ASME RAM-1–2013

Reliability, Availability, and Maintainability of Equipment and Systems in Power Plants

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Two Park Avenue • New York, NY • 10016 USA

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The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

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FOREWORD

Reliable plants meet owner expectations. Understanding these is the first step in designing for reliability. Based on expectations, a plan needs to be developed that achieves goals efficiently, subject to hardware/software constraints, and operating configurations and budgets. This plan is the basis of a design that will deliver the most consistent production possible.

Effective reliability plans must prevent functional failures that affect power plant performance, even though equipment itself fails. For this reason, most power plants are designed to tolerate failures of certain components. However, the design must also address ease of maintenance. It must ensure short downtimes when failures do occur, as well as when planning outage work. Maintaining reliable production requires a strategy supporting equipment monitoring, maintenance, and replacement. Successful maintenance strategies complement the plant design itself. Clear, actionable guidance based upon established strategies should provide effective tools to manage risk. This Standard provides an overview of common reliability program attributes to attain reliability, maintainability, and availability at minimum cost, based upon an experts' consensus approach.

This Standard provides guidance for those who manage high-value production facilities[1] with the reliability, availability, and maintainability characteristics expected in an asset management program. It emphasizes program requirements, not implementation methods. Its developers expect that companies with large generating facilities will benefit the most. This Standard considers existing reliability process standards (see references), but its use is voluntary. It does not supersede other accepted guidance, but rather it seeks to fill a gap.

This Standard will help those who operate, manage, and support generation facilities of all types. In addition, auditors, lenders, or responsible agencies who determine compliance or provide due diligence may use this Standard. By providing guidance for facilities that must comply with safety and environmental requirements, it helps develop reliability programs, while meeting production schedules to assure commercial success.

ASME RAM-1–2013 was approved by the RAM Standards Committee, under the jurisdiction of the Board on Standardization and Testing, on May 28, 2013, and approved by the American National Standards Institute (ANSI) as an American National Standard on August 28, 2013.

[1] Managers, engineers, accountants, and executives.

ASME RAM COMMITTEE
Reliability, Availability, and Maintainability of Power Plants

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The American Society of Mechanical Engineers
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http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued for the purpose of providing alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee Web page.

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Interpretations. Upon request, the RAM Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the RAM Standards Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not “approve,” “certify,” “rate,” or “endorse” any item, construction, proprietary device, or activity.

Attending Committee Meetings. The RAM Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the Secretary of the RAM Standards Committee.

RELIABILITY, AVAILABILITY, AND MAINTAINABILITY OF EQUIPMENT AND SYSTEMS IN POWER PLANTS

1 INTRODUCTION

A RAM program is a structured methodology to identify and deliver the reliability, availability, and maintainability (RAM) requirements of a power plant in the most cost-effective manner. This document is an assurance standard to govern the master planning process for a power plant RAM program. It is intended to provide a methodology to develop and implement a comprehensive availability assurance program for the design, construction, and operation phases of the RAM project. This Standard is applicable to both new and existing facilities.

2 SCOPE

This Standard provides the requirements to establish a RAM program for any power-generation facility. The program process includes

(a) establishment of RAM goals

(b) requirements for design, construction and commissioning, and operations

This Standard identifies the required RAM program elements and responsibilities.

3 PURPOSE

The purpose of this Standard is to meet the owner's power plant RAM performance goals. This Standard identifies program requirements that support effective reliability processes in design, construction and commissioning, and operations. It requires a risk-based approach to design and provides requirements to optimize performance effectively throughout the life cycle of the power plant.

4 DEFINITIONS

basis of design (BOD): the underlying assumptions and requirements that support the physical plant design.

criticality: the relative importance of equipment attributes that range from physical materials and hardware to design functions.

reliability, availability, and maintainability (RAM):

(a) the process of addressing all the associated concepts of reliability, availability, and maintainability and integrating them to meet the owner's performance objectives

(b) a set of requirements imposed on a plant, system, or component to ensure that it

(1) will be ready for use when required

(2) will successfully perform assigned design-intended functions

(3) can be maintained operationally over its specified life

5 RAM PROCESS

This process provides a procedure to develop and implement a program that is a written, defined, verifiable, and living document that will enable the owner to meet his/her performance goals. The steps in the RAM process are given in paras. 5.1 through 5.4 (see Fig. 5-1).

5.1 Predevelopment

The owner shall establish needs by defining required criteria that shall serve to develop objective requirements, goals, validation parameters, and acceptance criteria.

5.2 Program Development

The owner shall select a project delivery method, designer, and constructor to build the power plant to the designed program criteria described in para. 5.1.

