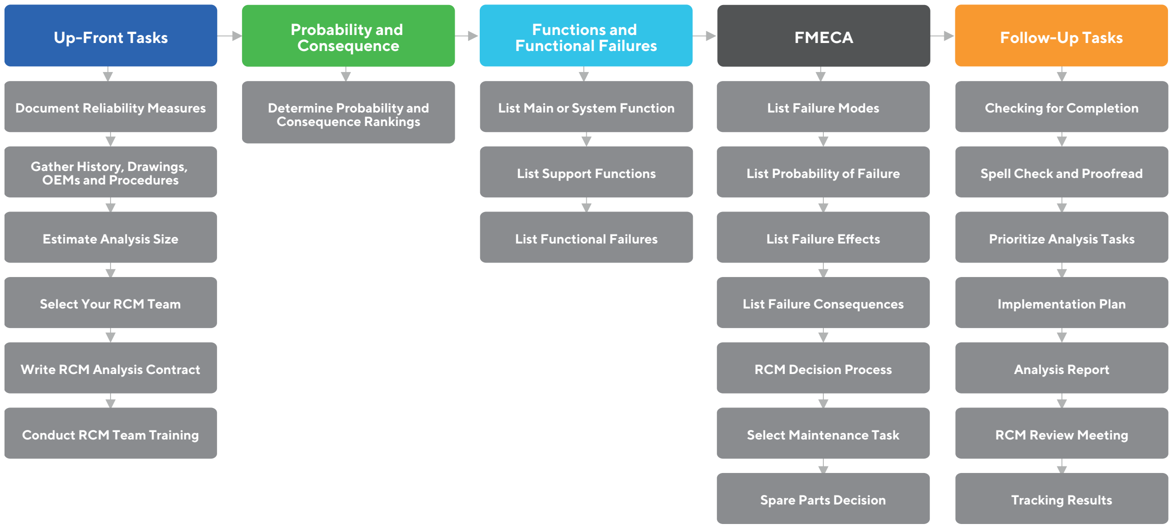


Figure 1: RCM Failure Curves from Nowlan & Heap

UPFRONT TASKS

SELECTING ASSETS FOR RCM ANALYSIS

RCM is a reliability tool, meaning that, like other tools, it was designed for a special use. Like other tools, if we try to use RCM for the wrong application, we may not end up with a positive result. In the past, it was commonplace to hear that "RCM should be applied to every asset your company owns; the business case for RCM is driven by safety performance and if you don't apply RCM to all your assets bad things will happen and people will die." This concept of how we should apply RCM came from its original use in the airline industry, and in that application, it makes sense. Think about this: on an airliner, the failure of even some of the smallest and seemingly insignificant devices could result in a fire, ending with catastrophic results. Worse than the thought of applying RCM to every single asset were the consequences of challenging this belief.

Consider the following list of potential benefits provided by a thorough Targeted RCM analysis:

- Improved equipment reliability, Overall Equipment Effectiveness (OEE)
- Reduced Health, Safety, and Environmental (HSE) incidents and accidents
- Reduced emergency and demand maintenance
- Reduced equipment downtime
- Reduced secondary equipment damage
- Lowered maintenance costs
- Improved process knowledge and troubleshooting skills for operations and maintenance personnel
- Improved productivity
- Improved product quality
- Reduced Unit Cost of Product
- Increased company/product profit margins

When beginning RCM, there is always a level of excitement that goes along with the first analysis. As a result, most companies choose to start with the problem child of the week or month. It is best to meet this situation with the request for formal data. RCM is all about leadership, structure, and discipline: "Show me the process you used to select your first asset for analysis." To make RCM become a part of company culture, we need to select winners – critical assets that are suffering with equipment-related quality, speed, and operational losses. Follow this formula, perform the RCM analysis, and implement the resulting tasks and you will have a huge winner.

To make this clear, we need to start with critical assets. If the organization you are working with does not have a properly formatted hierarchy and/or has not conducted a criticality analysis, it is strongly suggested that an asset hierarchy and/or criticality assessment be performed. The key to making RCM a part of the company culture is to provide an ROI for performing and implementing the RCM analysis. This is very easy to accomplish by performing Targeted RCM on the very top, critical assets.

Document Reliability Measures

Once the criticality analysis has been completed you should now begin to measure and track OEE/TEEP on these critical assets. Targeted RCM should be performed on critical assets where Overall Equipment Effectiveness is being impacted by equipment based, speed, quality, and operational losses.

Write Functional Summary

This summary is usually completed by a process engineer or someone considered an expert who can define the reason the system or piece of equipment exists and the performance standards the equipment is expected to maintain. The summary would also include the current performance, consequence of downtime, how long the equipment or system has been in service and the quality plus EHS standards applicable to the system of asset.

GATHERING INFORMATION NECESSARY TO PERFORM A TARGETED RCM ANALYSIS

In preparation for the upcoming RCM analysis, it is important to gather some critical information and documents to assist the team in performing a thorough analysis. The results and accuracy of the analysis will be dependent upon the accuracy of the information presented at the start of the analysis. The list below shows items to request to have on hand prior to the start of each analysis:

1. A complete list of all components within the boundaries of the RCM analysis. This can be created from Piping and Instrumentation Diagrams (P&ID) and/or a walkdown of the equipment. (At a minimum, this item is an absolute must and the drawings need to be up to date as well)
2. Drawings – preferably P&IDs; ask a local expert to review and update the drawings prior to the start of the analysis, if necessary.
3. A complete list of Preventive Maintenance (PM) and Predictive Maintenance (PdM) activities that are being performed on this asset. While each analysis is performed as if nothing is being done to maintain the asset, consider the value of each task that may be on that list.

4. Original Equipment Manufacturer (OEM) manuals for assets or components within the system being analyzed.
5. Operations and Maintenance History – it is nice to have on hand a list of failures that have occurred on the asset, provided the information the company enters the Computerized Maintenance Management System (CMMS) is accurate and/or available.
6. Control logic – this helps the team determine accurate evidence/alarms for a detailed troubleshooting guide.
7. Standard Operating Procedures
8. Set boundaries specific to they analysis

Being realistic, the items requested will arrive in various forms, possibly ranging from hopelessly inaccurate to totally nonexistent. In the event this takes place, your job as the RCM facilitator has become significantly more difficult. The lack of accurate information will slow the progress of the analysis and affect the accuracy of the final output. This also makes the selection of the RCM team extremely important as each person will need to truly know their portion of this asset from top to bottom. A lack of good information at the start of your analysis will always result in a large RCM "parking lot". The parking lot of an RCM analysis contains unfinished failure modes that require additional work outside of the analysis to determine accurate failure effects or failure symptoms.

ESTIMATE THE SIZE OF THE ANALYSIS AND THE TIME IT WILL TAKE TO COMPLETE THE ANALYSIS

As a guideline, a Targeted RCM analysis of 85-100 component functions (number of components x 1.5) that will result in 120 or more failure modes (number of components x 3) can be completed in 5 days. Boundaries can be adjusted to minimize or maximize time constraints of each analysis.

SELECTING THE RCM TEAM

To get the best results from each RCM analysis, it is necessary to select a cross-functional team of expert participants with representatives from operations, maintenance, engineering, and predictive technologies. The typical make-up of an RCM team includes the following people:

- **Maintenance Crafts Personnel, with representatives from mechanical, electrical, and instrumentation** – The maintenance crafts personnel will provide information on possible failure modes and are critical in making task decisions.
- **Operations** – Every RCM analysis MUST have 1 or 2 experienced operators. While this process is named "Reliability Centered Maintenance", the deliverable will be incomplete without representation from operations. Equipment operators live with the assets on a day-to-day basis; the experience they have in operating the equipment and the failures they have witnessed over the years will provide some of the most valuable information necessary to complete a good analysis. Operators provide the most accurate information when it comes to failure effects and failure symptoms.
- **PdM Technician** – The PdM technician is necessary in helping to determine what tools can be used to detect potential failures on failure modes that have a useful P-F interval. They also provide recommendations for precision maintenance techniques that can eliminate failure modes or drastically improve Mean Time Between Failures (MTBF) for many failure modes.

- **Process Engineer** – This is an engineer who has responsibility for the asset being analyzed. This person will provide information on how the asset is supposed to perform and the potential consequences to the business should it fail.

