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Regulatory Analysis of the Draft NRC Regulatory Guide for Implementing the §50.65 Rule

Final Report

Prepared by G. Zigler, F. Sciacca, and B. Walsh

Science and Engineering Associates, Inc.

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U.S. Nuclear Regulatory Commission

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TABLE OF CONTENTS

TABLE OF CONTENTS - CONTINUED

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The US Nuclear Regulatory Commission amended the Code of Federal Regulations, on July 10, 1991, by adding a new §50.65 entitled "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants", hereafter refered to as the §50.65 rule or simply as the Rule. This Regulatory Analysis evaluates the impacts (costs and benefits) which could result if the §50.65 rule were to be implemented in accordance with two alternative implementation guidance scenarios:

- Alternative A - No Guidance
- Alternative B - NRC Staff Guidance

The basis for the NRC Staff Guidance used in this Regulatory Analysis version is the August 1992 Draft Regulatory Guide included as Appendix C to this report.

For a licensee to comply with the §50.65 rule, a set of primary tasks were developed which must be performed, regardless of the implementation alternative. These tasks are summarized in Table 4-1 and form the backbone of this Regulatory Analyses. A set of questions which a licensee would generate in reading the §50.65 rule on how to implement each major task was developed and is included in Appendix B to this report. Scenarios were developed for the implementation of the Rule for each of the two alternatives analyzed based on how a licensee would answer the set of questions. Table 4-2 provides a summary of the differences between the two alternative implementation scenarios.

Costs for each alternative were developed based on estimates of labor and hardware for each of the one-time and recurring tasks. For the recurring tasks, the cost were present valued assuming a 20 year remaining average operational lifetime. The cost effects of License Renewal were also estimated based on a 40 year operation after conformance to the Rule. Benefits were based on estimates of the reduction in core damage frequency attributable to the effectiveness of implementing the tasks for each of the alternatives.

In developing the "No Guidance" scenario, the licensee is assumed to apply methods and technologies familiar to their maintenance staff: monitoring and preventive maintenance which emphasize the immediate condition and performance of a SSC. Additionally, decisions would be based on deterministic judgement.

The "NRC Guidance" scenario emphasizes statistical performance, specifically, historically based reliability and availability of a SSC, not just their immediate values. Under this latter alternative, the decisions tend to be based on probabilistic analysis rather than deterministic judgments.

The incremental cost of implementing Alternative A, the "No Guidance" scenario, on a typical reactor were estimated, in 1991 dollars, to be between a high of \$52.7 million and a low of \$20.5 million over a 20 year period. These values become \$71.6 and \$27.6 million for a 40 year period (reflecting the effects of License Renewal). When the benefits due to the estimated averted severe core damage are accounted, the net cost for implementing Alternative A were estimated to range between \$52.2 and \$18.5 million for the 20 year case and \$70.6 to \$23.5 million for the 40 year case. These minor cost variations when the benefits are accounted for reflects the small incremental decrease of core damage frequency (estimated to be between 2×10^{-5} per reactor year and 8×10^{-5} per reactor year) attributable to implementation of §50.65 pursuant to the "No Guidance" scenario developed for Alternative A.

Implementation pursuant to Alternative B, the "NRC Staff Guidance" scenario, was estimated to be between \$11.2 and \$18.7 million dollars more than Alternative A over 20 years and \$11.7 million and \$21.7 million more than Alternative A over 40 years. The estimated higher effectiveness in decreasing the core damage frequency (estimated to be between 1×10^{-4} per reactor year and 3×10^{-4} per reactor year) yielded a modest decrease in cost due to estimated averted cost. These more effective decrease in core damage frequency contributed significantly, however, in the estimated averted dose (both to the public and to the worker). When Alternative B is compared to Alternative A, the incremental cost for the increase in averted dose is in the order of \$2.2 thousand to \$5.7 thousand per person-rem which compares favorably with current industry cost estimates.

There are a number of benefits that are recognized but whose values were not accounted for in this analysis. These include the maintenance optimization which will occur as a direct consequence of the evaluation of the plant's overall maintenance program as well as each of the individual maintenance activities. This evaluation will also probably entail the re-establishement of the rationale for the selection of each maintenance activity as well as affording an opportunity to evaluate the effectiveness of the maintenance activity. This optimization could well result in cost savings due to the deletion of ineffective or unneeded maintenance activities. In addition to cost reductions due to maintenance optimization, no consideration was given to the impact of greater availability of a more reliable plant.

ACKNOWLEDGMENTS

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1.0 STATEMENT OF THE PROBLEM

In the Statement of Considerations accompanying the issuance of the §50.65 rule (Ref. 1), the Commission stated that a Regulatory Guide providing an acceptable method for implementing the §50.65 rule would be developed. The NRC's RES/DSIR staff was directed by the Commission to develop a Regulatory Guide to implement the provisions of §50.65. This analysis evaluates the impacts that could result if the §50.65 rule were to be implemented in accordance with the NRC Draft Regulatory Guide of August 1992 and compares them with the impacts attributable to a "No Guidance" scenario.

1.1 Purpose of a Regulatory Guide for the §50.65 Rule

This regulatory guide describes methods that are acceptable to the NRC staff for implementing the requirements of a rule. However, regulatory guides are not substitutes for regulations, and compliance with them is not required. A variety of approaches to goal setting, monitoring, and preventive maintenance may be used by licensees.

1.2 Summary of the §50.65 Rule

The §50.65 rule requires the monitoring of the overall continuing effectiveness of licensee maintenance programs. Paragraph (b) of the rule specifies that the scope of the monitoring program shall include:

(b)(1) safety-related structures, systems and components (SSCs) that are relied upon to remain functional during and following design basis events to ensure

- the integrity of the reactor coolant pressure boundary,
- the capability to shut down the reactor and maintain it in a safe shutdown condition, and
- the capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposure comparable to the 10 CFR 100 guidelines;

(b)(2) nonsafety-related SSCs

(i) that are relied upon to mitigate accidents or are used in plant emergency operating procedures (EOPs),

(ii) whose failure could prevent safety-related SSCs from fulfilling their safety-related functions, or

(iii) whose failure could cause a reactor scram or actuation of a safety-related system.

The objective of the final rule is to ensure that

(1) safety-related and certain nonsafety-related SSCs [those covered by (b)(1) and (b)(2)(i)] are capable of performing their safety-related functions;
(2) failures will not occur which prevent the fulfillment of safety-related functions, and
(3) failures resulting in scrams and unnecessary actuations of safety-related systems are minimized.

Two approaches, which are prescribed in paragraphs (a)(1) and (a)(2) of the rule, are provided for assuring maintenance effectiveness.

Paragraph (a)(1) requires that

- each licensee monitor the performance or condition of SSCs, against licensee-established goals, in a manner sufficient to provide reasonable assurance that such SSCs are capable of fulfilling their intended functions;
- such goals be established commensurate with safety and, where practical, take into account industry-wide operating experience; and
- when the performance or condition of a SSC does not meet established goals, appropriate corrective actions be taken.

Paragraph (a)(2) of the rule states that monitoring as specified in (a)(1) is not required where it has been demonstrated that the performance or condition of a SSC is being effectively controlled through the performance of appropriate preventive maintenance, such that the SSC remains capable of performing its intended function.

Finally, paragraph (a)(3) of the rule requires that

- performance and condition monitoring activities be evaluated at least annually, taking into account, where practical, industry-wide operating experience,
- adjustments be made where necessary to ensure that the objective of preventing failures of SSCs through maintenance is appropriately balanced against the objective of minimizing unavailability of SSCs due to monitoring or preventive maintenance, and

- in performing monitoring and preventive maintenance activities, an assessment of the total plant equipment that is out of service be taken into account to determine the overall effect on performance of safety functions.

2.0 OBJECTIVES

One of the broad objectives of a Regulatory Guide is to provide an acceptable methodology for implementing a rule. Specifically, a Regulatory Guide should:

(1) Explain the concepts of the rule;

(2) Provide illustrations;

(3) Provide for consistent implementation;

(4) Provide for consistent audit and inspection; and

(5) Define acceptable norms for implementation.

The broad objective of a Regulatory Guide for implementing the new §50.65 rule is to describe methods for monitoring the continuing effectiveness of licensee maintenance activities to ensure that:

(1) SSCs remain capable of performing their safety-related functions,

(2) Assumptions used in safety analyses, where available, continue to be valid;

(3) Failures will not occur that prevent the fulfillment of safety-related functions, or that cause faults or transients which result in scrams and unnecessary actuations of safety-related systems;

(4) The reliability benefits gained from performing preventive maintenance is appropriately balanced with the increase in risk derived from removing equipment from service to perform preventive maintenance; and

(5) The margins of safety, that exist because of the availability and reliability of additional components and redundant trains, are not reduced.

This Regulatory Analysis provides quantitative estimates of the consequences of performing the primary tasks or activities called for in the two implementation scenarios. This Regulatory Analysis also evaluates the safety improvements resulting from implementation of the recommendations and methods outlined in each of the two implementation scenarios analyzed.

3.0 RATIONALE FOR CHOICE OF REGULATORY INSTRUMENT

In adopting the regulatory position represented by the rule, the Commission decided that the rule would be revoked by a Regulatory Guide. The rationale for that decision is discussed in the regulatory analysis for the rule (Ref. 2).

4.0 ALTERNATIVE APPROACHES FOR IMPLEMENTING THE RULE

This section identifies two major alternative approaches considered for achieving the objectives of the regulatory guide. The Commission, by adopting the regulatory position represented by the §50.65 rule, has decided agai such alternatives as taking no action at all, making more effective use of existing enforcement mechanisms, establishing performance standards, and deregulation. The rationale for that decision is discussed in the regulatory analysis accompanying the issuance of §50.65 rule (Ref. 2).

This Regulatory Analysis is concerned with evaluating two possible alternative regulatory approaches that might be taken now that the Commission has promulgated the maintenance rule:

- Alternative A - No Guidance
- Alternative B - NRC Staff Guidance

For the purpose of evaluating the consequences of no guidance, this analysis assumes that licensees will comply with the Rule by applying methods and technologies that are familiar to their maintenance staffs. That is, monitoring and preventive maintenance will emphasize the immediate conditions of systems, structures, and components, and decisions will be based on deterministic judgments.

The NRC Draft Regulatory Guide, on the other hand, emphasizes performance parameters, such as operational success, even more than condition parameters. It also emphasizes the history of monitored parameters, not just their immediate values. Consequently, decisions tend to be based on probabilistic analysis, rather than deterministic judgments.

The NRC Draft Regulator Guide also emphasizes two other requirements that might be neglected in the absence of guidance. One is that the monitoring program be predictive, that it include trending of data to guide preventive maintenance. The second clarification is that the program must include monitoring the overall effectiveness of maintenance.

4.1 Primary Implementation Tasks

To comply with the maintenance rule, the licensee must perform certain primary tasks, regardless of which implementation alternative is used. These primary tasks, shown in Table 4-1, form the basic structure for this Regulatory Analysis. in addition to these generic steps, there may be secondary tasks that the licensee decides to add as a result of the evaluations and assessments required by the Maintenance Rule. Because such tasks are unique to a specific licensee's implementation approach, they are not addressed in this section.

In the matrix of Table 4-1, the primary tasks are categorized based on when and how often the tasks are performed (the left column of the table), whether they are plant-wide tasks or system-level tasks (columns two and three), and whether they are required to comply with Para. (a)(1) or (a)(2) of the maintenance rule (columns four and five). It should be noted that the table contains only those primary tasks that are common to all three alternatives. Additional primary tasks that apply to some of the alternatives are discussed in later sections.

The task timing column in Table 4-1 is divided into three categories. The first, called One-Time Startup Tasks, includes those primary tasks that are required for initial implementation of the maintenance rule, such as identifying which systems are in or out of the scope of the rule. The second category is recurring, or periodic, tasks. These are tasks that must be performed initially and then repeated on a regular but infrequent basis. The third category, continuing tasks, are ongoing tasks that must be performed routinely and frequently, such as monitoring the performance or condition of in-scope SSCs.

The column headings of Table 4-1 classify the tasks on another basis. The first two column headings categorize the primary tasks according to the level at which they are performed. The plant-wide tasks are global in nature and are concerned with the macroscopic aspects of the maintenance monitoring program. The system-level tasks are performed at the subordinate structure or component level for each system. The second two columns divide the tasks based on whether monitoring is required [Para. (a)(1)] or is not required [Para. (a)(2)]. Note that this division applies on both a plant-wide basis and a system-level basis, so these categories are independent of the classification in the first two columns.

The remainder of this section defines, in terms of a scope and a methodology for each task, how a licensee might perform these primary tasks for each of the three alternative approaches to implementing the maintenance rule. The scope and methodology chosen should be consistent with an overall approach to implementing the §50.65 rule. However, the choice of overall approach depends on how the various portions of the maintenance rule are interpreted. In determining how to interpret the rule, a prudent licensee might begin by writing down specific questions that arise from reading the rule. An example of such a list, included as Appendix B to this report, was the starting point for defining a scope and methodology for each primary task.

