



SMRP Certifying Organization

Reference Guide for Certification in
Maintenance and Reliability Management

Third Edition

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Purpose

The purpose of this reference guide is to enable manufacturing organizations to improve their asset management programs. On the organizational level, the greatest value in this document is the specification of the skills required by the professional maintaining those assets. . On the individual level, this guide supports candidates preparing to take the SMRP Certifying Organization examination for Certification in Maintenance and Reliability Management, or CMRP Certification.

A list of published references is also provided in this guide. These references comprise a sampling of many of the leading reference texts on the subject of maintenance and reliability. This listing does not intend to include all references that may be useful in increasing one's knowledge in maintenance and reliability, but rather a set whose information is valuable to the practitioner

The concepts and principles in these references may help a candidate find information on improving their knowledge and skills. However, the SMRPCO certification exam's focus is on applied knowledge. The study of references alone is highly unlikely to ensure success on the certification examination. Statistics from the early years of exam administration has shown a high correlation between applied experience and success on the exam.

In addition, a set of sample exam questions is provided. These are typical questions that will give the candidate exposure to the format of questions that are included on the exam. These sample questions will not appear on certification exams.

How to Use the Reference Guide

The user should read through the text of the study guide, and if the discussion covers unfamiliar material, the listed references may provide a starting point for further learning.

This reference guide is not intended to be the only source of preparation. It provides a general overview of the subject matter covered by the examination so candidates can identify those areas of the body of knowledge in which they need further development.

The material in this study guide describes the reasons for the development of the exam and addresses the body of knowledge encompassed by the exam.

Rationale for Certification: Achieving the SMRP Mission

The key elements of SMRP's mission are the improvement of the maintenance and reliability profession and supporting the education of maintenance and reliability practitioners.

From the first days of SMRP, it was clear that there were no consistent, well-defined standards for the body of knowledge and capabilities that Maintenance and Reliability practitioners should have to be effective. Further, there was no way to differentiate those who have mastered the various elements of excellence from those who simply hold the job. SMRP realized that without

a well-defined body of capabilities and a method of assessment it could not realistically fulfill all elements of our mission.

Improving the profession requires a standard of excellence and an incentive to attain the standard. Maintenance and reliability managers are often promoted because of technical skills, without regard for their ability to improve work processes, create change, or manage people. SMRP believes that maintenance and reliability practitioners need greater stature and credibility in their organizations and industry to be heard. We believe the message of Maintenance and Reliability adding value is often drowned out by day-to-day plant production demands.

In support of increasing the recognition and assurance of the capabilities of Maintenance and Reliability Professionals, SMRP has developed and continued to improve a certification process for Maintenance and Reliability Management. The CMRP Exam is fast on its way to becoming the international standard measure of competence in our field.

Certification History

The initial impetus to tackle the issue of standards came from a member of SMRP, an educational institution. This institution had created a series of courses to enhance the capabilities of people in the maintenance and reliability field. The question at the time was, “Would SMRP endorse their curriculum in some way?” This request raised the question, “*What is the body of knowledge a practitioner must have?*” For without a reliable standard, how could the worth of an educational program be evaluated?

Serious efforts towards developing a certification process began after an SMRP Strategic Planning meeting held in August of 1997. In this meeting the organizational structure of SMRP was changed to empower its directors to achieve the mission approved by the SMRP Board of Directors and Officers. This increased the activity of the SMRP working committees so that they actively worked on defined goals and objectives continuously throughout the year. The SMRP Board endorsed the certification goal of the Professional Certification Committee (PCC), and appointed Brad Peterson as the director.

In 1998 a team of volunteers gathered in Bowling Green, Kentucky to create a charter for the objectives, activities and goals of the new PCC. By early 1999, the PCC had identified the capabilities of high performing people leading Maintenance and Reliability initiatives. Approximately 400 maintenance and reliability practitioners who completed a survey on the SMRP website subsequently validated these capabilities. The majority of survey responses were very supportive of developing a certification process. Respondents overwhelmingly said that these capabilities are important, and stated many benefits of certification. The committee received nearly 20 pages of comments that encouraged us to proceed!

The PCC developed a strategic plan for certification by late 1999. They received a green light from the SMRP Board to proceed with creating an evaluation process, an administration process, and a way to market the program to industry.

In the first half of 2000, the development team worked industriously to develop definitions, references, certification test questions, methods, and documentation of the testing process. The PCC was renamed the SMRP Certifying Organization (SMRPCO). This was to clarify SMRP's role as the sponsoring organization and SMRPCO as the certifying organization that manages the certification program. Independent administration of the certification process is required to ensure impartiality, eliminate the possibility of bias, and for certification of the process by third party organizations.

Volunteer applicants took the first public beta exam during the 2000 SMRP Conference in Cleveland, Ohio. The results from this exam helped validate the exam content and improve it for use in the official certification exam.

At the end of 2005 over 2000 exams had been administered to professionals from 21 countries and counting. More than 1200 professionals have successfully completed the exam. Both the quantitative data and the inputs from the examinees suggest that the exam is fair, challenging and a good measure of the competencies necessary for the professional practitioner.

Certification Goals and Path Forward

We now offer the CMRP exam annually in fifty or more venues. As part of our expansion plans, we license maintenance societies around the globe to administer the exam for their home constituencies and the exam and this reference guide have been translated into Spanish and will soon be translated into Portuguese.

We continue to add content and improve the validity of the exam questions. There are many activities, including administrative tasks, quality checks, development of the question database (a never-ending task) and legal issues we deal with as part of the Certification Program.

In order to further increase credibility in the CMRP examination and to validate that world class, quality processes are used, SMRPCO is pursuing accreditation from ANSI (American National Standards Institute). ANSI offers an accreditation process for organizations that are certifying personnel.

Plans call for increasing the visibility and acceptance of the CMRP Certification within industry, not just by practitioners, but also by senior company managers and executives. In the future, we expect to create more specialist certifications, such as certification in Advanced Asset Management. SMRPCO's vision is that every manufacturing facility, worldwide, will have at least one CMRP.

Benefits of Certification

The benefits of certification are apparent for many fields and very attractive to practitioners in many industries. The following is a short summary of the benefits that were highlighted by practitioners who responded to the certification survey in 1999:

- Clearer direction for career development and education
- Improved visibility and recognition within your current organization
- Differentiated pay scales
- Portable job skills and knowledge between plants and companies
- Assists job promotion
- Greater job effectiveness
- Fewer frustrations with gaps in knowledge
- Improved ability to differentiate between candidates in the hiring and promotion process
- Improved On-the-Job-Training and outside training effectiveness

Distinction From Other Certification Programs

You may be aware of other organizations that offer a similarly titled certification in this or other related subjects. How does SMRPCO's process differ from these?

- SMRP is an independent, practitioner-based organization without ties to any commercial venture.
- The SMRPCO body of knowledge comprehensively addresses and examines equipment reliability as well as manufacturing management and technical skills, as opposed to other programs that deal strictly with the technical aspects of maintenance and reliability.
- SMRPCO used broad representation in developing the program by some of the best companies in the industry, and has done a thorough validation of the work to develop the certification process at each step.
- SMRPCO plans to be certified by ANSI, a distinction not shared by other "certifications".
- SMRPCO is sponsored by SMRP, the leading organization for Maintenance and Reliability practitioners. No other organization has that distinction.
- SMRPCO plans to enhance the value of certification to certified practitioners through other advanced certifications.

Ties with Education and Training

To date, a specification for the skills of our member practitioners and the industry at large has not existed. Academic curricula that identify themselves with the management aspects of Maintenance and Reliability have little resemblance to each other. SMRPCO has begun to coordinate with SMRP's Academic Liaison Director to establish a certification standard and skills inventory that could be interpreted by education and training organizations independently of any specific exam content. By promoting SMRPCO's inventory of standards and capabilities, it is hoped that educators will respond with improved offerings that cover more of the skill elements.