As stated previously, each person on the RCM team should be considered an expert by their peers on the process or asset being analyzed. Along with being considered an expert, everyone should be open to change, as well as new ideas and concepts. Taking this into consideration, when selecting participants, consider each person and their demonstrated abilities when it comes to not only troubleshooting failures, but also applying corrective actions that eliminate them from occurring again.

Outside of the RCM facilitator and the team participants, you should also consider part-time daily representation from both operations and maintenance supervision and management. Managers should not be expected to sit through an entire RCM analysis, but it is important for them to sit in for an hour or so each day to monitor the progress of the event, answer questions that may have come up in the analysis, and most importantly, show support for the process and the team.

program and then specifies to the oil lab which tests are to be run for which samples. This declaration of tests for a given sample is called a *test slate*. The test slate will vary not only based on the asset/component type, but also depending on the operating environment and operating context specific to the asset/component. For example, the test slates are not the same for all pumps as some pumps operate in different environments and under different running conditions.

CONDUCT TARGETED RCM PARTICIPANT TRAINING

The Targeted RCM Participant Training is a four-hour training module that is focused on instructing participants in RCM terminology and the Targeted RCM process flow. Simply put, only the facilitators need to be considered experts in regards to the RCM process; the team will learn the information required to participate during the training session, and then learn the remaining concepts as they participate in the analysis.

THE TARGETED RCM ANALYSIS CONTRACT

The Targeted RCM Analysis Contract is a critical step in successfully kicking off the RCM analysis and ensuring that all people and information needed to complete a thorough RCM analysis are accounted for prior to starting the event.

THE TARGETED RCM PROCESS

PROBABILITY AND CONSEQUENCE RANKINGS

Probability of Failure

When we rank the probability of each failure mode, we are assessing the likelihood that this failure will occur based on the history or experience of the RCM team. For each RCM analysis, we create a document that sets clear boundaries of what constitutes a High, Medium, or Low probability failure mode. To do so, the RCM facilitator will first list the main function and all the support functions for each component within the boundaries of the RCM analysis. In completing this list, we ask the team to highlight the top ten components that fail most often. With this complete, we then ask the question, "How often do these failures occur?"

The goal in asking this is to set a cutoff point for High probability failures that captures no more than the top 20% of our upcoming failure modes. With this step complete, we can now generate the criteria for High, Medium, and Low priority.

Note the example below:

Probability of Failure

High – This failure mode occurs 1 time in 3 months, or more frequently
Medium – This failure mode has occurred before
Low – This failure mode has never occurred

Consequence of Failure

Following the development of the failure mode probability criteria, we immediately move on to set the criteria for the consequence of each failure mode. As we rank the consequence of each failure mode, we are assessing the potential cost impact to the business regarding:

1. **Health, Safety, and Environment** – When developing consequence criteria for HSE, suggest any failure mode that could result in the loss of function that affects employee HSE be considered a High consequence of failure. In recognizing this, it elevates the potential mitigating tasks to a level that will ensure implementation. Splitting hairs on whether a potential spill will be less than 1 gallon or more than 50, or whether an employee will be cut or maimed, is dangerous and only slows the RCM process.
2. **Equipment Downtime** – To set the High consequence criteria for equipment downtime, we identify a set number of hours, should this failure occur, the resulting downtime will result in severe consequences. Remember, the recommendation of performing RCM on the top 5 – 10% of the most critical assets, failure modes that result in poor performing assets and loss of products over time, should be painful. To come up with this number, ask questions to find out:
   - How long can this equipment be down before the company is in danger of missing a shipment?
   - What point does upper management or corporate headquarters need to be alerted that the critical asset is not running?

   Once we have determined the High consequence criteria, the Medium and Low rankings become easy.

3. **Impact on Product Quality** – Product quality criteria, in most cases, is predetermined by a company's quality organization. If not, we again ask a series of questions to determine an unacceptable level of product loss or rework that may result from a given failure mode. In the event a company does not have a predetermined unacceptable number or percent for quality losses, simplify the process by discussing the cost of poor quality. What is the financial impact of 1% offspec product? What is the cost of the raw materials needed to make the product and how much time does it take to make 1%?
4. **Total Cost of Failure** – Total Cost of Failure takes into consideration, for each failure mode, the cost of lost product, the cost of maintenance, and the cost of replacement parts. Prior to starting an RCM analysis, ask the customer's management to set the dollar amount that constitutes a High consequence to the business. From this number, we then set dollar amounts for Medium and Low consequence failures.
5. **Impact on Efficiency/Energy Usage** – It is very rare to have efficiency losses end up in the High consequence category, but efficiency losses can add up and need to be taken into consideration. As an example, an RCM analysis was recently performed for a company on a compressed air system that had primary and standby air compressors and air dryers. While the system was designed to run on a single compressor and dryer, years of neglect forced them to run both compressors and both dryers. As a result, the failure of a single compressor would be enough to shut down several key assets. The resulting RCM tasks brought the system back in control, but as we performed the analysis, it was often discussed that we could mitigate some failures by again starting both compressors! To deter this action, the team calculated the inefficiency of running both units and the cost easily exceeded our total cost criteria for Low consequence failures. Inefficient operation can also be defined by the need for additional resources/people to operate or having to either slow your equipment or start and stop your equipment to make product.

Below is an example of what a consequence criteria document might look like:

Consequence of Failure

High

- Failure Mode affects employee HSE
- Failure Mode results in equipment downtime exceeding 4 hours
- Failure Mode results in the manufacturing of offspec product exceeding 2%
- Failure Mode results in a total cost exceeding $25,000.00

Medium

- Failure Mode does NOT affect employee HSE
- Failure Mode results in less than 4 hours of equipment downtime
- Failure Mode results in offspec product less than 2%
- Failure Mode results in total cost of less than $25,000.00
- Failure Mode results in inefficient operation of equipment at a cost greater than Low consequence criteria

Low

- Failure Mode does NOT affect employee HSE
- Failure Mode results in less than 15 minutes of equipment downtime
- Failure Mode does not impact product quality
- Failure Mode results in total cost of less than $500.00

Now that we have determined the criteria for ranking the probability and consequence of each failure mode, determining the criticality of the failure mode and the priority of the resulting tasks is simple. To do this, we use the matrix shown below.

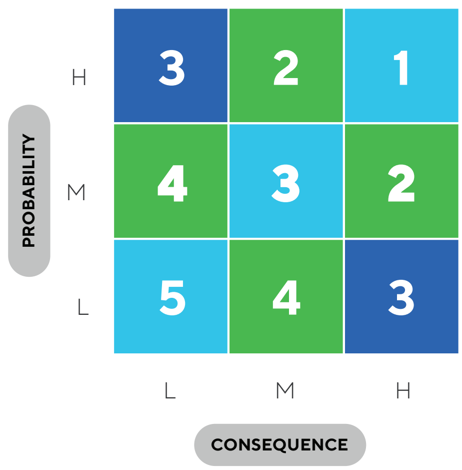


Figure 2: Probability and Consequence Rank Matrix

Failure modes that have a High probability of occurring and High consequence to your business should they occur have a criticality ranking of 1, and the resulting task will be considered priority 1. A failure mode with a Low probability of occurrence and a Medium consequence to your business should it occur will receive a criticality ranking of 4 and the resulting tasks will receive a priority 4 rank. Knowing the priority ranking of each task, we can now assign each priority a specific due date and assign the task for implementation.

FUNCTIONS

Identifying and listing equipment functions is the first step of the Targeted RCM analysis process. At this point, the RCM facilitators will begin working with the RCM team to list first the main function of the asset and then the support functions for all the components within the boundaries of the analysis. This list of function statements will create what we call the road map to a successful RCM analysis.

Listing the functions for each analysis is the first test of patience and leadership for every RCM facilitator. While listing functions typically takes less than four hours for a weeklong RCM event, the identification and listing of the main and support functions can be painful.

Main Functions

The Main Function is the first function we look at with the RCM team. This function is the reason the process or piece of equipment exists and the performance standards the equipment is expected to maintain. If the RCM facilitator and RCM analysis sponsor have done a good job writing the Functional Summary Report, writing the main function statement should be very easy. It is highly important at this stage of the process to understand the importance of writing a clear and concise main function statement. This first statement, combined with the support functions, will dictate the depth and accuracy of your entire RCM analysis.