4.2 Determination of Structures, Systems, and Components in the Scope of the Maintenance Rule

As indicated in Table 4-1, the licensee must identify the SSCs that are within the scope of the maintenance rule. The rule, in paragraph (b), addresses which safety and non-safety related SSCs fall

Table 4-1. Primary Tasks That May Be Added Pursuant to the Maintenance Rule

TASK TIMING	PRIMARY TASKS			
	Plant-Wide Tasks	System Level Tasks	Tasks Required by Para (a)(1) [Applicable to Plant and SSCs]	Tasks Required by Para (a)(2) [Applicable to Plant and SSCs]
One-Time Startup Tasks [Required for initial implementation of Maintenance Rule]	• Identify systems in scope of Maintenance Rule • For systems out of scope, identify subordinate structures and components which are in scope of Para. (b)(2)(ii) or (iii) • Assess safety implications of combinations of equipment out of service • Select and document methods for establishing goals, demonstrating control, and balancing objectives	• Identify subordinate structures and components which are in scope of Para. (b)(1) or (b)(2)(i) • Identify subordinate structures and components which are in scope of Para. (b)(2)(ii) or (b)(2)(iii) • Identify risk-significant components	• Identify performance or condition to be monitored • Implement enhanced monitoring	• Identify performance or condition to be controlled
Recurring Tasks [Initially and approximately annually]	• Identify risk-significant structures and components	• Balance unavailability due to maintenance monitoring and preventive maintenance against failure prevention • Re-evaluate structures and components in scope of each system	• Establish/review goals for monitored performance or condition	• Demonstrate effective control of performance or condition
Continuing Tasks [Ongoing]		• If maintenance monitoring or preventive maintenance takes equipment out of service, review assessment of safety implications	• Monitor as necessary to meet Para. (a)(1) requirements • When monitoring demonstrates that goals are not being met, evaluate and select corrective action	• Perform preventive maintenance as necessary to meet Para. (a)(2) requirements

within the scope. Paragraph (b)(1) selects those safety related SSCs which are relied on to remain functional. Paragraph (b)(2) selects those non-safety related SSCs. The rule differentiates two classes of SSCs: (1) those SSCs whose function is IN scope and (2) those SSCs whose failure mode is IN scope [pursuant to (b)(2)(ii) and (b)(2)(iii)].

A logic tree, Figure 4-1, was developed to illustrate how a licensee may determine which SSCs are within the scope of the rule. First, all plant Structures and Systems would be screened to determine if their respective function is within the scope of the rule. Those Structures and Systems whose function is not within the scope of the rule are further screened to determine if their failure (components of systems) would cause them to be within scope. Only after this second screening for failure impact would the structures and component set not within the purview of the rule be defined. Those Structures and Systems whose function is in scope would be further screened to determine those components whose failure mode is within the scope of the rule. As indicated in Figure 4-1, the outcome of the screening process is three sets of Structures, Systems, and Components:

(1) Structures, Systems, and Components whose **function** is IN scope

(2) Structures and Components whose **failure mode** is IN scope

(3) Structures and Components NOT in scope

4.3 Primary Tasks Under Alternative A

This first section covers only Alternative A, which is the case of no additional guidance. Lack of guidance will lead to greater diversity in the activities performed by the various utilities in attempting to comply with the rule. For purposes of comparison, Alternative A is represented by one particular approach that might be followed by a licensee attempting, without further guidance, to satisfying the requirements of the rule.

The Alternative A approach might be chosen by a licensee that thinks that the (a)(1) requires goal-setting and monitoring for each separate component unless that component is excluded under (a)(2). The actions chosen to represent Alternative A are consistent with an approach that emphasizes demonstrating control by preventive maintenance in order to avoid the requirements of (a)(1).

The approach summarized here assumes that the licensee plans to demonstrate control of a SSC by preventive maintenance by showing that the SSC satisfies its current licensing basis. Furthermore, the licensee plans to show this with normal preventive maintenance, because that should be sufficient to maintain the current licensing basis. If failures occurred, the licensee might attempt to demonstrate control with a higher frequency of preventive maintenance rather than institute monitoring, not realizing that the NRC staff considers that approach unacceptable.

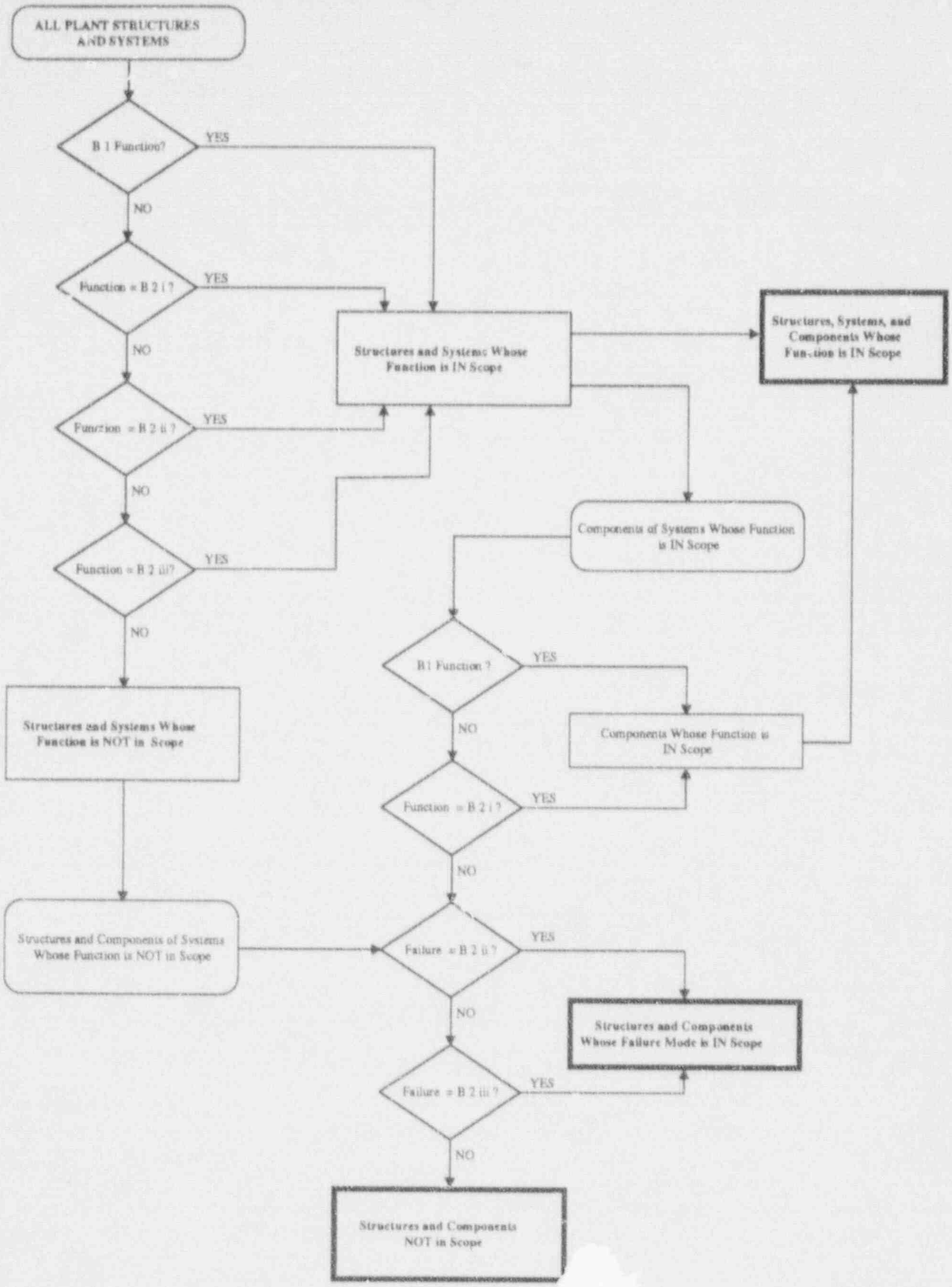

Figure 4-1. Determination of Structures, Systems, and Components in the Scope of the Maintenance Rule

Further, the licensee in Alternative A is assumed interpret paragraph (a)(3) as applicable only to monitoring and preventive maintenance activities added to satisfy the rule. Thus, (a)(3) is assumed not to apply to surveillance or testing that is conducted as part of normal preventive maintenance such as are described in documents such as technical specifications or ASME code requirements. Most of the at-least-annual evaluation, as well as the necessity to balance availability and reliability are, therefore, minimized or eliminated in the Alternative A scenario.

The major change in such a licensee s maintenance program would be an increased attention to management and performance of preventive maintenance. The licensee would not want errors in maintenance to cause it to fail to demonstrate control by preventive maintenance.

4.3.1 Plant-Wide Program Setup and Implementation Activities

4.3.1.1 Scope Evaluations

Identification of systems within the scope of the rule

Method:

(1) Is function relied upon for safety per (b)(1) or (b)(2)(i)? If yes, system is in scope.

(2) If function not relied upon for safety, does system have safety-significant failure modes per (b)(2)(ii) or (b)(2)(iii)? If yes, system is in scope.

For systems out of scope, identify subordinate structures and components that are in scope of Para. (b)(2)(ii) or (b)(2)(iii)

Scope: All structures and components of out-of-scope plant system

Method: Partial failure mode effects analysis to determine whether any failure mode is significant per (b)(2)(ii) or (b)(2)(iii). If so, the structure or component is in scope because of those failure modes.

4.3.1.2 Assessment of Combinations of Equipment Out of Service

Scope: Major possible combinations of equipment out of service.

Method: Technical specifications identify combinations already accepted as safe under current licensing basis after applying deterministic judgments. Where technical specifications do not provide guidance, such as for certain non-safety related equipment or for certain off-power modes, supplement technical specifications by making deterministic judgments.

4.3.1.3 Select and Document Methods for Establishing Goals, Demonstrating Control and Balancing Objectives

Scope: One per plant

Method:

(1) No goal-setting methods required. The performance or condition of all SSCs is effectively controlled per (a)(2).

(2) For demonstrating control, find a textbook method for projecting measurements forward in time and for establishing confidence intervals on those projections.

(3) Document argument that current licensing basis balances objectives.

4.3.1.4 Identification of Risk-Significant Structures, Systems and Components

Scope: Not required. All structures and components are controlled per (a)(2).

4.3.2 System-Level Setup and Implementation Activities

<u>Identify structures and components in scope of (b)(1) or (b)(2)(i)</u>

Scope: All structures and components in system

Method: Is function relied upon for system function? If yes, structure or component is in scope because of its function.

<u>Identify structures and components in scope of (b)(2)(ii) or (b)(2)(iii)</u>

Scope: All structures and components in system that are not in scope because of their function

Method: In this scenario a partial failure mode effects analysis is done to determine whether any failure mode is safety-significant per (b)(2)(ii) or (b)(2)(iii). If so, structure or component is in scope because of those failure modes.

4.3.3 Startup Tasks Pursuant to (a)(1)

<u>Identify performance or conditions to be monitored</u>

Scope: Not required. The performance or condition of all SSCs is effectively controlled per (a)(2).

<u>Implement enhanced monitoring</u>

Scope: Not required. The performance or condition of all SSCs is effectively controlled per (a)(2).

4.3.4 Startup Tasks- Pursuant to (a)(2)

Identify performance or condition to be controlled

Scope: All SSCs in the scope of the rule

Method: For each performance or condition measurement required by the current licensing basis, determine control limits on performance or condition that are no worse than expected between measurements under the current licensing basis.

4.3.5 Plant-Wide Recurring Activities

Identify risk-significant structures and components

Scope: Not required. All structures and components are controlled per (a)(2).

4.3.6 System-Level Recurring Activities

4.3.6.1 Balance Unavailability Due to Monitoring and Preventive Maintenance Against Failure Prevention

Scope: Not required. This provision is assumed to apply only to activities pursuant to (a)(1) or (a)(2). However, there are no activities pursuant to (a)(1), and those pursuant to (a)(2) are the minimum required under the current licensing basis.

4.3.6.2 Reassessment of SCs in the Scope of Each System

This is a repeat of the activities in Section 4.3.2.

4.3.7 Recurring Tasks Pursuant to (a)(2)

Establish goals

Scope: Not required. The performance or condition of all SSCs is effectively controlled per (a)(2).

4.3.8 Recurring Tasks Pursuant to (a)(2)

Demonstrate Effective Control of Performance or Condition Per (a)(2)

Scope: Every controlled performance and condition of SSCs in the scope of the rule.

Method:

(1) Apply standard method to project measurement forward in time.

(2) Apply standard method to determine confidence limits on projection.

(3) Are the confidence limits on the projection within the control limits for the performance or condition through at least one preventive maintenance interval? If yes, demonstration is complete.

(4) If demonstration is not complete, perform corrective maintenance on the SSC to improve the performance or condition. Repeat measurement to be sure that the current performance or condition is within the control limits. Adjust projection and confidence limits to start from new measurement with old trend.

(5) Are the new confidence limits on the projection within the control limits? If yes, demonstration is complete.

(6) If demonstration still is not complete, replace the component, perform additional corrective maintenance, or reduce the preventive maintenance interval until confidence limits on the projection are within the control limits for at least one preventive maintenance interval.

4.3.9 Continuing Tasks - All Systems In Scope

<u>If monitoring or PM takes equipment out of service, consider assessment</u>

Scope: All PM pursuant to (a)(2) that takes equipment out of service.

Method: Check restrictions in technical specifications, as supplemented by the activities described in Section 4.3.1.2, before taking equipment out of service.

4.3.10 Continuing Tasks Pursuant to (a)(1)

<u>Monitoring added pursuant to (a)(1)</u>

Scope: Not required. The performance or condition of all SSCs is effectively controlled per (a)(2).

<u>When goals not met, select corrective action</u>

Scope: Not required. The performance or condition of all SSCs is effectively controlled per (a)(2).