Overview of the Certification Examination Process

The Examination for Certification in Maintenance and Reliability Management consists of a multiple-choice examination, with 110 questions. Examinees are allowed two hours to complete it. The examination is closed book with no reference materials or computers allowed in the examination room. A hand-held calculator with arithmetic functions will be provided.

Examination Venues

The Examination for Certification in Maintenance and Reliability Management will be offered at many venues each calendar year, with one of the venues always being the SMRP annual conference held in the Fall. Where possible and practical, examinations will be coordinated with other SMRP activities (such as the annual conference) to reduce travel for persons who plan to participate in SMRP.

The venues and examination application forms are available on the SMRP web site by clicking on the Certification tab., You may access and download these at any time or complete your registration online.

Qualifications

There are no formal educational or experience requirements that have been set by SMRPCO for a practitioner before they may participate in the certification exam. SMRPCO recognizes that maintenance and reliability leaders gain their capabilities through a mix of work experience, education, and mentoring. It also recognizes that it is very difficult to define comprehensive prerequisites in these areas. However, we believe a candidate for Certification in Maintenance and Reliability Management will not pass the certification exam unless they have a majority of the following attributes:

- The candidate should have applied experience and education in maintenance and reliability technical fundamentals. Work management and reliability engineering skills are key areas.
- The candidate should have several year's experience as a maintenance and/or reliability leader in which work process improvement, management skills, and people development are key responsibilities.

Any individual may sit for the certification examination after payment of required application fees. Membership in SMRP is not required to sit for the examination.

Code of Ethics

The SMRP Certifying Organization Code of Ethics is as follows:

- All persons who sit for any SMRPCO examination agree to maintain the confidentiality of the examination content and to never disclose this content to others. Prohibited conduct includes disclosure of exam content, removal of exam materials from the examination room, copying by photography, use of audio recording equipment, or any other means that could be used to transfer the content to others.
- All persons who sit for any SMRPCO examination attest to their identity as the registered examinee, and will not represent anyone other than themselves in the taking of the exam.
- All persons who sit for any SMRPCO examination attest that the work and selections made on the subject examination are theirs and theirs alone.
- Those examinees that pass a SMRPCO examination (hereafter known as CMRP's) pledge to represent their profession ethically and honorably. Conduct by a CMRP that is detrimental to the stature of a SMRPCO Certification may result in revocation of said certification. Examples of detrimental conduct include dishonesty, misrepresentation of professional qualifications, and certain illegal acts. CMRP's have the right to appeal revocations of certification through due process that is described in the SMRPCO Policies and Procedures Manual.

Subject Areas Addressed by the Certification Exam

SMRPCO has developed a set of capabilities that are required to achieve Certification in Maintenance and Reliability Management.

1.0 Business and Management

This area describes the skills used to translate an organization's business goals into appropriate maintenance and reliability goals that support and contribute to the organization's business results.

1.1 Create Strategic Direction and Plan

Definition: The functional head must create a vision and plan in order to get staff and management working towards the same goals. Maintenance and reliability leaders should be able to create and implement strategic plans that will meet the plant's long-term business goals. A knowledge of how to gain upper management sponsorship and organizational support for the plan is key to its success. Leaders should also be able to draw on their experience and that of their staff to create a vision that enables attainment of goals and inspires the organization to achieve them. Key elements of the strategic plan include: establishing the business case; identifying current state, future state and gaps linked to key results areas; a progressive model for gap closure; a project plan with action items, timeline, resources and expected benefits; a process for management review and approval; communications to gain management and organizational support; and a review process for keeping the plan on track.

- 1.1.1 Identify sponsor(s) for change
- 1.1.2 Identify long-term business goals and what key results must be achieved
- 1.1.3 Identify today's performance and key results areas
- 1.1.4 Vision: What would be if we were good enough to achieve our goals?
- 1.1.5 List and group actions to close gap of vision with current status
- 1.1.6 Create agreement on maintenance and reliability improvement progression model
- 1.1.7 Create project description and prioritize
- 1.1.8 Create resource and benefits plan and key results areas
- 1.1.9 Develop implementation schedule
- 1.1.10 Achieve management review and approval
- 1.1.11 Communicate plan to gain "buy-in"
- 1.1.12 Revise plan on an annual basis
- 1.1.13 Present results to leadership periodically

1.2 Selling programs and change to stakeholders

Definition: Resources will only be allocated when management understands the value, direction, and performance expectations of applying them. Maintenance and reliability leaders should have a clear vision of where they are going and how they plan to get there. They must be able to communicate it to those with a stake in the process to get them on board with the plan. This

includes an understanding of the changes that will be involved for the organization, the people and the roles they will play, and the priorities for getting it done. Articulation of the benefits and the “what’s in it for me?” for all levels of the organization is key to success. Linking this to metrics will insure that goals are clear and that everyone knows “what success looks like”. Skill in positioning champions to lead the effort, obtaining management support for resources, and funding and enlisting customers and staff to support the plan is necessary.

- 1.2.1 Understand strategic direction
- 1.2.2 Identify who will be affected by changes, their role and motivation to change
- 1.2.3 Identify benefits and value for each stakeholder and how that is measured
- 1.2.4 Present value proposition to stakeholder groups and gain alignment
- 1.2.5 Agree on overall plant priorities for change
- 1.2.6 Gain agreement on path forward and plan
- 1.2.7 Identify accountabilities and champions for change
- 1.2.8 Gain resources to proceed
- 1.2.9 Staff time
- 1.2.10 Skills (internal and external)
- 1.2.11 Funding

1.3 Create measurement and performance evaluation system

Definition: Goals should be clear, measurable and established in a top-down manner: i.e., plant goals should drive business center goals that drive maintenance and reliability goals required to achieve them. Along with this, maintenance and reliability leaders should have knowledge of benchmarks for their industry to define long-term maintenance and reliability gaps for closure. An ability to identify the appropriate indicators to track is necessary for goal attainment and cultural change. For example, trending lagging indicators as bottom line measures of success and leading indicators as a means to effect performance improvement that impacts the bottom line. He/she must be able to define and implement methods to capture the required data, use appropriate indicators and identify when actions are required. Involvement of the organization in the development, implementation, and ownership of the systems is key to long-term success.

- 1.3.1 Identify plant goals and appropriate maintenance goals
- 1.3.2 Benchmark maintenance and reliability against industry leaders
- 1.3.3 Identify specific indicators to track:
 - 1.3.3.1 Plant level, production center, equipment
 - 1.3.3.2 Lagging indicators (cost, throughput, availability)
 - 1.3.3.3 Leading indicators (planned maintenance, %PM’s, schedule compliance)
- 1.3.4 Identify means of capturing and reporting progress
- 1.3.5 Create system to collect and report indicators
- 1.3.6 Identify owners and accountability for measures and KPI’s
- 1.3.7 Review report and identify change actions

Manage risk

Definition: Managing risk is a necessary task of today's maintenance and reliability professional. He/she should be familiar with various origins of risk for safety, environmental, maintenance, asset care, and capital investments and the financial, legal, and market impact they can have. To assess the risk and make decisions based on risk/benefit scenarios, one needs an understanding of the tools available for analyzing risk. One should be able to develop risk containment plans with compliance tracking methods to trigger variances and initiate follow-up response.

