ASME RAM-1–2020

(Revision of 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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This Standard will be revised when the Society approves the issuance of a new edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Periodically certain actions of the ASME RAM Committee may be published as Cases. Cases and interpretations are published on the ASME website under the Committee Pages at http://go.asme.org/RAPcommittee as they are issued.

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FOREWORD

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

Effective reliability plans prevent functional failures of power plants even if equipment components fail. To preserve production, most power plants are designed to tolerate these isolated component failures. Therefore, the design must also address ease of maintenance. It must ensure short downtimes when failures do occur, as well as during planned outage work. Maintaining reliable production requires policies and procedures that support equipment monitoring, maintenance, and replacement. Successful maintenance strategies complement the plant design itself. Clear, actionable guidance based upon established strategies provides effective tools to manage risk. This Standard provides an overview of some common approaches to attaining reliability, availability, and maintainability (RAM) at minimum cost, based on a consensus approach of experts.

This Standard provides guidance to managers of high-value production facilities concerning the RAM 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 Nonmandatory Appendix A), 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, this Standard helps stakeholders develop reliability programs while meeting production schedules to assure commercial success.

ASME RAM-1-2020 was approved by the RAM Standards Committee, under the jurisdiction of the Board on Standardization and Testing, on February 26, 2020, and approved by the American National Standards Institute (ANSI) as an American National Standard on March 19, 2020.

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FOR POWER PLANT RELIABILITY, AVAILABILITY, AND PERFORMANCE (RAP)

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, RAM Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
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 to provide 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.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the RAM Standards 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.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the RAM Standards Committee at the above address. The request for an 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 in one or two words.
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. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. 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 the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

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 and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the RAM Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at http://go.asme.org/RAPcommittee.

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

1 INTRODUCTION

A RAM program is a structured methodology to identify and meet the reliability, availability, and maintainability (RAM) requirements of a power plant in the most cost-effective manner. This Standard provides requirements to govern the master planning process for a power plant RAM program. It is intended to guide the development and implementation of a comprehensive availability assurance program throughout the design, construction, and operation phases of the RAM project. This Standard is applicable to both new and existing facilities.

2 SCOPE

This Standard identifies the elements and responsibilities required to establish a RAM program for any power-generation facility. The program process includes

(a) establishment of RAM goals

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

3 PURPOSE

The purpose of this Standard is to meet the owner's power plant RAM performance goals. This Standard requires the owner to determine those goals and the criteria to achieve them. To this end, it 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

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 much logistics support delays contribute to downtime.

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

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

condition assessments: judgements used to assess the state of equipment to determine the need to perform applicable maintenance; also called *predictive activities*.

condition-based response: an initiative taken after a structure, system, or component has failed to function in order to restore it to an acceptable condition. Also called *corrective maintenance*.

condition monitoring: used to trend degrading conditions of a structure, system, or component that is 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.

corrective maintenance: see *condition-based response*

criticality: the relative importance of tasks, equipment, systems, or components and their contributions to the mission.

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 assessment addressing how a structure, system, or component can fail; what can cause the failure; what the likelihood of failure is; what the consequences of failure are; and ways to mitigate the failure. The means are mainly through detection, maintenance, or design redundancy.

hard-time maintenance: the upkeep 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. Also *called time-based maintenance.*

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 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 (e.g., repair, monitoring, testing, inspection examinations), 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, or engineering staff, or supplemental personnel such as specialists and contractors).

performance criteria: a specific quantitative value or threshold 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 maintenance)

reliability, availability, and maintainability (RAM):

(a) the process of addressing all the associated RAM concepts 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

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 to the extent that plant performance is not affected. Diversity is a similar design concept that achieves the same outcome by using 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.

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

risk: the probability of a negative event occurring.

risk assessment: the method of assessing risk 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. (See also *risk*.)

system: a group of structures, components, instruments, and controls that together perform a specific function(s) within a plant. A system shall be capable of being defined by specific boundaries without overlap to establish clear ownership. System definitions improve the manageability of a RAM program. A system may be open or closed regarding 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 system(s), control system, high-voltage system. 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.

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 outlined in paras. 5.1 through 5.4 (see Figure 5-1-1).

5.1 Predevelopment

The owner shall establish needs by defining required criteria 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 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 described in this Standard.

6 RAM PROCESS DESCRIPTION

The steps in the RAM process are detailed in paras. 6.1 through 6.4.

6.1 Predevelopment Phase (See Figure 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 Figure 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 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. These responsibilities shall be performed by 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 RAM 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 comply with the following governing requirements:
(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 BOD

(b) The program shall address the following specific requirements:
(1) identify physical plant systems, boundaries, equipment, and structures

