Reliability Centered Maintenance Project Manager's Guide
a.k.a. - The RCM Scorecard (Expanded)

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Comments, criticisms and suggestions are invited year round at the RCM Scorecard discussion thread at http://www.maintenanceforums.com

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Introduction

This document provides vital tips on timing, avoiding pitfalls leading to potential failure and metrics information for use by anyone contemplating becoming a "champion" of a Reliability Centered Maintenance initiative within their organization.

RCM Project Manager's Guide terminology was developed using the following sources:

- Reliability Centered Maintenance by F. Stanley Nowlan and Howard F. Heap
- RCM: Gateway to World Class Maintenance by A. M. Smith and G. Hinchcliffe
- RCM Overview Workshop at 2004 SMRP Conference
- SMRP Best Practice Metrics document (Draft)
- Overall Equipment Performance by Robert C. Hanson
- Glossary of Reliability and Maintenance Terms by Ten McKenna and Ray Oliverson

Information on readiness and success factors and pitfalls leading to failure of RCM projects was developed from the book titled Advancing Reliability and Maintenance 2nd Edition by Jack R. Nicholas, Jr., P.E. CMRP and R. Keith Young

Definitions for terms and abbreviations used in this document can be found in the Glossary, starting on page 22.

To avoid confusion between terms and phrases used in other contexts within the fields of Maintenance and Reliability (M & R) the following notes are provided.

Note 1: Corrective maintenance in the context of the metrics included in the RCM Scorecard refers to **unplanned (unexpected or reactive)** maintenance to restore the functional capabilities of an asset. It includes repeat maintenance required **because initial attempt(s) at repair were not successful** for any reason. It does not include maintenance that results from preventive or predictive (PM and on condition or condition directed, or PdM) tasks, which can be anticipated, pre-planned and scheduled. Corrective maintenance is a subset of Emergency/Demand Maintenance.

Note 2: Corrective maintenance in the Total Productive Maintenance (TPM) sense refers to actions taken to **modify** the asset to improve its performance. The labor hours and material costs for these improvements (as well as those that improve asset maintainability) should be categorized separately and not be included as part of any metric associated with the RCM Scorecard, unless the recommendation of a design improvement results from RCM analysis on an asset.

Note 3: Maintenance labor hour expenditures described in this document do **not** include those labor hours expended by **operators** who perform PM and PdM tasks as part of their

normal duties, unless the operator position has been created and the number of operating staff personnel was increased exclusively for the purpose of maintenance.

Note 4: In an RCM-based program the analysis process is focused first at the level of functional failures, then at the level of failure modes (ways functional failures occur and their causes) and the tasks that are chosen to mitigate or prevent the failure mode or cause. For purposes of the RCM Scorecard, in order to give all task-related metrics a common base, it is important that **each task be related to a failure mode, not to a component**. This may be difficult to do for old, pre-RCM program tasks and indeed there may be tasks for which no related failure mode is evident, providing one basis (among several) for consideration of whether or not it should be retained in the RCM-based program.

Note 5: All tasks for an RCM-based program must be **applicable and effective**

– An **applicable** task will prevent or mitigate the failure, detect onset of failure or detect a hidden failure. It'll work to assure or restore reliability margin to a tolerable level.
– An **effective** task is the most cost-effective option among the technically feasible, applicable candidate tasks.

Note6. This guide is neutral and silent regarding RCM approaches and analysis techniques employed. Its contents are useable regardless of which approach to RCM you use. A discussion of the various approaches is contained in The Asset Management Handbook 4th Edition pp82-97 edited by John S. Mitchell and printed by Clarion Technical Publishers, Inc., Houston, TX. Prospective RCM project managers should read this before embarking on the decision to conduct an RCM Project.

Consensus on the metrics contained in this document was developed during a workshop attended by over 100 persons conducted 9 March 2005, the day before the RCM Managers Forum Conference in Clearwater Beach, Florida. This event occurred after progressive review and comment on proposed content by RCM-experienced users and practitioners during the period from May 2004 to January 2005 at various conferences and other events and via Internet exchanges of views facilitated by the author and Reliabilityweb.com.

Objectives and Outline of The RCM Project Manager's Guide

Objectives of a Reliability Centered Maintenance Project Manager's Guide are to:

- Provide leaders of RCM initiatives with the knowledge and identification of tools needed to be successful.
- Provide prospective and actual RCM **users, participants and other interested parties** with a tool to help decision making on whether or not to initiate an RCM Project and (given the decision to proceed) determine progress in or demonstrate how successful it is while in progress and was after completion. RCM Project metrics, measures or Key Performance Indicators (KPI's) use data collected:
  - When considering whether or not to conduct an RCM analysis on an asset

  - Prior to performing an analysis, (prior to the RCM Analysis Phase) as a baseline
  - During the RCM project Analysis Phase
  - During and/or after RCM analysis as resulting action items are implemented (RCM Project Implementation Phase)
  - From the point after implementation begins and throughout defined period(s) when benefits are realized. (RCM Project Benefits Phase)
- Provide cognizant **managers, supervisors and/or "champions"** with a tool to help justify an RCM project and to measure progress on a given asset or set of systems during analysis and implementation phases. In addition, it provides a basis for measuring the benefits derived from the overall effort.
- Provide a **basis for comparison** of differing approaches to RCM methodology.

The center-piece of this document provides a "menu" from which a selection of metrics, measures or Key Performance Indicators (KPI's) may be selected for evaluation at various periods before and during an RCM Project. It addresses four distinct phases that should be considered for any RCM project, which in turn provides the outline for the major parts of this document, namely:

- Decision Phase
- Analysis Phase
- Implementation Phase
- Benefits Phase

The relationship between metrics of the items listed above is illustrated in the following diagram (Figure 1).

RCM Project Phase Metrics Relationships

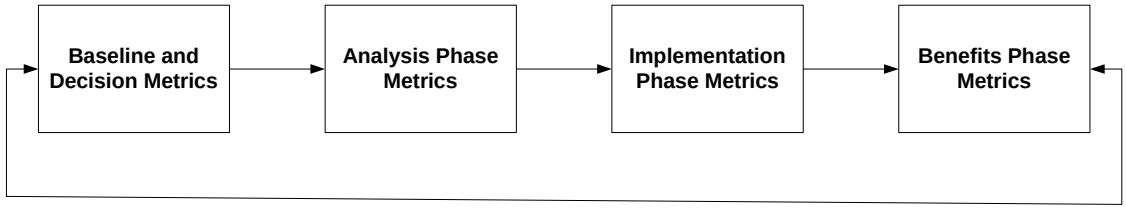
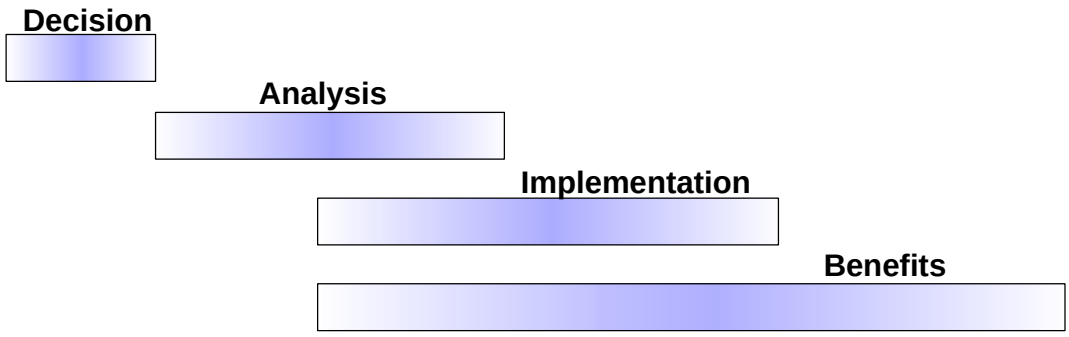


Figure 1 - Benefits Phase Compares "Before" and "After" Metrics

A major lesson of the success stories in RCM comes from a thorough understanding of the inter-relationships between phases of such a project. Relationship between phases of an RCM project can be illustrated in terms of the metrics that may be used to evaluate progress and ultimate outcome. In Figure 1, metrics for the various phases are depicted in the sequence they are developed and used. The final "Benefits Phase" metrics uses the original Baseline and Decision Metrics for comparison to show what results the effort has produced (or not).