- 1.3.8 Identify sources of risk and maintenance responsibility for risk (statutory compliance and business)
 - 1.3.8.1 Hazardous materials handling
 - 1.3.8.2 Process safety management (where applicable)
 - 1.3.8.3 Environmental requirements
 - 1.3.8.4 Community emergency response
 - 1.3.8.5 Hazardous work safety management
 - 1.3.8.6 Engineering standards and codes
 - 1.3.8.7 Lifecycle costing
 - 1.3.8.8 Repair vs. replace decisions
 - 1.3.8.9 Spares levels
 - 1.3.8.10 Asset care level and frequency
- 1.3.9 Quantify risk where possible
- 1.3.10 Identify appropriate risk management approach and tools
 - 1.3.10.1 Financial impact
 - 1.3.10.2 Legal impact
 - 1.3.10.3 Market impact
 - 1.3.10.4 Tools: criticality assessment, fault tree analysis, planned work assessment, etc.
- 1.3.11 Identify responsibility for implementing risk containment approach
- 1.3.12 Identify compliance tracking method and business risk containment success
- 1.3.13 Implement solutions
- 1.3.14 Measure results and identify variances
- 1.3.15 Take appropriate change actions

1.4 Business Case Preparation

Definition: A solid business case is required to get the funding, resources and support required. It provides a clear purpose (a demonstrated need) and benefits to be achieved. Components of a business plan include justification, current state, future state, gaps and an action plan to close them. Benefits should be tied to plant goals, measurable and expressed in financial terms whenever possible. Several potential solutions with risk/benefit scenarios and a recommended solution are desirable to provide options for the decision-makers.

- 1.4.1 Identify business need and direction

- 1.4.2 State the objective: what are we trying to achieve?
 - 1.4.2.1 Identify current status
 - 1.4.2.2 Production demand vs. capacity
 - 1.4.2.3 Operations cost opportunity
 - 1.4.2.4 Degrading capability
- 1.4.3 Identify expected/required state
 - 1.4.3.1 Production levels
 - 1.4.3.2 Costs
- 1.4.4 Identify method to close gap
- 1.4.5 Asset case strategy – component replacement
- 1.4.6 Capital strategy
- 1.4.7 Operational procedure
- 1.4.8 Quantify costs and benefits

1.5 Communicate to stakeholders

Definition: Maintenance leaders require the skills to communicate effectively to enlist support for improvement initiatives. This includes identifying the stakeholders, determining “what’s in it for them?” and communicating it to them in a manner to which they can best relate.

- 1.5.1 Identify stakeholders (to whom must we communicate?)
- 1.5.2 Identify what information the specific stakeholder requires (operational status, exceptions, improvement value)
- 1.5.3 Identify the source of information (e.g., key performance indicators)
- 1.5.4 Identify the method (system) of communication
- 1.5.5 Perform the communication task
- 1.5.6 Review effectiveness of communications and make action plans to change

1.6 Plan and budget Resources

Definition: Maintenance professionals need to be able to develop a plan and budget resources accordingly. A good plan draws on equipment and cost history, long-term asset care needs, and goals and uses them to develop an activity-based plan. This allows for creation of detailed plans for materials consumption, manpower and contract services that can be rolled up into a master plan. Load leveling can be utilized to provide the best balance of resources to minimize cost and disruption for the total plant. The appropriate accounting and CMMS systems should be utilized to monitor plan status and take actions in a timely manner.

- 1.6.1 Create annual production center staffing plan. By week for the year.
 - 1.6.1.1 Improvement efforts
 - 1.6.1.2 Scheduled maintenance (planned and preventive maintenance, outages, contractors, training)
 - 1.6.1.3 Corrective (estimate)
 - 1.6.1.4 Emergencies (estimate)
- 1.6.2 Create annual materials plan.
 - 1.6.2.1 Scheduled maintenance (PMs, outages, overhauls)

- 1.6.2.2 Estimates for corrective, emergencies (based on history)
- 1.6.3 Load level unit resource requirements
- 1.6.4 Roll up resource requirements to plant level.
- 1.6.5 Load level resources at the plant level
- 1.6.6 Contrast plan (proposed budget) with spending limits. Make adjustments as necessary.
- 1.6.7 Make adjustments in maintenance management system to reflect load leveling
- 1.6.8 Load budget into plant accounting system.
- 1.6.9 Report resource consumption against budget. Take appropriate action.

1.7 Maintenance/operations performance agreements / specifications

Definition: It is important for operating, maintenance, and other involved disciplines to agree on the goals and the measures used to quantify them. Equally important is an understanding the roles everyone plays, and the responsibilities they have in contributing to goal accomplishment. Clarity around this can be accomplished by providing written definitions of roles and responsibilities and discussing to insure agreement by all. Routine review and discussion of progress will provide team commitment and allow for the periodic adjustments that may be required.

- 1.7.1 Operations & maintenance agree on performance specifications at the production center (department) level (e.g., uptime, breakdown response, planned downtime, cost, etc.)
- 1.7.2 Agree on roles and responsibilities for operators and maintainers with respect to the maintenance function.
- 1.7.3 Put the agreement in writing
- 1.7.4 Track performance
- 1.7.5 Meet periodically to review the performance. Make adjustments as necessary.

2.0 Manufacturing Process Reliability

This subject area relates maintenance and reliability activities to the manufacturing process of the organization to *ensure* that maintenance and reliability activities improve the manufacturing process.

2.1 Maintain process and industry standards and specifications

Definition: Maintenance professionals use standards and specifications as a way of translating the efforts of the reliability program into better performance of their company. One approach is to use comparative analysis between company results and the results of other companies, particularly if their performance is seen as setting a standard for performance. Gaps in performance of the reliability program must be identified, interpreted, and communicated to other areas of the company, e.g. financial, operational and other service departments. Plans to close the gaps are created, reviewed, and improved on a continuous basis as part of a "living program" approach to reliability.

- 2.1.1 Review and understand specifications and standards
- 2.1.2 Identify and analyze gaps between industry standards and company practices
- 2.1.3 Develop and implement plan to close gaps
- 2.1.4 Measure results and adjust plan

2.2 Understand the manufacturing process

Definition: Operations and maintenance and reliability resources should have the same understanding of the manufacturing process they deal with, differing only in the level of detail they require for their job function. Process flows must be known and documented in terms of inputs, outputs, resources, and constraints to the process. Controls are established to ensure the process is stable. Once stabilized, operations and maintenance people must not over-react to within-process variations, or conversely, not under-react to out-of-control process variations. Customer's needs are placed at the forefront of process and product designs, and equipment reliability is used to provide the subsequent stability and control that is required. Therefore reliability improvement projects are identified and used to provide added value to the customer.

- 2.2.1 Identify and understand what you make and how you make it
 - 2.2.1.1 Process training
 - 2.2.1.2 Interactions with process managers and operators
 - 2.2.1.3 Participate in Operations Process Improvement Teams
 - 2.2.1.4 Spend time with maintenance craftsmen
- 2.2.2 Identify process variability criteria and relationships affected by maintenance and reliability
 - 2.2.2.1 Statistical Process Control variances
 - 2.2.2.2 Meetings with operations organization
 - 2.2.2.3 Serve on problem-solving teams
- 2.2.3 Identify customer requirements
 - 2.2.3.1 Visit customers to identify reliability requirements
 - 2.2.3.2 Discuss customer reliability requirements with sales organization
- 2.2.4 Relate costs of best maintenance and reliability practices to customer value
 - 2.2.4.1 Cost of unreliability
 - 2.2.4.2 Benchmarking
- 2.2.5 Develop and implement plan to capture benefits identified

2.3 Manufacturing effectiveness techniques

Definition: The maintenance and reliability and the operation and production resources must both have ways to measure their performance and progress against the business and manufacturing goals of the company. High-level key process indicators (KPIs) that align with the goals are co-developed by the people who own, operate, and maintain the process equipment. The responsibility for improving the effectiveness of the measures is shared by all parties, as evidenced by their participation in cross-functional activities that help achieve common goals.