Figure 5-1-1 RAM Process Overview

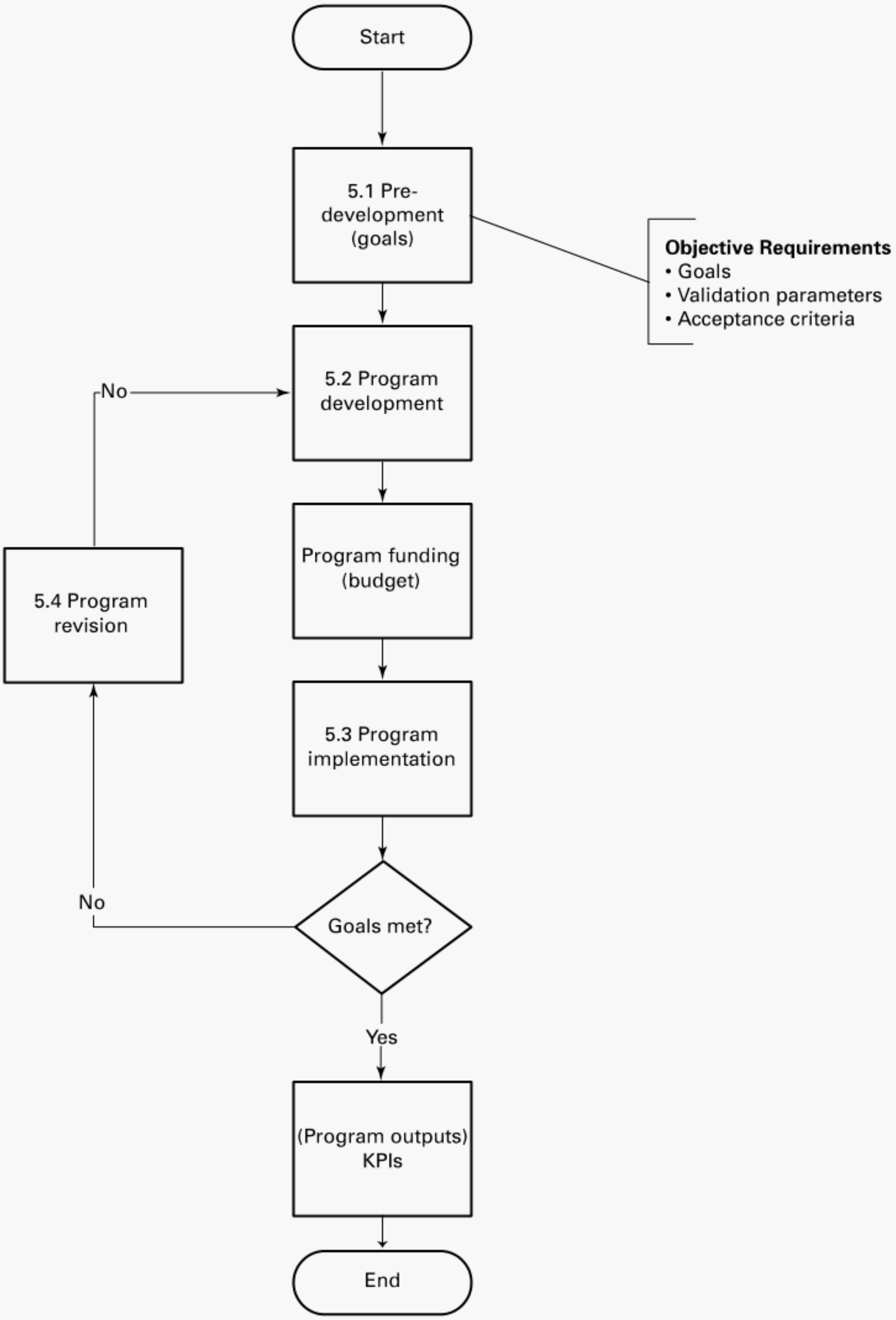


Figure 6.1-1 RAM Predevelopment