5.3 Program Implementation

The owner shall periodically review the program performance of the plant to determine if the plant is achieving the objectives and goals described in para. 5.1.

5.4 Program Revision

The owner shall modify the program described in paras. 5.2 and 5.3 to achieve the goals described in para. 5.1 or with new criteria that the owner establishes. Any owner-established criteria shall at least meet, or exceed, the criteria outlined in this Standard.

6 RAM DESCRIPTION

The following describes the steps in the RAM process.

6.1 Predevelopment Phase (See Fig. 6.1-1)

The owner shall define the top-level functional requirements for the plant. The output of the predevelopment phase is the BOD document, which will be used for the RAM program development. The BOD shall include the following:

(a) requirements for the implementation of the program

(b) basic plant description

(c) lifespan of plant and life-extension method

(d) functional requirements

(e) availability requirements

(f) reliability requirements

(g) maintainability requirements

(h) performance objectives and goals

6.2 Program Development (See Fig. 6.2-1)

The program design formalizes a plan to achieve the objectives and goals as detailed in the BOD. The defined information within the RAM program becomes the fundamental foundation for all plant operations and maintenance efforts. Program development includes the elements detailed in paras. 6.2.1 through 6.2.6.

6.2.1 Program Statement. A high-level management statement shall define the requirements for the RAM program and provide the organization direction to implement the RAM program.

6.2.2 Program Goals. The program goals are used to establish measurement criteria to validate requirements. The criteria shall be set in the areas of

(a) safety

(b) reliability

(c) availability

(d) maintainability

6.2.3 Program Organization. An organizational structure shall be designed and established to accomplish the goals of the RAM program. The organization shall provide accountability for achieving the objectives and goals. Functionally, these responsibilities include the following individuals:

(a) Owner. The owner provides requirements to the engineer pertaining to preferences and constraints of the design, and provides oversight to the program during implementation.

(b) Program Manager. The program manager acts as an agent of the owner and is responsible for the program implementation.

(c) Engineer. The engineer develops documents (e.g., drawings and specifications) and provides input for incorporating the availability, reliability, and maintainability requirements established by the owner.

(d) Operator. The operator represents the owner by providing input on preferences and constraints regarding operations and maintenance, and shall be a part of the program development process.

6.2.4 Program Design

(a) The program shall consider and address the following:

(1) government and agency requirements

(2) environmental, health, and safety laws and regulations

(3) safety standards

(4) agreements and contractual requirements

(5) equipment and operational codes as specified by jurisdictional agencies or insurance providers

(6) objectives as stated in the design basis

(b) The program should consider and address the following:

(1) identify physical plant systems, boundaries, equipment, and structures

(2) determine criticality definitions (classification bins for risk)

(3) establish criticality methodology

(4) classify equipment criticality

(5) assess risk to plant performance through failure analysis by

(-a) failure modes, mechanisms, and causes

(-b) failure probability

(-c) failure consequence

(6) identify methods that mitigate failure causes

(7) review technology that, when implemented, will mitigate risk of failure for critical equipment

(8) review monitoring and alarms required to determine plant performance deterioration or alert operators of incipient failure so as to mitigate plant performance risk identified above

(9) review testing that may be used to determine the critical equipment status and suitability for continued operation

(10) review inspection practices or overhauls that are required to periodically assure that the plant will achieve the objectives and goals set forth

(11) review maintenance practices that are required to mitigate plant performance risk as identified above

(12) evaluate the cost effectiveness of the proposed options

(13) evaluate methods for implementation

(14) evaluate methods for program modification

(15) fulfill goals as stated in the BOD

6.2.5 Program Manual. A program manual shall be developed to integrate guidance and operations requirements to achieve the objectives and goals set forth in the BOD. The program manual is a controlled document that addresses operations, maintenance, and costs, and shall include the following:

(a) Program Statement, consisting of scope, definitions, and objectives and goals

(b) Program Organization and Responsibilities

(c) plant BOD, consisting of functional and performance requirements, system descriptions, and exclusions and limitations

(d) criticality methodology to determine criticality definitions (categories) and establish criticality (risk-assessment) methodology

(e) develop an equipment criticality list
(f) identify system criticality
(g) identify risk assets and performance requirements
(h) establish a monitoring plan
(i) establish a testing plan
(j) establish an inspection plan
(k) determine condition-directed response to out-of-specification situations
(l) establish a maintenance plan to address tasks, plans, periodicity, and required resources
(m) establish a measurement plan to validate effectiveness

6.2.6 Program Budget. A budget shall be developed to identify the cost of the program as specified in the program manual.

