Assessing Your Reliability Programs

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By

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Introduction

If you were to look at almost any characteristic of a complex asset and try to determine how that characteristic came to exist, you would soon conclude that the characteristic was the result of some conscious effort. Reliability is a characteristic like many others that requires conscious effort to achieve. Unlike many other characteristics, reliability is a characteristic that many individuals tend to take for granted. They assume that reliability is a characteristic that is an inherent result of other efforts. For instance:

- While designing an asset, reliability will be considered in the design.
- When repairing an asset, the repair will be done in a manner that restores reliability.
- When modifying an asset, the design of the modification will automatically consider reliability and either maintain or improve it.

While in some situations reliability may be viewed as a critical part of the conscious effort involved in the design process, many other situations exist where individuals responsible for the design are not aware of the techniques or controls needed to properly address reliability. For instance, ask yourself how many design processes actually incorporate Design for Reliability as an element of the design process. Or, consider a typical maintenance or repair task. How often is it made certain that the task ensures that the Inherent Reliability has been completely restored? Or in making some form of modification, what steps have been taken to ensure that the modified asset is as reliable as or more reliable than the original asset.

If the reliability of the current asset (based on configuration and component selection) has never been determined, it is impossible to say with absolute certainty if a modified configuration will be equal or greater. Occasionally, some “rules of thumb” like the practice of replacing unspared equipment with redundant equipment might allow one to assume that reliability will be improved. On the other hand if one highly reliability item of equipment is replaced with two marginal equipment items, the change to a redundant arrangement may not result in an improvement.

The above examples tend to focus on only three key points in time during the entire life-cycle of an asset. In fact, specific activities are needed during each and every phase during the life of an asset to ensure that inherent reliability is maintained and that the full inherent reliability is being harvested from that asset.

It is possible to create an unreliable asset. That asset will deliver poor reliability for its entire life-cycle. It is also possible to create a reliable asset but then operate and/or maintain it in a manner that delivers only a portion of the inherent reliability for some or all of its life.

The processes and practices used by a specific company or a specific plant may integrate some activities needed to create reliable assets. The processes and practices may also include activities needed to harvest the inherent reliability of the asset. They may also do one and fail to do the other. In the case where resources are expended on one and not the other, the spent resources will be wasted, at least in part. Also, the reliability expectations of the asset owner will not be met.

Unlike an owner who spends nothing on any activity needed to deliver reliable performance and, in turn expects little or nothing in return, the owner who spends a great deal but does not cover all the critical elements will be sad and confused. The owner who makes a costly but incomplete effort will look at the cost and resources that have been spent and wonder why he is not receiving the expected results.

This course is intended to help the student understand all the elements needed to deliver solid reliability performance and how to evaluate the effectiveness of those elements in any situation. It is useful to think of the objective of a reliability assessment as a determination of "What you have a right to expect?" The assessment asks two questions:

1. Does each of the critical elements of a comprehensive reliability program exist?
2. If they do exist, are they effective in delivering the required results?

What you have a right to expect

There is an old saying, "Expect what you inspect". The wisdom of this saying is applicable to the overall philosophy being highlighted in this course. In other words, you should expect positive results only from those aspects where you have invested effort. If, for instance, you have failed to integrate reliability considerations into the design of your assets, it is unlikely that the inherent reliability of that asset will be robust. It is possible that the robustness of the design required for other purposes (e.g. structural integrity) will introduce some accompanying level of reliability, but that is more a matter of good fortune than conscious intent.

As another example, it is possible that repairs designed to restore functionality of a failed asset will also restore the inherent reliability. But that is not automatic. It is frequently possible to restore functionality while leaving the asset "good as old". If the process of addressing a failure is intended to restore the inherent reliability, it must also identify and replace the component containing the defect. And, it must do so with a component of equal or superior robustness as the original component.