4.3.11 Continuing Tasks Pursuant to (a)(2)

<u>Enhanced Preventive Maintenance and Corrective Actions</u>

Scope: All SSCs in the scope of the rule

Method: If the PM interval has been reduced in order to demonstrate control between intervals, then the additional PM is being performed pursuant to (a)(2).

4.4 Primary Tasks Under Alternative B

This section presents the primary task scopes and methodologies for Alternative B, which emphasizes statistical analysis of performance, particularly actually experienced reliability and availability, and the use of probabilistic analyses. This alternative includes monitoring of overall effectiveness of maintenance at the plant level and system level by periodically updating the PRA. Otherwise, most monitoring is performed at the system or train functional level; monitoring at the structure or component level need only be performed for risk significant structures and components. Therefore, there is no incentive for the licensee to exclude SSCs under paragraph (a)(2) of the rule.

Monitoring under Alternative B includes all immediate conditions and statistical performances that are applicable, including monitoring for predictive maintenance. All structures and components that are not risk significant are excluded from monitoring by controlling the measurable condition and performance parameters that form the current licensing basis.

Where a system, train, or risk-significant component or structure is required to be so reliable that it would take too long to gather significant statistics, Alternative B assumes that the licensee monitors the same measurable condition and performance parameters that form the current licensing basis. Further, paragraph (a)(3) is interpreted as applying to all monitoring and preventive maintenance activities performed on SSCs defined in paragraph (b), regardless of whether they are performed pursuant to (a)(1) or (a)(2).

4.4.1 Plant-Wide Program Setup and Implementation Activities

4.4.1.1 Scope Evaluations

Identify systems in scope of rule

Scope: All plant systems

Method:

(1) Is function relied upon for safety per (b)(1) or (b)(2)(i)? If yes, system is in scope.

(2) If function not relied upon for safety, does system have safety-significant failure modes per (b)(2)(ii) or (b)(2)(iii)? If yes, system is in scope.

For systems out of scope, identify subordinate structures and components that are in scope of Para. (b)(2)(ii) or (b)(2)(iii)

Scope: All structures and components of out-of-scope plant systems

Method. Partial failure mode effects analysis to determine whether any failure mode is safety-significant per (b)(2)(ii) or (b)(2)(iii). If so, the structure of component is in scope because of those failure modes.

4.4.1.2 Assessment of Combinations of Equipment Out of Service

Scope: All plant states, many possible combinations of equipment out of service.

Method:

(1) Requantify PRA for many combinations of equipment out of service.

(2) Determine acceptable duration for each combination.

(3) For off-power modes, supplement technical specifications by making deterministic judgments.

(4) Prepare maintenance instructions for determining when monitoring or PM can be performed.

4.4.1.3 Select and Document Methods for Establishing Goals, Demonstrating Control and Balancing Objectives

Scope: One per plant

Method:

(1) Participate in industry studies of industry experience with programmatic effectiveness indicators and their correlations with plant performance.

(2) Develop and document procedure for determining number of tests required to reject hypothesis that actual unreliability is less than one error factor above target unreliability, if actual unreliability is n error factors above target unreliability.

(3) Develop and document procedure for determining length of time required to reject hypothesis that actual unplanned unavailability is less than one error factor above target unplanned unavailability, if actual unplanned unavailability is n error factors above target unplanned unavailability.

(4) Select standard methods for projecting measurements forward in time and for establishing confidence intervals for those projections.

(5) Select and document methods for:

(a) modeling the age-dependence of unreliability and unplanned unavailability without corrective action,

(b) modeling the effect of a monitoring activity and its associated corrective action on the age-dependence of unreliability and unplanned unavailability, and

(c) balancing the benefits of the monitoring activity against the unavailability due to the monitoring activity.

4.4.1.4 Identification of Risk-Significant SSC

Scope: One per plant

Method:

(1) Update and enhance PRA.

(2) Calculate core damage frequency and reliability or unplanned unavailability of each system and train.

(3) Perform sensitivity or importance analysis on updated PRA to identify structures and components with significant failure modes.

4.4.2 System-Level Setup and Implementation Activities

Identify structures and components in scope of (b)(1) or (b)(2)(i)

Scope: All structures and components in system

Method: Is function relied upon for system function? If yes, structure or component is in scope because of its function.

Identify structures and components in scope of (b)(2)(ii) or (b)(2)(iii)

Scope: All structures and components in system that are not in scope because of their function

Method: Perform partial failure mode effects analysis to determine whether any failure mode is safety-significant per (b)(2)(ii) or (b)(2)(iii). If so, structure or component is in scope because of those failure modes.

4.4.3 Startup Tasks Pursuant to (a)(1)

4.4.3.1 Identification of Performance of Condition Parameters to Monitor

Scope: The plant and all systems in scope of rule and any risk-significant structures and components.

Method:

(1) If SSC is in scope because of its function, identify range of industry experience for SSC functional unreliability and/or unplanned unavailability.

(2) If structure or component is in scope because of failure mode(s), identify range of industry experience for unreliability with respect to failure mode(s).

(3) Determine number of tests or time required to reject hypothesis that actual unreliability and/or unplanned unavailability is less than one error factor above target unreliability and/or unplanned unavailability, if actual unreliability and/or unplanned unavailability is a few error factors above target unreliability and/or unplanned unavailability. If required number of tests can be expected to occur in a few years or required time is less than a few years, identify the unreliability and/or unplanned unavailability as a performance to monitor.

(4) Identify important degradation mode(s). Identify performance or condition parameters that measure such degradation(s).

(5) For plant, select

  (a) programmatic performance indicators based on industry studies,

  (b) calculated core damage frequency according to updated PRA,

  (c) experienced availability of full margin of safety (fraction of time at normal power that all safety-related systems and trains are available),

  (d) experienced frequency of SCRAMs or trips, and

  (e) experienced plant risk due to initiating events (calculated contribution to core damage probability from experienced initiating events).

(6) For a system or train, select calculated unreliability of unplanned unavailability according to updated PRA.

(7) Set up record-keeping system.

4.4.3.2 Implement Enhanced Monitoring

Scope: All identified degradation-measuring parameters of systems and risk-significant structures and components within the scope of the rule.

Method:

(1) Identify degradation mitigation activity or activities that could be initiated by monitoring the parameters.

(2) For each candidate mitigation activity, estimate the degree of renewal that could be achieved, taking into consideration the relative importance of the degradation mode and the effectiveness of the mitigation activity. Select the most cost-effective mitigation activity.

(3) Estimate the frequency with which the parameter, if perfectly monitored, would indicate the need for degradation mitigation.

(4) Identify method(s) for monitoring the parameter.

(5) For each candidate monitoring method, estimate the mean renewal rate, taking into consideration the monitoring interval, the probability that any parameter would indicate the need for mitigation, the probability that a parameter that would indicate the need is included in the sample, the probability that the method would detect the need given that a sampled parameter indicated the need, and the effectiveness of the selected mitigation activity. Choose the most cost effective monitoring method.

(6) Perform cost/benefit analysis of potential monitoring enhancement. Implement the enhancement if cost/benefit ratio is favorable.

4.4.4 Startup Tasks Pursuant to (a)(2)

Identification of Performance or Condition Parameters to Control

Scope: Structures and components in the scope of the rule that are not risk-significant.

Method: For each performance or condition measurement required by the current licensing basis, determine control limits on performance or condition that are no worse than expected between measurements under the current licensing basis.

4.4.5 Plant-Wide Recurring Activities

Update the Identification of Risk-Significant Structures and Components

Scope: One per plant

Method:

(1) Update and enhance PRA.

(2) Calculate core damage frequency and reliability or unplanned unavailability of each system and train.

(3) Calculate contribution to core damage probability from initiating events experienced during most recent period.

(4) Perform sensitivity or importance analysis on updated PRA to identify structures and components with significant failure modes.

4.4.6 Recurring Activities - All Systems in Scope

4.4.6.1 Balance Unavailability Due to Monitoring and Preventive Maintenance Against Failure Prevention

Scope: Monitoring and preventive maintenance activities that take systems of components out of service.

Method:

(1) Model the age-dependence of unreliability and unplanned unavailability without any corrective action.

(2) Model the effect of the activity and any associated corrective action on the age-dependence of unreliability and unplanned unavailability.

(3) Apply the method developed by the activities described in Section 4.4.1.3 to balance the benefits of the activity against the unavailability due to the activity.

4.4.6.2 Reassessment of SCs in the Scope of Each System

This is a repeat of the activities in Section 4.4.2

4.4.7 Recurring Tasks Pursuant to (a)(1)

<u>Review Goals for Monitored Condition or Performance</u>

Scope: The plant and all systems in scope of rule and any risk-significant structures and components.

Method:

(1) If experienced unreliability or unplanned unavailability has been identified as a performance to monitor,

(a) Establish target value and error factor that are at least as good as assumed in PRA and are challenging, taking into consideration industry-wide data.

(b) Determine number of tests or length of time required to reject hypothesis that actual value is less than one error factor too high, if actual value is three error factors too high. Establish long-term goal for failures in that many tests, or unavailability in that length of time, that is two error factors above desired failure rate.

(c) Determine number of consecutive failures or minimum down time required to demonstrate that desired failure rate is not met. Establish early warning goal for that many failures in a number of tests, or that unavailability in a length of time, such that the early warning goal would usually be achieved if the actual unreliability or unplanned unavailability is equal to the target value.

(2) If calculated risk, unreliability, or unplanned unavailability has been identified for monitoring, establish a goal that is at least consistent with the value calculated by the updated PRA and is challenging, taking into consideration industry and plant experience and NRC goals.

(3) If immediate performance and condition have been identified for monitoring, establish goals that are no worse than required under the current licensing basis and provide reasonable assurance, based on industry and plant experience, that the SSC is capable of fulfilling its intended function.

(4) For each programmatic effectiveness indicator that has been identified for monitoring, establish goals that are challenging, based on industry and plant experience.

(5) For experienced availability of full margin of safety, experienced frequency of SCRAMs or trips, or experienced plant risk due to initiating events, establish goals that are at least consistent with assumptions in the updated PRA and are challenging, based on industry and plant experience.

4.4.8 Periodic Tasks Pursuant to (a)(2)

Demonstrate Effective Control of Performance or Condition Per (a)(2)

Scope: Structures and components in the scope of the rule that are not risk-significant.

Method:

(1) Apply standard method to project measurement forward in time.

(2) Apply standard method to determine confidence limits on projection.

(3) Are the confidence limits on the projection within the control limits for the performance or condition through at least one preventive maintenance interval? If yes, demonstration is complete.

(4) If demonstration is not complete, perform corrective maintenance on the SSC to improve the performance or condition. Repeat measurement to be sure that the current performance or condition is within the control limits. Adjust projection and confidence limits to start from new measurement with old trend.

(5) Are the new confidence limits on the projection within the control limits? If yes, demonstration is complete.

(6) If demonstration still is not complete, replace the component, perform additional corrective maintenance, or reduce the preventive maintenance interval until confidence limits on the projection are within the control limits for at least one preventive maintenance interval.

4.4.9 Continuing Tasks - All Systems In Scope

If monitoring or PM takes equipment out of service, consider assessment

Scope: All monitoring and preventive maintenance activities that take out of service any SSC that is in the scope of the rule, regardless of whether the activity is performed pursuant to (a)(1) or (a)(2).

Method: Check maintenance instructions before taking equipment out of service.

4.4.10 Continuing Tasks Pursuant to (a)(1)

4.4.10.1 Monitoring Added Pursuant to (a)(1)

Scope: The plant and all systems in scope of rule and any risk-significant structures and components

Method: If the monitored parameter is unreliability or unplanned unavailability, the only added activity is recording the history and comparison with goals. If immediate performance or condition is being monitored, the frequency is determined by the current licensing basis, and the only added activity is recording the measurements. Programmatic effectiveness indicators usually only require the recording of events. Monitoring calculated risk, reliability, or unplanned unavailability requires no ongoing activity.

4.4.10.2 Corrective Action When Goal Not Met

Scope: The plant and all systems in scope of rule and all risk-significant structures and components.

Method:

(1) Perform root cause analysis of maintenance program failure.

(2) Identify potential corrective actions, including adding or revising procedures, revising training, or revising quality control, or increasing maximum failure rate and adjusting goals to match. (Correction of a previously undiscovered degradation might not be adequate if future such degradations would remain undiscovered.)

(3) Perform cost/benefit analysis of potential corrective actions. Sel... optimum action. (New tasks resulting from corrective action are secondary tasks, not primary tasks.)

4.4.11 Continuing Tasks Pursuant to (a)(2)

Perform PM pursuant to (a)(2)

Scope: All structures and components that are not risk-significant

Method: If the PM interval has been reduced in order to demonstrate control between intervals, then the additional PM is being performed pursuant to (a)(2).

4.5 Differences Among Alternative Regulatory Position

Table 4-2 provides a summary of the differences in guidance for the two alternatives considered. Each line presents a supposition about how a licensee should act to satisfy the requirements of the rule. For each of the two alternative guidance, the table shows which suppositions are included as suggestions in the guidance (or in the case of Alternative A, assumed by the licensee).

Table 4-2 does not show tasks, only suppositions. For instance, Alternative A includes the assumption by the licensee that monitoring pursuant to (a)(1) is applicable to all components in the scope of the rule, unless excluded under (a)(2). Partly because of this assumption, which the NRC staff considers unnecessary, the implementation under Alternative A has no tasks associated with (a)(1); instead, the licensee is motivated to demonstrate control pursuant to (a)(2) for all components.