Time relationships between the phases are illustrated in the following chart (Figure 2).

Figure 2 -Time Relationships Between Phases of an RCM Project



As illustrated on Figure 2, the phases of an RCM project (after the Decision Phase) should over lap. This provides continuity within the project. One of the main reasons for RCM project failure is failure to plan for and begin implementing results of analysis – even before analysis is complete. In a survey conducted in early 2005 by Reliabilityweb.com, respondents clearly pointed out that the hard part of any RCM. project was the Implementation Phase. If readiness to implement isn't carefully planned and expected, implementation may not ever occur. That brings up a bigger issue strongly related to the decision to start an RCM Project – readiness to start.

While the analysis phase may take only weeks, the decision phase may take a year or more. The implementation phase may take many, many months, if not a year or more and the full realization of benefits many take several years. Continuity of assignments and consistency of management support over these time-frames are two (2) key elements that lead to success of RCM projects.

In addition, particularly for the decision phase, the leader chosen to be in charge of the RCM effort must study not just the successes of others applying RCM, upon which much as been written, but also the failures, about which very little is written by those embarrassed to admit their defeats. Such unhappy endings are often predetermined and unavoidable to the inexperienced participants in most cases. This guide attempts to educate those who are unaware so they can get the most out of the very powerful methodology called Reliability Centered Maintenance in all of its forms.

Decision Phase Considerations

Readiness of an organization to initiate an RCM Project with a reasonable expectation of success is different from the decision to initiate one. After the decision is made, the commitments made by others must be called out consistently and

continuously. Determination of readiness for success of an RCM Project may be assessed using guidelines below.

The designated or self appointed "Champion" or prospective RCM project manager (organizer) must determine:

- Whether or not to perform RCM on the basis of expected outcome
  - ✓ See metrics described later in this document that may be used and other factors below to consider in making the decision
- Whether or not you are starting a "pilot" RCM project or a more extensive effort
- What the level of outside support will be and for how long it may be needed
  - ✓ Are you going to internalize the effort at some point?
    - – If yes, do you have good candidate(s) for facilitators/recorders internally?
  - ✓ Are you going to be able to get them adequate/training, experience and mentoring?

Level of outside support may be determined by:

- RCM Methodology or methodologies selected
- Cost per system
- Time commitment of internal RCM analysis and support team members

Leaders of RCM projects under consideration must also determine:

- Level of resources to be made available to support the project through all phases (Analysis, Implementation, Benefits)
  - ✓ Funding
  - ✓ Personnel to be assigned to the project (must be your best support & Subject Matter Experts – SME's)
  - ✓ Facilities & Equipment - RCM Team work space, computer, software
  - ✓ Prior history of organization in change management – bureaucratic elasticity – Will it work for a while then return to what you did before?
  - ✓ Steadfastness of management & supervisor support for new initiatives – Is your organization saturated by the "Flavors of the Month?"
  - ✓ Likelihood of recommended changes in <u>what</u> maintenance to perform being permanently adopted
    - – Does your organization have a commitment to procedure-based maintenance? If not how are changes to "stick?"
    - – Are maintenance requirements routinely performed on the basis of written schedules?

Having considered all of the above and determined that the factors listed will not impede or defeat a project, the designated organizer(s) must make sure that commitments for outside support are met.

After commitments are made for outside support needed, organizer(s) must determine:

- <u>Who</u> is going to provide outside support?
  - ✓ Determined by what RCM approach(es) you are going to use
    - – Want to assure during procurement phase that support selected has adequate experience, a good track record and credibility with prospective

RCM analysis & implementation team members (may be factors in contractor selection criteria)
  - Availability of outside person(s) may be a factor
- What RCM software is to be used and who will provide it?

Then the project manager must determine, coordinate and schedule:
- Training of analysis & implementation team(s) and support personnel
- Orientation of cognizant managers & supervisors
- Start date(s) for analysis
  - Must ensure no conflicts with major events or peak vacation periods
  - Set so most qualified & credible Subject Matter Experts (SME's) can participate on analysis and implementation teams
  - Ensure key internal support personnel will be available
  - Notify all prospective participants well in advance so no one is surprised or given rationale for opting out
  - Advise everyone chosen of seriousness of their commitment and expectations for constant participation in the long term
- Availability of dedicated work space conducive to good effort for duration of analysis & implementation phases of the project

Must schedule/acquire:
- Support equipment (computer & peripherals, RCM software)

Support personnel should assemble documentation needed by the project team:
- Maintenance history
- Copies of PM & PdM procedures/schedules,
- System & equipment tech manuals,
- Performance standards,
- P & ID's and Electrical Drawings,
- Stockroom or in-place spares inventory lists,
- Training manuals on systems and equipment,
- Operating procedures & checklists,
- RCM reference materials covering the analysis approach(es) to be applied, etc.,

The project manager must decide:
- What reports are to be made and to whom
- What the backup plan/schedule is in case of plant emergency
  - ✓ Include contingency for outside support
- What the plan is for implementation
  - ✓ Recommend implementation start before analysis is complete.

Decision Phase and Baseline "Current" or "Old" M & R Program Metrics and Traditional KPI's

Metrics listed in the table below and defined in the Glossary at the end of this document may not all be available to users of this RCM Project Manager's Guide. However, they are provided for possible use as follows:

- When considering whether or not to conduct RCM analysis on an asset.
- If the decision is made to proceed with RCM analysis on an asset, most of the same metrics selected may be used as a baseline set for comparison with the new, RCM based program results.

The decision of whether or not to conduct RCM analysis on an asset requires that many factors be considered. Among these are:

- Importance of the asset to the activity in which it is engaged
- Hazards involved in operating and maintaining the asset both to employees and people in surrounding areas and communities
- Level of risk involved in not doing RCM analysis to determine exactly what maintenance should be performed based on most likely dominant failure modes
- Problems encountered in operating the asset, such as its:
  - Availability, uptime and downtime relative to demand for most economical operation of an asset such as a production line, transport vehicle or whole plant
  - Quality of product or service produced, Scrap Rate
  - Cost of operation of an asset as expressed in efficiency (e.g., Heat Rate for a electricity generating plant or cost of energy for a production plant, vehicle or service facility)
  - Throughput and Yield or Capacity Factor relative to that needed to meet demand with current assets
  - Total Cost of Maintenance or Total Cost of Operations, Cost of Quality or other economic factor of production when it is affected by the maintenance and reliability program
  - Stress on maintenance and operating personnel under the current program
  - Overall profit margin for the product or service provided with the asset.