6.3 RAM Program Implementation (See Fig. 6.3-1)

The operator shall be responsible for implementing the RAM program that is to include the following:
(a) initial equipment condition (baseline)
(b) procurement and installation of the software and tools
(c) populating software program(s)
(d) procurement of services, equipment, and/or tools
(e) translating operations monitoring procedures into rounds
(f) development of procedures for response to out-of-specification situations
(g) metrics to monitor and gauge the plant performance against the established objectives and goals
(h) metrics to assess effectiveness of the RAM plan
(i) training of operators/maintenance
(j) execution of tasks to fulfill the RAM plan
(k) new equipment (e.g., breakers, automatic valves, motors) that can self-identify critical equipment failures and alert operators remotely to failure modes via distributed digital control systems
(l) evaluation of component system monitoring for reliability, longevity, and indirect failure risk where integrated with digital control systems
(m) execution of monitoring, testing, inspection, maintenance, and measurement plans

6.4 Program Revision (See Fig. 6.4-1)

The owner shall periodically review and adjust the program performance. The owner shall perform additional reviews when the plant fails to meet performance expectations, the plant mission changes, or the equipment fails unacceptably. This should include the following:
(a) develop comparative performance reports based on program objectives and goals.
(b) develop exception reports for action.
(c) identify and evaluate high-impact exceptions. This should include a review of plant outages or loss of production. Root cause analysis should also be considered.
(d) review critical equipment failure trends.
(e) compare actual to projected budget.
(f) review, assess, and adjust the plan according to performance and make changes in the program (owner/operator).