In the two examples described above, there are two elements important to achieving the desired results. The first is specification and the second is enforcement. The first element demands that the processes used throughout the lifecycle of an asset are specified and designed in a manner that will deliver a reliable asset. The second is that the processes are enforced in a manner that ensures they deliver the intended results. Simply specifying or designing a process is not sufficient. It is necessary that effort be invested into seeing that the processes always produce the desired results.

There is another saying that "Your systems are perfectly designed to deliver the results you are getting". In this case, your systems are the organization, processes and discipline being used at your facility. If those systems have been designed and are applied with reliability in mind, it is more likely your assets will perform in a reliable manner. On the other hand, if reliability is not a continual focus of your systems, the reliability your assets will experience is a matter of luck.

The basis for realistic expectations

The following are the phases during the lifecycle of an asset in which reliability must be considered:

- Purchase or Build for Reliability
  - The first phase in the life of an asset is the acquisition phase during which it is either designed and built, or when it is purchased. During this phase, the most certain way to ensure that reliability is being adequately considered is by applying techniques that exist in the process known as Design for Reliability (DFR). The DFR techniques ensure that the reliability of the resulting asset has been determined as a part of the design. DFR will help decide the configuration and component selection. Post assembly steps like HALT and HASS testing will help ensure that the required reliability has been delivered.

- Operate for Reliability
  - An asset can be operated in a manner that harvests the full inherent reliability or in a manner that results in harm and reduced reliability. When operators are unaware of the actions that either do harm or avoid doing harm, the results of their acts are a matter of luck rather than intent and control. A program designed to ensure an asset is operated in a manner that delivers the full inherent reliability begins with training operators on how equipment functions and, as a part of normal and abnormal functions, how their actions can cause harm or conversely extend the useful life. Since few operating organizations are structured to allow individual operators to structure operating schemes in a manner that will affect operation at all times round-the-clock, it is typically best if the operating scheme (operating rounds and activities) are structured be someone who can affect all operators and all times. Operating management with the help of reliability engineering can structure rounds and operator activities in a way that ensures a positive interaction between operators and the equipment they operate.

- Inspect for Reliability
  - Present in nature are a variety of Failure Mechanisms (like corrosion, erosion and fatigue) that tend to deteriorate components and result in failures. Man has created devices and techniques for halting the adverse effects of those Failure Mechanisms. For instance coatings and cathodic protection are tools used to prevent corrosion. Supports and brackets frequently prevent the vibrations that

are likely to result in fatigue. Filtration and lubricant changes are applied to remove the abrasive materials that can cause erosion. The objective of performing inspections is to ensure the controls intended to eliminate deterioration due to known Failure Mechanisms are in-place and effective. Inspection can identify Failure Mechanisms for which no current controls exist. When found, techniques for controlling new Failure Mechanisms can be installed to avoid deterioration. Keep in mind that the Failure Mechanisms are nature's tools for driving deterioration. For mechanical devices, Failure Mechanisms include corrosion, erosion, fatigue and overload. For electronic devices, there are all the mechanical Failure Mechanisms (because most electrical and electronic devices have mechanical characteristics subject to the same forms of deterioration as mechanical devices) and several additional Failure Mechanisms exclusive to electronic and electrical devices. These electronic Failure Mechanisms include: Insulation breakdown due to chemical or UV attack, Insulation breakdown due to overheating, Overload due to stall, and Overload due to supply transient, the electrical equivalent of fatigue (occasional operation at conditions beyond design capabilities).

  - If Failure Mechanisms are allowed to continue unabated, they will ultimately produce a defect. A defect is a flaw in a component that is unable to survive the system operation at its most severe conditions. If the system is not operating at its most severe conditions when a defect forms, the system will continue to operate until the loading is sufficient to drive the defect to failure. Think of a small crack in a pipe that is operating at a normal operating pressure that is only half of peak pressure. The pipe with the small crack can survive until the pressure increases to the level that the flawed pipe cannot no longer sustain. In situations where defects have occurred in the past and are expected to occur in the future, the inspection program should be designed to identify defects before they produce failures.