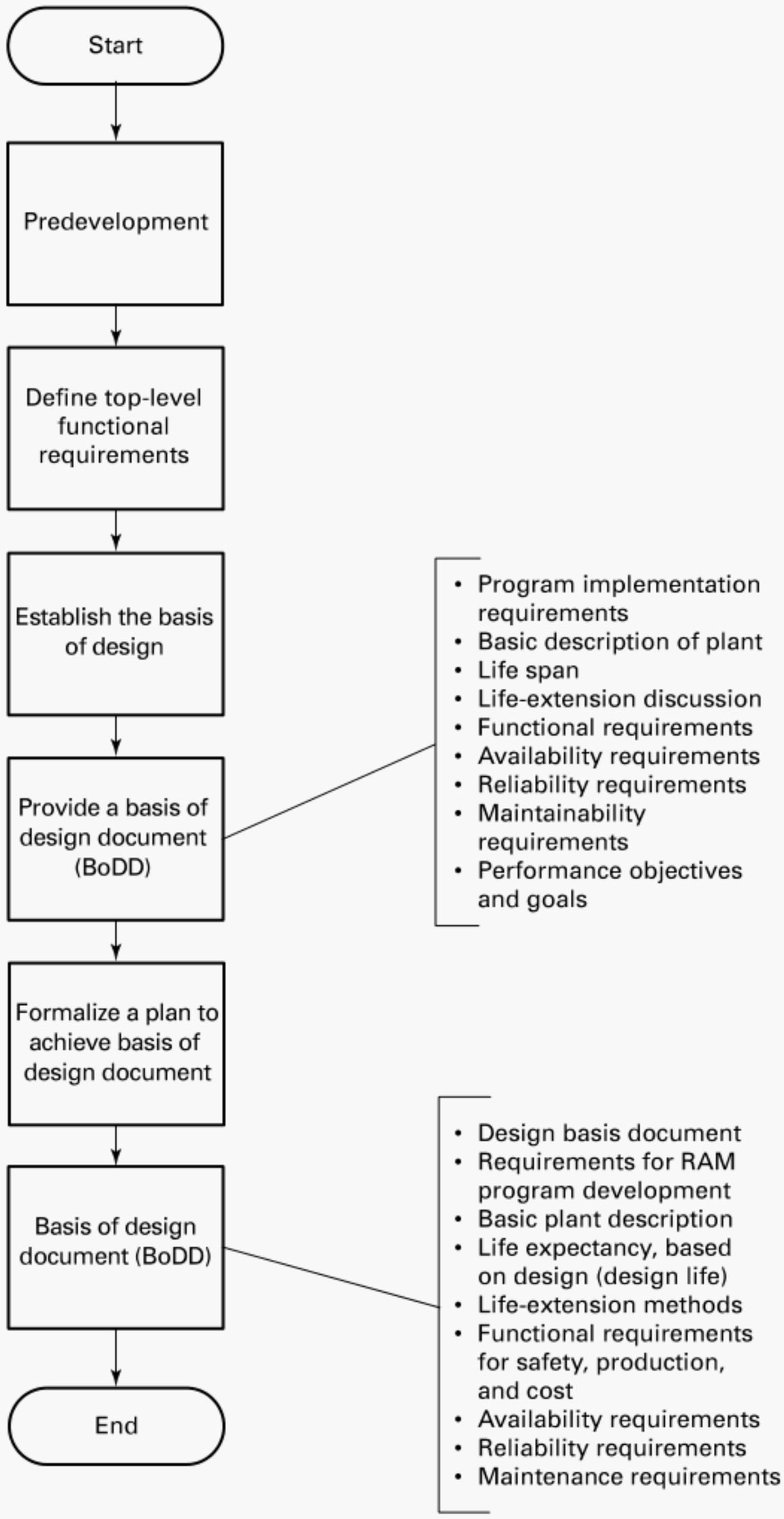
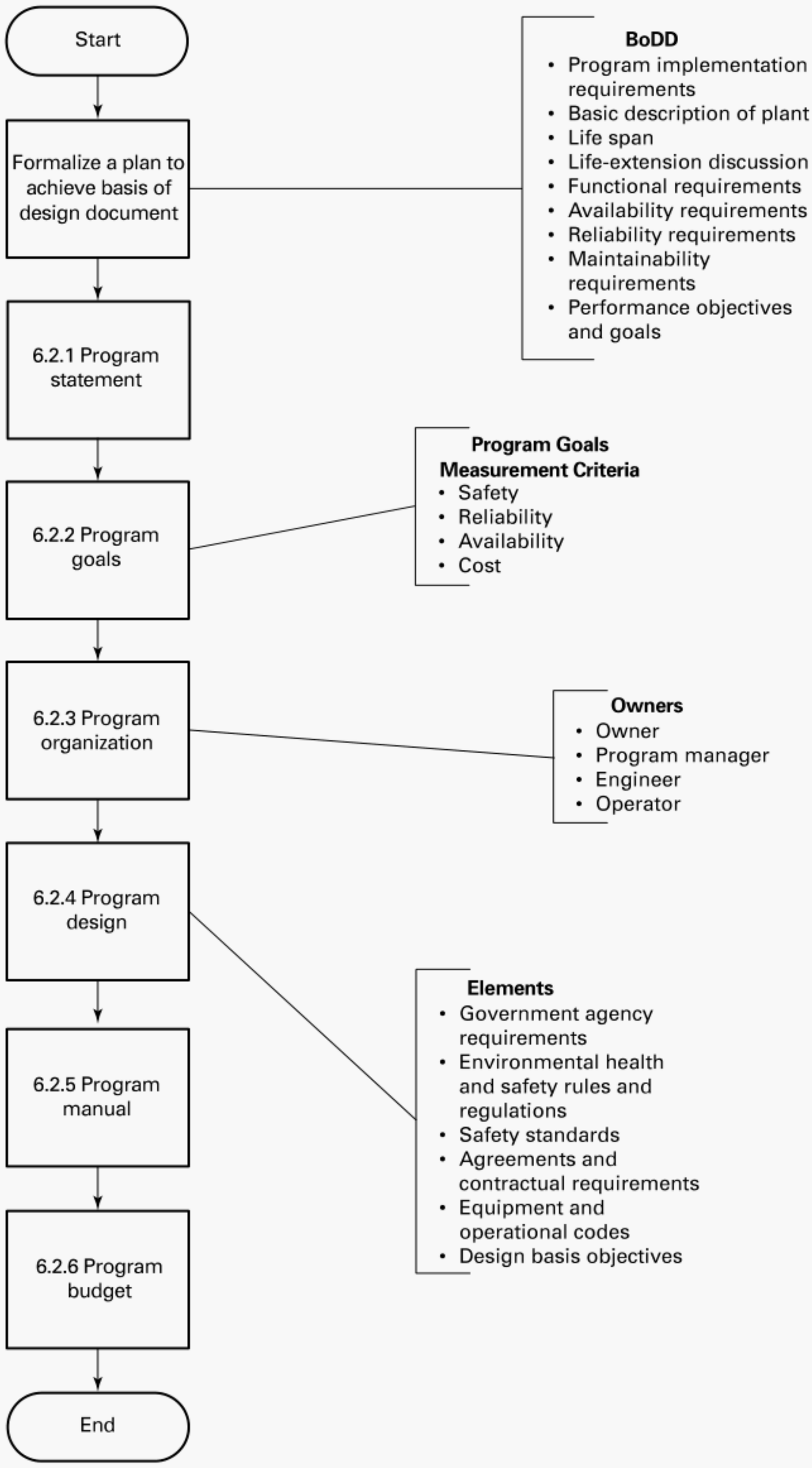