Fig. 5-1 RAM Process Overview

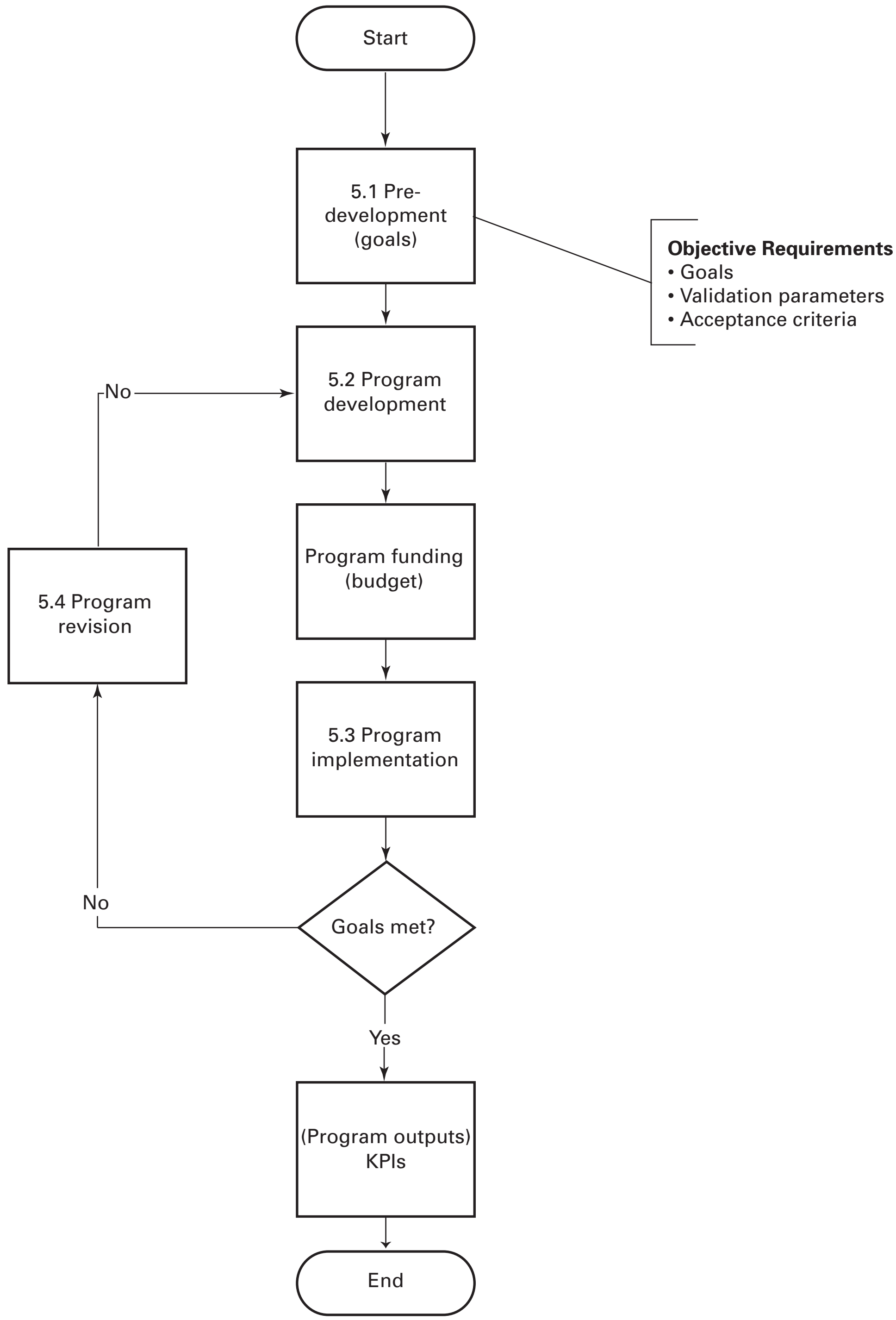


Fig. 6.1-1 RAM Predevelopment