- Maintain for Reliability
  - The primary objective of maintenance is to restore the Inherent Reliability of an asset. This means that when a repair is complete, the defects must be removed. Another way to say it is that rather than simply restoring the functionality, a repair must leave the asset "good as new". While this requirement is most apparent in situations where a defect has resulted in a system failure and the maintenance being performed is reactive maintenance, the same philosophy applies to proactive maintenance. Proactive Maintenance consists of two forms of maintenance, Predictive and Preventive. Predictive Maintenance is a non-invasive activity aimed at identifying current condition and deterioration well in advance of a failure. When Predictive Maintenance identifies a level of deterioration that suggests that a component is unable to survive until the next inspection, Preventive Maintenance is triggered. Preventive Maintenance is invasive maintenance that replaces the defective component. The objective of both Reactive Maintenance (repair) and both forms or Proactive Maintenance

(prevention) is to ensure the Inherent Reliability of the system is being preserved at all times.

- Repair for Reliability
    - Repairs are similar to Reactive Maintenance described above. In some cases, repairs go beyond simply replacing a single defective component. In some cases, numerous components need to be replaced or restored to "good as new" conditions. Since the reliability of a device is determined based on the Mean Time between Failures, the repairs must be made in a manner that ensures the device has an adequate expected MTBF. To accomplish this, you must understand both the expected deterioration rate and the deterioration allowance for each component of the equipment item. The deterioration rate is the rate at which critical clearances deteriorate in rotating equipment and at which metal thickness deteriorates in pressure retaining equipment. The deterioration allowance is the amount of deterioration that can occur before an equipment item can no longer perform its function. If the deterioration rate is so great that the deterioration allowance is consumed before the intended MTBF, the repair will not achieve the desired MTBF or reliability. It is critical that the deterioration allowance is capable of surviving the expected deterioration rate for the entire desired MTBF.
    - Assume that "as-found" and "as-left" conditions are recorded every time a piece of equipment is disassembled for repair and every time it is reassembled from a repair. Also assume that critical tolerances, fits, clearances and thicknesses of pressure retaining surfaces are recorded on each of those occasions. Then it is possible to make the following calculations:

      Deterioration = "As-found" condition minus "As-left" condition

      Deterioration Rate = Deterioration divided by time interval between readings

      Deterioration Allowance = Current thickness minus minimum thickness required

      Maximum Run-Length = Deterioration allowance divided by Deterioration Rate

      If the Maximum Run-length is less than the MTBF that is the objective for the equipment item, it will be necessary to take steps to increase the Deterioration Allowance or to decrease the Deterioration Rate. There are several approaches that can be used:
        1. Replace the component with new.
        2. Increase the Deterioration Allowance with some form of build-up material.
        3. Replace the component with a material with a lower Deterioration Rate.

- Modify for Reliability
  - While many assets go through their entire lives without modification, many other assets experience a significant transformation at some point during their useful life. All too often, designs for modifications are focused exclusively on the sole objective of the modification. For instance, a modification may focus solely on the actions needed to increase a plant's capacity. When this approach is used, it is possible that the reliability will suffer. Some obvious examples are when redundant equipment is used to provide the capacity increase leaving the system with no redundancy in critical locations. Another example is when system capacities are pushed to limits beyond which they were designed. In those cases, the deterioration rates might increase, thus decreasing the MTBF and ultimately reducing the reliability of the system. When modifications are done, they should be designed using the same DFR processes as recommended for new assets.