Looking at the definition of a main function statement, we can break the statement into two separate parts, the first being why do we own this asset and the second being the performance standards we expect it to maintain. In drafting the first part of the main function statement, ask the team: "Why do you own this asset?" At a basic level, what do we need this asset to do and what performance standards does it need to maintain while it is scheduled to run?

Support Functions

Once the team has determined the main function of the RCM analysis, we will now move on to describe the support functions. In simple terms, the support functions describe, at a high level, the functionality of each component within the boundaries of the RCM analysis. Knowing that listing functions can be painful (RCM teams tend to love discussing how things can fail, yet seem to struggle in describing what we need each component to do), when it came to equipment functions during the creation of the Targeted RCM methodology, the idea was to look for a simple way to accomplish two basic goals in terms of functionality:

1. Create a complete list that describes the basic function of each component within the boundaries of the analysis.
2. Develop a technique to identify potential hidden function components early in the RCM process.

Recognizing that the components that make up each asset are designed in some way to support the main function of the asset; we can accomplish the first goal in describing support functions. In preparation for the RCM analysis, we created a list of components to estimate the size and time it would take to perform the RCM. We can now use this list to list the component and then list the basic function of that component.

The second goal of identifying potential Hidden Function components is accomplished by asking one simple question as we identify the support functions of each component: Is the component active or passive?

Active Function Components

Active function components are components that perform an active function and do so each time the equipment is operated. During the normal operating condition of this asset, this component will be actively performing its intended function. As an example, a pump is a component that provides an active function. We describe active function components with the phrase "to be able to".

Examples of Active Function Components:

- Cooling Tower Pump – To be able to pump cooling water
- Continuous Level Device – To be able to continuously monitor the level of the tank
- Motor – To be able to convert electrical power into rotary motion
- Starter – To be able to provide electrical power to the motor

Note how each active function contains the phrase "to be able to" and that each function is written at a level that describes its basic function. At this point in the RCM analysis, there is no need to describe the performance standard of each support function; this will be discussed as we address the failure modes of each component as they relate to the performance standards of the main function.

Passive Function Components

Passive functions describe the functionality of components that have the potential for hidden failures. These devices are passive by design, meaning they are waiting to recognize a specific condition that will not exist under normal operating conditions for this asset. We describe passive function components by using the phrase "to be capable of". At this stage of performing the RCM analysis, it is extremely critical to take the time to recognize which components provide hidden functions. If we fail to identify these components at this point, it will likely result in failure to identify hidden failures that could have catastrophic effects on your business.

Examples of Passive Function Components:

- Emergency Stop (E-Stop) Button – To be capable of shutting down the system in the event of an emergency
- High Level Switch – To be capable of shutting down the tank supply and alarming the operator in the event of a high-level condition

FUNCTIONAL FAILURES

To truly understand the definition of the term Functional Failure, it is important that you first understand failure. In the past, it was just failure that defined and warranted the need for maintenance. Most people looked at failure as a black or white term; a component was either failed or working, running, or shut down. As a result, the world of maintenance became linked to this definition in many places. Maintenance as a group were the people you called when the equipment was broken. The definition of failure is very broad and can often be subjective. Consider the following definitions of the word "failure":

- Webster's dictionary defines failure as "a state of inability to perform a normal function".
- Nowlan and Heap defined failure as "an unsatisfactory condition".

Read these definitions and try to relate them to your equipment or the process you work with. Is it clear to everyone what your "normal functions" are? Does everyone know what a "satisfactory or unsatisfactory condition" is? If we asked everyone who works with or operates this equipment, would they all have the same definition of failure, normal functions, and unsatisfactory condition? Of course not, and this is what drives us to become more specific in defining failure. As the definition becomes more specific, our ability as a group or business to clearly understand and pinpoint failure increases.

To understand failure, we must first understand the criteria that define failure. These criteria should be set when defining the performance standards for the function of your system (main function) and the components that make up the system (support/primary functions). In defining these performance standards, you will in turn help clearly define what failure is for your process or equipment.

In the world of RCM, we use the term "functional failure" to help clarify the understanding of what failure is. Nowlan and Heap defined functional failure as "*the inability of an item (or the equipment containing it) to meet a specified performance standard*".

With the understanding that it is the functional failure of an item (component or system) that dictates how we define failure, it should now be clear to all people working with or operating the equipment when the equipment has failed.

Writing Good Functional Failure Statements

Writing good functional failure statements is clearly dependent on how well your team has defined the functions of your RCM analysis. Some tips to remember as you identify the main and support functions for your equipment:

- Your main function statement should be written in a manner that clearly identifies the equipment's intended use and all the performance standards it is expected to maintain, including HSE standards.
- Do not rush through the process of writing function statements; it is, after all, the function statements that create the roadmap to a complete and thorough RCM analysis.
- Try to identify active and passive functions; this will help to ensure that your team does not miss any hidden function components.

Example:

- Chilled Water System Main/Primary Function Statement:
  - To be able to supply high quality, chilled water at a temperature of 40° F plus or minus 5° F and a rate of 120 gallons per minute while meeting all environmental, health, and safety standards.
- Functional Failures of the Chilled Water System:
  - Unable to supply chilled water at all
  - Unable to maintain water temperature above 35° F
  - Unable to maintain water temperature below 45° F
  - Unable to supply water at a rate of 120 gallons per minute
  - Unable to maintain water quality standards
  - Unable to maintain (company, state, or federal) environmental, health, or safety standards

The Importance of Listing Functional Failures

With these functional failures identified, it should now be clear to those who operate or maintain the chilled water system when the system is failed. More importantly, having identified these functional failures, we can now begin to discuss the causes for each functional failure. These causes are known as "failure modes". Think about this: for each functional failure identified, there are several failure modes that could result in that functional failure. Some failure modes will result in total system shutdown or being unable to supply water at all, some will result in chilled water flow falling below the required 120 gallons per minute, and still others may affect the quality of the chilled water within the system. The importance of identifying and listing functional failures should now be evident within the RCM analysis. In sorting failure modes by functional failure, we begin to create a high-level troubleshooting guide for our process or piece of equipment. When this chilled water system RCM analysis is done, we will have a complete listing of failure modes that cause each functional failure for both operations and maintenance. Now, as we execute this process, our equipment operators can begin looking for performance trends. If the temperature of the chilled water were to begin to trend up or down, they will have a complete listing of the failure modes that cause these changes.

The Pitfalls of Skipping Functional Failures

One of the curses of being human is the burning desire to do everything faster. From the time we first learn to walk, we have a desire to run; the minute the first automobiles hit the road, someone had to make a faster one. Speed can be a good thing in the world of manufacturing and maintenance, but it can also be a bad thing. From the time Nowlan and Heap first designed and implemented RCM, people have been in search of ways to make it faster – in most cases, they do so by eliminating some of the key process steps. In many cases, identifying functions and functional failures are steps that are completely or partially eliminated. In each case, the result is an incomplete RCM analysis and an incomplete maintenance strategy. The well-meaning attempt to save time is usually driven by an inexperienced facilitator who does not have a full understanding of the consequences, or an impatient manager with even less understanding. The list below outlines consequences of skipping functions and/or functional failures when performing RCM analyses.

Skipping functions, listing only a main function, or skipping functional failures results in:

- **Incomplete listing of failure modes** (How can one expect a complete listing of failures without identifying each component?)
- **Incomplete listing of hidden failures** (If we do not discuss each component and its intended function, do we expect to discover failures that are not evident?)
- **The inability to recognize when functional failure has occurred** (Failure to recognize functional failure is key in beginning to recognize and understand potential failures and the P-F Curve.)
- I**mproper applications of PM and on-condition maintenance** (functions, performance standards, and functional failures are all key components in understanding the use of on-condition maintenance and predictive technologies. Failure to identify these key components often results in PM being applied where on-condition maintenance would be more applicable and effective.)
- **An incomplete, and therefore less effective, maintenance strategy** (With all the above being true, how would one expect to have an effective maintenance strategy as a finished product?)