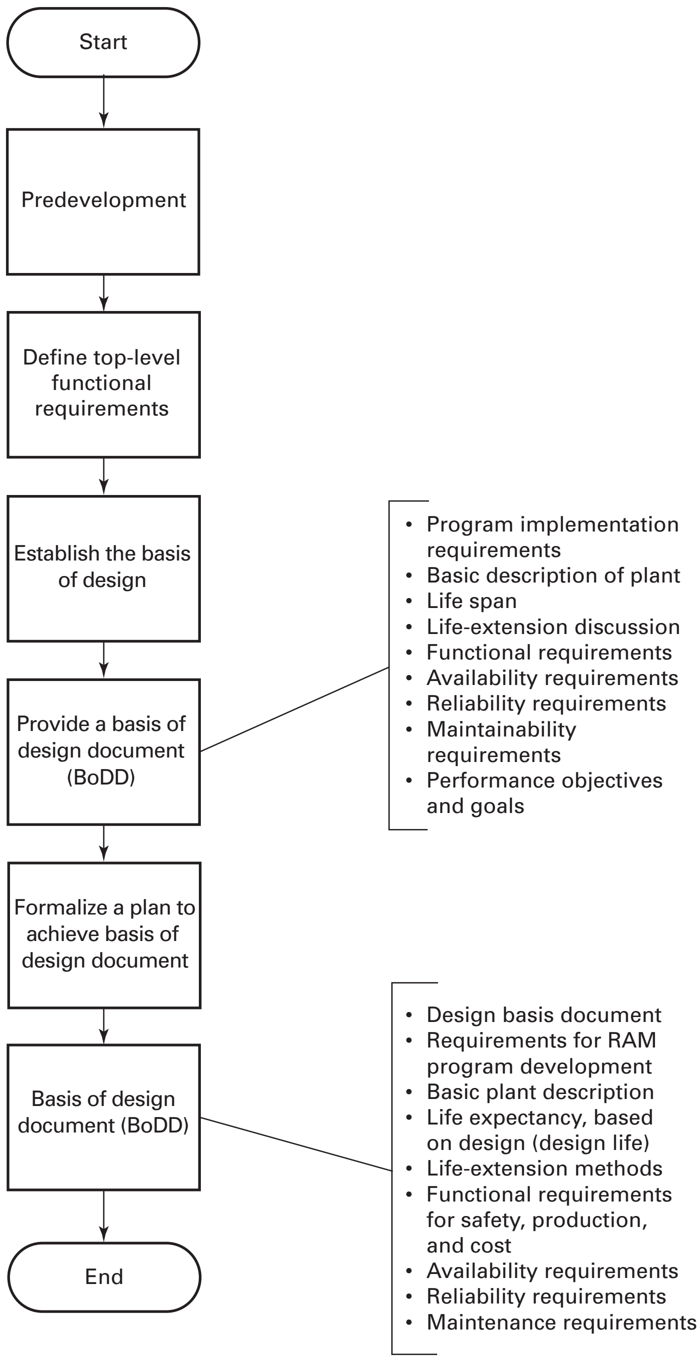


Fig. 6.2-1 RAM Program Development

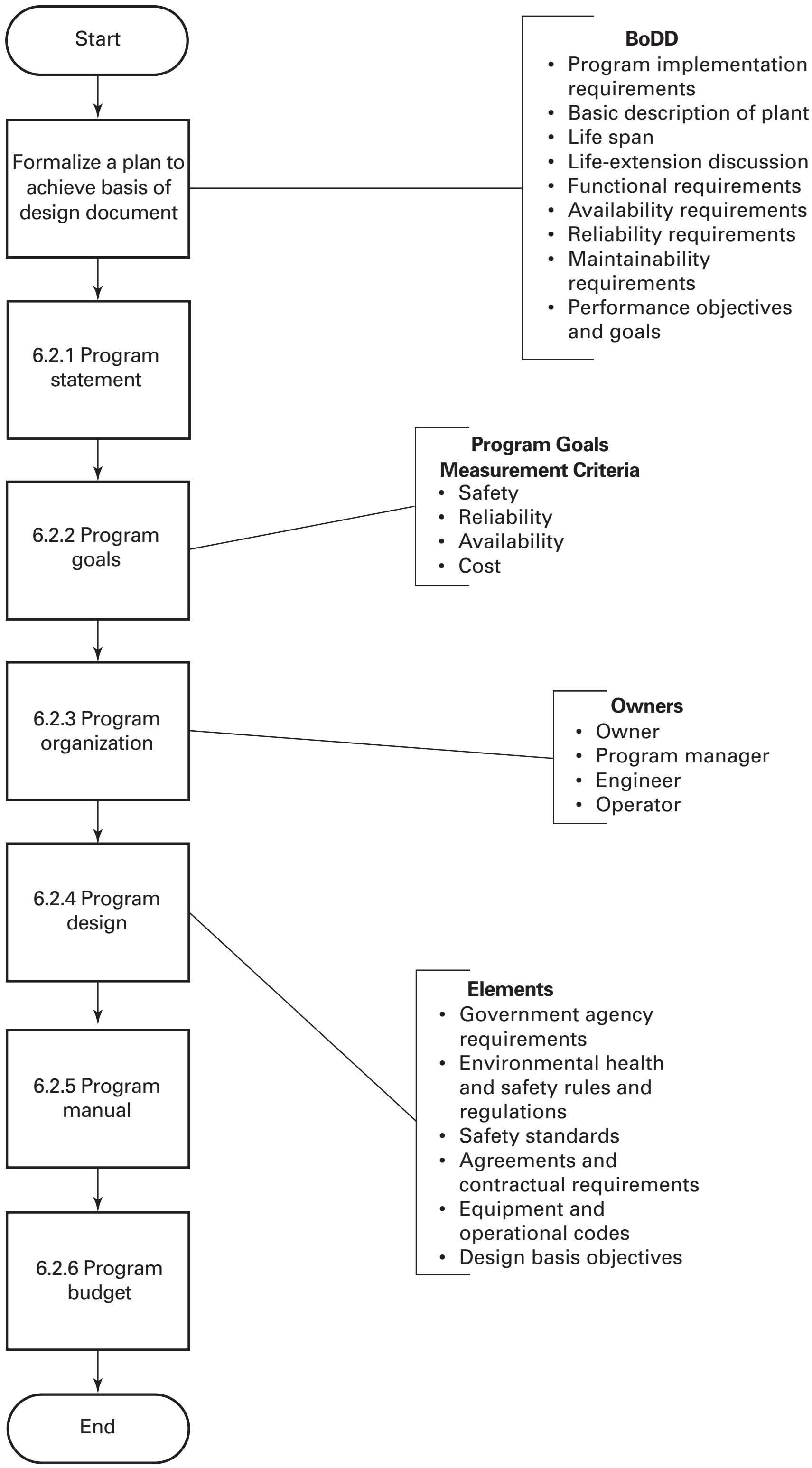