- Renew for Reliability
  - The renewal step is something that few individuals consider as their assets age. Aging introduces a variety of conditions not considered in day-to-day operation or maintenance. One example is creep in furnace or boiler tubes. After long years of use, hanging furnace or boiler tubes will slowly extend in length and, in doing so; reduce the wall thickness of tubes. Long-term fatigue is another form of deterioration that is easy to overlook. Frequently components can withstand billions of fatigue cycles before fatigue cracks form. On some occasions it might take thirty or forty years to accumulate the required number of fatigue cycles to produce cracking. While it takes a long time, it still happens. While the most visible cases where long-term fatigue has occurred is in the external skins of commercial aircraft, the form of deterioration exists in all components experiencing cycles of alternating tension and compression at levels above the fatigue limit. It is critical that renewal plans include tasks to replace components nearing the end of their fatigue life despite the fact they are not currently displaying cracks.

The Reliability Gap – The difference between your Requirements and your Programs

Even if they are not clearly articulated, most individuals and most business entities have some expectations for the reliability of their assets. When those expectations are not clearly articulated, there is a lower likelihood of them being met. Even when clearly articulated, unless specific programs are in place to deliver the stated requirements, it is unlikely that the desired performance will be achieved.

The term used to describe the difference between expectations and actual performance is the "gap". If reliability expectations are clearly articulated and all the programs are in place to deliver the required performance, measuring the "gap" is a simple exercise of comparing the stated requirements to the actual performance.

In most cases, things are not so simple. In those cases, the desired performance has not been clearly articulated and the programs needed to deliver that performance are missing in whole or in part. In these more common case, measuring the gap begins with an exercise of determining the requirements. Once requirements are defined, the next step is determining which reliability programs currently exist in some form. Finally, it is necessary to determine how effective the current reliability programs are.

While this second form of "gap analysis" are not as fulfilling as the first, it is far more revealing. The second form of gap analysis reveals why you are not achieving the desired level of reliability and what steps must be taken to correct the situation.

Articulating Reliability Objectives

While it is relatively simple to identify the characteristics used in stating reliability objectives, it is less simple to identify the programs and activities needed to deliver those objectives. It is even less easy to identify if your current programs and activities are sufficiently effective to deliver the objectives as stated.

Let's begin by identifying the high level objectives.

High level goals are stated most simply using the terms:

- Reliability
- Availability
- Maintainability

Reliability is defined as the likelihood a device will survive without failure for a specific interval of time. This definition results in reliability being quantified in several different ways. Mean Time between Failure (MTBF) is a common way to quantify reliability of a device or equipment item. Failure Rate of the number of failures in a specific interval of time is another approach. Obviously, these terms are the inverse of each other. Another useful term is the usable life of a component. For devices that are discarded at the end of their life, this term is the same as MTBF.

While the analysis of reliability begins at the component level, it grows upward to the equipment level (where an equipment item is a combination of a number of components) and the system level (where the system consists of a number of equipment items or devices). There are a number of tools like the Reliability Block Diagram (RDB) techniques used in calculating or modeling the composite reliability of systems. Using RBD, owners can determine if a system is likely to be able to meet his requirements while still in the design stage.

A complete understanding of reliability requires that reliability at each of the levels described above be tracked and evaluated.

Well-articulated objectives will identify the desired reliability performance for each of the levels described above. While the asset-level has the greatest impact of profitability and other corporate objectives, it will be impossible to achieve asset level objectives unless equipment level objectives and component level objectives are clearly understood, articulated and measured.

Availability is defined as the portion of time an asset is able to perform its intended function. There are two forms of unavailability: Planned unavailability and Unplanned availability. Planned unavailability is the time an asset is unable to perform its intended function because of known maintenance activities. Unplanned unavailability is the time an asset is unable to perform its intended function because of unplanned failures resulting from poor reliability.

Planned availability is determined by two factors. The first factor affecting planned availability is the length of time the asset can operate before needing to be taken out of service to address some run-limiting element. For simplicity, these run-limiting elements are called "Run-Limiters". The second factor affecting planned unavailability is the duration the asset must be out of service when taken down for planned outages. Again, for simplicity, the elements that determine the duration of a planned outage are called a "Duration Setter". The "Duration Setter" is the element or elements that determine the minimum or "critical path" duration of the planned outage.