Other, more direct measures related to the type of **tasks** employed in maintenance have been found to characterize the most successful organizations. KPI's related to tasks may also be useful in reaching a decision on whether or not to engage in RCM analysis for an asset. In addition, if the decision is taken to conduct an RCM analysis, task metrics may be used for comparison of the pre and post RCM maintenance programs. In general, the following statements apply to types of tasks employed in RCM Based and Pre-RCM programs:

- Non-intrusive maintenance tasks are preferred because there is less likelihood of functional failure caused by human error after conducting them than there is for intrusive tasks.
- The more non-intrusive maintenance tasks, relative to intrusive tasks the more effective a program is in avoiding unscheduled downtime and lost production.
- The greater the percentage of on condition or condition directed tasks, the lower the overall cost of maintenance due to the fact that no actions other than monitoring are performed until condition directs a repair.
- Old (Pre RCM) programs, developed under methodologies that predate RCM generally do not recognize many "Hidden Failures." RCM based programs, which emphasize "Functional Failures" having safety or operational impact, will normally account for all of the important Hidden Failure possibilities.

- Old, current or existing (pre-RCM) programs seldom document Run-to-Failure (RTF) or other decisions, whereas RCM-based programs allow for RTF or other decisions (e.g., for statutory or regulatory reasons) under certain conditions. Under RCM methodology, RTF may also be a valid choice when all other task options are more costly and there is no safety and little or no operational considerations involved in allowing a failure to occur and correcting the problem (restoring the function) afterwards.
- In some cases "old" re-RCM programs specify tasks for which there is no justification, when an attempt is made to align failure modes identified by RCM analysis with "old" program requirements or tasks. This gives rise to the possibility of "old" program tasks not being continued under the new RCM-based program. These non-applicable tasks are cancelled, removed from maintenance schedules and not replaced by other tasks.

A set of metrics may be used in whole or in part to aid the decision making process and to support obtaining the assets needed to do so. Metrics proposed for these purposes are listed in the table, entitled **Table 1 "Current" or "Old" Maintenance and Reliability (M & R) Program (Baseline) Metrics"** on the following page. These metrics, for use in making the decision whether or not to conduct RCM analysis on an asset, are then used for baseline comparison with the new M & R program after RCM implementation has begun to take effect.

It is stressed that only a few of the metrics in the following tables in this section may be meaningful to a given organization and that those presented are not the only ones available. For example, in M & R Programs suspected of having too many or too burdensome maintenance requirements, Maintenance Backlog is often very high and compliance with the current PM program is very low. The metric that may be most useful in this case is PM Compliance. In the consensus workshop it was suggested, without any objection, that as few as 6 or 8 metrics may be all that are needed to make the case for an RCM Project and to determine benefits derived from it.

Where applicable, the time period for the collection of some of the metrics or KPI's in the tables that follow will vary from organization to organization and differ between industries and various types of facilities, activities, services or missions. In some applications metrics may be affected by seasonal factors. For these reasons, no specific time frame is provided **other than to recommend that those timelines selected provide a representative baseline for later comparison**, should the decision be made to go forward with an RCM Project. In some cases a graphical or tabular representation of the metric or KPI over time may be more meaningful than a single number. It is important, however, to ensure that the metrics collected be for the same asset or combination of assets before and after implementation (during the benefits phase of an RCM Project).

Table 1 "Current" or "Old" M & R Program (Baseline) Metrics

Number of Time Directed Intrusive (TDI) Tasks scheduled to be performed
Number of Time Directed Non-intrusive (TDN) Tasks scheduled to be performed
Total Number of Time Directed (TD) Tasks Sum of TDI + TDN
Number of Predictive (On-Condition or Condition Directed – CD) Maintenance (PdM) Tasks identified
Percent PdM Tasks that identify onset of functional failures on an annualized basis
Number of Failure Finding (FF) Tasks identified
Number of Protective Functions identified
Number of Run-to-Failure (RTF) or Other Decisions concerning functional failures that can be identified (Usually this is difficult, if not impossible)
Total Preventive Maintenance (PM) Items = TD Tasks + CD Tasks + FF Tasks + RTF Decisions
PM Compliance
Preventive Maintenance labor hours as a percentage of total maintenance labor hours performed. See Note 1 below.
Predictive (On-Condition or Condition Directed) Maintenance Labor Hours as a percentage of total maintenance labor hours (including all labor hours for restoring abnormal conditions found)
Emergency/Demand Maintenance labor hours as a percentage of total maintenance labor hours. See Note 2 below.
Corrective Maintenance labor hours as a percentage of total maintenance labor hours
Total Cost to Perform Maintenance on an asset (and for the whole facility)
Overall Equipment Effectiveness (OEE)
Total Effective Equipment Performance (TEEP
Hours of Unscheduled Downtime Hours of Scheduled Downtime
Total Cost of Replacement Parts for a representative period
Total Cost of Consumables

Note 1: Where a metric involves labor hours, it may be useful to break out subsets by trade category (e.g., Electrical, Mechanical, etc.,)
**Note 2: It has been useful in some instances to distinguish between labor hours and replacement parts cost for repair of the primary asset to be subjected to RCM analysis and conversion to a new program and labor hours and replacement parts cost for or collateral damage in secondary assets beyond the primary. **

In addition to the metrics for an asset listed in the first table, some more "traditional metrics" may be used to decide whether or not to conduct an RCM analysis on an asset. The table on the following page, entitled **Table 2 - "Traditional (Baseline) KPI's for Decision on RCM Analysis**" lists the types of measures typically being tracked already in many facilities. However, a special effort may be required to obtain metric values focused on the asset or assets of concern.

Table 2 - Traditional (Baseline) KPI's for Decision on RCM Analysis

Throughput or Output and trend(s) (e.g., tons, widgets, gallons or barrels processed, megawatt-hours)
Yield, or Capacity Factor and trend
Scrap Rate and trend for an asset Quality Rate, or Heat Rate and trend
Rework Rate and trend
Overtime labor hours by maintenance personnel as a percentage of total maintenance labor hours expended on an asset or for an entire facility and trend
Failure Rate(s) and/or failure frequency trends
Maintenance Backlog for a facility and trend

Given that the decision is made, based on readiness factors described above, to conduct an RCM Project, the next consideration for the project manager is to manage the program so as to ensure success. Given that a large percentage (estimated at 50% or more) of RCM projects fail, a review of some of the reasons for failure might be instructive.

RCM projects fail for individual as well as multiple reasons. Some of the many pitfalls that cause failure and that must be avoided are described briefly below.

- Too much analysis and time off the "real" job required by Subject Matter Experts (SME's) either because proper preparation wasn't made in advance or the tools available to support the analysis didn't support high productivity.

- Failure to provide for prompt, if not simultaneous, recording of results of analysis so they are immediately available to the team for each new day's effort or failure to provide a competent recorder of results (ideally from inside the organization who can control and provide access to them later)

- Failure to plan, before analysis begins, for implementation of results at the earliest possible time, resulting in delay in realizing return on investment of time and resources in the project.

- Failure to pick a field-proven RCM project software program for use during and after the analysis phase – Constant updating during analysis is nearly impossible without good software because it causes long delays between team sessions.

- Manpower requirements and costs for training, orientation, analysis and implementation underestimated or ignored resulting in lack of "buy-in" by stakeholders in the outcome of the project

- No "buy-in," especially when created by outsiders without any substantive input from stakeholders inside the organization

- Lack of failure data or will to conduct thorough Root Cause Failure Analysis and Failure Modes and Effects Analysis and follow-up, or difficulty or impossibility of collecting data on maintenance history or equipment failures

- Failure to assign most experienced SME's to RCM Analysis either because they simply aren't available or are able to avoid such assignments

- Lack of commitment by those who control assignment of SME's time and expenses, when the RCM project manager or "champion" does not control the personnel assets assigned to the project or the travel and living budget for those who come from outside a facility to support the project

- Failure to have those engaged in the analysis phase lead the implementation of results

- Too little knowledge of or aversion to PdM Technologies – clinging to time-based, intrusive tasks

- Failure to involve parties skilled in predictive maintenance, at least during the task selection step of the analysis phase

- Getting bogged down having to "slog" through analysis results to identify "new" tasks to be scheduled and "old" tasks to be deleted because analysis reporting mechanism isn't definitive enough

- Review and approval chain too long and over-controlling, causing unnecessary delays in implementation and subsequent realization of benefits from the project

- Culture of the organization really does not embrace change or lacks a support mechanism for incorporating change on a permanent basis (See readiness factors.)