- 2.3.1 Develop measures to relate equipment reliability to manufacturing process
 - 2.3.1.1 Overall Equipment Effectiveness

- 2.3.1.2 Reject Rate
- 2.3.1.3 Product quality
- 2.3.1.4 Production rate improvement
- 2.3.2 Establish partnership between maintenance and operations for most effective asset management
 - 2.3.2.1 Total Productive Maintenance
 - 2.3.2.2 Create manufacturing teams
 - 2.3.2.3 Cross-functional, problem-solving, and process improvement teams

2.4 Safety, Health, Environmental

Definition: Occupational health and safety (H&S) and the environment must not be sacrificed to achieve manufacturing and production goals. The benefits of good H&S and environmental practices should be recognized for helping create a safer, happier work environment that nurtures improved job satisfaction. Given the degree of regulation that has been applied and people's sensitivities about these areas, it becomes vital to use pro-active programs to identify and eliminate any deviation from accepted environmental and H&S practices.

- 2.4.1.1 Identify benefits of good safety practices to bottom line
- 2.4.2 Identify specific Environmental, Safety, and Health (ESH) issues applicable to manufacturing process
 - 2.4.2.1 Process Hazard Analysis
 - 2.4.2.2 Job Safety Analysis
 - 2.4.2.3 Accident investigation (root cause failure analysis)
 - 2.4.2.4 Safety audits
- 2.4.3 Identify applicable regulatory issues/activities
 - 2.4.3.1 ESH-required inspections, tests, and PM activities
 - 2.4.3.2 Inspections of safety equipment (fire extinguishers, personal protective equipment inspections, eyewash/shower tests, etc.)
 - 2.4.3.3 Safety inspections of process and maintenance equipment (lifting equipment, ladders, safety valves)
 - 2.4.3.4 ESH activities associated with maintenance activities (lock-out/tag-out, confined space entry, hot work permits, waste disposal, personal protective equipment)
 - 2.4.3.5 ESH specifications that regulate how maintenance, reliability, and design activities must be done (boiler maintenance regulations, water treatment process and equipment, permit-regulated operations)
- 2.4.4 Prevent acceptance of normalized deviation
 - 2.4.4.1 Internal audits
 - 2.4.4.2 Third party audits

2.4 Manage effects of changes to processes and equipment

Definition: It is possible for the people who administer reliability and maintenance programs to not achieve their goals because either: I) the process is intentionally changed without people evaluating the effect on equipment, or, II) equipment condition degrades over time to the point

where it can no longer reliably meet the goals. To avoid these pitfalls, a formal change management process is needed to identify any significant changes to the process or equipment capability. Having identified any changes, a modification plan is developed to ensure that the process continues to have capable and reliable equipment assets.

- 2.4.1 Create process to identify when changes are being made (Management of Change process)
- 2.4.2 Apply analytical assessment process to identify effects of changes being made
 - 2.4.2.1 Reliability Centered Maintenance Analysis
 - 2.4.2.2 Failure Modes and Effects Analysis
- 2.4.3 Implement and manage changes in:
 - 2.4.3.1 Policies
 - 2.4.3.2 Procedures
 - 2.4.3.3 Designs
 - 2.4.3.4 Process/equipment modifications

3.0 Equipment Reliability

This subject area describes two kinds of activities that apply to the equipment and processes for which the maintenance and reliability professional is accountable. First are those activities used to assess the current capabilities of the equipment and processes in terms of their reliability, availability, maintainability, and criticality. Second are the activities used to select and apply the most appropriate maintenance practices, so that the equipment and processes continue to deliver their intended capabilities in the safest and most cost-effective manner.

3.1 Determine equipment and process performance expectations from the business plan.

Definition: Review the business plan and identify how its goals and expectations may affect implementation of the maintenance strategy, either directly or indirectly, by changing how equipment and process assets will be operated and maintained while meeting all business, licensing, environmental, safety and other regulatory goals and requirements.

- 3.1.1 Review business goals to identify those that must be supported by maintenance and reliability strategies.
 - 3.1.1.1 Changes in sales goals
 - 3.1.1.1.1 Changes to production goals
 - 3.1.1.1.2 Changes in product mix sales goals
 - 3.1.1.2 Changes to production processes
 - 3.1.1.2.1 New equipment
 - 3.1.1.2.2 New uses for existing equipment
 - 3.1.1.3 Changes to staffing levels
 - 3.1.1.4 Changes to budgets/capital spending
- 3.1.2 Calculate required equipment/process availability, based on production requirements to meet business goals including effects of changeovers to different products.
- 3.1.3 Establish equipment maintenance plan resources budget

- 3.1.3.1 Labor costs
- 3.1.3.2 Cost of spare parts/replacement parts
- 3.1.3.3 Cost of external contractors and services
- 3.1.3.4 Cost of product replacement or service interruption due to equipment maintenance or failures

3.2 Establish current performance levels and analyze gaps

Definition: Determine the current capabilities of the production equipment to meet the expectations of the business plan. Identify and quantify gaps between capabilities and expectations.

- 3.2.1 Prioritize equipment assets and processes to assure that maintenance and reliability resources are appropriately allocated
 - 3.2.1.1 Criticality
 - 3.2.1.2 Capacity
 - 3.2.1.3 Cost
- 3.2.2 Select and apply appropriate metrics to assess current condition and capabilities of equipment assets and production processes.
 - 3.2.2.1 MTBF/Failure rate/MTTR/Repair rate
 - 3.2.2.2 Maintenance cost/unit of production
 - 3.2.2.3 Equipment availability
 - 3.2.2.4 Process availability or system availability
 - 3.2.2.5 Scrap rate
 - 3.2.2.6 Production delays
 - 3.2.2.7 Total maintenance cost as percentage of asset
 - 3.2.2.8 Replacement value
 - 3.2.2.9 Delay rate
 - 3.2.2.10 Percent planned or unplanned maintenance
 - 3.2.2.11 Maintainability
- 3.2.3 For existing equipment and processes, review results of performance assessment to identify opportunities for improvement and potential performance shortfalls.
 - 3.2.3.1 Changes in operating conditions that may change maintenance requirements
 - 3.2.3.2 Changes in performance expectations
 - 3.2.3.3 Inadequacies of existing maintenance practices
 - 3.2.3.4 Newly identified maintenance requirements discovered through failure investigation
 - 3.2.3.5 Opportunities to apply more sophisticated new maintenance technologies
 - 3.2.3.6 Chronic problem equipment
 - 3.2.3.7 Root Cause Failure Analyses of significant past failures
 - 3.2.3.8 Pareto Analysis
 - 3.2.3.9 Bottleneck Analysis
 - 3.2.3.10 Weibull (distribution) Analysis
- 3.2.4 Identify anticipated maintenance requirements for new equipment

3.3 Establish a maintenance strategy to assure performance

Definition: The equipment maintenance plan provides the following functions: 1) It describes the specific maintenance practices to be applied to assure the day-to-day reliability of the equipment being maintained. 2) It supports and helps achieve the company's stated business goals. 3) It supports and helps implement the vision of the corporate maintenance strategy (also see Section 1.0, Business and Management).