FAILURE MODES

To help with understanding proper failure mode identification, a three-part formula is used to assist teams in this stage of the process. Every failure mode should include the following three components:

(Part + Problem + Specific Cause of Failure = Failure Mode)

- The definition of "Part" is a group of pieces that make up a component.
  - Examples from ISO standard: impeller, seal, shaft, bolt, nut, bearing
- The definition of "Problem" is the effect of the failure mechanism.
  - Examples from ISO standard: failed, damaged, out of adjustment, seized, fatigued, burnt, broken
- The definition of "Specific Cause" is the physical cause of the problem.
  - Examples from ISO standard: age, improper lubrication, misalignment, imbalance, improper installation

Example:

- Cooling water pump bearing (Part) seizes (Problem) due to lack of lubrication (Specific Cause of Failure).

Having identified a proper failure mode, the team can now move on to describe the failure effects and consequences, and easily make a sound decision on how to best mitigate this specific failure mode. Looking at the previously identified failure mode, can you venture a guess at what the task might be? If your answer was to develop a lubrication task that identifies the correct type, amount, and interval of lubrication, and we set that task up as part of our maintenance strategy for this failure mode, we have now ensured that this failure mode is not likely to ever occur.

Common Mistakes in Writing Failure Modes

While this three-part formula may seem simple, there are many examples of how people stumble when it comes to writing failure modes.

Examples:

1. **Writing failure modes at a level too high to make sound decisions:**
   a. Using a cooling water pump as an example, what would happen if we decided to make the RCM analysis go faster by writing the failure mode "the cooling water pump fails"?
   b. What task should be implemented to mitigate this failure mode?
   c. Moving a step closer to actual failure mode, we could also write "the cooling water pump bearing fails".
   d. Looking at that failure mode, are we any closer to understanding why the bearing failed? As a result, could we develop a sound maintenance task?

   As an example, we could elect to perform vibration analysis to detect if the bearing is in the process of failing. The question then becomes do we want to use vibration analysis to inform us that someone forgot to lubricate the pump bearing?

2. **Combining/grouping failure modes:**
The second most common mistake is combining or grouping failure modes. Looking back at the failure mode "cooling water pump bearing fails due to lack of lubrication", what would happen if we made the decision to write the failure mode as "cooling water pump bearing fails due to improper lubrication"?

   In making the decision to group the individual lubrication failure modes, can we now expect the team to come up with a sound task?

   How many individual failure modes are grouped into this one statement? The list below is a partial look at what might be included in the failure mode grouping of improper lubrication.

   a. Cooling water pump bearing fails due to lack of lubrication
   b. Cooling water pump bearing fails due to incorrect type of lubrication
   c. Cooling water pump bearing fails due to contaminated lubrication
   d. Cooling water pump bearing fails due to over lubrication
   e. Cooling water pump bearing fails due to lubrication breakdown

3. **Using failure modes lists:**
Having instructed, mentored, and certified RCM facilitators for many years, we are often asked; "Why don't you make a pulldown list in your Targeted RCM software of like three hundred failure modes? It would make it so much easier as a facilitator."

   While failure modes lists can be helpful and can speed up the RCM analysis process, these lists often create more problems than they solve. The overall objective of an RCM analysis should be more than listing the known failure modes of the components that make up the system being analyzed. The discussion and discovery of the likely failure modes in the plant is an educational tool for facilitators and team members. It opens discussion to build an understanding of the failures that have occurred, and could occur, at the plant. Consider this: in visiting manufacturing plants around the world, those with what would be considered the worst equipment reliability have the highest levels of reactive maintenance. As we begin to perform RCM analyses at these sites, we see one glaring problem: their reactive maintenance culture has morphed their maintenance personnel into component replacers instead of equipment maintainers. As a result, when asked to begin failure mode identification, they rarely know or understand the specific causes of failures. Listed below are some of the problems with failure modes lists:

   a. No list is complete.
   b. They dumb down the learning process of failure mode identification.
   c. They slow the learning/certification process for RCM facilitators.
   d. They often result in discussion/consideration of failure modes that are highly unlikely at the plant.

4. **Overuse of the "black box" failure mode:**
A common question asked during RCM analyses is: "We're not really sure how this component works; can we black box that failure mode?" In most cases, the answer is No!

   The term "black box" in RCM comes from airline industry flight data recorders and is used to describe the chunking of several failure modes into a twopart failure mode. "The component fails."

The excuse to black box typically comes into play for two reasons:

a. We do not know how the component works.
b. Regardless of the cause, the failure effect is identical for all its failure modes.

Regarding the first excuse, if we do not know how a component works, now is a good time to learn.

The second excuse is normally used when a team is pushing to complete a given RCM analysis and, as the week goes on, there is a tendency to rush the process. At this point, urge the team to list and discuss the failure modes and tasks, as we often miss significant improvement opportunities when pressed to complete.

FAILURE EFFECTS

Failure Effect Statement – Requirements

1. Events that lead to failure or functional failure
2. First sign of evidence
3. Secondary effects/damage
4. Effects that impact product quality
5. Effects that could result in HSE incidents and accidents
6. Events required to bring the process back to normal operating condition

Understanding the Requirements

Listing failure effect statements can seem a bit slow and punishing at times; the trick here is to understand the value in fulfilling each of the requirements. There are specific reasons why the RCM team needs to take the time to consider and write each requirement for the failure effect statement. To make this clear, each requirement is listed below, with a description of what it takes to fulfill the requirement, why we need this information, and the danger of not considering or including each step.

FIRST REQUIREMENT - Events that lead to failure or functional failure:

Part one of the failure effects requirements should help the RCM team understand if the failure mode falls under one of the three wear-based failure curves or the three random failure curves.

Events leading up to failure should clearly describe the effects of wear-based failures with statements that describe what occurs as the component wears.

Example:

If the failure mode we are assessing is "fuel piping leaks due to corrosion", we want the team to describe what happens to the component (piping) as it corrodes. The failure effect statement should start with the phrase "corrosion of the fuel pipe results in thinning of the pipe walls". This description clearly

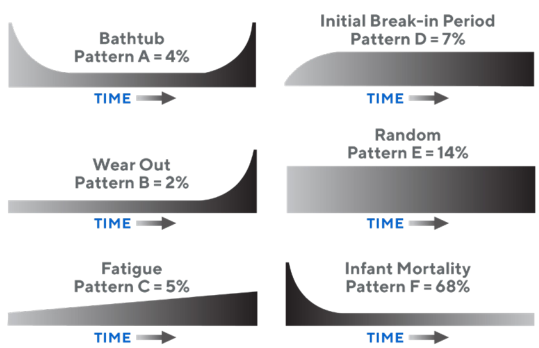


Figure 3: Failure Curves

tells us what the failure mode is (corrosion) and gives possible evidence of what is occurring to the component as the failure progresses along the potential failure curve.

Wear-based failure modes should always have events that lead to failure, such as corrosion, erosion, abrasion, and normal wear. They fit the conditional probability of failure curves:

1. Failure Pattern A - This pattern is known as the Bath Tub Curve and represents components that will suffer a period of early life failures, followed by an extended period of low probability random failure and then a rapid increase in conditional probability of failure cause d by wear out.
2. Failure Pattern B – This pattern is known as the classic wear curve. They are a result of wear-based failure modes where the conditional probability of failure rapidly increases. This is the failure mode we wish all components would fall under, but Nowlan & Heaps study found only 2% of aircraft components fall in this category.
3. Failure Pattern C – This pattern is known as the steady wear pattern. From the point of installation, the conditional probability of failure on these components increases over time such as pipes, tires, and clutches.

Random failures can be a bit trickier to understand as some show signs of failure with a useful P-F interval, while other random failures happen immediately with limited or no evidence of failure. They fit the conditional probability of failure curves:

1. Failure Pattern D - This pattern is known as the Best New failure pattern, as this pattern shows little to no conditional probability of failure when the component is first installed and put into service. The conditional probability of failure then quickly rises to a low level of random failure. It is thought that hydraulic and pneumatic components fit this failure pattern.
2. Failure Pattern E – This pattern is completely random having a constant probability of failure at all ages. Items fitting this pattern can be maintained using PdM provided they have a useful P-F interval where the potential failure can be detected, and replacement can be both planned and scheduled.
3. Failure Pattern F – This pattern is known as Infant Mortality pattern; these items have a high probability of failure at installation providing they survive start-up or burn-in. The conditional probability of failure quickly drops to a slow level of random failure such as electrical components.