Figure 6.2-1 RAM Program Development



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

(3) establish criticality methodology

(4) classify equipment criticality

(5) use failure analysis to assess risk to plant performance from

(-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 herein

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

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

(11) review maintenance practices required to mitigate plant performance risk as identified herein

(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) 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) an equipment criticality list

(f) system criticality

(g) risk assets and performance requirements

(h) a monitoring plan

(i) a testing plan

(j) an inspection plan

(k) condition-directed response to out-of-specification situations

(l) a maintenance plan to address tasks, plans, periodicity, and required resources

(m) a measurement plan to validate effectiveness

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

6.3 Program Implementation (See Figure 6.3-1)

The operator shall be responsible for implementing the RAM program including 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 (DCS)

(l) evaluation of component system monitoring for reliability, longevity, and indirect failure risk where integrated with DCS

(m) execution of monitoring, testing, inspection, maintenance, and measurement plans

6.4 Program Revision (See Figure 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. Program revision 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. (This step may be performed by the owner and/or the operator.)

Figure 6.3-1 RAM Program Implementation

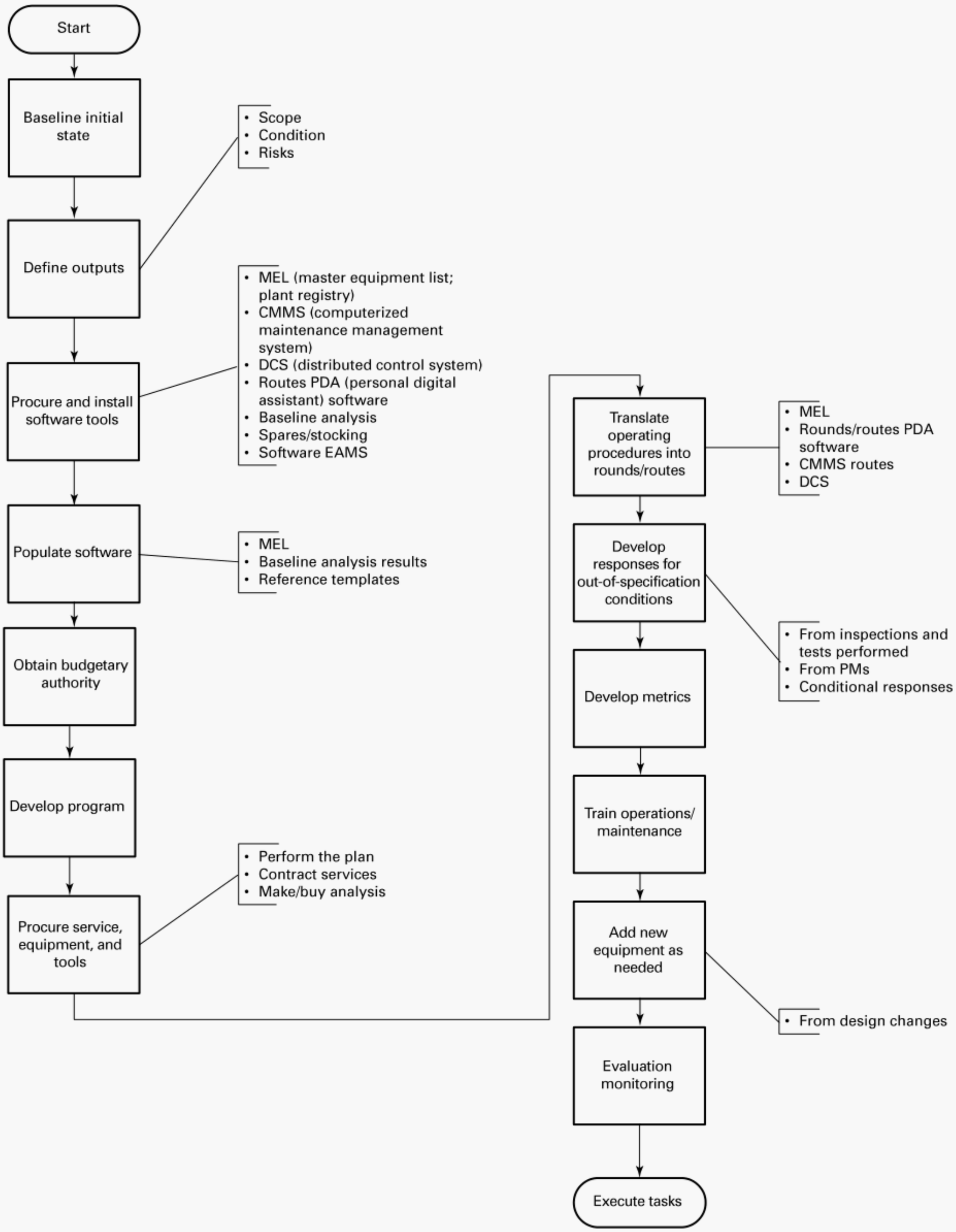
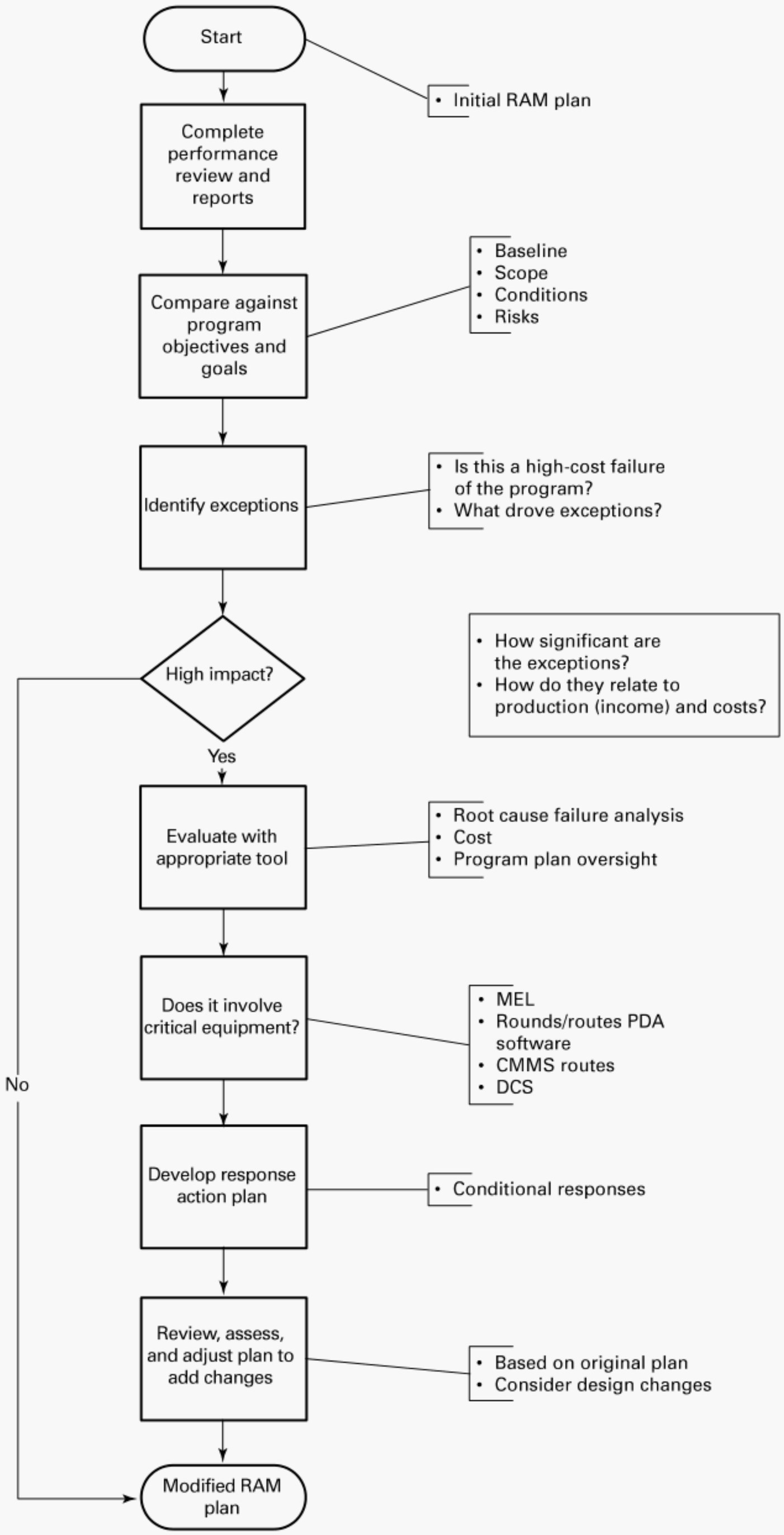


Figure 6.4-1 RAM Program Revision



NONMANDATORY APPENDIX A
REFERENCES

The following is a list of related publications for further information:

Defense Manufacturing Management Guide for Program Managers (PQM for PMs)
Publisher: Defense Acquisition University, 9820 Belvoir Road, Ft. Belvoir, VA 22060-5565 (https://www.dau.edu/)

Nowlan, F. S. and Heap, H. F., Reliability-Centered Maintenance, Department of Defense Report AD-A066579, 1978

Publisher: Department of Defense (DoD), 1400 Defense Pentagon, Washington, D.C. 20301-1400 (www.defense.gov)

SAE JA1011-2009, Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes
Publisher: Society of Automotive Engineers (SAE International), 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

NONMANDATORY APPENDIX B
EXAMPLE EVALUATION CHECKLISTS

B-1 GENERAL

This Appendix provides two examples of how to evaluate a program to establish a current RAM baseline for a power plant. Tables B-1-1 and B-1-2 represent just one possible format; the evaluation tool can be in any format that suits the facility's needs.

(a) The first column references the paragraph number in this Standard that contains the category and program requirement.

(b) The second column offers a brief, general description of the requirement (typically, the heading of the referenced paragraph).

(c) The third column is a summary of the evaluation evidence. It is intended to be very concise.