- 3.3.1 Establish performance improvement targets
 - 3.3.1.1 Process availability improvement
 - 3.3.1.2 Reliability analysis and reliability growth
 - 3.3.1.3 Maintenance cost reduction and overall maintenance performance
 - 3.3.1.4 % Reduction in Unplanned Maintenance
 - 3.3.1.5 Overall Equipment Effectiveness
 - 3.3.1.6 Process capability improvement
 - 3.3.1.7 Percent planned and scheduled maintenance
 - 3.3.1.8 Return on Net Assets (RONA)
- 3.3.2 Select activities (tactics) to meet targets and close gaps
 - 3.3.2.1 For equipment and processes where maintenance issues and requirements are clearly understood, select and apply appropriate maintenance practices:
 - 3.3.2.1.1 Restoration/replacement activities
 - 3.3.2.1.2 Condition-based maintenance activities
 - 3.3.2.1.3 Failure-finding tasks
 - 3.3.2.2 For equipment or processes where maintenance costs are high, where reliability is low, or where chronic problems exist, perform additional analysis to identify appropriate maintenance practices.
 - 3.3.2.2.1 Root Cause Failure Analysis
 - 3.3.2.2.2 Failure Modes and Effects Analysis
 - 3.3.2.2.3 Reliability-centered maintenance analysis
 - 3.3.2.3 For planned new equipment purchases and installations where no maintenance history exists, apply M&R "best practices" to assure maximum reliability
 - 3.3.2.3.1 During initial design
 - 3.3.2.3.1.1 To assure ease of maintenance
 - 3.3.2.3.1.2 To maximize process and component reliability
 - 3.3.2.3.1.3 Life-cycle Cost Analysis
 - 3.3.2.3.1.4 Design for maintainability
 - 3.3.2.3.2 During procurement
 - 3.3.2.3.2.1 To minimize life-cycle cost
 - 3.3.2.3.2.2 To assure most reliable materials of construction are used
 - 3.3.2.3.2.3 Purchasing specifications
 - 3.3.2.3.2.4 Qualification of vendors
 - 3.3.2.3.3 During installation or acquisition of equipment with known or unknown history
 - 3.3.2.3.3.1 Reliability-centered Maintenance Analysis

- 3.3.2.3.3.2 Failure Modes and Effects Analysis
- 3.3.2.3.3.3 Precision installation
- 3.3.2.3.3.4 Performance tests
- 3.3.2.3.4 During startup and operation
 - 3.3.2.3.4.1 Use detailed commissioning, startup and operating procedures
 - 3.3.2.3.4.2 Institute operator basis care/PM (TPM) and tour requirements
 - 3.3.2.3.4.3 Conduct operator condition monitoring of both process and equipment
 - 3.3.2.3.4.4 Sustain team focus on excellence including during shift hand-over between teams
 - 3.3.2.3.4.5 Emphasize teamwork between operations, maintenance and engineering
- 3.3.2.3.5 During maintenance activities throughout the life cycle
 - 3.3.2.3.5.1 Reliability-centered maintenance analysis living program
 - 3.3.2.3.5.2 Emphasize use of detailed procedures sustained by a continuous improvement program

3.4 Cost-justify (budget) tactics selected for implementation

Definition: Prepare maintenance and reliability budget to help manage costs to implement the maintenance and reliability strategy. Prepare business cases as required to justify maintenance and reliability efforts to correct exceptional equipment deficiencies.

- 3.4.1 Establish cost/manpower resource requirements to implement maintenance tactics selected
 - 3.4.1.1 Determine cost (or potential cost) of unreliability for critical components
 - 3.4.1.1.1 Repair cost
 - 3.4.1.1.2 Cost to repair collateral damage
 - 3.4.1.1.3 Lost opportunity cost
 - 3.4.1.1.4 Product replacement cost
 - 3.4.1.2 Allocate resources to reduce cost of unreliability
- 3.4.2 Prioritize and allocate costs as required to meet business plan

3.5 Execute a maintenance strategy (See Work Management, section 5.0)

Definition: Apply the Work Management Skill to execute the Maintenance and Reliability strategy.

- 3.5.1 Allocate resources to carry out each element of the strategy
- 3.5.2 Ensure each strategic action is brought to closure

3.6 Review performance and adjust maintenance strategy

Definition: Continually review maintenance and reliability key performance indicators to track effectiveness of the maintenance and reliability strategy. Adjust strategy as required when key performance indicator deviations begin to occur.

- 3.6.1 Identify and assess gaps between actual performance and improvement targets
 - 3.6.1.1 Review planned maintenance activities
 - 3.6.1.1.1 Are maintenance intervals correct?
 - 3.6.1.1.2 Do procedures assure proper execution of the maintenance activity?
 - 3.6.1.1.3 Do scheduled inspections and tests identify the faults they are intended to find?
 - 3.6.1.1.4 Are maintenance activities still cost-effective?
 - 3.6.1.1.5 Are PM's optimized in all respects?
 - 3.6.1.2 Review Predictive Maintenance (PdM) programs
 - 3.6.1.2.1 Are PdM and condition monitoring technologies detecting known failure modes and have 'saved' justified Predictive Maintenance costs?
 - 3.6.1.2.2 Are there new or additional technologies to consider adding to the Predictive Maintenance program?
 - 3.6.1.2.2.1 Vibration analysis
 - 3.6.1.2.2.2 Shock Pulse analysis
 - 3.6.1.2.2.3 Ultrasonic and acoustic analysis
 - 3.6.1.2.2.4 Lubricant quality analysis
 - 3.6.1.2.2.5 Wear Particle analysis
 - 3.6.1.2.2.6 Temperature measurement and infrared analysis (thermography)
 - 3.6.1.2.2.7 Eddy current analysis
 - 3.6.1.2.2.8 Electrical circuit analysis
 - 3.6.1.2.2.9 Transformer condition analysis
 - 3.6.1.2.3 Are operators applying process trend and control chart and "look, listen, feel, smell" routinely?
 - 3.6.1.2.4 Is PdM and process condition monitoring fully integrated with planning and scheduling?
- 3.6.2 Identify best practices and new technologies which might improve equipment process reliability
 - 3.6.2.1 Benchmarking
 - 3.6.2.2 Trade associations and professional societies
 - 3.6.2.3 Industry standards and specifications
- 3.6.3 Audit performance of and compliance with M&R initiatives and programs.
- 3.6.4 Adjust targets or performance as required to close performance gaps
- 3.6.5 Analyze system or equipment failures and assure that maintenance strategy addresses potential future failures as required (Root Cause Failure Analysis (RCFA), Failure Modes and Effects Analysis (FMEA), etc.)
 - 3.6.5.1 Establish a process to qualify high-impact failures for failure analysis
 - 3.6.5.2 Establish a process to transfer failure analysis findings back into the maintenance strategy
 - 3.6.5.3

4.0 People Skills

This inventory describes processes for assuring that the maintenance and reliability staff is the most qualified and best assigned to achieve the maintenance and reliability organization goals.

4.1 Assess organizational competence and direction

Definition: The people responsible for reliability at the management level must constantly scan their environment for trends, issues and opportunities that might impact the reliability program. This is essential for keeping it relevant and supportive of the business goals of the company. Keeping any new information in mind, the ability of the maintenance and reliability program to support business goals is evaluated and changes made according to any new requirements. Strategic and tactical plans are developed and used in tandem with a communication plan to ensure the changes are understood and accepted at all levels of the maintenance and reliability workforce.