The opening statement for writing failure effects for quick random failures would look like the following example.

Example:

The failure mode we are assessing is "product jam proximity switch fails open". The opening failure effect statement for this failure mode would be "in the event the product jam proximity switch fails open". The statement "in the event" indicates the failure mode happens very quickly and is random in nature. When this component fails, it provides little or no evidence that the failure is about to occur.

The value in having the RCM team consider events leading up to the failure is that in describing this part of the failure effect statement, they should now understand if the failure mode is random or wear based. This clear understanding will also help the team when assigning a task using the Targeted RCM decision process.

SECOND REQUIREMENT – First sign of evidence:

Part two of the RCM failure effects requirements is the first sign of evidence. The first sign of evidence requirement forces the RCM team to consider how each specific failure mode becomes evident to the operating crew as they perform their normal duties. In other words, what notifies the operators that a failure has occurred?

Looking at the failure mode example of "fuel piping leaks due to corrosion," to fulfill the requirements for first sign of evidence, we need to enter into the failure effect statement how the operators or people who work at this plant will first recognize that the corrosion of the pipe has resulted in a fuel leak.

Depending on the plant, how they operate the asset, and the presence of backup protective devices, the way the failure first becomes evident could be very different. Consider for a minute the different ways this failure could become evident:

- Plant 1 has an internal tank pump and all fuel piping installed above ground and has also installed fuel vapor detectors at three strategic locations between the fuel tank and the load out truck. Should the vapor detectors detect the presence of fuel vapors, there will be an audible alarm and the system will shut down.
- Plant 2 has an internal tank pump and all piping is installed underground between the fuel tank and load out truck. Fuel leaks are detected by taking inventory each week and looking for discrepancies between what was delivered to the fuel tank and what was loaded out to the trucks.
- Plant 3 has an internal tank pump and the piping is installed above ground between the tank and load out truck. There are no fuel vapor detectors, but the operators are required to inspect the fuel piping for leaks each time they load out a truck.

Looking at these three examples, we now see three different ways that the same failure mode can become evident, as well as three quite drastic differences in how long it takes for the failure mode to become evident. Some might even be tempted to say that the failure at Plant 2 is not evident, or hidden, asking the question, "How long would it take for them to recognize this failure?" It is questions like these that clearly point out the danger of not discussing evidence as part of your failure effect statements. The answer here is that although the failure is evident, the time it takes to reveal itself is just longer than at Plants 1 and 3. When the leak at Plant 2 becomes large enough, it will become very evident.

We cannot close the discussion of first sign of evidence without discussing hidden failure modes. Hidden failure modes result from the functional failure of a component that is not evident to the operating crew under performance of their normal duties. As your plant runs in normal operating condition, the failure of these devices will not be evident. In fact, the process will run perfectly, as if nothing has occurred. The two failure modes listed below are hidden failure modes:

1. Fuel system estop button is failed closed – This estop button is wired normally closed; should it fail in the closed state during normal operating conditions, the process would continue to run as if nothing has occurred. The only way this failure will become evident is if something else happens or occurs to make the failure evident. For example, the operator notices a gasket leak and presses the estop button to stop the process; with the button failed in the closed state, the process will not shut down, but the operator now knows the button has failed.

2. Backup fuel pump motor is failed due to lack of lubrication – The key part of this failure mode is the word "backup"; this should indicate that the failure mode for the pump specified is on a backup system. During normal operating conditions, we use the primary or main fuel pump to transfer fuel from the fuel tank to the load out truck. The failure of a backup device is not evident during normal operating conditions. The only way this failure mode will become evident is if some part of the primary or main pump system fails and requires us to now start the backup system.

THIRD REQUIREMENT - Secondary effects/damage:

The third failure effects requirement deals with secondary effects or damages that result from the failure mode that the team is assessing. It is in this portion of the failure effect statement that we begin to discuss what will happen when the failure becomes evident and the possible extent of the damage to our business. It is important to also understand at this point that we should discuss each failure as if nothing is being done to prevent or stop the failure from occurring. When writing this portion of the failure effect statement, it is a good idea to use the phrase "if left to its own devices" or "if left to fail".

The importance of discussing secondary effects or damage is that this allows the team to understand the potential consequences at risk if we ignore each specific failure. One of the most underestimated benefits of performing an RCM analysis and implementing the tasks is that when fully implemented, RCM will provide a maintenance strategy that will ensure the inherent designed reliability of the asset at a minimum cost. The key phrase here is "minimum cost". The cost of maintenance for companies who fail to understand the value of reliability is astronomically higher than the cost for companies who do. The difference in cost comes from performing maintenance in a firefighting mode. Emergency and demand maintenance costs are typically 3 to 5 times higher than planned and scheduled maintenance; one of the big reasons why is secondary equipment damage.

Imagine that you are driving down the road in your car and suddenly you notice the oil pressure light come on. At this moment in time, you have a decision to make. You can ignore the light and drive on; after all, you do have some important things to do. Or, you can quickly find a safe place to pull over and investigate why the light came on. Knowing just this information, which decision would you make?

In the years we have been asking this question when instructing facilitators and leading RCM teams through the analysis process, not one person has said, "Drive on, it's just an alarm." Yet, while at work, we continue to ignore similar alarms daily. Then we ask the follow-up question, "Why would you stop your car to investigate the cause of the low oil pressure light?" Again, we get the consistent answer, "Your engine oil could be low or leaking, and you might seize your engine; that would cost you a lot of money."

This is exactly the point we are trying to make. The cost of stopping, determining the cause of the light, and making the repair would be far less than the cost of ignoring the alarm and allowing the engine to seize. The exact same scenario occurs day-to-day in manufacturing equipment, yet in many cases, we make the choice to ignore these alarms. In the end, the resulting secondary damage drives up the cost of maintenance, as well as the time the equipment is down for repair.

FOURTH REQUIREMENT - Effects that impact product quality:

Recently, RCM analyses have been performed for two major companies who made the request that we not consider product quality as part of the RCM process. Their reasoning was that Quality is a separate organization in their business, and it is their job to deal with product quality issues. Maintenance, on the other hand, is charged with equipment reliability, so the company needs them to only be concerned with keeping the equipment running. This is a disturbing business concept; after all, if your equipment were running, but making mountains of rejected product, would you consider this process to be reliable? Of course not! As we look at the reliability measures of Overall Equipment Effectiveness (OEE) and Total Effective Equipment Performance (TEEP), quality is identified as one of the key manufacturing loss categories. In recognizing this, we should also understand that maintenance provides a key role in terms of eliminating or reducing the occurrence of failure modes that result in offspec product.

As we discuss failure effects, we should always consider if the failure mode will in any way affect product quality. Should this be the case, we should identify the potential effects in the failure effect statement.

As an example, in discussing the failure mode of worn wear strips on the side of a beer conveyor, we would mention in the failure effects statement that if left to their own devices, the wear strips could wear to a point where the beer cases come in contact with the wear strip hardware, resulting in damaged cases. Again, if we ignore the failure, the resulting consequences will now impact the quality of our product and a simple maintenance task could eliminate the failure.

FIFTH REQUIREMENT - Effects that could result in HSE incidents and accidents:

HSE effects are the resulting consequences for failure modes that result from a loss of function that could affect the environment or the health and safety of personnel. It is again important to note that as we list failure effects and make RCM decisions, we will always default to the best failsafe decision. Therefore, when we ask the question in the iRelaibility RCM decision diagram (Figure 4), we use "could" instead of "will". The failsafe decision ensures we do not make an RTF decision when it comes to failure modes that impact HSE.

As we identify these effects during the analysis process, we will want to clearly state the possible hazards and impact to our people, customers, and business if the failure is ignored.

For instance, looking at the failure of a beer conveyor estop switch in a closed condition, we would write: "In the event the beer conveyor estop was to fail in a closed condition, it would not shut down the system when pressed. This failure could result in serious injury to company personnel."

SIXTH REQUIREMENT - Events required to bring the process back to normal operating condition

This is the easiest step in listing failure effect statements. We simply want to identify what we want our operator to do should this failure occur. In most cases, we enter the phrase, "the operator will shut down the equipment and contact maintenance to troubleshoot and repair". There are, however, cases where the resulting phrase would be different. As an example, if we were discussing the failure of a pumping system that had primary and backup pumps that did not activate automatically on failure, we would then say the operator would lockout the primary pump and start the backup.