Table 4-2
Differences Among Alternative Guidances

	A No Guidance	B Draft NRC Staff Guidance
MONITORING AGAINST GOALS PER (a)(1)		
<u>Plant Parameters</u>		
Licensee should monitor programmatic maintenance effectiveness indicators.	no mention	included
Licensee should monitor calculated risk (cdf) per updated PRA.	no mention	included
Licensee should monitor availability statistics for each safety-related system and train.	no mention	included
Licensee should monitor SCRAM or trip statistics against goals that are consistent with PRA assumptions.	no mention	included
Licensee should calculate increase in cdf that results from experienced initiating events.	no mention	included
<u>System and Train Parameters</u>		
Licensee should calculate reliability per updated PRA.	no mention	included
Licensee should monitor statistics on unreliability and unplanned unavailability against goals consistent with PRA assumptions.	no mention	included
Licensee should monitor immediate performance or condition against corrective maintenance criteria.	included	included
<u>Structures to Monitor [unless excluded under (a)(2)]</u>		
Licensee should monitor theoretically risk-significant structures.	included	included
Licensee should monitor structures that are not risk-significant but have critical failure modes.	included	included
Licensee should monitor structures that have neither significant risk nor critical failure modes, but could degrade unacceptably or fail.	included	included[d]
Licensee should monitor structures that could neither degrade unacceptably nor fail, but are within the scope of the rule.	included	no mention
<u>Structure Parameters</u>		
Licensee should monitor immediate structure conditions against criteria for corrective action.	included	included
Licensee should extrapolate structure condition trends for one monitoring period and compare against criteria for corrective action.	no mention	included
Licensee should monitor theoretically risk significant components.	included	included
Licensee should monitor components that are not risk-significant but have critical failure modes.	included	included
Licensee should monitor components that have neither significant risk nor critical failure modes, but have caused SCRAMS or transients.	included	included

Table 4-2 (Continued)
Differences Among Alternative Guidances

	A No Guidance	B Draft NRC Staff Guidance
MONITORING AGAINST GOALS PER (a)(1) (cont.)		
<u>Components to Monitor [unless excluded under (a)(2)]</u>		
Licensee should monitor theoretically risk significant components.	included	included
Licensee should monitor components that are not risk-significant but have critical failure modes.	included	included
Licensee should monitor components that have neither significant risk nor critical failure modes, but have caused SCRAMS or transients.	included	included
Licensee should monitor components that have neither significant risk, critical failure modes, nor history of causing SCRAMS or transients, but have caused a system goal to be missed.	included	included
Licensee should monitor components that have neither significant risk, critical failure modes, nor history of causing SCRAMS or transients, nor have caused a system goal to be missed, but are within the scope of the rule.	included	no mention
<u>Component Parameters</u>		
Licensee should monitor statistics on unreliability and unplanned unavailability against goals consistent with PRA assumptions.	no mention	included
Licensee should monitor immediate component performance or condition against corrective maintenance criteria.	included	included
Licensee should extrapolate component performance or condition trends for one monitoring period and compare against criteria for corrective action.	no mention	included
CORRECTIVE ACTION PER (a)(1) WHEN GOALS NOT MET		
Licensee should perform appropriate corrective maintenance on SSC.	included	included
Licensee should conduct root cause analysis of maintenance program failure.	no mention	included
Licensee should perform cost/benefit analysis of potential corrections to maintenance program.	no mention	included
DEMONSTRATING CONTROL PER (a)(2)		
Licensee should document statistics on unreliability and unplanned unavailability to demonstrate control of a SSC by preventive maintenance.	no mention	included
Licensee should document most recent performance or condition to demonstrate control of a SSC by preventive maintenance.	no mention	included
Licensee should document trend of immediate performance or condition to demonstrate control of a SSC by preventive maintenance.	included	included

Table 4-2 (Continued)
Differences Among Alternative Guidances

	A No Guidance	B Draft NRC Staff Guidance
DEMONSTRATING CONTROL PER (a)(2) (Cont.)		
The occurrence of a maintenance-preventable failure negates any prior demonstration of control of a risk-significant SSC by preventive maintenance.	no mention	included
The occurrence of a maintenance-preventable failure negates any prior demonstration of control by preventive maintenance, even if the SSC is not risk-significant.	no mention	no mention
PERIODIC EVALUATION PER (a)(3)		
The licensee should update all demonstrations of control per (a)(2).	included	included
The licensee should perform root cause analysis of any failure to control per (a)(2).	included	included
The licensee should perform corrective maintenance or enhance preventive maintenance as necessary to assure control per (a)(2).	included	included
The licensee should compare latest monitoring results with goals.	no mention	included
The licensee should evaluate overall effectiveness of maintenance.	no mention	included
The licensee should conduct root cause analysis of any maintenance program ineffectiveness.	no mention	included
The licensee should perform cost/benefit analysis of any potential maintenance program modification.	no mention	included
The licensee should update the full-power Level I PRA and all associated goals.	no mention	included
The licensee should model effects on equipment reliabilities of all monitoring and preventive maintenance activities that take in-scope SSCs out of service, should balance availabilities & reliabilities, and should evaluate costs and benefits of proposed adjustments	no mention	included
ASSESSMENT OF EQUIPMENT OUT OF SERVICE		
The licensee should develop PRAs for off-power modes.	no mention	no mention
The licensee should assess combinations of systems out of service using normal-power PRA.	no mention	included
The licesee should use deterministic judgment of combinations of systems out of service as reflected in the intent of the technical specifications.	included	no mention
The licensee should use deterministic judgment to extend the intent of the technical specifications to off-power modes.	included	included
The licensee should take the assessment into account in performing activities pursuant to (a)(1) and (a)(2) that take equipment out of service.	included	included
The licensee should take the assessment into account in performing all monitoring and preventive maintenance activities on SSCs in the scope of the rule that take equipment out of service, even if the activities are not pursuant to (a)(1) or (a)(2).	no mention	included

5.0 CONSEQUENCES OF THE TWO ALTERNATIVES

Each of the two alternatives for implementing the maintenance rule will result in specific consequences and benefits for licensees and the NRC. The direct consequences will be in the form of cost impacts and increases in occupational radiation exposure. Expected benefits include averted costs associated with cleanup and power replacement following a core damage event, as well as averted public occupational radiation exposure. This section addresses the anticipated consequences and benefits for implementing the guidance to the maintenance rule for each of the two alternatives. The information used to determine the consequences was based on NRC technical reports, IAEA publications, and discussions with NRC staff and industry personnel with maintenance experience. As explained in Section 4, the alternatives selected for this Regulatory Analysis are:

- Alternative A - No Guidance
- Alternative B - NRC Staff Guidance

The direct consequences to licensees (costs and occupational radiation exposure) for alternatives A and B are discussed in Section 5.1. Within this section, the consequence discussions are organized based on (1) actions that are expected to take place prior to full implementation of the maintenance rule and (2) actions that recur periodically throughout the life of a nuclear plant after implementation of the rule. Section 5.2 presents similar discussions of NRC direct consequences (costs). Benefits associated with the alternative regulatory guide positions are presented in Section 5.3. In Section 5.4, the overall consequences and benefits are summarized and presented as comparisons among the alternatives.

Table 4-1 indicated the generic steps or primary tasks that a licensee would be expected to undertake to comply with the maintenance rule, regardless of the specific guidance provided for such compliance. Some of these tasks are plant-wide in nature in that the steps or processes involved can be done at the plant level and need not be repeated separately for each system, structure, or component (SSC) in the plant subject to the maintenance rule. Plant-wide activities might include risk assessments, general methodology development and/or tailoring of such methodology for use at a particular plant, and documentation of rationale, approaches, and bases. Other activities performed to comply with the maintenance rule guidance will be performed at the SSC level.

In assessing consequences, this evaluation attempted to establish a probable course of action by a typical licensee, and by the NRC, in applying the Maintenance Rule to a particular plant. This effort endeavored to identify the likely types of actions and when they might occur. For each activity, estimates were made of the type and quantity of incremental resources required to accomplish the activity objectives. This included labor efforts required to perform additional inspections, tests, and maintenance; labor and capital costs needed to accomplish any required physical modifications such as the addition of enhanced monitoring systems; and engineering and analytical efforts needed to set up programs and provide periodic evaluations. Only incremental effects were accounted for; that is, only actions over and above those currently practiced by licensees (or the NRC) and which are anticipated to be performed in response to the maintenance rule guidance, were taken into account.

5.1 Licensee Direct Consequences

The following discussions present the results of the direct consequence assessments for Alternatives A and B. Whether a consequence is plant-wide in nature or is specific to particular SSCs is noted in the discussions. The organization of the following discussions closely parallels that of Section 4.

5.1.1 Alternative A Direct Consequences

5.1.1.1 Plant-Wide Program Setup and Implementation Activities

5.1.1.1.1 Scope Evaluations

Identification of systems within the scope of the rule

A practical early step in a licensee's program to respond to the maintenance rule requirements is the performance of a scope evaluation to determine which plant systems fall within the scope of the rule. This activity would include a review of all major plant systems, structures and components. Initial focus would probably be at the system level. Those systems identified as being within the scope of Section 50.65(b)(1) and (b)(2)(i) of the rule by virtue of their safety-related functions would be flagged for further detailed assessments. This system identification/classification activity is estimated to be reasonably modest, and could reasonably be accomplished with an effort of about one to two person-months. This estimate includes documentation of the results and conclusions.

All nonsafety-related systems would be screened for consideration of Sections 50.65(b)(2)(ii) and (iii); i.e., nonsafety SSCs whose failure could prevent safety-related SSCs from fulfilling their safety-related functions or that could cause a reactor scram or actuation of a safety-related system. Here the anticipated effort is greater than that required for the overall system screening since all SSCs which can possibly adversely affect the performance of safety-related systems must be identified by careful review.

For systems out of scope, identify subordinate structures and components that are in scope of Paragraphs (b)(2)(ii) and (b)(2)(iii)

The components and structures of a system may be within the scope of the rule even though the system is not itself in scope. This is possible under the provisions of (b)(2)(ii) and (b)(2)(iii). That is, a component may fail in a way that does not affect its own system but does prevent a safety-related system from performing its function or does cause a reactor scram. Such events will typically be in electrical systems and may become more important in advanced instrumentation and control systems. A failure modes and effects analysis (FMEA), or other equivalent method, would have to be used for all affected SSCs to identify critical failure modes. The results would also have to be thoroughly documented. The required effort for this element of the plant-wide scoping activity is estimated to require between one and two person-weeks of engineering staff time per system. Assuming there are on the order of forty systems subject to this effort, the total associated effort is estimated to be between ten and twenty person-months for the FMEA-related scope activities.

The evaluation of the plant SSCs included within the scope of the maintenance rule is expected to require about the same level of effort, regardless of which regulatory guide alternative is pursued.

5.1.1.1.2 Assessment of Combinations of Equipment Out of Service

Section 50.65(a)(3) of the rule recommends that licensees perform an assessment of the overall effect on the performance of safety functions of the total plant equipment that is out of service due to preventive maintenance and monitoring activities. Alternative A, by providing no additional guidance, should lead to wide variations in the interpretation and implementation of this recommendation. Licensees may argue that such an assessment has already been performed in the development of the plant Technical Specifications, the Final Safety Analysis Report (FSAR), and other design documentation. The Tech Specs deal primarily with power operation and do not explicitly or comprehensively treat all stages of plant operation such as low power and off power, nor do they deal with all combinations of equipment and systems out of service. Therefore, some effort would be required by licensees to perform at least a deterministic assessment of all plant equipment out of service, and most combinations thereof, not specifically addressed by the Tech Specs or other plant documentation. This evaluation is estimated to require three to four person-months of effort to complete, including development of the supporting documentation.

5.1.1.1.3 Select and Document Methods for Establishing Goals, Demonstrating Control and Balancing Objectives

Section 50.65(a)(2) of the maintenance rule provides relief from the monitoring requirements of paragraph (a)(1) where it has been demonstrated that the performance or condition of a SSC is being effectively controlled through the performance of effective preventive maintenance such that the SSC remains capable of performing its intended function. Under Alternative A, most licensees are expected to adopt the provisions of paragraph (a)(2) as much as possible. This approach removes the need for establishing goals. One way that the required demonstration of preventive maintenance program effectiveness can be accomplished is through an evaluation of conditions and performance for SSCs of interest. Selected parameters must be assessed against appropriate standards or criteria regarding acceptable vs. not acceptable levels of performance and conditions. Acceptable conditions or performance levels could be established from the plant Tech Specs, FSAR, and other design documentation. A relevant plant-wide activity, therefore, would be to collect and organize licensing basis information such that it is in a form most useful to licensee personnel addressing this element of the maintenance rule. This effort would also document the basis and rationale being used to justify the widespread use of paragraph (a)(2). For example, this plant-wide effort could cite the plant maintenance program adherence to appropriate ANSI Standards and pertinent sections of the ASME O&M Code.

Demonstration of the effectiveness of maintenance, as noted above, can be made by reviewing previous performance and condition data, and comparing this information against acceptance standards and criteria. The provisions of paragraph (a)(2) might lead to the conclusion by licensees that forward trending of condition and deterministic performance data should also be accomplished to better assure that preventive maintenance activities are performed on a schedule consistent with assured effectiveness. Part of the plant-wide effort, therefore, could be the establishment of general trending analysis tools, along with the documentation explaining their application and use at the SSC level.