- 4.1.1 Identify business goals, direction, plans, and drivers
 - 4.1.1.1 Strategic direction
 - 4.1.1.2 Capital upgrades
 - 4.1.1.3 Markets
 - 4.1.1.4 Acquisitions and plant expansions/contractions
 - 4.1.1.5 Outsourcing
 - 4.1.1.6 Organizational changes
 - 4.1.1.7 Specific cost and volume goals
 - 4.1.1.8 Safety and environmental requirements
- 4.1.2 Identify constraints
 - 4.1.2.1 Culture
 - 4.1.2.2 People
 - 4.1.2.3 Resources
 - 4.1.2.4 Contracts
 - 4.1.2.4.1 Organized Labor
 - 4.1.2.4.2 Customer performance
 - 4.1.2.5 Asset condition
 - 4.1.2.6 Existing policies, practices, processes
- 4.1.3 Assess and document current structure, skills, and effectiveness
 - 4.1.3.1 Workforce demographics
 - 4.1.3.2 Skills certifications/documentation/training
 - 4.1.3.3 Key performance indicators – rework, job estimate variation
 - 4.1.3.4 Schedule compliance
- 4.1.4 Develop consensus with facility leadership team

4.2 Develop the maintenance and reliability organization structure

Definition: The reliability professional must understand the importance of an enabling organizational structure, without which the best intended maintenance and reliability efforts may not succeed. Organizational development aims to take the "as-is" structure of the company and

move it forward into the desired "to-be" state. If maintenance and reliability is not included in the planning and transition stages of any re-organization effort, a good maintenance and reliability program may fall by the wayside, or an improvement program may never get off the ground.

- 4.2.1 Define future state for organization
 - 4.2.1.1 To correct deficiencies
 - 4.2.1.2 To assure highest priority work is done
 - 4.2.1.3 To enable change and improvement
 - 4.2.1.4 To maximize flexibility of workforce
 - 4.2.1.5 To achieve common goals
- 4.2.2 Design organizational structure to achieve future state
 - 4.2.2.1 Reporting structure
 - 4.2.2.2 Define roles and relations to other functions
- 4.2.3 Define job objectives, responsibilities, and performance criteria
 - 4.2.3.1 Job descriptions
 - 4.2.3.2 Assess competence to fill jobs
 - 4.2.3.3 Document gaps
- 4.2.4 Assign staff and communicate organization plan
 - 4.2.4.1 Develop training materials
 - 4.2.4.2 Train and present (inside and outside the maintenance and reliability organization)
 - 4.2.4.3 Communicate expectations
- 4.2.5 Evaluate performance of organizational structure and take corrective action

4.3 Develop the maintenance and reliability staff

Definition: The people resources assigned to the reliability program need to be evaluated and developed according to their skills inventories and training needs evaluations. Based on these, personal development plans are used to transfer the required skills that will provide the required level of performance on the job. An "evergreening" process is desirable to help keep the workforce skills current with new developments in equipment technology and manufacturing processes. Using the strategy, plan and goals above, determine skills requirements over the short and long term, review current skills and identify skills gaps.

- 4.3.1 Develop skills acquisition and development plan
 - 4.3.1.1 Plan for existing employees (movement in and out of organization)
 - 4.3.1.2 Requirements for new hires
 - 4.3.1.3 Requirements for contractors
- 4.3.2 Train and certify in skills and track development
- 4.3.3 Setup and record skills database
- 4.3.4 Measure job performance
 - 4.3.4.1 Supervisor and peer evaluation
 - 4.3.4.2 Craftsman productivity
 - 4.3.4.3 Annual goal achievement
 - 4.3.4.4 Individual goals
 - 4.3.4.5 Unit goals

- 4.3.5 Provide feedback and counseling
 - 4.3.5.1 Staff
 - 4.3.5.2 Recruiter/HR
 - 4.3.5.3 Contractor
- 4.3.6 Design career development and succession plans

4.4 Communicate maintenance and reliability to the organization

Definition: Reliability and maintenance professionals need to use a good communication plan to avoid many of the pitfalls associated with their improvement and sustaining efforts. Providing people at all levels of the organization with the appropriate news about program changes or successes will foster acceptance and increase the demand for better reliability programs. Conveying the right message at the right time help maintenance and reliability resources maintain a good profile that is relevant to the company.

- 4.4.1 Identify information exchange requirements
 - 4.4.1.1 Who needs what information within maintenance and reliability organization
 - 4.4.1.2 Who needs what information outside maintenance and reliability organization
- 4.4.2 Identify methods to measure if communications was successful
 - 4.4.2.1 Surveys: progress, measures and comprehension
 - 4.4.2.2 Management by walking around (MBWA)
- 4.4.3 Establish decision communication vehicles
 - 4.4.3.1 E-mail
 - 4.4.3.2 Presentations
 - 4.4.3.3 Reports
 - 4.4.3.4 Bulletin boards
 - 4.4.3.5 Memos
 - 4.4.3.6 Intranet
- 4.4.4 Develop implementation plan
 - 4.4.4.1 Implement communication plan
 - 4.4.4.2 Measure results and make adjustments

5.0 Work Management

This subject area focuses on the skills used to get the maintenance and reliability work done. It includes scheduling and planning activities, quality assurance of maintenance activities, stores and inventory management.

5.1 Comprehensive work identification

Definition: It is important for those who identify needed maintenance work to understand the different types of actions that can be taken and when they should be applied from a technical standpoint. Of equal importance is the ability to assess the business justification for the maintenance plan and to develop the needed data support systems for it. The ability to manage the work, to keep the appropriate backlog, and to minimize overdue work must also be evident.

- 5.1.1 Applies life cycle or asset management tools/techniques
 - 5.1.1.1 Establishes critical equipment list
 - 5.1.1.2 Establishes equipment data base in CMMS
 - 5.1.1.3 Establishes hierarchy of equipment and systems
 - 5.1.1.4 Develops and implements planned and predictive maintenance strategy using tools such as RCM
- 5.1.2 Differentiates types of work accurately
 - 5.1.2.1 Failure finding
 - 5.1.2.2 Preventive
 - 5.1.2.3 Predictive / Condition based
 - 5.1.2.4 Corrective
 - 5.1.2.5 Small projects - Maintenance & Repair
 - 5.1.2.6 Major shutdowns
 - 5.1.2.7 Operational support
- 5.1.3 Applies backlog management techniques
- 5.1.4 Monitors overdue jobs

5.2 Plant-wide formal prioritization system

Definition: The maintenance professional needs to be able to develop a logical and easily followed system of prioritization for the work of a plant-wide work group with multiple skill sets. The prioritization system needs to address all the factors critical to both business success and the maintenance function.

- 5.2.1 Applies factors used for prioritization
 - 5.2.1.1 Equipment / system criticality
 - 5.2.1.2 Production needs
 - 5.2.1.3 Safety or environmental impact
 - 5.2.1.4 Manpower requirements for major shutdowns or emergencies
- 5.2.2 Develops and implements prioritization system that defines and assigns time factors for completion of work

5.3 Effective work planning prior to scheduling

Definition: The proper understanding of the planning process is critical to those managing the maintenance function. The maintenance professional needs to be able to articulate the business value derived from the planning process. Planning is the key to increased efficiency of the maintenance work force, and those who manage it must know the steps involved in creating an effective and efficient plan. They must also know how to utilize the systems that support the planning process. The differences between day-to-day maintenance planning and the planning of a major turnaround need to be understood.

- 5.3.1 Applies the elements of job planning
 - 5.3.1.1 Job review and consulting with appropriate people

- 5.3.1.2 Using the CMMS for planning
- 5.3.1.3 Specifying and providing materials
- 5.3.1.4 Sequence of work
- 5.3.1.5 Special tools, equipment or safety needs
- 5.3.1.6 Safety, Health, and Environmental concerns
- 5.3.1.7 Special permits
- 5.3.1.8 Job estimating
- 5.3.1.9 Job monitoring
- 5.3.1.10 People resource requirements
- 5.3.1.11 Contractor interface and requirements
- 5.3.1.12 Requirements for work order close out
- 5.3.2 Adds business value (reduced costs) through properly planned and scheduled work
 - 5.3.2.1 Turnaround (shutdown) planning
 - 5.3.2.2 Creating and structuring the turnaround team
 - 5.3.2.3 Critical path methodology
 - 5.3.2.4 Use of a computerized shutdown planning tool
 - 5.3.2.5 Sets proper lead times
 - 5.3.2.6 Shutdown time minimization techniques
 - 5.3.2.7 Turnaround period extension techniques
- 5.3.3 Establishes and applies metrics to analyze the performance of planning and scheduling

5.4 Effective, cooperative work scheduling and backlog management

Definition: The maintenance professional needs to understand the key success factors to proper work scheduling. The multiple needs from plant groups and the business need to be considered in the scheduling process. An understanding of how to balance all factors and create a logical and achievable schedule is required. The systems that are connected to and support the scheduling process need to be well understood.