Finishing Out Failure Effects

As we finish completing the failure effect statements, the RCM facilitator will now ask two quick questions to complete the effects information:

1. What is the frequency of this failure mode?
2. How much downtime will result from this failure mode?

The question of frequency addresses the estimated occurrence of this specific failure mode for the component we are discussing pertaining only to the asset on which we are performing the analysis. This information is used to remind the RCM team how often we experience this failure prior to making task decisions.

The question of downtime delivers a key piece of information for consequence decisions that are not HSE related. Knowing the equipment downtime informs the team of the operational consequences of each specific failure mode. Note that, as the facilitator, this question should be directed at the equipment operators as they have the best perspective of what downtime is.

TARGETED RCM DECISION PROCESS

The Targeted RCM decision diagram is a flow diagram used to lead the RCM team to the best decision for mitigating the consequences for each failure mode addressed in the RCM analysis as seen in figure 4 on next page.

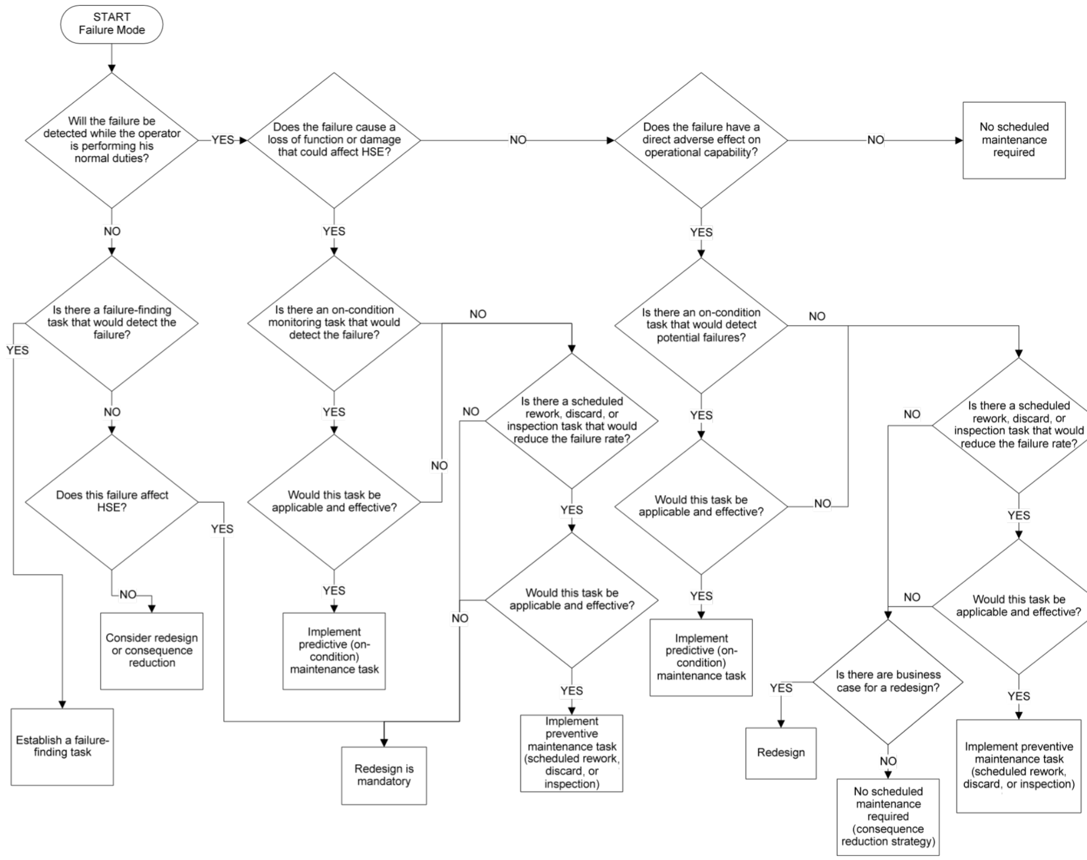


Figure 4: Targeted RCM Decision Diagram

The first question in the decision process is: "Will the failure be detected by the operating crew as they perform their normal duties?"

While this question may sound simple enough, the question often needs to be explained. We are looking to determine right off the bat if this failure is hidden or evident. As we look at the word "failure", inform the team that we are really discussing functional failure here. If we were discussing the failure mode of a bearing seizing due to misalignment, many operators would never know that it was a bearing that seized, let alone what caused the failure. However, when the bearing seizes, the motor overloads and shuts down. Once the machine shuts down, the operator then gets a motor overload alarm. The process has stopped and there was an alarm; both things are evident.

When we refer to the operating crew in this question, we mean anyone who works with or around this equipment. That could be an equipment operator, a maintenance mechanic, an engineer, or a manager.

So, when is a failure not evident?

Hidden failures are not evident; they allow your equipment to run perfectly during normal operating conditions when the hidden function component is in a failed state. For example, if you have an estop button on your equipment, the estop could be failed in a state where if pressed to stop the machine, nothing happens. The machine would continue to run because the estop was in a failed state, but it was not evident.

Once the RCM team has made the decision that a failure is not evident, the diagram then leads to the question, "Is there a failurefinding task that would detect the failure?"

The question is not referring to "right now, this moment". Rather, we need to know if there is some (failurefinding) task we can do on a scheduled basis to detect failures that have already occurred but are not evident to the operating crew. In other words, is there any way to test the functionality of this device on a scheduled basis to see if it still works properly?

Answering yes to the failurefinding task question leads to the question, "Is this task applicable and effective?" This is the most common question in the Targeted RCM decision diagram. The intent of the applicable and effective question is to double check that the team is selecting the best task to mitigate the failure mode being discussed. In terms of failure finding tasks, applicable and effective mean the following:

- Applicable – The task selected will clearly detect that the component is in a failed state.
- Effective – The task selected is cost effective and will produce a consistent result using a concise job plan.

Answering yes to whether a task is applicable and effective leads to implementing the failurefinding task; answering no leads to the last question in the hidden failure leg of the decision tree: "Does the failure impact health, safety, or environment?" Answering yes to this question means redesign is mandatory, making clear that any hidden failure that affects HSE and cannot be addressed through a failurefinding task must be resolved through redesign.

HEALTH, SAFETY, AND ENVIRONMENTAL DECISIONS

Going back to the start of the decision diagram, we begin to address each failure mode with the question, "Will the failure be detected by the operating crew as they perform their normal duties?" Answering yes to this question leads us to the first question in the HSE leg of the decision diagram, "Does the failure cause a loss of function that could affect health, safety, or environment?"

Going into some detail on this question, there are some hard and fast rules when it comes to HSE failure modes:

1. Never argue about the word "could". If someone on the team says the failure mode could have HSE consequences, we will go down the HSE leg of the decision tree.
2. Never allow the RCM team to set standards to define HSE. A spill is a spill regardless if it is 1 drop or 1,000 gallons. A specific safety hazard could be a near miss one day and the next day it could blind someone.

Addressing failure modes in the HSE leg of the decision diagram is the fail-safe way to address potential problems.

Answering yes to the previous question leads to the question, "Is there an on-condition task that would detect potential failure?"

In order to answer yes to this question and have the task be both applicable and effective, the task must be able to detect a specific condition (i.e. vibration) with an explicit task (i.e. vibration analysis) at a reasonably consistent P-F interval. This task must also reduce the risk of failure to a tolerable level and be cost effective.

If there is not an applicable or effective on-condition task, we then ask, "Is there a scheduled rework, discard, or inspection task that would reduce the failure rate?"

To answer yes to the PM task question, an applicable mitigating task must identify a consistent age at which the conditional probability of failure rapidly increases and show that ALL failures occur after this age. To be effective, the task must reduce the rate of failure to a tolerable level and be cost effective in doing so.

In the event the team does not select an on-condition or PM task, the decision process proceeds to the statement that redesign is mandatory. The failure mode must be eliminated.

OPERATIONAL DECISIONS

Should the RCM team answer no to the question regarding HSE, the diagram then leads to the operational leg of the decision tree and asks the question, "Does the failure have a direct adverse effect on operational capability?"