(d) The fourth column is a compliance ranking. In this Appendix, the following ranking system was used:

Rank	Compliance Level
1	No information or system exists. Frequent unpredictable failures/issues. Not compliant.
2	Personnel are aware of the requirement, but do not use it. Many failures/issues, but plant still operational. Partially compliant.
3	Some implementation by specific personnel. Some failures, but plant meeting minimum goals. Compliant and functional.
4	Most personnel are aware of and using the requirement. Few failures. Meeting goals well.
5	All personnel are aware of and using the requirement. Very few failures, and those that occur are unpredictable. Meeting and/or exceeding goals, and goals are controllable.

Tables B-1-1 and B-1-2 are examples of summary sheets that can be used to identify a system's compliance with this Standard. It assumes all the individual requirements carry equal weight. The "compliance factor" (or "percent compliance") is simply the average of the compliance rankings and is used to establish a baseline. Additional columns may be added to these checklists to present other relevant ratings or factors, such as recommended improvement techniques, estimated costs, and estimated improvement in compliance ranking.

B-2 EXAMPLE 1

Table B-1-1 depicts an old, legacy power plant that has been operating successfully for many years but it has performance gaps that warrant the implementation of a RAM program. The plant has gone through many modifications and expansions as well as management and staff changes. In addition, the plant's operations and maintenance programs have changed and progressed over the years, mostly due to advances in technology.

B-3 EXAMPLE 2

Table B-1-2 depicts a newly-built and recently commissioned power plant that is starting commercial operation. ASME RAM Standards were used throughout the design and construction of this plant. A RAM Program has been created and a RAM Manager has been appointed.

Table B-1-1 RAM-1 Summary Sheet: Example 1 — Coal Power Plant

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6	RAM description	...	...
6.1	Predevelopment phase	...	...
6.1(a)	Requirements for the implementation of the program	There is no RAM program in effect; however, multiple components exist but are uncoordinated.	**2**
6.1(b)	Basic plant description	There are some good documents describing some systems within the plant, but there are areas/components that are not adequately described.	**3**
6.1(c)	Lifespan of plant and life-extension method	Lifespan and life-extension methods are not clearly addressed.	**2**
6.1(d)	Functional requirements	Functional requirements are stated in many of the standard operating procedures (SOPs), but many systems are not addressed.	**2**
6.1(e)	Availability requirements	These are written but not clearly defined. Difficult to use as a metric.	**2**
6.1(f)	Reliability requirements	These are not addressed.	**1**
6.1(g)	Maintainability requirements	These are implied, but not clearly defined or written.	**2**
6.1(h)	Performance objectives and goals	These are implied, but not clearly defined or written.	**2**
6.2	Program development	...	
6.2.1	Program statement	There is some data for some systems and components.	**2**
6.2.2	Program goals	...	...
6.2.2(a)	Safety	There are good documented safety measures in place. There have not been any reported major safety violations or injuries.	**5**
6.2.2(b)	Reliability	Reliability has been an issue resulting in a greater dependency on redundancy.	**1**
6.2.2(c)	Availability	Overall plant availability is good, with very few major excursions.	**4**
6.2.2(d)	Maintainability	Maintenance is working with limited manpower and trying to stay ahead of reactive maintenance. Extensive work order backlog.	**2**
6.2.3	Program organization	...	...
6.2.3(a)	Owner	The hierarchy is clearly defined in the organization chart, but responsibilities are not shown.	**3**
6.2.3(b)	Program manager	The hierarchy is clearly defined in the organization chart, but responsibilities are not shown.	**3**
6.2.3(c)	Engineer	The hierarchy is clearly defined in the organization chart, but responsibilities are not shown.	**3**
6.2.3(d)	Operator	The hierarchy is clearly defined in the organization chart, but responsibilities are not shown.	**3**
6.2.4	Program design	...	...
6.2.4(a)	The program shall comply with the following governing requirements:	...	...
6.2.4(a)(1)	Government and agency requirements	There are good records and clear written requirements. There have not been any reported major legal violations.	**5**

Table B-1-1 RAM-1 Summary Sheet: Example 1 — Coal Power Plant (Cont'd)

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6.2.4(a)(2)	Environmental, health, and safety laws and regulations	There are good measures in place to protect the environment, health, and safety.	**5**
6.2.4(a)(3)	Safety standards	There have not been any reported legal violations.	**5**
6.2.4(a)(4)	Agreements and contractual requirements	There have been no problems with any agreements.	**5**
6.2.4(a)(5)	Equipment and operational codes as specified by jurisdictional agencies or insurance providers	There have been some minor recommendations/violations from (boiler) inspections.	**4**
6.2.4(a)(6)	Objectives as stated in the BOD	No design basis has been provided; however, most power plant objectives appear to be understood.	**3**
6.2.4(b)	The program shall consider and address the following:	...	**...**
6.2.4(b)(1)	Identify physical plant systems, boundaries, equipment, and structures	Most of the equipment are identified, but the boundaries/extents are not clearly stated.	**2**
6.2.4(b)(2)	Determine criticality definitions (classification bins for risk)	Criticality has not been clearly defined.	**1**
6.2.4(b)(3)	Establish criticality methodology	Criticality methodology has not been clearly defined.	**1**
6.2.4(b)(4)	Classify equipment criticality	Certain pieces of equipment/systems have been labeled as critical.	**1**
6.2.4(b)(5)	Use failure analysis to assess risk to plant performance from	...	**...**
6.2.4(b)(5)(-a)	Failure modes, mechanisms, and causes	Failure modes, mechanisms, and causes have not been identified.	**1**
6.2.4.b(5)(b)	Failure probability	Failure probability has not been identified.	**1**
6.2.4(b)(5)(-c)	Failure consequence	Failure consequence has not been identified.	**1**
6.2.4(b)(6)	Identify methods that mitigate failure causes	Some failure causes have been identified through experience.	**2**
6.2.4(b)(7)	Review technology that, when implemented, will mitigate risk of failure for critical equipment	Implementation of new technology is infrequently reviewed for risk mitigation.	**2**
6.2.4(b)(8)	Review monitoring and alarms required to determine plant performance deterioration	Implementation of new locations for measurement is monitoring are occasionally reviewed.	**3**
6.2.4(b)(9)	Review testing used to determine critical equipment status and suitability for continued operation	Implementation of new testing procedures is infrequently reviewed for equipment status.	**2**
6.2.4(b)(10)	Review inspection practices or overhauls required to periodically assure the plant will achieve the objectives and goals set forth	Implementation of new inspection practices is occasionally reviewed.	**3**
6.2.4(b)(11)	Review maintenance practices required to mitigate plant performance risk as identified herein	Implementation of new maintenance practices is occasionally reviewed.	**3**
6.2.4(b)(12)	Evaluate the cost effectiveness of the proposed options	Cost effectiveness of new options is regularly evaluated.	**4**
6.2.4(b)(13)	Evaluate methods for implementation	New implementation methods are occasionally evaluated.	**3**
6.2.4(b)(14)	Evaluate methods for program modification	New program modification methods are infrequently evaluated.	**2**
6.2.4(b)(1)5	Fulfill goals as stated in the BOD	No basis of design has been provided; however, many plant goals appear to be understood.	**2**
6.2.5	Program manual	...	**...**