Fig. 6.3-1 RAM Program Implementation

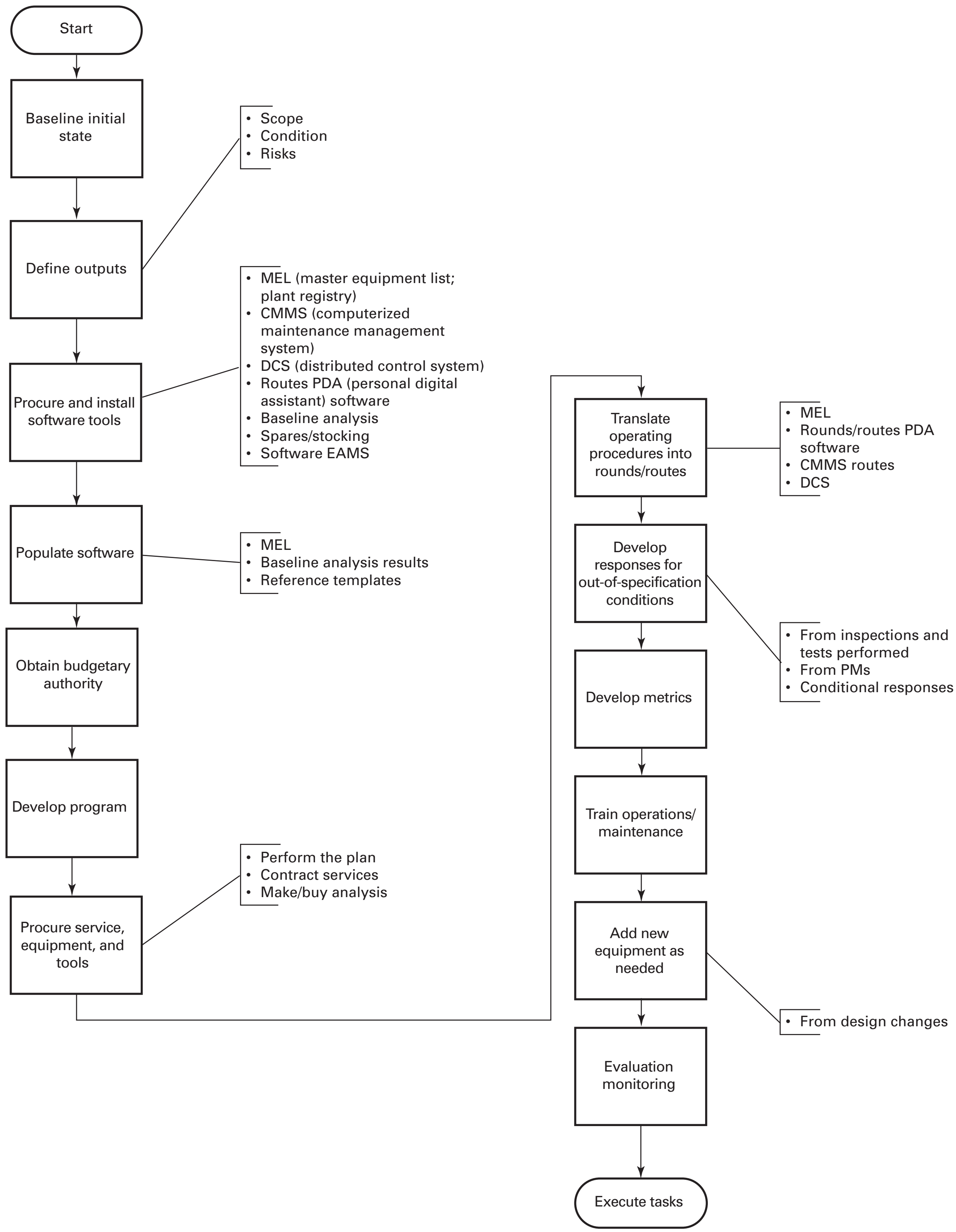
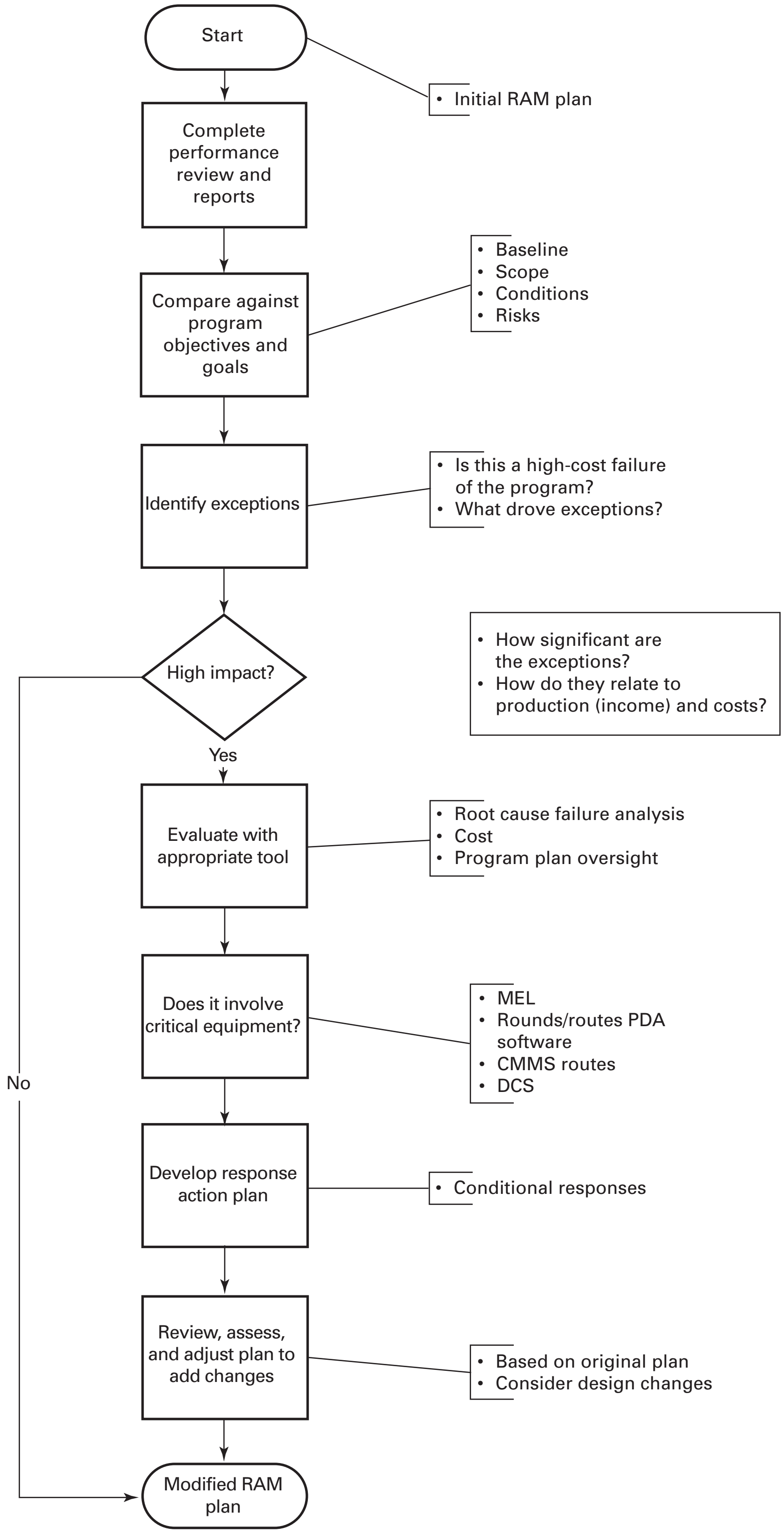