The operational leg of the decision tree asks a series of questions designed to mitigate failure modes that affect the scheduled operating use of equipment. Every failure mode that costs money has an impact on operational consequences.

Operational consequences include the following:

1. Cost of lost production
2. Cost of waste
3. Cost of replacement parts
4. Cost of maintenance
5. Inefficient use of operating equipment (energy waste)

Answering yes to the operational consequence question leads again to the question, "Is there an on-condition task that would detect potential failures?" Again, for the on-condition task to be considered applicable and effective, it must be able to detect a specific condition (i.e. vibration) with an explicit task (i.e. vibration analysis) at a reasonably consistent P-F interval. This task must also reduce the risk of failure to a tolerable level and be cost effective.

If there is not an applicable or effective on-condition task, we then ask the question; "Is there a scheduled rework, discard, or inspection task that would reduce the failure rate?"

To answer yes to the PM task, an applicable mitigating task must identify a consistent age at which the conditional probability of failure rapidly increases and show that only a tolerable number of failures occur after this age. To be effective, the task must reduce the rate of failure to a tolerable level and be cost effective in doing so.

In the event there is not an applicable or effective on-condition or PM task, the diagram then asks, "Is there a business case for redesign?" For a redesign to be considered applicable or effective, it must do one of the following:

1. Reduce the conditional probability of failure to an acceptable level.
2. Eliminate the failure using the words and/or.
3. Change the failure of this item from hidden to evident.

In the event there is not a business case for redesign, the decision diagram then leads to a "No scheduled maintenance required, consequence reduction task" decision. No failure mode should ever lead to deciding to-do-nothing regarding mitigating the failure. As a result, we should always consider what can be done to reduce the Mean Time to Restore (MTTR) for each failure mode, and this is the intent of the consequence reduction task. For every RTF or No Scheduled Maintenance decision, there are several things we should consider reducing the consequences of the failure, such as:

1. Spare Parts – If we are considering running this component to failure, it may be a good idea to have this part stocked on site or with a vendor who can deliver the part in an acceptable period. The Targeted RCM Spare Parts decision diagram is a flow diagram used to lead the RCM team to the best decision for managing spare parts requirements addressed in the RCM analysis as seen in figure 5.

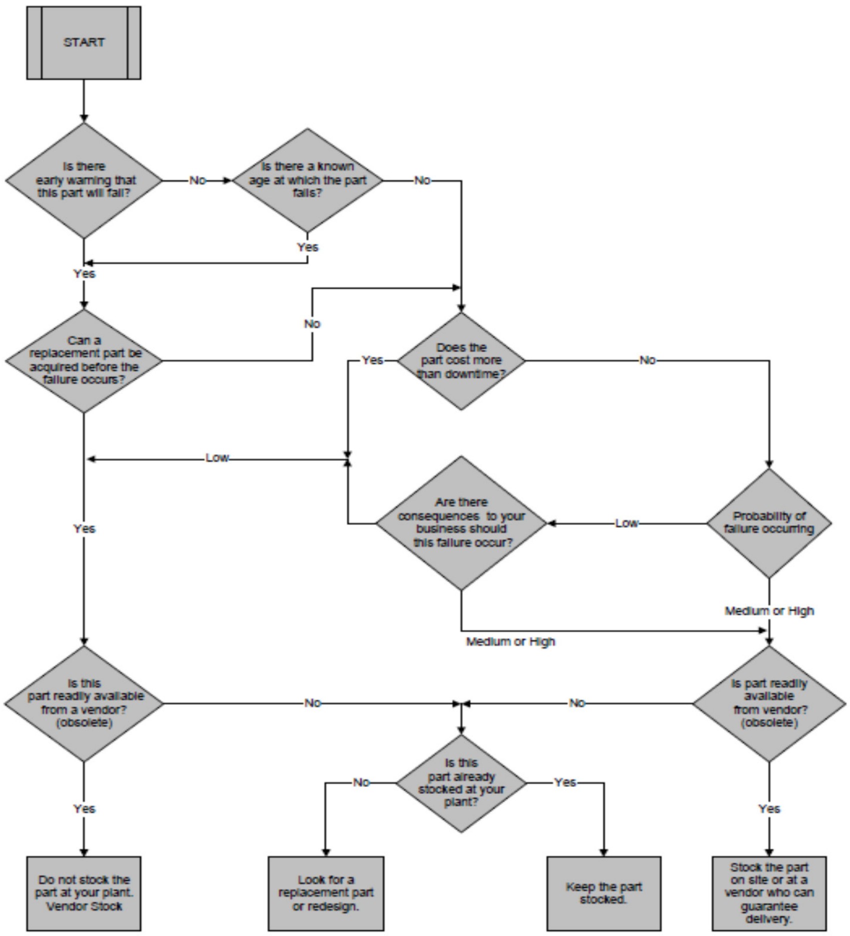


Figure 5: Targeted RCM Decision Diagram

2. Job Plans – A well-written job plan that includes lockout/tagout, tools needed, and a clear step-bystep plan to facilitate replacement, including who is responsible for getting parts while the failed part is removed. This plan will go a long way in reducing downtime for your critical asset while the repair or replacement task is performed.

3. Bypass Permit – When acceptable, it may be possible to safely bypass the component until repair/replacement can be scheduled.

The diagram below (fig. 6) represents some of the many individual steps that take place for each emergency or demand failure at a plant.

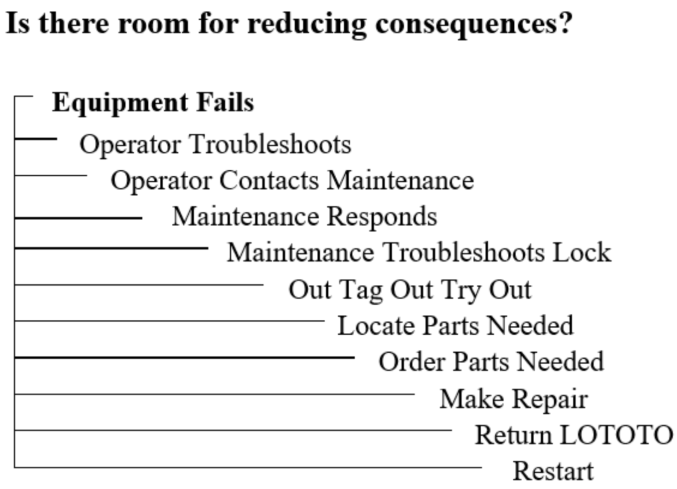


Figure 6: Reducing Consequences of Emergency Failure

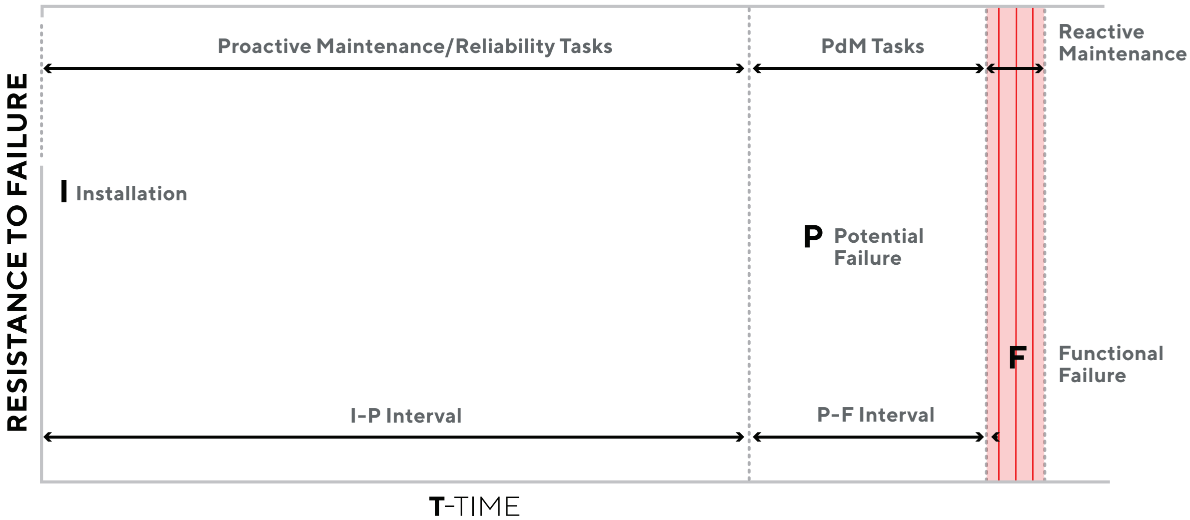
MAKING SOUND RCM DECISIONS

As we performed Targeted RCM analyses of several assets at our clients' facilities, it became clear why some were not having the success they had expected from their PdM program. In working with their PdM service provider to set up their PdM program, they had simply generated a list of assets for each specific technology. The list generated for critical assets set up PdM routes and intervals for each asset based on the provider's recommendations. In most cases, Vibration Analysis and Airborne Ultrasonic tasks were performed monthly, Thermographic inspections were set up on a quarterly basis, and Motor Current Analysis was performed every six months. Not one single PdM inspection detailed the failure modes that the tasks were looking to detect. While they all understood the P-F curve and the P-F interval, they failed to understand or determine why the assets were failing over-and-over again.