- Lack of appreciation that the Analysis Phase is easy compared to the Implementation Phase of an RCM project and that the longer time between analysis and implementation the lower the probability of ever getting tangible results

- Lack of assurance that management will provide the resources to support the whole effort or be supportive at all either in short or long term

- Failure to keep sponsoring "champion(s)" and other stakeholders current on progress of the project and/or selection of inadequate report elements (e.g., no meaningful metrics)

- Failure to select the right systems or components for analysis – that is, the most troublesome with the greatest payback potential

- Committing to do analysis on too many systems at once or in sequence before seeing any return on investment from the first ones analyzed

- Failure to ensure that any other initiatives being implemented concurrent with RCM projects don't interfere or supplant them

Frequent adverse, long term outcomes of RCM projects, which imply things to avoid, are**:**

- Results under-utilized or ignored

- Time and budget overruns

- Deferred or truncated programs
  - ✓ No funding or manpower allowance for implementation

- Living Program never established so as to provide for feedback on items missed during analysis or that emerged later and no follow-up to ensure prompt implementation of new maintenance requirements

- No attention paid to long term benefits realized from the analysis (Benefits Phase too short to document return on investment) which in turn results in RCM being under-utilized and full potential never realized

Requirements for success include:

- Clear, understandable goals, objectives, and expectations
- Strong and continuous management support
- Dedicated staff
- Ownership and continuity of assignments to the project
- Processes and systems selected to gain best results
- Strategic and rapid implementation
- Accurate measurement of results

RCM Project Analysis Phase Metrics

The tables below list sets of metrics that are useful in determining the nature of maintenance tasks in the new program to be put in place (or now in place) compared to the old program for a given asset selected as a candidate for RCM analysis. During the analysis itself, progress may be reported in terms of total tasks of each type, which have been determined to be needed at the points in the analysis process when the reports are made.

An example of a table of metrics comparing new with old programs in terms of tasks and run-to-failure decisions and entitled **Table 3 - "Tasks and Decisions Profile"** is shown below.

Table 3 - Tasks and Decisions Profile

Task Type	RCM based Program Number	RCM based Program Percent	Old Program Number	Old Program Percent
Time Directed Intrusive (TDI)				
Time Directed Non-Intrusive (TDN)				
Condition Directed (CD)				
Failure Finding (FF)				
Run-to-Failure (RTF) or Other Decisions				
Total PM Program Tasks and Decisions				

To these are added two additional metrics described in the table below that will be useful when implementation begins. These metrics in the table below entitled **Table 4 -** "**RCM Based Decision Metrics**," like those above, should be readily available from the RCM analysis report or analysis software package.

Table 4 - RCM Based Decision Metrics

Post-RCM Analysis Statistic	Remarks
Number of Design Modification Recommendations	**Made when a safety, environmental or significant economic impact can be mitigated or eliminated more effectively than any maintenance task. Design changes may also be used to allow monitoring a condition indicative of the onset of failure having safety or economic significance.**
Number of Operating Procedure Recommendations	**Made when changes to Operating Procedures have been recommended as part of the RCM analysis.**

The numbers for each category of action item (Task, RTF or Other Decision, Design Modification, Operational Procedures Change Recommendation) to be implemented under the new program should be used in RCM-based program implementation progress reports. These reports should establish what has been done. In addition, some of the metrics described in the next table entitled "Task Similarity and Decision Profile Metrics" (particularly those identifying tasks that may be cancelled) should be used as a target against which progress is reported in terms of how many have actually been acted upon during the implementation phase. See page 12 for Implementation Phase Metrics.

The set of metrics describing Pre and Post RCM Programs in terms of tasks and decisions is presented in the following table, entitled **Table 5 -** "**Task Similarity and Decision Profile Metrics**." This is a one-time set of metrics to provide an understanding of the **nature** of changes that must be made to implement the new (RCM Based) program.

Table 5 - Task Similarity and Decision Profile Metrics

Tasks or Decisions for System(s) Summarized	Number	Percentage of Total Decisions#
RCM Task = (Old) Current Program Task		
RCM Task = Modified (Old) Current Program Task		
RCM Specifies New Task. No (Old) Current Program Task exists.		

RCM Specifies Run-to-Failure or Other Decision. No (Old) Current Task exists		
RCM Specifies Run-to-Failure. (Old) Current Task exists that may be cancelled.		
(Old) Current Task exists, but no matching failure mode was developed in RCM analysis. Task may be cancelled if no other rationale exists for continuing it (Statutory/Regulatory).		
(Old) Current Task exists for an identified failure mode, but RCM analysis specifies a different task.		
Total Decisions required to complete the analysis #		
Total Changes from the current program due to RCM. See note below.		

 # Percentage of total decisions should add up to ~100
Note: Total changes = Sum of all Modified Old Tasks + New RCM tasks +RTF or Other Decisions + Old program Tasks to be Cancelled + RCM Program Tasks that are different than Old Program Tasks for the same failure mode.

Another set of data, **Table 6 -** "**RCM Project Commitment Metrics**," may be useful to sustain momentum during early phases of an RCM project and to gain acceptance of the new program from personnel unfamiliar with RCM and its benefits.

Table 6 - RCM Project Commitment Metrics

Number of Maintenance, Operations and Engineering personnel employed (including management involved in any way with an RCM Project)	
Number of the above personnel trained or oriented in RCM Methodology	
Percentage of above trained personnel who participated in RCM analyses	
Number of above employees qualified as RCM facilitators	
Total labor hours allocated to performing RCM analysis to date. See note below.	

Note: Labor hours may be broken down further, for example for RCM Project Manager, Facilitator(s), and Analysis Team Members

A final set of metrics for the Analysis Phase explains in RCM terms (Functions, Functional Failures, Failure Modes, Hidden Failures, etc.,) the results of the analysis. The set in the table on the following page, entitled **Table 7 -** "**Asset Analysis Profile,"** is usually reported at the end of the RCM Project Analysis Phase and only one time. However, these may also be reported periodically during the Analysis Phase to define progress, if that phase is drawn out for an extended period.

The final **Asset Analysis Profile** for the complete analysis of an asset may be used for comparing efforts on future RCM projects and for orientation and training of personnel new to RCM Methodology. In the latter instance the numbers are useful for giving these personnel an idea of the magnitude of the effort involved in an RCM analysis project.

Table 7 - Asset Analysis Profile

For Asset(s) Identified As:	**Number**
Number of Functions Identified	
Number of Functional Failures Identified	
Number of Analyzed Components Within the Boundary	
Total Number of Failure Modes Analyzed	
Number of the Total (Failure Modes) That Are Defined As	

Hidden Functional Failures	
Number of Total Failure Modes Classified as Critical / Operational	
Number of RCM Based Tasks Identified Plus Run-To-Failure Decisions	
Number of Run-To-Failure or Other Decisions Made for Identified Failure Modes	
Number of Items of Interest	

Concerning the last metric "Number of Items of Interest," what follows is pertinent more to facilitators using team meeting-based approach to analysis. However, RCM project managers may occasionally have to become involved to restore emphasis on analysis rather than on subjects which, while important, aren't within the task at hand.