Unplanned availability is also determined by two factors. The first factor is the number of failures resulting in unplanned outages. This is simply the reliability as was described above. The second factor determining the unplanned availability is the capacity to recover once an unplanned failure occurs.

The ability to recover from unplanned failures is, in turn, determined by two factors. The first factor determining the ability to recover is the maintainability of the asset. Asset maintainability will be described further in the next few paragraphs. The second factor determining the ability of an asset to recover is the capabilities of the organization that is responsible for the recovery. An organization's ability to ensure expedient and effective recoveries is enhanced by tools like remote diagnostics, directed troubleshooting and failure mapping.

Availability objectives are typically articulated and monitored at the asset level. For assets that produce goods, the total capacity is determined by the thru-put or production rate of the asset and the asset availability. The effective capacity of an asset is determined by the following equation:

Effective Capacity = Nameplate capacity times Asset availability

For instance, if the nameplate capacity of a production unit is 1,000,000 pounds of product per year, the planned unavailability is 10% and the unplanned unavailability is 10%, the effective capacity will be as follows:

Effective Capacity = 1,000,000 #/yr. times (100% - 10% - 10%) = 800,000 #/yr.

As a result, asset owners must clearly articulate the required asset availability to determine the actual production rate and basis for profitability.

While availability can be monitored and tracked at the asset level, it is important to track the causes of unavailability at the equipment or component level. Specific items that chronically cause unavailability can justify significant investments to ensure improved performance.

Maintainability is defined as a measure of the ability to restore the Inherent Reliability of an asset in a ratable (or pre-determined and repeatable) period of time. Restoring the Inherent Reliability of an asset is an objective for both Proactive and Reactive maintenance. In order to restore the Inherent Reliability of an asset, it is necessary that defects and deterioration leading to failure causing defects be found and removed during the maintenance task. In effect, the asset should be "good as new" at the conclusion of the maintenance.

A proactive or reactive maintenance task is ratable only when it can be done in a "certain" amount of time with "certain" results. If a task requires the mechanic to "stand on his head", perform work that he cannot see or perform in conditions that cause "hit-or-miss" results, the time required for the task is not ratable.

For an asset to be "maintainable" all the tasks needed to maintain it over its entire life must be done in a manner that has "certain" results and "certain" duration. Viewing this requirement from an auditor's viewpoint, in order to be truly maintainable, the following characteristics are required:

1. All the tasks required over the life of the asset must be identified.
2. All the identified tasks must be converted to discrete steps and the steps evaluated.
3. Each step must have "certain results'.
4. Each step must have "certain" duration.
5. The overall maintenance task (either Proactive of Reactive) must restore the Inherent Reliability.

While maintainability cannot be directly measured as with reliability and availability, the effects of poor maintainability can and should be measured:

- Tasks that are not completed as scheduled should be reviewed. Was it impossible for them to be completed in a ratable manner? Or was it possible for them to be completed in a ratable manner and the individual performing the task failed to do so?
- Tasks that result in repeat failures should be reviewed. Was the Inherent Reliability associated with the known defect restored?
- Tasks that do not provide the desired MTBF should be reviewed. Was the Inherent Reliability relative to all known Failure Modes restored?

Assessing the Elements of Reliability

As mentioned at the beginning of the previous section, assessing your ability to achieve your stated reliability objectives involves two levels of evaluation:

First, you must have the programs that are designed to deliver your stated objectives. Second, your programs must be effective. Assessing the first characteristic requires a review of the programs and processes currently installed at your plant or enterprise. Assessing the second characteristic is more abstract. Assessing the second characteristic requires determining if your employees are performing those programs and processes in a manner that delivers the desired results.