- 5.4.1 Applies a comprehensive scheduling process
 - 5.4.1.1 Daily, weekly, monthly schedules
 - 5.4.1.2 Coordinated with operations needs
 - 5.4.1.3 Manpower balancing
 - 5.4.1.4 Materials expediting process
 - 5.4.1.5 Conflict resolution
 - 5.4.1.6 Be sure job is “ready to schedule”
- 5.4.2 Arrange for permits & special requirements and lock & tag requirements
- 5.4.3 Controls the impact on productivity of schedule break-ins by restricting unscheduled work
- 5.4.4 Establish metrics for performance

5.5 Effective resource management (people, materials, financial)

Definition: The methods and best practices for effective use of maintenance resources need to be clearly understood. The maintenance professional needs to understand the process of keeping the workforce skill inventory abreast of the needs of the maintenance plan. The systems needed to properly support the management of the critical resources of maintenance should be well understood. The criteria for the appropriate use of the various methods of making spare parts available to the maintenance function, along with the values and risks associated with each, need to be known. Methods for sound cost management of the maintenance function and how the value of the work performed impacts the business financial metrics needs to be understood. The maintenance professional needs to be able to select the most appropriate metrics to support the needs of the business and guide the workforce to higher levels of performance.

- 5.5.1 Applies best practice concepts of people management
 - 5.5.1.1 Effective use of mechanics time
 - 5.5.1.2 Roles of planner, coordinator, supervisor
 - 5.5.1.3 Auditing and benchmarking performance
 - 5.5.1.4 Establishing the proper skill mix
- 5.5.2 Establishes training plans and skills evaluation
 - 5.5.2.1 Up-to-date maintenance procedures
 - 5.5.2.2 Task - skill analysis
 - 5.5.2.3 Developing individual training requirements
 - 5.5.2.4 Creating a site or crew training plan
- 5.5.3 Applies best practice concepts of materials management
 - 5.5.3.1 Applies spare parts management models
 - 5.5.3.2 Assures use of the CMMS for equipment /parts bills of materials
 - 5.5.3.3 Ensures complete and correct bill of materials for critical equipment
 - 5.5.3.4 Stores/sub-stores inventory control
 - 5.5.3.5 Implements use of integrated suppliers and consignment parts
 - 5.5.3.6 Establishes quality assurance program for spare parts
 - 5.5.3.7 Develops spare parts kitting strategy for planned jobs
 - 5.5.3.8 Ensures optimum stock availability and cost (free-issue vs. controlled issue)
 - 5.5.3.9 Develops and implements spare parts justification methods
 - 5.5.3.10 Applies a holistic, work-process view of materials (right part at right place at right time)
 - 5.5.3.11 Analyzes life cycle costs and adjusts materials management strategy
 - 5.5.3.12 Analyses purchase cost vs. maintenance, lost opportunity and operating costs
- 5.5.4 Applies best practice concepts of maintenance costs management
 - 5.5.4.1 Ensures an accurate cost accounting system
 - 5.5.4.2 Develops comprehensive cost reporting and monitoring monthly
 - 5.5.5 Analyzes how performance affects costs and performs “look-backs” to adjust strategy
 - 5.5.6 Analyzes the effect of maintenance and reliability costs on business metrics such as RONA (return on net assets), EVA(economic value added), PIT, etc.
 - 5.5.6.1 Maintenance budgeting – forecasting and zero based budgeting
 - 5.5.6.2 Applies standards for effective use of contractors

- 5.5.7 Establishes contracting principles
 - 5.5.7.1 Best practice contractor management techniques
- 5.5.8 Establishes metrics of performance

5.6 Document work execution and update records / history

Definition: Maintenance professionals must demonstrate their ability to create, update and manage work orders in a way that insures that those who will do the work understand what needs to be done, how long it should take, what safety precautions need to be taken, and the materials they will need. Also, they must assure that valuable historical data is kept, and this data can be used to guide improvements. The proper methods for cost estimation and the use of the appropriate work order type for the situation should be known.

- 5.6.1 Applies the basic elements of an excellent work order system
 - 5.6.1.1 Writing quality work orders
 - 5.6.1.2 Preparing accurate estimates of labor and materials requirements
 - 5.6.1.3 Applies use of blanket orders appropriately
 - 5.6.1.4 Develops and applies visual maintenance systems
- 5.6.2 Ensures good work order history records
 - 5.6.2.1 Ensures closing out work orders in timely manner
 - 5.6.2.2 Ensures backlogs are current
 - 5.6.2.3 Makes modifications to the job plan, such as adjustments to estimates
 - 5.6.2.4 Ensures as found and repair histories are kept and are accurate
 - 5.6.2.5 Establishes data entry requirements for useful reporting
- 5.6.3 Utilizes labor effectively
 - 5.6.3.1 Conducts time and motion analyses and studies
- 5.6.4 Ensures task staffing
- 5.6.5 Applies best practice work assignment processes
 - 5.6.6.1 Controls unplanned work and emergency work
 - 5.6.6.2 Ensures safety aspects are considered

5.7 Equipment history review and failure identification

Definition: The proper methods for assessing both equipment reliability and resource effectiveness must be understood. The maintenance professional needs to know the methods for assessing where to most effectively apply their resources so as to bring the most value to the business they support. The different methodologies for finding the sources of defects, the root causes of failure, and how to bring about the needed changes to prevent reoccurrence needs to be known. A reliability and defect elimination mindset needs to be evident.

- 5.7.1 Applies techniques for analyzing equipment history
 - 5.7.1.1 Calculates mean time between failures (MTBF)
 - 5.7.1.2 Calculates mean time to repair (MTTR)
 - 5.7.1.3 Weibull analysis
 - 5.7.1.4 Identifies costliest pieces of equipment (Pareto charts - cost of lost production, plus maintenance cost)

- 5.7.1.5 Analyzes equipment effects on production capability
- 5.7.2 Learns from failures, applies root cause analysis
- 5.7.3 Applies a continuous defect elimination mindset
 - 5.7.3.1 Analyzes and understands sources of defects
 - 5.7.3.2 Identifies chronic versus sporadic failures and how they differ
 - 5.7.3.3 Develops methods for preserving and collecting failure evidence
- 5.7.4 Uses multi-functional teams for failure analysis and problem solving
 - 5.7.4.1 Identifies failure patterns
- 5.7.5 Applies CMMS reporting capabilities to support failure identification

5.8 Effective performance measures and follow-up

Definition: The understanding of maintenance performance metrics and how to apply them needs to be demonstrated. The ability to identify and use complementary metrics to give a well-rounded assessment of performance and to support the needs of the business should be evident.

- 5.8.1 Applies frequently used performance metrics
 - 5.8.1.1 Percent planned work
 - 5.8.1.2 Percent schedule compliance
 - 5.8.1.3 Backlog hours
 - 5.8.1.4 PM completion versus scheduled
 - 5.8.1.5 Uptime

5.9 Capital project planning

Definition: The maintenance professional understands all the steps required to plan and implement a capital project. The requirements of each step need to be known. The ability to use tools and techniques critical to the success of a project planning process needs to be evident.