- Many other problems, deficiencies and issues with the current maintenance program will be brought up during the RCM analysis phase
- Such items should be recorded as one line entries and discussion of them shut down as soon as possible so the RCM project does not get diverted from its goal
- The list of "Other Items of Interest" should be included in the report of analysis results which is passed to management for action as they deem appropriate

RCM Project Implementation Phase Metrics

RCM based implementation metrics provide measures that signify progress towards implementing an RCM based maintenance program. Using numbers identified during the Analysis Phase as a basis, the metrics concentrate on the number and percentage of each category (new task, modified task, cancellation of specified old program tasks, design modifications, operational procedure changes, etc., that have actually been implemented.

Implementation will (or should) usually begin during the Analysis Phase of an RCM project, and may provide information for improvement of the analysis. Implementation involves many activities, such as:

- Identification of resources (money, time, manpower)
- Coordination with governing authorities or other parties affected
- Procedure writing, walk down and approval
- Procurement of special tools, parts and consumables needed to carry out the procedures mandated under the new program
- Training or at least orientation on the new procedures for those who are to perform them
- Planning and scheduling of new RCM based procedures
- Actual execution the first time on the asset that was subject of the RCM Project

Action items should be tracked and periodically reported during the Implementation Phase. The table below, entitled **Table 8 - "RCM Based Program Implementation Metrics"** provides proposed measures that signify progress towards implementation .

Table 8 - RCM-Based Program Implementation Metrics

Task Type or Decision	Number Identified	Number Implemented	Percent Implemented
Time Directed Intrusive (TDI)			
Time Directed Non-Intrusive (TDN)			
On Condition or Condition Directed (CD)			
Failure Finding (FF) Tasks			
RTF or Other Decisions			
Total PM Tasks & Decisions (Sum of the above items)			
Old Program Tasks to be Cancelled			
Design Modifications			
Operating Procedure Changes			

All of the above implementation action items require labor hours. To the metrics above may be added the set on the following page, entitled **Table 9 - "RCM Based Program Implementation Labor Hours Metrics"** that deals with the effort expended to date (of report) to implement an RCM based program for a given asset or set of assets. The metrics report labor hours expended to date compared to the last report.

Table 9 - RCM Based Program Implementation Labor Hours Metrics

	Last Report (Date) Hours	This Report (Date) Hours
Management, Maintenance, Operations & Engineering personnel, including training and/or orientation		
Support personnel, including, procurement, contractor and any others involved directly in implementation		
Total Labor Hours Expended to Implement RCM Analysis Tasks		

RCM Project Benefits Phase Metrics

Each of the metrics selected from table below, entitled "RCM Based M & R Program Benefits Metrics" should use as a starting point and constant reference to the same metrics tracked for the same asset or set of assets for the representative periods selected prior to implementation of the new RCM based program. (See **Table 1 - "Current" or "Old" M & R Program (Baseline) Metrics** on pages 7). A useful presentation may consist of a set of graphs with the metric(s) plotted against time and the point where implementation began clear marked. Periods selected should be "representative" of what are considered to be the "normal" operating profile for the asset being evaluated. Trends will then be evident and referenced to a definite point in operating time when results of the RCM project should begin to emerge. These metrics, although entitled **Table 10 - "RCM Based Maintenance (M& R) Program Benefits Metrics,"** must be presented in a broader context, since many other initiatives may be affecting them during the same period of time as the implementation and benefits phases of an RCM project. However, the metrics relating to the new RCM based program may have to be tracked for longer, if all expected benefits haven't been realized, or implementation is taking a long time.

Again it is emphasized that only a few of the metrics in the following tables may be meaningful and that those presented are not the only ones available. In the consensus workshop it was suggested, without any objection that as few as 6 or 8 metrics may be all that are needed to make the case for an RCM Project and to determine benefits derived from it. Metrics should be collected on the same asset studied prior to the decision to proceed with an RCM Project and for a period of time that provides a true representation of each value for valid comparison and characterization of "before" and "after" performance.

Table 10 - RCM Based M & R Program Benefits Metrics

PM Compliance
Preventive Maintenance (PM) labor hours as a percentage of total maintenance labor hours performed See Note 1 on the following page.
Predictive (On-Condition or Condition Directed) Maintenance (PdM) as a percentage of total maintenance labor hours (including all labor hours for restoring abnormal conditions found)
Emergency/Demand Maintenance labor hours as a percentage of total maintenance labor hours and trend
Corrective Maintenance labor hours as a percentage of total maintenance labor hours during a representative period and trend
Total Cost to Perform See Note 2 on the following page.
Overall Equipment Effectiveness (OEE) and
Total Effective Equipment Performance (TEEP)
Hours of Unscheduled Downtime and
Hours of Scheduled Downtime Total Cost of Replacement Parts See Note 2on the following page.
Total Cost of Consumables

Note 1: Where a metric involves labor hours, it may be useful to break out subsets by trade category (e.g., Electrical, Mechanical, etc.,)
Note 2: It has been useful in some instances to distinguish between labor hours and replacement parts cost for repair of the primary asset subjected to RCM analysis and conversion to a new program and labor hours and replacement parts cost for collateral damage to secondary assets beyond the primary asset.

Consistent with the goal of RCM Scorecard to measure and evaluate benefits (or lack of them) after an RCM based maintenance program is implemented, the last table, entitled **Table 11 - Benefits Phase RCM Based M & R Program KPI's**, below, contains "traditional metrics." In the same vain as was used for the metrics in the table above, these "traditional metrics" should be used for comparison with those listed for the "old" program. **See Table 2 on Pages 8.**

Table 11 – Benefits Phase RCM Based M & R Program KPI's

Throughput or Output and trend(s) for an asset (e.g., tons, widgets, gallons or barrels processed megawatt-hours)

Yield or Capacity Factor and
Scrap Rate and trend for an asset over a representative period Quality Rate, or Heat Rate and trends for an asset over a representative period after implementation of an RCM based program
Rework Rate and trend
Overtime labor hours by maintenance personnel expended on an asset or an entire facility as a percentage of total maintenance labor hours expended and trend
Failure Rate(s) and/or Failure Frequency Maintenance Backlog for a facility trend as a percent of total backlog

Because RCM tasks may lead to correction of many problems previously tolerated, the metrics from the table above may be deceiving shortly after implementation and not be well received, unless analyzed and explained very carefully. For example, it is not uncommon to see growth in work orders, cost of replacement parts and labor hours for maintenance as RCM action items are implemented. This is due to the fact that many problems either not evident or tolerated under the old program are identified for correction under the new program. This "hump" in work orders, parts requisitions and associated costs and labor hours must be overcome before positive results, reflected in other benefits such as improved reliability, availability, product quality and throughput, are realized in other metrics. It may take 12 to 18 months to work through this. For that reason, any of the metrics used during the Benefits Phase should be tracked for at least this long or longer after the end of the implementation phase of an RCM Project.

Some chronic problems may not yield to an RCM solution or other methodology, such as Root Cause Failure Analysis follow up actions. It may be useful to report metrics, such as failure rates, on these items separately or with caveats explaining the situation.