Fig. 6.4-1 RAM Program Revision



MANDATORY APPENDIX I
DEFINITIONS

availability: a measure of the degree to which an item is in an operable state and can be committed at the start of a mission when the mission is called for at an unknown (random) point in time; or the ability of an item to be in a state to perform a required function under given conditions, at a given instant of time or during a given time interval, assuming that the required external resources are provided. Availability is measured by the user and is a function of how often failures occur and corrective maintenance is required, how often preventive maintenance is performed, how quickly indicated failures can be isolated and repaired, how quickly preventive maintenance tasks can be performed, and how long logistics support delays contribute to downtime.

basis of design (BOD): the underlying assumptions and requirements that support the physical plant design.

boundaries: define where each system begins and ends; interfaces. For a typical plant, the boundary will include physical, mechanical, and electrical isolation physical points, e.g., isolation valves or piping locations, heat exchanger tube bundle interfaces, electrical breaker, or switch or termination points. This Standard requires system boundaries to be defined.

condition assessments (predictive activities): used to assess conditions for determining the need to perform applicable maintenance.

condition monitoring: used to trend degrading conditions of a structure, system, or component that are not readily revealed by unavailability, reliability, and plant-level indicators for which advance awareness of degradation is needed. Some types of condition monitoring are vibration characteristics, temperature, acoustics, and electrical parameters, which should be included at a minimum to provide awareness of owner-defined conditions.

corrective action: assignment to take action after a structure, system, or component has failed to function and to restore it to an acceptable condition.

criticality: relative importance of tasks, equipment, systems, or components and their contributions to design functions. A criticality ranking scheme should codify this into a simple classification schema, e.g., 1–2–3 or C–O–S. Compliance with this Standard requires that the owner establishes criticality criteria for appropriate ranking of structures, systems, and components.

design basis: see *basis of design*.

failure finding tests: used to assess operational capability (operability) of standby or redundant equipment.

failure mode analysis (FMA): an analysis encompassing how a structure system or component can fail, what can cause the failure, what the likelihood of failure is, what the consequences are, and ways to mitigate the failure. The means are mainly through detection, maintenance, or design redundancy.

hard time (time-based) maintenance: maintenance of equipment with known time-dependent aging characteristics. These consist primarily of explicit rework or replacement tasks. Hard time can include compound tasks that comprise equipment overhauls.