The plant-wide effort required to collect and organize the licensing basis information, document the rationale and guidelines for the use of paragraph (a)(2) of the rule, and set up the recordkeeping/data collection system and trending analysis tools is estimated to require about three to four person-months to accomplish. This level of effort assumes that the plant licensing basis information is readily available.

Under Alternative A, licensees are expected to argue that the current licensing basis balances objectives regarding balancing downtime against availability of safety-related SSCs. Therefore, no additional effort is foreseen relative to balancing objectives.

5.1.1.1.4 Identification of Risk-Significant Structures, Systems and Components

Under the Alternative A approach, no additional activity is anticipated to identify risk-significant SSCs because such identification is not relevant to this approach.

5.1.1.2 System-Level Setup and Implementation Activities

SSC Categorization

a) **Identification of structures and components in the scope of (b)(1) or (b)(2)(i).**
For those systems within the scope of the maintenance rule, the licensee must perform an evaluation of which structures and components within the system are also in scope. This activity entails an assessment of whether the structure or component function is relied on for the system to perform its function. If so, that SC is in the scope of the rule.

b) **Identify structures and components in the scope of (b)(2)(ii) or (b)(2)(iii).**
Some SCs will be found to be out of scope by virtue of their function. However, these SCs must be evaluated according to the provisions of paragraphs (b)(2)(ii) and (b)(2)(iii) of the rule. This activity could be accomplished by performing a partial failure mode effects analysis for each affected SC to determine whether any failure mode corresponds to the criterion (b)(2)(ii) or (b)(2)(iii).

These efforts to review and categorize each applicable SSC, as well as document the results and their basis, are estimated to be fairly modest. A licensee could perform a review and categorization of each applicable system and the SCs within the safety-significant systems with an effort of about one to two person-weeks. Additional effort would be required to document the results of the evaluation and the basis and rationale used in assessing the scope of each system covered by the maintenance rule. The overall effort, including allowance for documentation and reviews, is estimated to be on the order of one to two person-months per system. Also, this activity is carried out at the implementation phase of the program, and need not be repeated unless the system configuration, content, or functions change.

5.1.1.3 Startup Tasks Pursuant to (a)(1)

The rule requires that SSCs within the scope of paragraph (a)(1) have their performance or conditions monitored. However, Alternative A treats essentially all SSCs as falling under the purview of paragraph (a)(2), and monitoring is not required for such SSCs. The Alternative A scenario, therefore, expends no effort relative to meeting the monitoring requirements of paragraph (a)(1). Similarly, enhanced monitoring would not be needed to meet the requirements of paragraph (a)(1) of the rule.

5.1.1.4 Startup Tasks Pursuant to (a)(2)

Identification of Performance or Condition Parameters to Control

Structures and components of the systems within the scope of the rule would have to be evaluated to establish which conditions and performance parameters should be controlled to meet the requirements of the paragraph (a)(2) of the rule.

The identification of parameters to control could start with a review of the design basis information collected in the plant-wide plant effort. This review should yield a basic set of performance and condition parameters and limits based on Tech Specs, the FSAR, and other design documentation. However, this evaluation may indicate that additional parameters need also be controlled and trended to better assure the capabilities of the system to perform its safety functions. This evaluation activity for the systems within the scope of the rule is estimated to require about one to two person-months of effort per system to complete. This effort includes any related recordkeeping and parameter trending. This activity will utilize the general recordkeeping/data collection setup and evaluation methodology established in the plant-wide activity discussed in Section 5.1.1.1.3, but would be tailored somewhat for each specific system.

5.1.1.5 Plant-Wide Recurring Activities

Recurring and ongoing activities associated with the maintenance rule are anticipated both plant-wide and at the system level. Some of the activities must be performed at least annually per the requirements of paragraph (a)(3) of the rule. Others are performed as the need arises.

Identification of Risk-Significant Structures and Components

This identification is not relevant to the envisioned program. Hence, this activity was not [illegible] for Alternative A.

5.1.[illegible] System-Level Recurring Activities

The system level recurring activities identified for Alternative A include efforts to balance unavailability [illegible] to monitoring and preventive maintenance against failure prevention and to periodically [illegible] the SCs in the scope of each system.

5.1.1.6.1 Balance Unavailability Due to Monitoring and Preventive Maintenance Against Failure Prevention

This balancing activity is not expected to require any substantial effort for Alternative A since most SSCs will be treated under the provisions of Paragraph (a)(2) of the rule. Any monitoring and preventive maintenance performed on these SSCs is assumed to be the minimum required by the current licensing basis. Therefore, little balancing could be performed.

5.1.1.6.2 Reassessment of SCs in the Scope of Each System

For each system within the scope of the maintenance rule, periodic assessments must be performed of the structures and components that fall within the purview of the rule. The SCs within scope could change with time due to system configuration changes, equipment changes, increasing or decreasing rates of degradation, and similar events which have an impact on the system and its performance. The evaluation effort required is estimated to be in the range of a few person-days to about one-half person-month per system on an annual basis.

5.1.1.7 SPC Recurring Tasks Pursuant to (a)(1)

There are no recurring tasks needed to meet the requirements of Paragraph (a)(1) with Alternative A.

5.1.1.8 SPC Recurring Tasks Pursuant to (a)(2)

Demonstrate Effective Control of Performance or Condition Per (a)(2)

The demonstration of effective control of the pertinent system-specific performance or condition parameters through an effective preventive maintenance program must be accomplished periodically. The actual PM activities and related efforts are accounted for as described in Section 5.1.1.11. At the system level, however, system-specific reviews and assessments would be performed, and the results of these efforts would be documented. This review and documentation activity is estimated to require about one to one and one-half person months of effort per system per year.

5.1.1.9 SPC Continuing Tasks - All Systems in Scope

Assess Safety Implications of SCs Out of Service

The rule requires that a safety evaluation be performed whenever SSCs within the scope of the rule are taken out of service to perform monitoring or preventive maintenance. Alternative A relies on deterministic evaluations to fulfill this requirement. This would require, as a minimum, that the Technical Specifications (with assumed updates per Section 5.1.1.1.2) be consulted for applicable restrictions. Additional analyses may also have to be performed for situations not adequately covered by existing plant documentation. While these assessments are system level activities and will occur on a case-by-case basis, the overall effort is best estimated on a plant-wide basis. These safety assessments are estimated to require about four to six person-months of effort per year per plant.

5.1.1.10 Continuing Tasks Pursuant to (a)(1)

For Alternative A there are no continuing tasks pursuant to (a)(1).

5.1.1.11 Continuing Tasks Pursuant to (a)(2)

Enhanced Preventive Maintenance and Corrective Actions

Under Alternative A licensees are expected to utilize the provisions of paragraph (a)(2) of the rule to the maximum extent possible. Keeping SSCs under (a)(2) requires that licensees demonstrate that they have effective preventive maintenance programs. To accomplish these objectives, the assumption has been made that most licensees would opt to enhance their preventive and predictive maintenance programs. These enhancements would entail efforts above those currently being practiced at most plants. As noted in Section 4.2, associated activities could include: projecting performance trends to identify patterns signaling the need for potential corrective actions, performing the corrective actions as needed, and changing the types and intervals of preventive maintenance to better assure effectiveness. This enhanced program is estimated to increase the current levels of plant maintenance-related efforts by roughly 10%, or about the equivalent of an additional 120 to 360 person-months of effort per year.

The increased level of preventive maintenance is also expected to result in some increase in occupational radiation exposure. Nuclear power plant annual exposures to radiation workers have averaged about 350 person-rem in recent years. If occupational exposures increase in proportion to the incremental labor expended in carrying out enhanced preventive maintenance, then exposures can be projected to increase by about twenty to fifty person-rem annually per plant. Nuclear utilities currently expend about $9,160 per person-rem for the health-physics-related services to control and limit occupational exposures. These costs, estimated to be between $180,000 and $460,000 annually, must be added to the incremental labor costs.

5.1.2 Alternative B Consequences

Alternative B emphasizes statistical performance and probabilistic analyses in fulfilling the requirements of the maintenance rule. It also includes predictive monitoring and overall effectiveness assessments. This approach results in several differences compared to the Alternative A consequences.

5.1.2.1 Plant-Wide Program Setup and Implementation Activities

5.1.2.1.1 Scope Evaluations

The scope evaluations performed under Alternative B are expected to be the same as those performed with Alternative A as discussed in Section 5.1.1.1.1. The level of effort anticipated is the same as that discussed for Alternative A.

5.1.2.1.2 Assessment of Combinations of Equipment Out of Service

Alternative B, which emphasizes statistical performance and probabilistic analyses, can potentially require a very large effort to assess the effects on safety functions of total plant equipment out of service due to maintenance-related activities. This alternative could follow a probabilistic approach, one that might use existing PRAs. However, PRAs which cover low power and off power conditions are currently still in the development stage and not yet available. The methodology for probabilistically treating the many plant states and the multitude of system condition states pertinent to these assessments is not yet mature. The NRC-sponsored studies being conducted by the National Laboratories have thus far shown that this process is complex and time-consuming. These efforts, however, are expected to yield acceptable methodologies which licensees would be able to draw on to assess the effects on safety functions of equipment and systems (and combinations thereof) out of service. Because of the very large numbers of possible combinations of systems and components out of service due to maintenance and monitoring activities, a basic plant assessment of this type is expected to require about ten to twenty person-years of effort. This range is based on the National Laboratory efforts currently underway. The results of such plant-specific assessments are expected to be a reasonably comprehensive set of criteria covering allowable combinations of systems and components out of service for maintenance-related activities. Documentation of the effort, including generation of practical guidance criteria for the performance monitoring and maintenance activities, is estimated to require an additional effort of two to four person-years, giving a total effort range of twelve to twenty-four person-years for this plant-wide activity.

The rule does not require licensees to conduct probabilistic analyses of the type discussed above. However, such evaluations are expected to yield much valuable information to help optimize maintenance programs and better assure plant safety during all plant conditions and states. Some licensees will opt for this more sophisticated approach, while others will opt for approaches which rely on the Technical Specifications, deterministic evaluations, and simpler assessment methods. Even with the probabilistic and statistical emphasis of Alternative B, the lack of a requirement for licensees to use a probabilistic approach here will likely result in about one half of the licensee population pursuing a probabilistic approach, and the other half opting for the simpler, less costly approach discussed for Alternative A. Industry-wide consequences estimates are based on this type of split.

5.1.2.1.3 Select and Document Methods for Establishing Goals, Demonstrating Control and Balancing Objective

This activity for Alternative B would review, develop, select and document the methods to be used for establishing goals, demonstrating that goals are or are not being met, and balancing preventive maintenance and monitoring against any unavailability caused by such actions. Because Alternative B adopts a statistical or probabilistic approach, the effort for this activity would be expected to develop, or at least review and select, appropriate statistical methodologies to establish goals for SSCs within the scope of the rule. Similarly, methods would have to be developed or selected for assessing whether or not goals had been met. This methodology would indicate the type of performance or condition data suitable for use in comparisons against goals, the numbers of tests required for such evaluations, and the test intervals relevant to the comparisons against goals. This effort is expected to develop the methodology needed to perform the evaluations called for by the rule, to document the methodology, and the develop guidelines for applying the methodology at the SSC level.

This development and documentation effort is estimated to require from one to three person-years of effort to complete.

5.1.2.1.4 Identification of Risk-Significant SSCs

The Alternative B interpretation of the rule requirements and suggestions calls for the identification of risk significant SCs. A plant-specific PRA provides a method for establishing the risk significance of SSCs. However, some plants have not completed a PRA. In addition, existing PRAs may have to be extended in terms of the level of detail pertinent to some systems, especially non-safety systems typically modeled very crudely if at all. This level of detail will be needed to assess the risk significance of SCs within the scope of the maintenance rule. The identification of risk significant SCs would also entail performing sensitivity or importance analyses on the updated PRA to identify those structures and components with significant failure modes.

The level of effort required to assess the risk significance of pertinent SCs is estimated to range from a low of about six person-months to a high of about twenty-four person-months. The low estimate applies to a plant with an existing, fairly detailed PRA. Some expansion of the details pertinent to non-safety systems is assumed, so that the PRA is enhanced in detail to evaluate the risk significance of all affected SSCs. The high estimate is based on the assumption the some plants have a low level of detail in their PRAs, and that considerable effort will be required to develop the necessary level of detail.

5.1.2.2 System-Level Setup and Implementation Activities

<u>SSC Categorization</u>

The system level activities performed during the implementation phase for Alternative B include the identification of systems and components in the scope of (b)(1) or (b)(2)(i) and those in the scope of (b)(2)(ii) or (b)(2)(iii) as discussed in Section 5.1.1.2. For those systems within the scope of the Maintenance Rule, the licensee must perform an evaluation of which SCs within the system are also in scope. For Alternative B fewer SSCs in scope will be treated as per paragraph (a)(2) of the Rule than for Alternative A. The required effort needed to review and categorize each applicable SSC, as well as document the results and their basis, is estimated to be between one and two person-months per system.

5.1.2.3 Startup Tasks Pursuant to (a)(1)

5.1.2.3.1 Identification of Performance or Condition Parameters to Monitor

Both plant-wide and system level goals are assumed to be established for Alternative B. At the plant level, a review would be needed of practical goals. Once goals are chosen, effort would be needed to define what evaluations are needed to assess whether or not the goals are being met. Pertinent performance parameters would have to be established, and the monitoring of these parameters would have to be defined. This plant-level goal setting activity is estimated to require about one to two person months of effort.