Table B-1-1 RAM-1 Summary Sheet: Example 1 — Coal Power Plant (Cont'd)

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6.2.5(a)	A program statement, consisting of scope, definitions, objectives, and goals	Power plant goals are not explicitly stated.	**2**
6.2.5(b)	Program organization and responsibilities	Program organization hierarchy is clear, responsibilities are not as clear.	**2**
6.2.5(c)	Plant BOD, consisting of functional and performance requirements, system descriptions, and exclusions and limitations	There are many good SOPs developed (which include requirements and descriptions), but there are many more systems that do not have any.	**3**
6.2.5(d)	Criticality methodology to determine criticality definitions (categories) and establish criticality (risk-assessment) methodology	Criticality is not defined.	**1**
6.2.5(e)	Equipment criticality list	There is no complete criticality list, but the core critical components are understood (boilers, turbines, etc.)	**2**
6.2.5(f)	System criticality	Criticality is not defined, but the boiler, turbine, and distribution systems are understood to be critical.	**2**
6.2.5(g)	Risk assets and performance requirements	There are some data for some systems and components.	**2**
6.2.5(h)	A monitoring plan	There is no formal monitoring plan.	**1**
6.2.5(i)	A testing plan	There is no formal testing plan.	**1**
6.2.5(j)	An inspection plan	There is no formal inspection plan.	**1**
6.2.5(k)	Condition-directed response to out-of-specification situations	The responses to out-of-specification situations are identified as some emergency operating procedures (EOPs) included in the SOPs.	**4**
6.2.5(l)	A maintenance plan to address tasks, plans, periodicity, and required resources	A preventive/predictive maintenance plan is currently being developed and implemented.	**3**
6.2.5(m)	A measurement plan to validate effectiveness	There is no formal measurement plan.	**1**
6.2.6	Program budget	The budget for operations, maintenance, and repair is currently not calculated based upon RAM requirements.	**1**
6.3	Program Implementation	...	**...**
6.3(a)	Initial equipment condition (baseline)	There is very limited documentation for the current condition of most of the equipment in the plant.	**2**
6.3(b)	Procurement and installation of the software and tools	The power plant has recently purchased and is implementing the new maintenance software system.	**4**
6.3(c)	Populating software programs(s)	The maintenance database is currently being populated and there are plans to further utilize it in the future.	**4**
6.3(d)	Procurement of services, equipment, and/or tools	There are service agreements for some of the larger assets.	**5**
6.3(e)	Translating operations monitoring procedures into rounds	Rounds consist of gathering the basic monitoring information of the major equipment.	**3**
6.3(f)	Development of procedures for response to out-of-specification situations	There are some emergency operating procedures EOPs included in the SOPs, but these are not extensive.	**3**
6.3(g)	Metrics to monitor and gauge the plant performance against the established objectives and goals	There are very few plant performance metrics to determine performance relative to objectives and goals. Header pressures and power generation is monitored, but major equipment reliability and maintainability are not monitored.	**2**

Table B-1-1 RAM-1 Summary Sheet: Example 1 — Coal Power Plant (Cont'd)

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6.3(h)	Metrics to assess effectiveness of the RAM plan	There are no current metrics for reliability and maintainability.	**1**
6.3(i)	Training of operators/maintenance	There is an extensive operator training program, but no program defined for maintenance.	**3**
6.3(j)	Execution of tasks to fulfill the RAM plan	There is a limited quality control program for operations and maintenance tasks.	**3**
6.3(k)	New equipment that can self-identify critical equipment failures and alert operators remotely to failure modes via DCS	There are some components utilized that provide self-identification of failure modes.	**3**
6.3(l)	Evaluation of component system monitoring for reliability, longevity, and indirect failure risk where integrated with DCS	There are no components identified for monitoring reliability and very few to monitor indirect failure risk.	**2**
6.3(m)	Execution of monitoring, testing, inspection, maintenance, and measurement (MTIMM) plan	There is no active MTIMM plan in effect.	**1**
6.4	Program Revision	...	**...**
6.4(a)	Develop comparative performance reports based on program objectives and goals	Multiple reports are generated utilizing the monitored data that address some of the objectives and goals.	**4**
6.4(b)	Develop exception reports for action	There is a written (in progress) program for evaluating rework and failures.	**4**
6.4(c)	Identify and evaluate high-impact exceptions; root cause analysis (RCA) should also be considered	High-impact exceptions are given the proper attention, which can include RCA.	**3**
6.4(d)	Review critical equipment failure trends	Critical equipment failures are investigated thoroughly and trended.	**5**
6.4(e)	Compare actual to projected budget	The projected budget does not include the level of detail suggested in this Standard.	**2**
6.4(f)	Review, assess, and adjust the plan according to performance and make changes in the program	The current program is still in development with only portions of it effectively utilized.	**2**
		Overall Compliance Factor:	**2.53**
		Percent Compliance:	**50.7**

GENERAL NOTE: Table B-1-1 depicts an existing legacy coal plant that has been operating for many years with some RAM activities initiated and implemented. It shows how some RAM activities are supported with ample resources and manpower, while others are completely ignored.