maintainability:

(a) the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair

(b) the ability of an item, under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources.

maintenance: the aggregate of those functions required to preserve or restore safety, reliability, and availability of plant structures, systems, or components. Maintenance includes not only activities traditionally associated with identifying or correcting actual or potential degraded conditions (i.e., repair, monitoring, testing, inspection examinations, etc.), but also all supporting functions required for the conduct of these activities. These include all activities associated with the planning, scheduling, isolation, performance, restoration, post-maintenance testing, and return to service for surveillance and preventive and corrective maintenance. These activities are considered maintenance regardless of who performs them (e.g., maintenance, operations, engineering, and supplemental personnel such as specialists and contractors).

performance criteria: specific quantitative value or threshold that is established to provide a basis for determining satisfactory performance. Performance criteria are generally based on the safety significance or economic success of a particular task, activity, or project. Performance criteria are used to monitor the effectiveness of operation and maintenance of a plant or structure. For this Standard, the owner shall set performance criteria.

preventive maintenance: predictive, periodic, and planned maintenance actions, including calibrations and operational tests, taken prior to structure, system, or component failure, to identify degradation and maintain the structure, system, or component within the design operating conditions by controlling degradation or failure. These shall comprise, at a minimum, the following:

(a) condition monitoring
(b) condition assessments (predictive activities)
(c) failure finding tests
(d) hard time (time-based) maintenance, including overhauls
(e) condition-based response (corrective action)

probabilistic risk assessment (PRA): a quantitative method of assessing damage frequency or other risk measure, e.g., risk of failure.

RAM program: the underlying assumptions and requirements of a RAM performance enhancement program, based on plant design, which, if implemented, should ensure program success.

redundancy: a method of design where a duplicate structure, system, or component is provided such that if one fails, the redundant structure, system, or component will operate in its place such that plant performance is not impacted. Diversity, a similar concept, achieves the same outcome by an alternative technical means.

reliability: the probability of an item to perform a required function under stated conditions for a specified period of time, or the ability of an item to perform a required function under given conditions for a given time interval. Reliability can be further divided into mission reliability and logistics reliability.

requirements: specific, quantifiable characteristics that define the success of a project. These may define plant function, plant life, plant output, and plant performance, e.g., plant efficiency, plant staffing, plant availability, plant reliability, plant maintainability, and plant financials and other characteristics that are important to the owner. This Standard expects that the owner will provide specific plant requirements that will identify the success of the project.

risk: encompasses what can go wrong (an event), its likelihood (probability), and its resulting level of damage (consequences).

risk assessment: the method of assessing the risk (see definition above) and quantifying the impact to public safety and/or plant performance. A risk assessment is done with the goal of reducing the risk such that the plant can safely achieve the performance required by the owner. Generally, risk can be quantified as direct or indirect (or degraded, multiple path), and falls into safety, production, and cost consequences for direct risk threats.

system: a group of structures, components, instruments, and controls that together perform a specific function(s) within a plant. A system should be capable of being defined by specific boundaries. The system definitions improve the manageability of a RAM program. A system may be open or closed with regard to the fluids that it contains (e.g., air, steam water, oil, or gas such as H_2). Examples include condensate system, feedwater system, service air system, boiler system, turbine systems, control system, high-voltage system, etc. The system definition can be either broad or very detailed, as best serves the plant and RAM program. Systems will often be defined by piping and instrumentation drawings (P&ID). Systems must be defined for this Standard. Systems are typically identified by the plant's designer as a part of the design process.

total ownership cost (TOC): an attempt to capture the true cost of design, development, ownership, and support of a power plant. At the individual program level, TOC is synonymous with the life-cycle cost of the system. To the extent that new systems can be designed to be more reliable (fewer failures) and more maintainable (fewer resources needed) with no unacceptable increase in the cost of the system or spares, the TOC for these systems will be lower.

NONMANDATORY APPENDIX A
REFERENCES

The following is a list of related publications for information:

Defense Manufacturing Management Guide for Program Managers

Publisher: Department of Defense, Acquisition Community Connection, Defense Acquisition University, DAU-GLTC, 9820 Belvoir Road, Ft. Belvoir, VA 22060-5565 (http://acc.dau.mil)

Nowlan, F. S. and Heap, H. F., Reliability-Centered Maintenance

Publisher: National Technical Information Service (NTIS), 5301 Shawnee Road, Alexandria, VA 22312 (www.ntis.gov)

SAE JA1011, Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes (2009)

Publisher: Society of Automotive Engineers (SAE International), 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

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