The system-level effort associated with the identification of the performance or conditions to be monitored is estimated to range from one to two person-months for each system within the scope of the rule. The effort envisioned here would take the general methodology developed as part of the plant-wide activities and would apply the methods to each system within the scope of the rule. The methods should then provide system-specific guidance as to the parameters to be monitored, the frequency of monitoring activities, and the use of the data collected in assessing whether or not system goals were being met. The focus here is not strictly on risk-significant SSCs, but rather is broader and more encompassing.

5.1.2.3.2 Implement Enhanced Monitoring

Alternative B suggests the expansion of current monitoring capabilities to better assure that the performance or condition of SSCs within the scope of the maintenance rule can be adequately tracked and assessed. The emphasis is on predictive monitoring to identify degradation trends which, in turn, are used to guide preventive maintenance activities.

A comprehensive assessment of monitoring enhancements to typical power plants has not been performed. However, the evaluations performed for the Nuclear Power Plant License Renewal Rule, 10 CFR Part 54, did define what such an enhancement program might entail (Ref. 5). While the Part 54 analyses deal specifically with aging-related degradation issues, the actions identified there provide a reasonable surrogate for similar monitoring enhancements pursued to accomplish the goals of the maintenance rule. The license renewal rule analysis indicated that licensee's implementation costs associated with the installation of enhanced monitoring systems was on the order of $4.1 million per plant (1991$). The enhanced monitoring included installation of improved or additional instrumentation systems, some of which were installed in radiation areas. About 40 person-rem of exposure was estimated to be incurred in carrying out these implementation activities. The foregoing estimate is an average for boiling water reactors and pressurized water reactors, and it includes the cost of health physics-related services as well as labor and equipment costs.

The enhanced monitoring activities performed pursuant to Alternative B guidance for the maintenance rule will not be identical to those characterized for the license renewal rule, but they should be roughly comparable in scope and in consequence effects. Therefore, based on the license renewal rule surrogate the installation of enhanced monitoring capabilities for the maintenance rule is estimated to cost between $2 and $6 million per plant, with associated occupational radiation exposures of about 20 to 60 person-rem.

5.1.2.4 Startup Tasks Pursuant to (a)(2)

Identification of Performance or Condition Parameters to Control

With Alternative B licensees are expected to put some SSCs under paragraph (a)(2) of the Rule. Structures and components of the systems within the scope of the Rule would have to be evaluated to establish which conditions and performance parameters should be controlled to meet the requirements of the paragraph (a)(2) of the Rule. Since fewer SSCs would be treated under the provisions of paragraph (a)(2) of the rule for Alternative B compared to Alternative A, this effort is judged to be about one-half of that for Alternative A as discussed in Section 5.1.1.4, i.e., about one-half to one person-months effort would be needed.

5.1.2.5 Plant-Wide Recurring Activities

Update the Identification of Risk Significant Structures and Components

This periodic activity would update and enhance the plant PRA bas[illegible] [illegible]dated reliability data and any system configuration changes made since the previous update. T[illegible] [illegible]ed PRA would be used to perform sensitivity or importance analyses to reassess the [illegible]sk significance of the structures and components included in the PRA. This update activity is expected to require an annual effort of about two to six person-months per plant, depending on the extent of the changes to be made compared to the previous evaluations.

5.1.2.6 Recurring Activities - All Systems in Scope

The recurring system level activities identified for Alternative B include efforts to periodically balance unavailability due to monitoring against failure prevention and reevaluate the SCs in the scope of each system.

5.1.2.6.1 Balance Unavailability Due to Monitoring and Preventive Maintenance Against Failu[illegible] [illegible]evention

For each SSC within [illegible] of the rule, an assessment must be considered whenever the SSCs are unavailable due to ISTM-related activities. The intent of this effort would be to assess the effectiveness of the activity in preve[illegible]ting failures, and to evaluate the activity frequency that balances the benefits against the unavailability incurred in per[illegible]rming the activity. The general methodology develop[illegible]d on a plant-wide basis would be applied to perform the system-level assess[illegible]s. This balancing activity is expected to require between one and two person-months per year per system.

5.1.2.6.2 **Reassessment of SCs in the Scope of Each System**

This activity is the same a that described in Section 5.1.1.6.2, and the anticipated level of effort is the same as for Alternative A (a few person-days to one-half person-month per system annually).

5.1.2.7 Recurring Tasks Pursuant to (a)(1)

Review Goals for Monitored Condition or Performance

Both plant-wide and system-level goals are assumed to be established for Alternative , and are to be revisited periodically. At the plant level, this activity would evaluate how well plant level goals are being met. Depending on the outcome, goals might be adjusted and/or monitoring and preventive maintenance programs might be modified to better assure that goals are met. This effort is estimated to require about two to four person-months of effort per year.

Goals for each SSC within the scope of paragraph (a)(1) of the rule are to be periodically reviewed and adjusted as necessary. Alternative B emphasizes monitoring at the system level. However, this alternative also includes considerable monitoring at the structure and component level. This activity would evaluate the monitored parameters and compare them against goals to assess whether or not system-specific goals are being met. This activity would help identify if corrective actions were needed and if goal adjustment was needed for any reason. The effort required is estimated to range from about one-half to one person-month per system per year.

5.1.2.8 Recurring Tasks Pursuant to (a)(2)

Demonstrate Effective Control of Performance or Condition Per (a)(2)

Although fewer SSCs will be treated under the provisions of Paragraph (a)(2) for Alternative B than for Alternative A, the demonstration of effective control of the pertinent system-specific performance or condition parameters through an effective preventive maintenance program must still be accomplished periodically. Fewer SCs will be involved compared to Alternative A so the total associated effort will be reduced for Alternative B. This activity is estimated to require about one-half to three-quarters person months of effort per system per year.

5.1.2.9 Continuing Tasks - All Systems in Scope

Assess Safety Implications of SCs Out of Service

The assessment of monitoring and maintenance activities on equipment and system availability, and the safety implications of this structure or component unavailability, is essentially a continuous process. This activity is somewhat related to the assessment of combinations of SSCs out of service and their effect on safety functions, but it is much simpler in that the focus is on a single or a few SSCs at one time. This ongoing effort would utilize the general methodology developed during the program implementation phase. This effort would also be expected to apply the general criteria and guidelines for arriving at appropriate balances between ISTM activities, SC availability, and plant safety. The types of actions contemplated here include assessing the effectiveness of each ISTM activity in preventing failures, assessing the frequency that balances the benefits of the activity against the unavailability necessary to perform the activity, and making adjustments as appropriate to strike a suitable balance. On a plant-wide basis, considering all SCs within the scope of the rule, this activity is estimated to require from eight to twelve person-months of effort per year.

5.1.2.10 Continuing Tasks Pursuant to (a)(1) or (a)(2)

5.1.2.10.1 Monitoring as Necessary to Assure that Goals are Being Met

Alternative B emphasizes the monitoring of performance and conditions of important SSCs per paragraph (a)(1) of the rule. The monitored parameters will be assessed on an ongoing basis. For each SSC within the scope of the rule, these assessments are needed to determine whether or not goals are being met. The evaluations may be simple or complex, depending on the sophistication of the methods selected and the extent of the monitoring activities. Alternative B also establishes plant-level goals. This alternative emphasizes extensive data collection and analysis at all levels to compare against goals and to establish whether or not goals are being met. The expected effort to accomplish this extensive action is estimated to range between ten and forty person-months per year. The level of effort will vary, depending on the number of SSCs within the scope of paragraph (a)(1) of the rule and the thoroughness of the licensee's programs.

5.1.2.10.2 Corrective Action as Needed to Meet Paragraph (a)(1) or (a)(2) of the Rule

Licensees will undoubtedly encounter situations where corrective actions are needed because of the requirements of paragraphs (a)(1) or (a)(2) of the rule. The specific conditions and occurrences which trigger the need for corrective action will vary widely from one plant to another. Also, the number of corrective actions is expected to be highly plant-specific. However, a very large number of required corrective actions would likely indicate goals that are too stringent and/or poor preventive maintenance. A very low number of such actions might indicate goals which are too lax, at least for the initial years of the maintenance rule implementation. If the maintenance rule works as intended, licensees should improve their programs over time such that the number of corrective actions will decrease as the programs mature. However, the rule suggests that goals should be challenging, and that they will be changed over time to provide direction for continuing program improvements.

Whenever a corrective action is called for, a prudent licensee would likely perform a root cause analysis to establish to cause of the failure or degradation in performance. A typical root cause analysis is expected to require about one person-month of effort to complete. Once the cause of the problem has been established, a licensee would likely identify alternative solutions to the problem. The optimal corrective action would typically be chosen through the use of a cost/benefit analysis. Such analyses can reasonably be performed with about four person-months of effort per occurrence.

While the number of corrective actions per plant is highly speculative at this time, a reasonable estimate would be between five and fifteen occurrences per year per plant. This number range for corrective actions is assumed to remain constant over the life of the plant once the maintenance rule goes into effect. Thus, the associated level of effort for corrective actions is estimated to be in the range of twenty-five to seventy-five person-months per year per plant. Some of these actions will entail work in radiation areas and some incremental radiation exposure of workers can be expected. Based on rough averages dose accumulations per worker-month as reported for current nuclear utility experience, the exposure rate is estimated to be in the range of 0.14 to 0.17 person-rem per person-month of effort expended in corrective action activities. At this rate, the expected exposures for such work are estimated to in the range of four to ten person-rem per year associated with corrective actions. This is the incremental exposure expected from implementing this aspect of the maintenance rule under Alternative B guidance.

5.1.2.10.3 Enhanced Monitoring Activities

As noted in Section 5.1.2.3.2, enhanced monitoring systems are assumed to be installed in a plant to best follow the guidance provided with Alternative B. The approach envisioned also requires ongoing activities to utilize the enhanced monitoring systems. The effort associated with these ongoing monitoring activities is estimated to be comparable to the effort identified with enhanced monitoring for the license renewal rule to better detect and mitigate age-related degradation of important SSCs. For the license renewal rule the annual effort for such monitoring activities was estimated to be about $0.7 million per plant, including labor, materials, and other associated expenditures (Ref. 5). This estimate can reasonably serve as a mean about which similar expenditures might be incurred in carrying out this aspect of the maintenance rule per the guidance of Alternative B. Therefore, the enhanced monitoring activities for Alternative B are estimated to cost from $0.35 to $1.05 million per year.

Some of the incremental, enhanced monitoring activities are performed in radiation areas. Based on the analysis performed for the license renewal rulemaking, about fifteen person-rem per year might be expected to be incurred from the types of monitoring activities anticipated. The comparable estimates for Alternative B are judged to be in the range of seven to twenty-three person-rem per year.

5.1.3 Licensee Direct Consequence Summary

Based on the above discussions, preliminary estimates of licensee costs associated with implementation of the maintenance rule regulatory guidance have been generated. These estimates include the labor efforts, costs, and exposures identified in Sections 5.1.1 - 5.1.3.

5.1.3.1 Assumptions and Bases

The major assumptions and bases used in developing licensee direct consequence estimates are as follows:

- The results developed apply to a single plant.
- Costs are presented in 1991 dollars.
- All costs are shown as the current value (present value) of a program with the following characteristics;
  - The licensee's implementation efforts start with the issuance of the Maintenance Rule Regulatory Guide. This guide is to be issued in mid-1993. The period from 1993 to 1996 will be devoted to planning for the actual implementation, which must be completed by July of 1996. Initial scoping efforts, goal setting, methodology development, and similar activities will take place during this period. Beyond 1996, annual evaluations and other recurring activities take place for the remainder of the plant life. Plant lives of both 20 and 40 years beyond the 1996 date has been considered. The shorter period assumes no license renewal; the 40 year period assumes extended plant life through license renewal.
- A discount rate of 5% has been used.
- An average loaded labor rate of $50/hr has been assumed for licensee technical staff performing the activities defined in support of the maintenance rule.
- All consequence estimates are assumed to be incremental to current licensee maintenance programs.

- No allowance has been made for possible plant availability improvements due to the implementation of the maintenance rule.

5.1.3.2 Licensee Direct Consequence Summary

The estimated cost and occupational radiation exposure consequences to a typical licensee for performance of primary activities at one plant are displayed in Tables 5-1 and 5-2. Table 5-1 presents consequences assuming no license renewal and a 20-year period of operation under the maintenance rule. Table 5-2 assumes a 40-year period with license renewal. Both tables show the costs attributable to each of the major activities, and include both one-time, up-front costs as well as recurring costs. The tables also display estimates of the overall program occupational radiation exposure incurred in implementing enhanced ISTM activities or carrying out additional corrective maintenance actions. Low and high estimates, derived from the low and high labor estimates in Sections 5.1.1-5.1.3, are shown, and these are shown separately for Alternatives A and B. The tables display the information for each of the major activities discussed in the previous sections. Implementation activities, those assumed to be performed during the period from 1993-1996, are shown first, followed by recurring activities (those anticipated for years 1996-2016 without license renewal and 1996-2036 with license renewal). In addition, the tables indicate whether the activity is plant-wide in nature or is applicable at the individual system level.

The implementation costs shown in Tables 5-1 and 5-2 represent the totals for start-up activities. The recurring activity values indicate the present worth of the licensee incremental expenditures experienced during the 20 or 40 year period that the individual plants are assumed to be subject to the effects of the rule. A comparison of the figures displayed in Tables 5-1 and 5-2 readily indicates that the recurring costs are considerably larger than the up-front implementation costs. Extended plant life through license renewal adds 32% to 36% to the total program costs, depending on the alternative.