Table B-1-2 RAM-1 Summary Sheet: Example 2 — Combined Cycle

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6	RAM description	...	...
6.1	Predevelopment Phase	...	...
6.1(a)	Requirements for the implementation of the program	There is a written RAM program implemented and in effect. The facility has just been commissioned so little data exists to prove effectiveness of the feedback and revision process.	**4**
6.1(b)	Basic plant description	The plant description is clearly provided with the BOD.	**5**
6.1(c)	Lifespan of plant and life-extension method	Lifespan and life-extension methods are clearly identified in the BOD.	**5**
6.1(d)	Functional requirements	These are included in the BOD.	**5**
6.1(e)	Availability requirements	These are included in the BOD.	**5**
6.1(f)	Reliability requirements	These are included in the BOD.	**5**
6.1(g)	Maintainability requirements	These are included in the BOD.	**5**
6.1(h)	Performance objectives and goals	These are included in the BOD.	**5**
6.2	Program development	...	...
6.2.1	Program statement	The power plant's Program Statement is defined in the RAM manual.	**5**
6.2.2	Program goals	...	
6.2.2(a)	Safety	The goals for safety are stated in the RAM manual.	**5**
6.2.2(b)	Reliability	The goals for reliability are stated in the RAM manual.	**5**
6.2.2(c)	Availability	The goals for availability are stated in the RAM manual.	**5**
6.2.2(d)	Maintainability	The goals for maintainability are stated in the RAM manual.	**5**
6.2.3	Program organization	...	...
6.2.3(a)	Owner	The hierarchy is clearly defined in the organization chart, with responsibilities pertaining to the RAM program identified.	**5**
6.2.3(b)	Program manager	The hierarchy is clearly defined in the organization chart, with responsibilities pertaining to the RAM program identified.	**5**
6.2.3(c)	Engineer	The hierarchy is clearly defined in the organization chart, with responsibilities pertaining to the RAM program identified.	**5**
6.2.3(d)	Operator	The hierarchy is clearly defined in the organization chart, with responsibilities pertaining to the RAM program identified.	**5**
6.2.4	Program design	...	...
6.2.4(a)	The Program shall comply with the following governing requirements:	...	...
6.2.4(a)(1)	Government and agency requirements	There are good records and clear written requirements are documented.	**5**
6.2.4(a)(2)	Environmental, health, and safety laws and regulations	Documentation regarding the environment, health, and safety laws and regulations is current and readily available.	**5**
6.2.4(a)(3)	Safety standards	A fully integrated safety plan exists and all personnel are trained.	**5**
6.2.4(a)(4)	Agreements and contractual requirements	All requirements are documented and understood by management.	**5**

Table B-1-2 RAM-1 Summary Sheet: Example 2 — Combined Cycle (Cont'd)

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6.2.4(a)(5)	Equipment and operational codes as specified by jurisdictional agencies or insurance providers	All requirements by jurisdictions having authority have been approved during commissioning.	5
6.2.4(a)(6)	Objectives as stated in the BOD	Objectives are identified in the RAM program.	5
6.2.4(b)	The program shall address the following specific requirements:	...	...
6.2.4(b)(1)	Identify physical plant systems, boundaries, equipment, and structures	All of the equipment is identified and the boundaries/extents are clearly stated.	5
6.2.4(b)(2)	Determine criticality definitions (classification bins for risk)	Criticality has been clearly defined during design.	5
6.2.4(b)(3)	Establish criticality methodology	Criticality methodology has been clearly defined in design.	5
6.2.4(b)(4)	Classify equipment criticality	All critical equipment/systems have been labeled.	5
6.2.4(b)(5)	Use failure analysis to assess risk to plant performance from	...	...
6.2.4.(b)(5)(a)	Failure modes, mechanisms, and causes	Failure mode effects analysis has been performed during design. Insufficient run time to validate the model.	4
6.2.4(b)(5)(-b)	Failure probability	Failure probability has been identified and quantified for all critical equipment. Insufficient run time to validate the model.	4
6.2.4(b)(5)(-c)	Failure consequence	Failure consequence have been identified and quantified for all critical equipment. Insufficient run time to validate the model.	4
6.2.4(b)(6)	Identify methods that mitigate failure causes	Failure causes have been estimated through engineering evaluation. Insufficient run time to validate the model.	4
6.2.4(b)(7)	Review technology that, when implemented, will mitigate risk of failure for critical equipment	New technology was evaluated during design and implemented during commissioning.	5
6.2.4(b)(8)	Review monitoring and alarms required to determine plant performance deterioration	Monitoring and alarm methods were evaluated during design and implemented during commissioning.	5
6.2.4(b)(9)	Review testing used to determine critical equipment status and suitability for continued operation	Testing was evaluated during design and implemented during commissioning.	5
6.2.4(b)(10)	Review inspection practices or overhauls required to periodically assure the plant will achieve the objectives and goals set forth	Inspection practices were evaluated during design and implemented during commissioning.	5
6.2.4(b)(11)	Review maintenance practices required to mitigate plant performance risk as identified herein	Maintenance practices were evaluated during design and implemented during commissioning.	5
6.2.4(b)(12)	Evaluate the cost effectiveness of the proposed options	Cost effectiveness options were evaluated in pre-design and design.	5
6.2.4(b)(13)	Evaluate methods for implementation	Implementation methods were evaluated during design.	5
6.2.4(b)(14)	Evaluate methods for program modification	Program modification methods were evaluated during design and validated during commissioning.	5
6.2.4(b)(15)	Fulfill goals as stated in the BOD	Methods of fulfillment were proven during commissioning (to the extent possible).	4
6.2.5	Program manual	...	...
6.2.5(a)	A program statement, consisting of scope, definitions, objectives, and goals	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	5

Table B-1-2 RAM-1 Summary Sheet: Example 2 — Combined Cycle (Cont'd)

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6.2.5(b)	Program organization and responsibilities	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(c)	Plant BOD, consisting of functional and performance requirements, system descriptions, and exclusions and limitations	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(d)	Criticality methodology to determine criticality definitions (categories) and establish criticality (risk-assessment) methodology	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(e)	Equipment criticality list	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(f)	System criticality	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(g)	Risk assets and performance requirements	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(h)	A monitoring plan	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(i)	A testing plan	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(j)	An inspection plan	Included in the RAM manual (compiled during design). Applicable personnel have been trained.	**5**
6.2.5(k)	Condition-directed response to out-of-specification situations	Included in the RAM manual (developed during design, validated during commissioning). Applicable personnel have been trained.	**5**
6.2.5(l)	A maintenance plan to address tasks, plans, periodicity, and required resources	Included in the RAM manual (developed during design, validated during commissioning). Applicable personnel have been trained.	**5**
6.2.5(m)	A measurement plan to validate effectiveness	Included in the RAM manual (developed during design, implemented during commissioning). Applicable personnel have been trained.	**5**
6.2.6	Program budget	The budget has been estimated during design; insufficient run time to validate the estimate.	**4**
6.3	RAM program implementation	...	**...**
6.3(a)	Initial equipment condition (baseline)	Completed for all critical equipment.	**5**
6.3(b)	Procurement and installation of the software and tools	Completed and tested during commissioning.	**5**
6.3(c)	Populating software programs(s)	Completed and tested during commissioning.	**5**
6.3(d)	Procurement of services, equipment, and/or tools	Completed.	**5**
6.3(e)	Translating operations monitoring procedures into rounds	Completed and validated during commissioning.	**5**
6.3(f)	Development of procedures for response to out-of-specification situations	Completed and validated during commissioning.	**5**
6.3(g)	Metrics to monitor and gauge the plant performance against the established objectives and goals	Completed and validated during commissioning.	**5**
6.3(h)	Metrics to assess effectiveness of the RAM plan	Developed during design and validated during commissioning.	**5**
6.3(i)	Training of operators/maintenance	Completed prior to commissioning.	**5**