While the technologies our client had invested in were successfully detecting failures, our client had never asked the service provider why some assets continued to fail over-and-over again. This is where the addition to the P-F curve comes in. Note the difference in the P-F curve shown in figure 7. Starting at the far left (point I - Installation) and moving right, we have a very long flat line going between point I and point P (Potential Failure). This is what we call the I-P interval,

which represents the time it takes to move from the point of Installation to the point where Potential Failure is first detected. The objective of all world class maintenance and reliability organizations should be to work to maximize the I-P interval. This can only be achieved through a thorough understanding of your assets, proactive maintenance techniques, and reliability tools. In viewing the P-F curve in this manner, it became clear to our client that a large percentage of the failure modes they were detecting through the use of predictive technologies could in fact be identified and eliminated using RCM and proactive maintenance techniques.

COMPLETING THE P-F CURVE



The Modified P-F Curve and I-P Interval are intellectual property of Reliability Solutions, Inc. (Patent Pending)

Figure 7: The Modified PF Curve

As an example, one of the failures our client was seeing over-and-over again was on a blower that was mounted to an undersized foundation. Each time they replaced the blower, they used precision alignment to ensure the blower and motor sheaves were properly aligned. Without proper foundational support, continued stopping and starting of the blower over time resulted in misalignment and degradation of the blower and motor bearings. In performing the Targeted RCM analysis of this asset, we listed all the probable failure modes for the blower and determined that the blower base and foundation would need redesign to eliminate the failure mode. The result: a blower that had failed three times in eighteen months has not failed in over four years.

In completing the P-F curve, we have identified several proactive maintenance techniques and reliability tools that can be used to extend the I-P interval. These tools and techniques include:

- RCM
- FMEA
- Design Targeted RCM
- Five Rights of Reliability
- Select Supplier Agreements
- Requirements Documents
- Design Standards
- Precision Alignment
- Precision Balancing
- Installation Standards
- Torque Specifications
- Precision Tools

THE VALUE OF UNDERSTANDING THE MODIFIED P-F CURVE

While many companies and maintenance organizations around the world have seen the value of understanding the original P-F curve, it is important to also understand the additional value provided by our Modified P-F Curve. Start at the far-right end of the P-F curve, at the point of complete failure (where the P-F curve contacts the x-axis). Moving from there back to the left and up to point F (Functional Failure), this interval between Functional Failure and Failure is the interval where reactive maintenance takes place. It is the area of time where a piece of rotating equipment starts smoking, shaking, stinking, and squealing. As a result, we quickly send someone out to shut the asset down so that it can be replaced. Performing maintenance in this area is costly and minimizes maintenance effectiveness to less than ten percent.

Moving back to the left and up from point F, we encounter point P. This is the well-known P-F interval, the time frame where PdM is employed. The value of performing maintenance here is that we can detect failures in the process of occurring, then plan and schedule repair or replacement to minimize equipment damage and reduce operations downtime. Performing maintenance in the P-F interval provides a cost benefit that increases maintenance effectiveness to as high as 50%.

Finally, we move left on the P-F curve from point P (Potential Failure) back to point I (Installation). The I-P interval is the time frame from installation (I) to potential failure (P); this interval should take years to elapse, provided the correct proactive reliability tools are employed and precision maintenance techniques and tools are used at installation.

Performing these proactive maintenance techniques will provide a cost benefit that increases maintenance effectiveness to 100%!

To reach this level of effectiveness, it is necessary to understand how proactive maintenance techniques and reliability tools can increase the I-P interval of assets.

UNDERSTANDING PROACTIVE MAINTENANCE TECHNIQUES AND RELIABILITY TOOLS

While it would take a full textbook to be able to completely explain the value of each proactive maintenance technique and reliability tool, each is listed here with a summary of how they can extend the I-P interval.

Reliability Centered Maintenance

As discussed, RCM is a reliability tool that uses a structured team approach to analyze a process or piece of equipment. In performing an RCM analysis, your team will assess all likely failure modes for the asset and develop a maintenance strategy to mitigate the consequences for each failure mode. The value in performing RCM is the proactive assessment of these failure modes and the resulting tasks developed to eliminate reoccurring failures.

Failure Modes and Effects Analysis (FMEA)

Like RCM, FMEA is a reliability tool used in the design phase to identify likely failure modes. In performing FMEA your design team will discuss these failure modes and attempt to design out failure modes that result from poor design and installation decisions.

The Five Rights of Reliability

Design it right, purchase it right, build it right, operate it right, and maintain it right. This produces an overall reliability program focused on educating employees at all levels and organizations on the importance of reliability. The five rights of reliability develop a reliability plan across engineering, purchasing, construction, operations, and maintenance that clearly describes how each business unit can improve reliability.

Select Supplier Agreements

Often a part of your reliability plan, select supplier agreements should be made consulting engineering, operations, maintenance, and purchasing. These agreements should be developed using the company's reliability data while working with suppliers to provide the most robust and reliable assets. Inferior parts or components are a common cause for reoccurring failures.

Requirements Documents

If this is not part of a company's capital design and engineering program, it needs to be. Requirements documents are binding agreements written to ensure the highest level of reliability in design and installation. As an example, many companies now have requirements documents written for the acceptable level of vibration on startup of new rotating equipment. The document will clearly state what that acceptable measure will be, and the resulting action taken if the requirement is not achieved. Again, the intent of these documents is to eliminate failure modes inherent to poor design or installation practices.

Design Standards

Company design standards should always be used as a tool to improve equipment reliability. Used in combination with select suppliers and requirements documents, design standards will help your company ensure all new installations are safe and reliable. Some examples of design standards that will eliminate reoccurring failure modes include standard mass requirements for pump foundations, standards requirements for piping supports, and standards for starter panel installations.

Precision Alignment and Balancing

Precision maintenance tools are known for increasing the life of rotating equipment. While these tools have been available for several years, few of us have taken advantage of their use. Precision alignment and balancing will both dramatically reduce vibration that results in reoccurring failures of bearings, seals, and couplings.

Installation Standards

Used for both new installation and maintenance, these standards are put in place to ensure proper craft skills are used when working on equipment/assets. Some examples of installation standards would be the identification of the proper type and grade of flange hardware and gasket material. Developing installation standards eliminates reoccurring failures such as leaks caused by using incorrect gasket material.

Torque Specifications

While almost everyone working in maintenance knows what a torque wrench is and what torque specifications are, they are seldom used. Leaking connections, loose rotating equipment, and sight glass failure are often the result of improper torque. While using a torque wrench and following the specifications may take more time, the resulting reliability will increase the IP interval.

Precision Tools

To ensure proper maintenance and installation practices, personnel need precision tools to do the work. It is easy to quickly assess the level of understanding concerning reliability with a quick look in the toolboxes of the company's maintenance people. Hammers, channel-locks, pry bars, and screwdrivers alone will begin to ensure reliability. Precision work requires precision tools, and if the maintenance personnel do not have these tools, do not expect results to improve.

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Understanding how critical asset failures impact the environment, production, financials, and safety enables us to deliver the right monitoring, analytics, decision making and maintenance plans.

We bring unique asset management content along with best practices, advanced tools, and proven methodologies to help customers move forward in their Digital Transformation journey to deliver enhanced performance.

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- PM Evaluation
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