- 5.9.1 Develops scope of work
- 5.9.2 Estimates cost and timing
- 5.9.3 Creates credible justification
- 5.9.4 Establishes design requirements
- 5.9.5 Builds reliability in up-front by design that applies Life Cycle Cost and RCM/FMEA principles
- 5.9.6 Recruits project team members from operations and maintenance
- 5.9.7 Applies best practice use of engineering and construction contractors
- 5.9.8 Estimates of construction time
- 5.9.9 Effectively manages contractors
- 5.9.10 Applies critical path scheduling tools
 - 5.9.10.1 PERT diagrams
 - 5.9.10.2 Software such as Timeline, Microsoft Project, etc.

5.10 Effective use of information technologies (CMMS, etc)

Definition: The maintenance professional needs the ability to use a wide variety of computerized systems for the management of the information used in the management of the maintenance function. An understanding of the functionality of a Computerized Maintenance Management System as well as systems used to transfer or share data and documents between both people and various databases needs to be evident. The ability to manipulate data into information on a host of computerized systems commonly used by maintenance needs to be demonstrated. An understanding of when and how to most appropriately use computerized tools to manage maintenance work, assess the health of equipment, and to guide improvement efforts should be part of the maintenance professional's abilities.

- 5.10.1 Applies technologies for documents transfer and record keeping
 - 5.10.1.1 Examples: Prism, Mockingbird, etc.
 - 5.10.1.2 Examples: Lotus Notes, Microsoft Office, etc.
- 5.10.2 Applies basic functions of a CMMS
 - 5.10.2.1 Equipment records / bill of materials
 - 5.10.2.2 Work order control system
 - 5.10.2.3 Planning and scheduling work
 - 5.10.2.4 Equipment history records (inspection, failure and cost data)
 - 5.10.2.5 Process Safety Management records
 - 5.10.2.6 Interfaces to other systems like accounting, personnel, sourcing
 - 5.10.2.7 Reporting capabilities (converting data to information)
- 5.10.3 Applies predictive maintenance information technology tools, such as vibration monitoring
 - 5.10.3.1 Discriminates appropriate level of data to include
 - 5.10.3.2 Critically evaluates required data entry to ensure meaningful information/reporting output

References

The following listings of published references are a sampling of many of the leading reference texts on the subject of maintenance and reliability. This listing does not include all references that may be useful in increasing one's knowledge and skills in maintenance and reliability.

The concepts and principles in these references may help a candidate find information on improving their knowledge and skills. However, the SMRPCO certification exams focus on applied knowledge, and study of references alone is highly unlikely to ensure success on the certification examination. Experience with testing of our certification exams has shown that a high degree of applied experience is necessary for success on the examination.

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Sample Examination Questions

Pages 40 through 42 contain 15 typical examination questions that represent the format and style of questions that could be expected on the Examination for Certification in Maintenance and Reliability Management.

If you would like to simulate an exam setting, take no more than 15 minutes to answer these questions without using reference materials. Circle what you believe are the best or most correct answers, and then check your results against the answer key on page 43. Taking this sample exam may give you an appreciation for the actual examination setting.

Sample Examination Questions

1. Which one of the following is generally true?
 - A) Construction contractors are usually equally skilled at performing all maintenance tasks
 - B) Maintenance is often reduced through project designs that provide in-place spares for all rotating equipment and heat exchangers
 - C) Reliability Centered Maintenance can be applied on capital projects in the pre-construction stage to determine the maintenance plan
 - D) Most mechanics can easily alternate between doing capital project work and doing equipment diagnosis and repair work

2. What is the best criterion for changing a known and controlled variable to meet a new customer requirement?
 - A) Engineering analysis
 - B) Operator and maintainer experience
 - C) Senior management directive
 - D) Reliability and maintainability analysis

3. From the choices below, select the formula for Reliability, R:
 - A) $R = e^{-(MTTR/t)}$
 - B) $R = e^{-(t/MTBF)}$
 - C) $R = \text{Downtime}/(\text{Downtime} + \text{Uptime})$
 - D) $R = \text{MTBF} / (\text{MTBF} + \text{MTTR})$

4. A reliability leader has noted that the air supply to the pneumatic drill and stamping center is intermittently inadequate, resulting in costly process interruptions. Three potential solutions have been identified: 1) Purchase a new, larger air compressor for \$40,000 2) Perform and overhaul of the existing compressor for \$10,000 3) Contract a performance investigation of the air system for \$3,500. Which is the best alternative and why?
 - A) Overhaul the existing compressor to see if that solves the problem
 - B) Buy a new compressor because Mean Time Between Failure is guaranteed by the supplier
 - C) Buy a new air compressor because the existing compressor seems too small
 - D) Investigate system performance to determine the root cause of the problem

5. If a machine is run for 500 hours and five failures are observed during this period, what is the Mean Time Between Failure?
 - A) 500 hours
 - B) 0.01 hours
 - C) 2500 hours
 - D) 100 hours

6. Which of the following most effectively makes up the members of a Manufacturing Team?
 - A) Sales/Customer/Production/Supplier/Senior Management
 - B) Maintenance/Engineering/Production/Human Resources
 - C) Production/Maintenance/Supplier/Engineering
 - D) Senior Management/Production/Human Resources

7. What is the most important purpose of performing risk evaluations?
 - A) To determine what level of response is cost justified
 - B) To clearly define activities required to contain risks
 - C) To identify what events may have serious consequences
 - D) To assure compliance with company policies

8. Of the following, what is the best method for measuring employee skills and training?
 - A) Create and maintain a skills inventory tracking database
 - B) Ask employees to keep a training notebook
 - C) Keep records of all formal training courses taken
 - D) Have employees complete annual self-evaluations

9. When training maintenance workers, it is best to first:
 - A) List all the tasks the workers need to perform
 - B) Check the budget to set how much to spend per worker
 - C) Review the list of classes already taken by the workers
 - D) Give classes to all workers on basic skills

10. What relationship should Maintenance and Reliability Teams have with customers and suppliers for optimum effectiveness?
 - A) Purchasing should be the only communicators with suppliers
 - B) Supervision should be the only communicators with customers and suppliers
 - C) Team members should be involved in communicating with customers and suppliers
 - D) Sales should be the only department communicating with customers

11. Which of the following metrics definitions is not accurate?
- A) Uptime - % of time you run producing quality product at design rate
 - B) Schedule compliance – how often mechanics are pulled off their current work to another task
 - C) MTBF – a measure of equipment life expectancy
 - D) Backlog – how long it takes to fix broken equipment
12. Which of the following does not support people development?
- A) Providing feedback only when asked
 - B) Defining result areas, goals, and measurements
 - C) Coaching, feedback, and encouragement
 - D) Defining training and skills goals
13. From the following list, which is not a critical structural element of a strategic plan for maintenance and reliability?
- A) Current levels of performance
 - B) Benefits available through implementation
 - C) Historical direction of the business
 - D) Vision of the future state
14. Which performance result best shows a maintenance and reliability manager that the scheduled maintenance activities being implemented are effective?
- A) Hours spent on unscheduled maintenance have decreased
 - B) Maintenance cost per unit of production has decreased
 - C) Total annual maintenance cost has decreased
 - D) Production rate has increased
15. When the time period between the testing which detects a failure and the failure actually occurs is highly variable, and the life expectancy is highly variable, a good approach is:
- A) More frequent periodic predictive testing
 - B) Structured preventive maintenance
 - C) On-line condition monitoring
 - D) Time based rebuild or changeout

Answers to Sample Questions

1. C
2. A
3. B
4. D
5. D
6. C
7. A
8. A
9. A
10. C
11. D
12. A
13. C
14. A
15. C