Table B-1-2 RAM-1 Summary Sheet: Example 2 — Combined Cycle (Cont'd)

Reference Paragraph	Description	Comment Summary	Compliance Ranking
6.3(j)	Execution of tasks to fulfill the RAM plan	Completed.	**5**
6.3(k)	New equipment that can self-identify critical equipment failures and alert operators remotely to failure modes via DCS	All equipment types have been evaluated during design and implemented during construction.	**5**
6.3(l)	Evaluation of component system monitoring for reliability, longevity, and indirect failure risk where integrated with DCS	Evaluations occurred during design.	**5**
6.3(m)	Execution of monitoring, testing, inspection, maintenance, and measurement plan	Execution of plans were tested during construction and commissioning.	**5**
6.4	Program revision	...	**...**
6.4(a)	Develop comparative performance reports based on program objectives and goals	Not enough data—insufficient run time.	**N/A**
6.4(b)	Develop exception reports for action	Exceptions report developed and addressed during commissioning.	**4**
6.4(c)	Identify and evaluate high-impact exceptions; root cause analysis should also be considered	Not enough data—insufficient run time.	**N/A**
6.4(d)	Review critical equipment failure trends	Not enough data—insufficient run time.	**N/A**
6.4(e)	Compare actual to projected budget	Not enough data—insufficient run time.	**N/A**
6.4(f)	Review, assess, and adjust the plan according to performance and make changes in the program	Not enough data—insufficient run time.	**N/A**
		Overall Compliance Factor:	**4.88**
		Percent Compliance:	**97.6%**

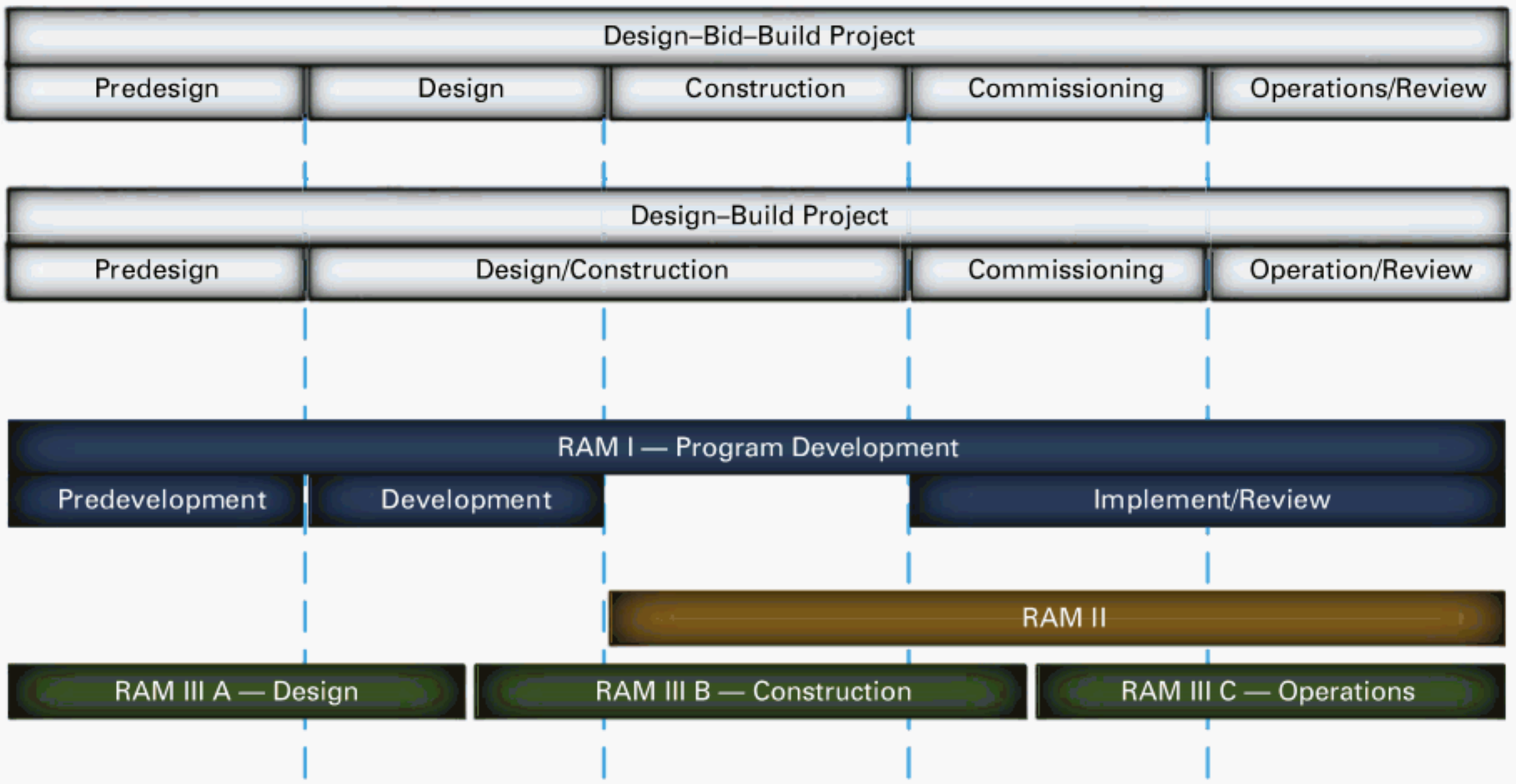
GENERAL NOTE: This example depicts a brand new cogeneration power plant utilizing a gas turbine and heat recovery steam generator. It assumes that a RAM Manager is assigned to the facility and RAM measures were incorporated during the design process. Since the facility is new, the RAM Manager made sure that all of the needed documentation was generated and gathered throughout the design, construction, and commissioning processes, and then retained to be readily available.

NONMANDATORY APPENDIX C
RAM DOCUMENT CROSS-FUNCTIONAL RELATIONSHIPS DIAGRAM

C-1 General

Figure C-1-1 is a graphical representation of the interactions between standard construction phases, RAM program development phases, and associated RAM standards.

Figure C-1-1 RAM Document Cross-Functional Relationships



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