Interpretation of RCM Project Metrics or KPI's

As illustrated in the diagram entitled "RCM Project Phase Metrics Relationships" (Figure 1) on page 4 of this document, Benefits Phase Metrics are compared to Baseline and Decision Metrics. Conditions **before** RCM are compared to conditions **after** RCM to determine gain (or loss) resulting from the investment of resources (money, labor and time). In general, desirable trends, relative to baseline in the metrics or KPI's are as follows:

Metric or KPI	Desirable Trend
PM Compliance	**Up**
PM Labor Hours as a percentage of Total Labor Hours	**Up**
Predictive (On-Condition or Condition Directed) Maintenance Labor Hours as a percent of Total Labor Hours	**Up**
Emergency/Demand Maintenance Labor as a percentage to Total Labor	**Down**
Corrective Maintenance Labor Hours as a Percentage of Total Labor	**Down**
Total Cost to Perform Maintenance on an Asset	**Down**
OEE	**Up**

TEEP	**Up**
Hours of Unscheduled Downtime	**Down**
Hours of Scheduled Downtime	**Down**
Total Cost of Replacement Parts	**Down**
Total Cost of Consumables	**Down**
Throughput	**Up**
Yield or Capacity Factor	**Up**
Scrap Rate	**Down**
Quality Rate	**Up**
Heat Rate	**Down**
Rework Rate	**Down**
Overtime Labor Hours as a percentage of Total Labor Hours	**Down**
Failure Rates	**Down**
Maintenance Backlog	**Down**

Summary

This RCM Project Manager's Guide presents many things that those in charge of maintenance and reliability for an organization should take into account before committing to and starting an RCM project. During its existence there are many pitfalls to avoid in order to bring the project to a successful conclusion. It must be appreciated that the whole effort may take a long time, up to several years in all, but the results of successful projects have proved it's worth it. As Previously stated, the purpose of this document is to increase chances for success of a project by calling attention to causes of previous failures and providing the most meaningful basis for proving success – metrics during decision and all follow-on phases of a typical RCM project.

It provides a comprehensive menu from which metrics may be selected to aid in deciding whether or not to proceed with an RCM Project. Once the decision is made to proceed, it provides metrics to use to evaluate project progress (during analysis and implementation phases) and results (during the benefits phase). Many of the metrics are representative of what have been used in the past on actual projects. Other metrics may be added or substituted, as long as the principles of comparison for like assets and operating conditions are followed.

This project guide does not favor any RCM methodology (e.g., Classical RCM, RCM Variant or Derivative). Nor does its approach discriminate against any analysis method (e.g., Team-based or Analyst-based).

However, some of the metrics, particularly during the analysis phase may be used to compare results of different approaches to RCM, should this be of interest.

Glossary of RCM Project Manager's Guide Terms, Abbreviations and Definitions

Analysis Phase of an RCM Project – The period during which RCM analysis is in progress to determine *what* maintenance strategy should be performed on an asset. A portion of the Analysis Phase may overlap with the Implementation and the Benefits Phases of an RCM Project.

Asset Utilization – Operating (Calendar) Time divided by Total (Calendar) Time in a specific period (Month Quarter, Year) times 100 to give the percentage of total calendar time that an asset runs.

Availability – The percentage of time an asset is available to run a product or provide a service. Some organizations may use the term "Operational Availability – A_0" which infers readiness for functional performance such as for a military mission, power generation, or transportation of passengers or freight.

Benefits Phase of an RCM Project – The period starting with regular execution of the first task or other action item (such as cancellation of an "old" program task proven of no value) resulting from an RCM analysis. The Benefit Phase may overlap Analysis and Implementation Phases of an RCM project. The period is characterized by adoption, calculation and evaluation of RCM based program benefits metrics and their trends. These are used to evaluate effectiveness of efforts aimed at failure mitigation, avoidance of functional degradation or failure elimination. This phase, usually divided into monthly or yearly intervals, may end at a time established by management or may be ongoing until benefits of the entire RCM effort have been fully realized.

Bureaucratic elasticity – The characteristic of an organization that begins a new initiative and then because of departure, shift of attention or lack of firm leadership of the initiating manager or supervisor returns to the "traditional" way of doing whatever the new initiative was supposed to change.

Capacity Factor - The ratio of actual output divided by rated output. As commonly used in the Electric Power Generating Industry, it is the ratio of actual Megawatt Hours produced on an annual basis to the Megawatt Hours that could have been produced during that period if the plant was operating at 100% of its rated output every hour of the year.

Champion: An individual with sufficient clout, position of authority and/or reputation within an organization who can support and defend an initiative or permanent portion of a ongoing program or methodology in the face of conflicting budget, production or other requirements. Within the fields of Maintenance and Reliability, "champions" may be assigned or be self appointed to an RCM Project, the Predictive Maintenance Team, a Total Productive Maintenance or Procedure Based Maintenance initiative. Typically the title "champion" does not appear on an organizational chart, although the official title of a supervisor or manager may imply that the incumbent is the logical choice.

Condition Directed (CD) Task– See On Condition or Condition Directed (CD) Task.

Corrective Maintenance (CM) – *Unscheduled (until requirement emerges)* work to restore the functional capabilities of a malfunctioning or failed asset. This includes repeat maintenance which is labor expended after a first attempt at Emergency/Demand Maintenance has not restored required function(s) of an asset. Corrective maintenance is a subset of Emergency/Demand Maintenance and is reactive work. A goal of a maintenance and reliability program should be to reduce corrective maintenance to as low as possible.

Consumables – Materials such as small components of an asset (nuts, bolts, washers, gaskets, paint, sealers, light bulbs, fuses, thermal lagging, small inexpensive parts etc.,) used or replaced in the course of maintenance and/or operation, which are disposed of and not repaired or restored to their original location. Some organizations place a monetary value on what is defined as consumable (e.g., <US$50.00). Materials such as lubricants and wiping rags are considered consumed even though they may ultimately be recycled through cleaning and reused in another portion of an asset or plant.

Critical Failure – A failure involving loss of function or secondary damage that could have a direct adverse effect on operating safety of an asset or safety of people that could be affected by its failure.

Critical Failure Mode – A failure mode whose ultimate effect can be a critical failure. If critical/operational, the failure has economic consequences, such as loss of revenue or profits.

Design Modification – An alteration to the configuration of an asset or its process (in this case driven by the RCM Analysis) that improves its reliability, safety margin or operational performance or makes a formally hidden failure evident to operators and maintainers in the course of their normal duties. Labor hours spent on design modifications are categorized separately (not included in PM or Emergency/Demand categories).

Decision Phase of an RCM Project – The period during which a determination, is made using a selection of metrics, measures or Key performance Indicators (KPI's)as to whether or not an RCM Project will meet an organization's investment criteria and for improvement in safety and/or economic performance. The improvement will be created by execution of a maintenance program based on principles of RCM. The project may involve a critical system, set of systems, a vehicle or fleet of vehicles, a plant or set of plants that produce a product or a facility or set of facilities that provide services such as utility services.

Emergency/Demand Maintenance or Reactive Work – *Unscheduled* reactive repairs performed on an asset so that the equipment may be restarted. These jobs can range from minor adjustments to temporary or complete replacement of a component or asset. Maintenance work is performed on an unplanned basis only a short time (e.g., within 48 to 72 hours) after a specific, unanticipated failure event. Some planning may be performed once the need for emergency/demand maintenance is recognized. Emergency/Demand Maintenance falls outside of the PM program and can be classified as reactive maintenance. Corrective maintenance is a subset of Emergency/Demand Maintenance. The definition of an "emergency" and "demand" depends upon the context in which the asset is operating or is to operate and the consequences of an impending or actual functional failure on safety (of people, environment or the asset), operating performance and/or economic factors involved.

Failure-Finding (FF) Tasks – Periodic or fixed interval tasks performed to detect the failure of a hidden function. These failures will not be evident to the operating or maintenance crews while performing their normal duties and require overt action to find a problem. FF Tasks are a subset of Preventive Maintenance. Failure finding tasks are inclusive of the tasks required to restore the failure found. FF tasks may be incorporated into operational procedures.