For instance, to deliver assets with the desired level of Inherent Reliability, it is necessary that the design process being used during the development of a new asset include the Design for Reliability process. It would be possible to apply a DFR process during the design of a new asset, but do it in a manner that does not deliver the desired results. The DFR process could be done too late in the design process to have an affect on configuration design or component selection. Or it might be possible that current procedures result in components being selected solely on the basis of first cost rather than the Lifecycle Costs including the costs of failures throughout the life of the asset.

While it is beyond the intent of this short course to either be prescriptive as to specifically which form of program must be used during each phase in the life of an asset or to describe the entire array of programs that are available for each phase, it suffices to say that the asset owner must have an effective program for addressing reliability needs during each phase of asset life.

As mentioned above, a specific program must be in place to address reliability needs during each of the following phases during the life of an asset:

- Asset Design
- Asset Operation
- Asset Inspection
- Asset Maintenance
- Asset Repair
- Asset Modification
- Asset Renewal

While the specifics of the programs used during each phase of the life of an asset can vary, it is critical that the design of each program be consistent with the specific needs of that life-phase. For example:

- Asset Design – must deliver an asset with the desired Inherent Reliability. The asset must be capable of the required Availability. The asset must be Maintainable.
- Asset Operation – must be completed in a manner that does no harm and, if possible, extends the useful life of the asset.

- Asset Inspection – must be designed in a manner that acknowledges the Failure Mechanisms that exist for the asset in its current operating environment and focuses on past and future likely Failure Modes.
- Asset Maintenance – must restore the inherent reliability and do it in a ratable manner.
- Asset Repair – Must restore the inherent reliability in a ratable manner and must provide an asset capable of surviving for the desired MTBF.
- Asset Modification – must account for the same considerations and objectives as did DFR for new asset designs.
- Asset Renewal – must account for long-term forms of deterioration and issues needed to renew the required asset life.

Once it is determined that the appropriate programs are in place, it is necessary to assess the actual behavior of individuals involved in leading and executing those programs and processes. Do they understand the objectives of the processes in which they are involved? Are they taking the steps and performing their role in a manner that will deliver the required results? If not, why? What changes are necessary to deliver the required results?

Here are a few examples:

- Asset Design
  - Is expected reliability actually determined using modeling or calculations during the design process?
  - Does the anticipated reliability meet the owners stated requirements?
  - Are components being purchased that meet performance levels used during the reliability analysis?
  - Have all maintenance tasks needed over the life of the asset been identified?
  - Have maintenance tasks been converted into steps?
  - Can all those steps be completed in a “certain” amount of time and have “certain” results?

- Asset Inspection
  - Have all Failure Mechanisms expected to be found in the ultimate operating environment for the asset been identified?
  - Are there inspection procedures for evaluating the deterioration being caused by each of the expected Failure Mechanisms?
  - What Failure Modes are expected?
  - Do inspection programs look for the deterioration leading up to those Failure Modes or for the defects that result from them?

Each element of a comprehensive reliability program covering the entire life of an asset has a set of questions similar to the ones above. Those questions can be used to assess the actual behaviors of individuals responsible for your reliability program. If their behaviors are consistent with the objectives and required activities of those programs, the programs are likely to be effective. If not, the programs will be ineffective.

Summing things up

Reliability is a characteristic that requires attention and discipline in various ways over the entire life of an asset.

It is not possible to achieve Reliability, Availability and Maintainability by focusing solely on one aspect or characteristic of an asset. One must focus on the characteristics that determine performance in each of these areas.

Performance is the result of:

- Clearly articulating objectives
- Providing programs and processes designed to deliver those objectives
- Ensuring individuals with roles in these programs and processes are behaving in a manner that will deliver the desired results.

A useful approach is to identify the “gaps” between current results and desired results. If gaps in performance exist, it is necessary to look further for gaps in programs and then for gaps in behaviors. Once gaps are eliminated it is likely that the desired performance will be achieved.

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