The system level activities and their consequences as displayed in the tables are based on the assumption that there are roughly eighty systems in the plant that would fall within the scope of the maintenance rule. Efforts were estimated on a per-system basis and multiplied by eighty to arrive at the total system level costs for a plant. This number of systems is based on a review of the systems employed in a typical PWR and was judged to be reasonably representative of the U. S. reactor plant population.

Table 5-1

Licensee Resources Required to Implement the Maintenance Rule Without License Renewal

	Plant Level	System Level	ALTERNATIVE A LOW	ALTERNATIVE A HIGH	ALTERNATIVE B LOW	ALTERNATIVE B HIGH
Implementation Activities						
Scope Evaluations						
Identification of Systems within the Scope of Rule	x		7,000	15,000	7,000	15,000
Evaluation of SCs in Scope When Systems Not in Scope	x		70,000	150,000	70,000	150,000
Assess Combinations of Equipment Out of Service	x		20,000	30,000	540,000	1,070,000
Develop Methods for Goal Setting, Preventive Maintenance Effectiveness, and Balancing Objectives	x		20,000	30,000	90,000	260,000
Identification of Risk Significant SSCs	x		0	0	40,000	180,000
SC Categorization		x	580,000	1,170,000	580,000	1,170,000
Startup tasks Pursuant to (a)(1)						
ID of Perf. or Cond. to be Monitored (plant)	x		0	0	7,000	15,000
ID of Perf. or Cond. to be Monitored (system)		x	0	0	580,000	1,170,000
Enhanced ISTM Implementation, $	x		0	0	1,690,000	5,060,000
Startup tasks Pursuant to (a)(2)						
ID of Perf. or Cond. to be Controlled per (a)(2)		x	580,000	1,170,000	290,000	580,000
Recurring Activities						
Annual Assessments						
Update ID of Risk-significant SCs	x		0	0	170,000	520,000
Bal. Unavail. due to Monitoring & PM Against Flr Prev.		x	0	0	6,940,000	13,870,000
Reevaluate SCs in Scope of System		x	1,390,000	3,470,000	1,390,000	3,470,000
Recurring tasks Pursuant to (a)(1)						
Review Goals for Monitored Cond. or Perf. (plant)	x		0	0	170,000	350,000
Review Goals for Monitored Cond. or Perf. (system)		x	0	0	3,470,000	6,940,000
Recurring tasks Pursuant to (a)(2)						
Demonstrate Eff. Control of Perf. or Cond. per (a)(2)		x	6,940,000	10,400,000	3,470,000	5,200,000
Continuing Tasks - All Systems in Scope						
Assess Safety Imp. of SCs Out of Service	x		350,000	520,000	690,000	1,040,000
Continuing Tasks Pursuant to (a)(1) or (a)(2)						
Monitor as needed to meet (a)(1) Requirements	x		0	0	870,000	3,470,000
Enhanced Monitoring Activities	x		0	0	3,500,000	10,510,000
Eval. & Select Preventive/Corrective Action as needed to meet (a)(1) or (a)(2)	x		10,500,000	35,790,000	2,530,000	7,420,000
TOTAL LICENSEE PROGRAM COST CONSEQUENCES			$20,457,000	$52,745,000	$27,094,000	$62,460,000
TOTAL LICENSEE PROGRAM EXPOSURE CONSEQUENCES, person-rem			400	1000	240	720

Table 5-2

Licensee Resources Required to Implement the Maintenance Rule With License Renewal

	Plant Level	System Level	ALTERNATIVE A LOW	ALTERNATIVE A HIGH	ALTERNATIVE B LOW	ALTERNATIVE B HIGH
Implementation Activities						
Scope Evaluations						
Identification of Systems within the Scope of Rule	x		7,000	15,000	7,000	15,000
Evaluation of SCs in Scope When Systems Not in Scope	x		70,000	150,000	70,000	150,000
Assess Combinations of Equipment Out of Service	x		20,000	30,000	540,000	1,070,000
Develop Methods for Goal Setting, Preventive Maintenance Effectiveness, and Balancing Objectives	x		20,000	30,000	90,000	260,000
Identification of Risk Significant SSCs	x		0	0	40,000	180,000
SC Categorization		x	580,000	1,170,000	580,000	1,170,000
Startup tasks Pursuant to (a)(1)						
ID of Perf. or Cond. to be Monitored (plant)	x		0	0	7,000	15,000
ID of Perf. or Cond. to be Monitored (system)		x	0	0	580,000	1,170,000
Enhanced ISTM Implementation, $	x		0	0	1,690,000	5,060,000
Startup tasks Pursuant to (a)(2)						
ID of Perf. or Cond. to be Controlled per (a)(2)		x	580,000	1,170,000	290,000	580,000
Recurring Activities						
Annual Assessments						
Update ID of Risk-significant SCs	x		0	0	240,000	720,000
Bal. Unavail. due to Monitoring & PM Against Flr Prev.		x	0	0	9,550,000	19,100,000
Reevaluate SCs in Scope of System		x	1,910,000	4,770,000	1,910,000	4,770,000
Recurring tasks Pursuant to (a)(1)						
Review Goals for Monitored Cond. or Perf. (plant)	x		0	0	240,000	480,000
Review Goals for Monitored Cond. or Perf. (system)		x	0	0	4,770,000	9,550,000
Recurring tasks Pursuant to (a)(2)						
Demonstrate Eff. Control of Perf. or Cond. per (a)(2)		x	9,550,000	14,320,000	4,770,000	7,160,000
Continuing Tasks - All Systems in Scope						
Assess Safety Imp. of SCs Out of Service	x		480,000	720,000	950,000	1,430,000
Continuing Tasks Pursuant to (a)(1) or (a)(2)						
Monitor as needed to meet (a)(1) Requirements	x		0	0	1,190,000	4,770,000
Enhanced Monitoring Activities	x		0	0	4,820,000	14,470,000
Eval. & Select Preventive/Corrective Action as needed to meet (a)(1) or (a)(2)	x		14,460,000	49,280,000	3,490,000	10,220,000
TOTAL LICENSEE PROGRAM COST CONSEQUENCES			$27,677,000	$71,655,000	$35,824,000	$82,340,000
TOTAL LICENSEE PROGRAM EXPOSURE CONSEQUENCES, person-rem			800	2000	460	1380

The total incremental occupational radiation exposure attributable to the maintenance rule under the two regulatory guide alternatives ranges from a low of 240 person-rem to a high of 2000 person-rem, depending on the case considered. These estimates of exposure apply to the conduct of the program over the remaining life of the plant. The Alternative A exposures are higher than those for Alternative B because of the projected increase in preventive and corrective maintenance for A compared to B.

The summary costs shown in Table 5-1 indicate that licensee consequences, without license renewal, due to implementation of the maintenance rule are estimated to be in the range of $20 million to $62 million over the range of alternatives. Table 5-2 indicates that with license renewal and extended plant life, the costs range from about $27 million to $82 million.

5.2 NRC Direct Consequences

The NRC will incur consequences as a result of the Maintenance Rule Regulatory Guide activities. The primary consequences are costs incurred in the development and implementation of guides, inspection procedures, staff training, and conducting inspections of licensee maintenance programs. Benefits to the NRC may also accrue in terms of a reduction in the number of maintenance-related incidents at nuclear plants which trigger NRC investigations and analyses.

The following discussions present estimates of the consequences to the NRC related to the development and implementation of the Maintenance Rule Regulatory Guide.

5.2.1 NRC Consequences for Alternative A

Alternative A is the "no regulatory guide" option. Had this option been followed, the NRC would not have expended effort to develop a regulatory guide or a regulatory analysis of the guide. The activities that the NRC would undertake in support of the maintenance rule, whether or not a regulatory guide is implemented, include:

- Development of inspection procedures. Inspection procedures are needed to guide inspectors in assessing the effectiveness of licensee maintenance programs.
- Staff training. NRC staff and any contractors assisting in the effort will have to be trained prior to conducting licensee inspections.
- Workshops for licensees. The NRC anticipates that it will conduct workshops for licensees to promote understanding of the maintenance rule requirements and what the NRC expects relative to its implementation.

- Licensee inspections. Once the Maintenance goes into effect in 1996, the NRC expects to conduct on-site inspections of licensee programs. Both initial and follow-up inspections are likely.

In the absence of a regulatory guide, the NRC must still develop inspection procedures to assist NRC evaluators in assessing the effectiveness of licensee maintenance programs. Without a regulatory guide, this procedure development process is anticipated to be less focused and less efficient that would be the case with a guide. These inspection procedures would have to be highly flexible and quite broad to encompass the probable wide variations in maintenance rule implementation among the population of licensees in the absence of a regulatory guide. The procedure development process would entail a greater number of iterations and internal reviews than would be the case with a guide. Also, much of the thinking that went into the development of the regulatory guide would essentially have to be performed to develop inspection procedures in the absence of the guide. This would be necessary to provide procedures which reflect a sound interpretation of the rule and its statement of considerations.

The other developmental aspects of NRC's efforts for Alternative A, staff training and conduct of workshops, are also estimated to be somewhat more difficult and time consuming that would be the case for Alternative B. Without a guide, the training and workshops would have to cover a broader range of possible licensee implementation actions. NRC staff providing the training and workshops would have to develop more comprehensive programs to better deal with the diverse ways of satisfying the requirements of the maintenance rule.

The effort to develop inspection procedures, develop training courses, provide training and conduct workshops is estimated to require from three to five full time equivalent (FTE) NRC staff from the current time through mid-1996 when the maintenance rule goes into effect. This excludes the NRC regional staff and inspector trainee time as their efforts not assumed to be incremental. The cost of presenting regional workshops for licensees is estimated to be about $35,000 per occurrence. This estimate allows for rental of facilities, providing for transcripts, preparation of workshop materials and handouts, and contractor expenses involved in handling much of the details of such workshops. These costs are based on recent NRC experience in conducting public workshops on the proposed changes to 10 CFR Part 51. About six workshops on the implementation of the maintenance rule are expected.

During this development period the NRC anticipates that contractor assistance will be needed from the current time through the implementation of the rule. The current estimate for this assistance is $100,000 per year.

The maintenance rule is currently scheduled to go into effect in July of 1996. Over the two year period following this implementation date, the NRC expects to perform initial inspections of each licensee's maintenance program. Each inspection is expected to involve a team of four inspectors for a period of about five to six weeks. Thus, each initial inspection is anticipated to require an average of about four and one-half to five and one-half person-months of staff effort. Once the initial inspections are completed, the NRC expects to perform maintenance inspections at each plant about once every five years. These periodic efforts are expected to require about two-thirds as much time as the initial inspections (i.e., four staff months each).

5.2.2 NRC Consequences for Alternative B

The NRC's costs for Alternative B include basically the same elements as those described above for Alternative A. In addition, however, the NRC has expended and will continue to expend efforts related to the development of the regulatory guide and a regulatory analysis of the regulatory guide.

The NRC's efforts to develop the regulatory guide for the maintenance rule are estimated to be about five staff years. This includes the efforts expended thus far and those needed to complete the development of the guide. In addition, the NRC has obtained contractor support to assist in the drafting of the regulatory analysis. This contractor assistance is projected to cost about $400,000.

The development of the regulatory guide serves to simplify and focus the inspection procedure development efforts. Similarly, the staff inspector training and the conduct of workshops should be simplified somewhat compared to that needed with Alternative A. This simplification accrues by virtue of the fact that the regulatory guide provides a template for the development of the inspection procedures. More importantly, it should act to reduce the variation in licensee maintenance rule implementation plans. These factors allow for more efficient and less time-consuming training of inspectors. For Alternative B, the NRC's efforts for procedures development, staff training, and conduct of workshops is estimated to require the equivalent of two to three staff full time from the present through the implementation of the maintenance rule in mid-1996. In addition, contractor support during this period is needed and is expected to cost about $100,000.

The conduct of the workshops for licensees is anticipated to be simpler and less time consuming for Alternative B than for Alternative A. These workshop costs for Alternative B are estimated to be about $25,000 per event, and about six such workshops are envisioned.

The on-site inspection activities for Alternative B would follow the same schedule and pattern as those described for Alternative A. Each plant would have its initial inspection during the 1996-1998 time period. Each initial inspection is expected to require the services of three and one-half to four and one-half staff for a period of one month. This effort is less than that for Alternative A because the existence of the regulatory guide should promote greater uniformity among licensee programs. Also, the guide should help reduce the number of violations and subsequent NRC follow-up actions associated with maintenance rule compliance. Once the initial inspections are completed, each plant's program would be inspected at least once every five years. These inspections are expected to involve a team of four inspectors for a period of about three weeks.

5.2.3 Summary of NRC Direct Consequences

Tables 5-3 and 5-4 summarize the projected direct costs to the NRC for the development and implementation activities assumed under Alternatives A and B and are exclusive of secondary activities. Table 5-3 applies to the case of no license renewal; Table 5-4 assumes extended plant life through license renewal. The bottom line costs for both tables indicate the expenditures on a per-plant basis. The economic assumptions used in generating the figures in Tables 5-3 and 5-4 are the same as those discussed in Section 5.1.3.1.

5.3 Comparison of Direct Consequences

Table 5-5 presents a comparison of the direct consequences (costs and routine occupational radiation exposure) of Alternative B relative to Alternative A. The values shown are presented on a per plant basis both for licensees and for the NRC. The table entries reflect the mean or average values for the direct consequences. That is, the low and high estimates were averaged for each alternative, and the average for Alternative A was then subtracted from the average for Alternative B. This approach takes Alternative A to be the base case.