Failure Mode – The specific manner of failure; the circumstances or sequence of events, which leads to a functional failure

Failure Frequency – number of failures for a component, equipment or asset per unit of time (Month, Quarter or Year) or per some multiple of operating hours (e.g., per 1000 operating hours)

Failure Rate – A ratio (per Nowlan & Heap). The number of failures of a component, specific equipment or of a whole asset during a specified period divided by the total number of all failures in all similar components equipment or asset in operation during that period, usually expressed in numbers of failures per period of time (e.g., months or years) or per number of operating hours. May be qualified by certain conditions. Other measures of failure impact, such as mean time between failures for a given asset may be used instead of the Nowlan & Heap (United Airlines) one.

Function – The primary and/or secondary purposes of an asset or its normal or characteristic actions , sometimes defined in terms of performance capabilities.

Functional Failure – Failure of an item to perform its primary and/or secondary purposes or its normal and/or characteristic actions within specified limits.

Heat Rate – A measure of the efficiency of a plant in converting one form or source of energy (such as coal, oil or gas) into another (such as electricity). Typically this is measured in British Thermal Units (BTU's) per Megawatt Hour in electricity generating plants. The lower the heat rate, the higher the efficiency in conversion. Since fuel is the major cost factor in production of electrical energy, Heat Rate is an important measure of a plant efficiency and potential profitability. Application of the best maintenance practices can greatly affect plant efficiency.

Hidden Function – A function whose failure will not be evident to operating or maintenance personnel during performance of their normal duties. Examples are a pressure gauge that indicates a normal condition but in fact has "stuck" and cannot change position, and a relay switch that should close to energize a standby pump when pressure drops below a specified value but cannot function because it has lost its power source.

Hidden Functional Failure – A failure that is not evident to either operators or maintainers in the course of their normal duties, unless and until the function is needed but not performed. The cause of such failures will also be hidden.

Implementation Phase (of an RCM Project) – The period beginning with preparation for execution of the first RCM-based recommendation for a revised or new maintenance and reliability strategy.. The Implementation phase ends with initial execution of the last recommended action item of an RCM Project for an asset. The Implementation Phase may overlap with both Analysis and Benefits Phases of an RCM Project. Implementation involves management of change, design of the new strategy and its execution. The most successful implementations use an organized approach such as the Sheuhart "Plan, Do, Check, Act" methodology articulated in Six Sigma and other problem solving process. (See www.isixsigma.com). .

Implemented Task or Decision – An RCM project action item that has been formally executed for the first time as part of an RCM based maintenance program. For tasks this means it has been incorporated into an approved step-by-step procedure (with or without other RCM tasks), formally scheduled and carried out at least once by personnel who have been oriented or trained (if needed) to carry it out. For RCM based decisions, such as RTF items which previously required a task which was not applicable and/or effective and other old program tasks for which there is no justification, this means that all steps have been taken to exclude them from the new program.

Item of Interest – An issue raised during RCM analysis that cannot be solved using RCM Methodology. During any RCM analysis, a number of issues are raised which are unrelated to the task at hand. Many of the issues are important and may indicate problems that the organization should address in another forum. Dwelling on them interrupts the RCM analysis process. To refocus analysis team efforts quickly, these items are simply listed as "Items of Interest" and reported along with the RCM analysis results to the project sponsor.

Key Performance Indicators (KPI's) – Metrics or measures that may be used to evaluate how well an asset is carrying out its function. A KPI usually can be compared to some reference, such as the designed capability, accepted industry measure or national or internationally accepted value.

Lost Production or Lost Production Opportunity – The result of unscheduled downtime that consumes time previously scheduled for creation of a product or service. Cost of lost production equals the production rate times the number of hours of unscheduled downtime experienced plus the overtime cost for labor to make up the lost production, if this is possible in the calendar time remaining in a given operating period.

Lubrication Task – A time directed task involving addition or exchange of lubricant (such as grease or oil). These may be intrusive or non-intrusive. Obtaining a lubricant sample for purposes of analysis is generally considered to be an on-condition or condition directed (CD) task

Maintenance Backlog – Represents the maintenance work planned to be done at some time in the (near) future, usually expressed in labor hours and weeks, commonly on a graph where all labor hours (including support labor hours such as those expended for planning) are plotted against weeks in the future for a

facility. Some maintenance may be "deferred" beyond the normal period for calculation of maintenance period for a wide variety of reasons, such as expected date of receipt of parts needed for a repair action.

On-Condition or Condition Directed (CD) Tasks – *Scheduled, preplanned, periodic* maintenance tasks performed at specific times in calendar or operational time to detect the onset of potential failures or a symptom that indicates the onset of failure. These may also be called Predictive Maintenance (PdM) tasks. When a CD task results in finding the onset of a failure or a symptom indicating the onset of failure, a task is scheduled to mitigate the problem and ensure the functions of the asset are maintained or restored. Labor hours expended to maintain or restore the asset functions resulting from condition monitoring or a predictive task are categorized, along with the CD Task labor, as Preventive Maintenance (PM) labor hours. CD tasks are inclusive of the repair or restoration tasks that flow from the monitoring tasks used to detect the onset of functional failure. A goal of an RCM Project should be to maximize on-condition maintenance, since it required no action other than monitoring until a condition directs otherwise.

Operating Procedure – A detailed step-by-step written procedure(s) and/or checklist(s) used to start up, run or shutdown an asset in the most safe, economical, productive and effective way. Changes initiated through RCM analysis are usually intended to eliminate or mitigate failure modes resulting from human error or to alter the way the equipment is operated in order to protect it from functional failure. This may be done to protect the environment, the people who might be affected by a failure or the quality of the product or service provided by it. Failure Finding Tasks are often incorporated into operating procedures as the most logical and convenient way of performing them.

Operating Speed Rate – Total Number of Units (of Product or Service) Produced times Theoretical Cycle Time divided by Actual Cycle Time and expressed as a decimal number equal to1.00 or (usually) less. See Speed Rate. Used in Overall Equipment Effectiveness calculation.

Overall Equipment Effectiveness (OEE)– A reliability measure that compares the amount of time a machine was running at an expected speed and manufacturing good quality product to the time it was scheduled to do so. One source((Hanson – See Page 3) defines it mathematically as Availability times Performance Efficiency times Quality Rate or (Runtime divided by Scheduled Time) times Operating Speed Rate times Quality Rate. Other sources may use different formulae.

Overtime Labor Hours – Labor hours performed for which a premium is paid (e.g., 50%).Rates for premium pay and when they are to be paid may be established by organization policy, law, regulation or negotiation.

Performance Efficiency – Net Operating Rate (which is 1.0 by definition) times Operating Speed Rate

Pilot Project – A initial effort undertaken to test the feasibility of applying results on a broader scale, and to determine whether such an initiative can be successful given the culture, resources required and benefits expected of it when applied throughout all applicable assets.

Predictive Maintenance or PdM Task – See On-condition or Condition Directed (CD) Task. A measure of Predictive Maintenance Program effectiveness is the "Percent of PdM tasks that identify onset of functional failures on an annualized basis for an asset." This is defined as the number of PdM tasks resulting in work orders requiring some sort of follow-up action divided by the total number of PdM tasks conducted on an asset on an annualized basis. Annualized implies any given 12 month period such as may coincide with an operating year, budget year or other 12 month period commonly in use for an asset.

Planned Maintenance or Planned Work – Jobs of a defined scope where all labor, materials, tools, safety considerations and supporting documentation have been estimated, identified and/or assembled and coordination required to complete the job has been arranged with production or area management assuring availability of the asset before commencement of work. Includes all Time Directed, Condition Directed Failure Finding Tasks, and work resulting from RTF decisions and related (PM) labor hours, including the hours expended for repairs resulting from any problems identified through performance of these types of actions or decisions. See Preventive Maintenance.

PM Compliance – PM tasks accomplished divided by PM tasks scheduled (or required) times 100 and expressed as a percentage.

PM Labor Hours – All maintenance hours chargeable to a PM task or related action, including wrench time, wait time, planning and scheduling, testing, lockout/tagout and return to ready status.

Predictive Maintenance (PdM) - Those activities involving continuous or periodic monitoring, diagnosis and prognosis using a wide variety of installed, portable and remote (laboratory, vehicle, handheld or plant based) sensing instruments, human observation, and various analysis methods and tools in order to assess whether a functional failure of an asset will occur at some time in the future.

Predictive (PdM) Maintenance Labor Hours – Hours expended to monitor, maintain or restore the asset functions resulting from a condition monitoring or predictive task. These hours are a subset of Preventive Maintenance labor hours.

Preventive Maintenance - PM – *Scheduled, preplanned and periodic* tasks such as servicing or inspection at specific points in calendar, operational time or after specific events to assure the functional capabilities of an asset are maintained or restored to within acceptable limits. PM Tasks are the sum of all TD, CD & FF Tasks and RTF Decisions. **Also may be called Planned Maintenance.** In this context an RTF Decision leads to a conscious plan for restoration to occur after failure in order to reduce overall material cost and labor hours or to meet other goals of the maintenance and reliability program.

Protective Functions – Capabilities of an asset designed (as delivered or a subsequently modified) to preserve its function, quality of the product, meet legal or regulatory requirements and/or to protect against damage to the asset itself, the environment around it (including surrounding communities) and/or the people whose safety may be affected if the functions fail.

Quality Rate – The number of "good" units divided by the total number of units produced, a factor expressed as a fraction or a decimal number equal to or (usually) less than 1.00. Included in calculation of Overall Equipment Effectiveness and Total Effective Equipment Performance.

Repeat Maintenance – Maintenance conducted a second time on an asset to restore its functionality. Repeat maintenance is a subset of corrective maintenance. Repeat maintenance is an indicator of the effectiveness of a maintenance and reliability program. A goal of a maintenance and reliability program should be to eliminate repeat maintenance.

Rework Rate – The percentage of product produced that must be processed further (or again) to correct defects so as to meet the required (prime) quality standards, and thus commanding the highest sales price.

Rework Task – The scheduled removal of specific components of an asset to perform whatever maintenance tasks are necessary to ensure the asset meets its defined condition, level of reliability and functional performance standards. Referred to as an overhaul task in some organizations.

Run-to-Failure (RTF) Decisions – Deliberate choices to allow a functional failures under certain conditions of acceptable risk. (Usually made when a failure has little or no safety, environmental and/or economic consequences.) May lead to decisions to cancel PM's called out by the "old" pre-RCM program for which there is no link to a failure mode identified in RCM analysis. Run-to-Failure may also be a de-facto decision when no applicable and effective task can be found to mitigate or eliminate a valid failure mode. If safety, critical operations or environment is of concern a design modification may be appropriate or a new PdM technology acquired for monitoring may be acquired to detect the onset of degradation leading to failure. In such circumstances an action item to resolve RTF de-facto situations should remain open and be held at a high priority until resolved. Usually, there are no RTF decisions identifiable from the "old," pre-RCM program. RTF Decisions are a subset of total PM Program Tasks.

Scheduled Downtime – Time (usually measured in hours or days) to do required work on an asset that is on a finalized periodic (e.g., weekly or monthly) schedule. Synonyms include shutdown, outage and overhaul period.

Scrap Rate – The amount (tons, widgets, etc.,) of irreversibly damaged product divided by the amount of total product (in the same units) produced by an asset. Damaged product must be scrapped. That is, recycled or disposed of and generally can't be sold at a price that recovers its total cost of production. Usually expressed as a percentage of Throughput or Output.

Speed Rate - The ratio of Theoretical Cycle Time divided by Actual Cycle Time where Theoretical Cycle time equals Ideal Speed (Equipment Capacity as Designed or Highest Accredited Speed, if higher) and Actual Cycle Time equals Runtime divided by Actual Amount Produced. This yields a decimal number equal to or (usually) less than 1.00. Used in calculation of Total Effective Equipment Performance (TEEP).

Subject Matter Expert (SME) An individual widely recognized for knowledge and expertise in maintenance and/or operation of an asset. SME's may be in-house or from an outside source such as from an original equipment manufacturer. He or she may also be a retiree whose expertise was not fully captured prior to retirement but may be hired as a consultant for a limited period such as for the analysis and/or implementation phase of an RCM Project

Task or Tasks – Specified maintenance action(s) taken to mitigate, prevent or identify the onset of or presence of an actual functional failure in an asset

Task Periodicity – Frequency with which a specified maintenance action is taken on the same asset.

Throughput or Output– The number of units of product or service delivered in a specific period of time. May be expressed in tons or barrels, gallons per day, week, month or year, widgets per hour, megawatts-hours, etc.,

Time Directed (TD) Tasks – Periodic actions or tasks aimed directly at failure prevention or retardation, a subset of Preventive Maintenance. There are two types of TD actions or tasks:

Intrusive (TDI) Tasks –Actions requiring asset or process interruption where human error or just executing the task (in and of itself) may cause a functional failure upon resumption of operations after some inspections, adjustments and lubrication tasks requiring shutdown/restart, tagout, opening or disassembly. Intrusion implies introduction of induced risk of functional failure caused by the maintenance action itself. A goal of an RCM Project should be to minimize time directed intrusive maintenance tasks.

Non-Intrusive (TDN) Tasks– Actions not requiring process or asset interruption, equipment shutdown, tagout, entry or disassembly that minimize the possibility of human error that could cause a functional failure ..

Total Cost to Perform Maintenance – The total cost of labor, material (Including cost of replacement parts) and overhead charged to a specific asset (or an entire facility) over a set period of time, including all maintenance support (indirect labor) personnel cost, contracted (outsourced) maintenance and related expenses (transportation, packaging, storage, handling), training and annual capital investment in tools, instrumentation and materials used to maintain an asset as well as allocated cost of utilities, insurance, taxes and factory supplies and consumables used by maintenance personnel in their daily work.

Total Cost of Replacement Parts – Money spent annually to replace failed, worn or scheduled replacement components on a given asset (or an entire facility), a subset of Total Cost to Perform Maintenance.

Total Effective Equipment Performance – TEEP - Asset Utilization times Speed Rate times Quality Rate, where Asset Utilization is Operating (Calendar) Time divided by Total (Calendar) Time, Speed Rate equals Theoretical Cycle Time or Ideal Speed (for equipment capacity as designed or accredited capacity, if higher, expressed in time (seconds, minutes) for each unit produced) divided by Actual Cycle Time (Runtime divided by actual amount produced, in units of product or service), and where Quality Rate

equals “Good” Units (or Hours of “Good” Service) Produced divided by Total Units (or hours of Any Service) Produced

Total RCM Program Decisions = Sum of all TDI, TDN, CD, FF tasks and RTF Decisions

Unplanned work – See Corrective Maintenance

Unscheduled Downtime – The amount of time an asset is not capable of running due to unscheduled repairs, i.e., repair work not on the finalized periodic (e.g., weekly, monthly or annual) schedule plus the amount of time beyond that formally allocated for scheduled downtime or scheduled outage. (For example if a formally scheduled outage runs 8 hours longer than scheduled, the 8 hours should be categorized as unscheduled downtime and added to the total for the period(s) to which the metric applies. Downtime includes time waiting for parts. A unit that is capable of partial functionality is **not** “down” if it is operating at some level of output meeting minimum quality standards.

Yield - Throughput minus waste or scrap. Yield may be categorized into grades by level of quality (e.g., Prime, Seconds, etc.,)