Table 5-3

NRC Costs, Alt. Reg. Guidance for Maintenance Rule Implementation, Without License Renewal

	Alternative A		Alternative B	
Implementation Activities	Low(1991 $)	High(1991 $)	Low(1991 $)	High(1991 $)
Develop Regulatory Guide	0	0	499,000	499,000
Develop Reg. Analysis of Reg. Guide	0	0	400,000	400,000
Develop Insp. Proc., Training Workshops	1,062,000	1,770,000	708,000	1,062,000
Conduct Workshops, ea.	173,000	173,000	123,000	123,000
Contractor Support per year	355,000	355,000	355,000	355,000
Costs per Plant	14,000	21,000	19,000	22,000
Recurring Activities				
Initial Inspections, per Plant	29,000	35,000	22,000	29,000
Periodic Inspections, per Plant	44,000	52,000	33,000	42,000
TOTAL COSTS PER PLANT	87,000	108,000	74,000	93,000

Table 5-4

NRC Costs, Alt. Reg. Guidance for Maintenance Rule Implementation, With License Renewal

	Alternative A		Alternative B	
Implementation Activities	Low(1991 $)	High(1991 $)	Low(1991 $)	High(1991 $)
Develop Regulatory Guide	0	0	499,000	499,000
Develop Reg. Analysis of Regulatory Guide	0	0	400,000	400,000
Develop Insp. Proc., Training Workshops	1,062,000	1,770,000	708,000	1,062,000
Conduct Workshops, ea.	173,000	173,000	123,000	123,000
Contractor Support,per year	355,000	355,000	355,000	355,000
Costs per Plant	14,000	21,000	19,000	22,000
Recurring Activities				
Initial Inspections, per Plant	29,000	35,000	22,000	29,000
Periodic Inspections, per Plant	63,000	75,000	48,000	61,000
TOTAL COSTS PER PLANT	106,000	131,000	89,000	112,000

Table 5-5

Comparison of Direct Consequences

	Individual Plant Impacts for Alternative B Relative to Alternative A Estimated Impacts			
	Without License Renewal		With License Renewal	
	Cost (1991$)	Exposure (person-rem)	Cost (1991$)	Exposure (person-rem)
Licensee Direct Consequences	8,100,000	(220)	9,400,000	(480)
NRC Direct Consequences	($14,000)	--	(18,000)	--
Overall Direct Consequences	8,100,000	(220)	9,400,000	(480)

The results shown in Table 5.5 indicate that the overall costs for Alternative B compared to Alternative A are higher by about \$8.1 million and \$9.4 million, respectively, without and with license renewal. On the other hand, Alternative B is estimated to reduce occupational radiation exposure by about 220 person-rem compared to Alternative A for the no-license renewal case, and about 480 person-rem with license renewal. NRC differential costs for Alternative B relative to Alternative A are quite small and do not noticeably affect the bottom line costs. Alternative B is estimated to reduce NRC's costs compared to those with Alternative A. This is the case both with and without license renewal.

5.4 Benefits (Value)

Making judgements about the benefits of actions taken by a licensee involved estimating the actual risk at a typical plant and the degree of improvement that might result from the actions.

The results of the Commission's Maintenance Team Inspections identified some common maintenance-related weaknesses, such as inadequate root cause analysis leading to repetitive failures, lack of equipment performance trending, and the consideration of plant risk in the prioritization, planning and scheduling of maintenance. These weaknesses are not reflected in core damage frequencies calculated by the usual methods. In order to estimate the benefits of the rule, it is first necessary to estimate the extent to which the actual core damage frequency exceeds that calculated by a PRA.

The problem of estimating the actual risk was approached by considering the fraction of observed failures that are maintenance-related. Depending on the definition of maintenance-related and the data examined, one finds that 20% to 60% of failures are maintenance-related. If the failure rates at a plant experiencing ineffective maintenance are actually 25% higher than the values used in a PRA, then the actual frequency for a cut set of order 6, for example, is about 4 times higher than the frequency calculated by the PRA. Based on these observations, it is conceivable that actual core damage frequencies at plants experiencing ineffective maintenance may be two to ten or more times greater than their calculated core damage frequencies.

The measurable benefits or values that would result from implementing the maintenance rule are in the form of avoided radiation exposures and avoided costs associated with the resulting reduced core damage frequency. Specifically, these benefits (values) are:

- Avoided public dose (person-rem)
- Avoided worker dose (person-rem)
- Avoided cleanup cost (current \$)
- Avoided replacement power cost (current \$)

5.4.1 Basis for Estimation of Benefits (Value) of Reduced Core Damage Events

The more detailed calculations of core-damage frequency reduction and public risk reduction that appeared in the maintenance rule regulatory analysis (Ref. 2) are not applicable to this analysis. Those calculations assumed that implementation of the rule affects neither human reliability during maintenance nor duration nor frequency of planned maintenance outages, whereas the various alternatives considered in this analysis do differ in just such effects. Therefore, this analysis adopts the assumptions used in the analysis of the license renewal rule instead of those in the maintenance rule analysis.

The average remaining plant life was estimated for two assumptions. Without license renewal, the average remaining life was estimated to be 20 years. License renewal was assumed to extend the remaining life to 40 years.

The avoided public dose is based on the probability of containment failure given core damage being 0.1 and that the public dose given a release being 1.0×10^7 person-rem. These are the same assumptions that were used in the regulatory analysis for the license renewal rule (Ref. 5).

The avoided worker dose per core damage event was assumed to be 40,000 person-rem, also based on the assumptions used in analysis of the license renewal rule. This is higher than the range (10,000 to 34,000 person-rem) that was used in the maintenance rule regulatory analysis.

The avoided on-site cleanup cost is based on an estimate of $1200 million per core damage event, spread over ten years following the event. The avoided replacement power cost was assumed to be $0.4 million per day over a ten-year period, for a total of $1,500 million. If there are less than ten years of remaining life when the event occurs, the cost should be proportionately reduced. However, for this analysis we assumed that the full cost was incurred if there were more than five years remaining, but no cost if there were less than five years remaining. This compares with a range of $1,210 million to $1,440 million used in the maintenance rule regulatory analysis. All of the future costs were discounted to 1991 dollar values by using a 5% present worth factor.

5.4.2 Basis for Estimation of Benefits of Alternative A

Benefits of Primary Activities.

Alternative A focuses attention on assuring competent performance of preventive maintenance. The average effect of assuring that the performance of preventive maintenance is at a high standard at all plants is very uncertain.

A PRA is normally based on reliability data that reflects either competent preventive maintenance or average industry performance. Therefore, the effect of weaknesses in the performance of preventive maintenance is to increase the core damage frequency above that calculated by a PRA.

The Commission's 1985 assessment of maintenance at domestic nuclear power plants found wide variations in maintenance practices and effectiveness, with a significant proportion of operational problems attributable to improper or inadequate maintenance. A 1988 industry study found that 38% of the root causes of a sample of significant events were maintenance related. The lack of consideration of risk in the prioritizing and planning of maintenance was identified as a common weakness during the NRC's Maintenance Team Inspections. Based on these considerations, the average reduction in core damage frequency that would result from assuring a high standard of preventive maintenance was judged to be between 2×10^{-5} per reactor-year and 8×10^{-5} per reactor-year, starting when the rule becomes effective.

Costs and Benefits of Secondary Activities.

There are no secondary activities under Alternative A, hence there are no additional secondary costs or benefits.

5.4.3 Basis for Estimation of Benefits and Additional Secondary Costs of Alternative B

Benefits of Primary Activities.

Alternative B enhances Alternative A by providing not only assurance of competent performance of current preventive maintenance activities, but also providing enhanced predictive maintenance and avoidance of high-risk configurations.

The assessment of the benefits of avoiding high-risk configuration took into account that the Maintenance Team Inspections identified lack of consideration of risk in the scheduling of maintenance as a common weakness. The risk associated with configurations occurring during plant shutdown is an area of current study and still uncertain.

Another major source of uncertainty is in the estimate of the net benefit available through enhanced predictive maintenance.

The judged benefit from all primary activities was estimated as a reduction in the core damage frequency by 1×10^{-4} to 3×10^{-4} per reactor-year, starting when the rule becomes effective. The upper end of this range reflects the possibility that there may be some plants where greater consideration of risk in the scheduling of maintenance will be necessary for continued operation.

Costs and Benefits of Secondary Activities.

Secondary activities associated with Alternative B were:

- corrective actions pursuant to (a)(1) and

* activities added (or eliminated) to balance planned unavailability against failure prevention.

Benefit (Value) of Corrective Actions.

In estimating the primary activities, the total number of corrective actions and adjustments that are analyzed was judged to be five to fifteen per year. Some of these will not be implemented because of unfavorable cost/benefit ratios. These actions are expected to be mostly adjustment for the first few years and mostly corrective actions thereafter. Although there will be a tendency to take the most effective actions first, there will also be more opportunities for corrective actions as the plant ages. In order to be conservative in estimating the benefits of this alternative, no credit was taken in the reduction of core damage frequency for the effects of the secondary activities.

The average person-rem of benefit from a years action was obtained by assuming that the reduction in core damage frequency was effective over the remaining life of the plant. Therefore, the benefit of the corrective actions taken during a year late in the plant life are less than those of the actions taken in an earlier year.

Costs and Benefits of Secondary Activities.

Although the evaluation of proposed secondary activities has been considered under primary activities, the costs of their implementation were not included with the primary costs. The cost of implementing the corrective actions can be estimated based on the anticipated person-rem benefit. The average direct cost of an action was taken to be $3,000 per person-rem of benefit, as discounted during the licensee's cost/benefit analysis to the initiation of the corrective action. A reasonable alternative would take $3,000 as the net cost after taking credit for avoided cleanup and replacement power costs, because a licensee would be justified in skipping any corrective action that would have a net cost over $10,000 per person-rem of benefit, whereas some corrective actions might have negative net costs.

The total cost of corrective actions decreases with time, reflecting the rejection of more expensive actions as the remaining life dwindles. Consistent with the licensee's discounting, the cost is concentrated at the initiation of the action. A estimate of the average discount factor was obtained by using a rate of 5% over a time equal to the mid-point of the currently remaining life.

5.5 Impact and Benefit Summary

Possible impacts, consequences and benefits which could occur as the result of adoption of a regulatory guide were developed for each of the proposed regulatory approaches based on the above mentioned underlying basis. In particular, the following impacts were estimated:

I1 - Direct Costs of Implementation of Maintenance Rule

I2 - Additional Occupational Dose due to Enhanced ISTM Activities

I3 - Additional Costs of Corrective Actions

The Benefits (Values) estimated were:

V1 - Averted Public Dose due to Reduction in the Probability of a Release of Radioactive Material

V2 - Averted On-Site Cleanup Occupational Dose due to Reduction in the Probability of a Core Damage Event

V3 - Averted Cleanup Costs due to Reduction in the Probability of a Core Damage event

V4 - Averted Power Replacement Costs due to Reduction in the Probability of a Core Damage event

Two implementation scenarios were developed for each of the categories of impact: a more cost effective implementation and a less cost effective implementation. The more cost effective implementation scenario was developed by associating the lower direct cost estimates with highest reduction in core damage frequency. The less cost effective scenario associates the higher direct costs with the lowest reduction in core damage frequency. Additionally, in each scenario considered, the effect of an additional 20 years of operation under a license renewal was analyzed.

The following two tables summarize the impacts for the more cost effective scenario and less cost effective scenario for each of the alternatives for one reactor operating for 20 years after the implementation of the maintenance rule.

Tables 5-8 and 5-9 summarize the impacts for the more cost effective scenario and less cost effective scenario for each of the alternatives for one reactor operating for 40 years after the implementation of the maintenance rule.

Table 5-6

Impact Summary for the Less Cost Effective Scenario

(Without License Renewal)

	A	B
Direct Licensee Cost	$52.7 M	$62.4 M
NRC Costs	$110K	$90K
Additional Occupational Dose	1,000 PR	720 PR
Cost of Corrective Actions	0	$3.6M
Averted Public Dose	400 PR	2,000 PR
Averted Occupational Dose	16 PR	80 PR
Averted Cleanup Costs	$0.2 M	$1 M
Averted Power Replacement	$0.32 M	$1.6 M

Table 5-7

Impact Summary for the More Cost Effective Scenario

(Without License Renewal)

	A	B
Direct Licensee Cost	$20.5 M	$27 M
NRC Costs	$90 K	$70 K
Additional Occupational Dose	400 PR	240 PR
Cost of Corrective Actions	0	$18 M
Averted Public Dose	1,600 PR	6,000 PR
Averted Occupational Dose	64 PR	240 PR
Averted Cleanup Costs	$0.8 M	$3 M
Averted Power Replacement	$1.3 M	$4.8 M

Table 5-8

Impact Summary for the Less Cost Effective Scenario

(With License Renewal)

	A	B
Direct Licensee Cost	$71.6 M	$82.3 M
NRC Costs	$130 K	$110 K
Additional Occupational Dose	2,000	1,380 PR
Cost of Corrective Actions	0	$5 M
Averted Public Dose	800 PR	4,000 PR
Averted Occupational Dose	32 PR	160 PR
Averted Cleanup Costs	$0.4 M	$2.0 M
Averted Power Replacement	$0.6 M	$3.2 M

Table 5-9

Impact Summary for the More Cost Effective Scenario

(With License Renewal)

	A	B
Direct Licensee Cost	$27.6 M	$35.8 M
NRC Costs	$110 K	$90 K
Additional Occupational Dose	800 PR	460 PR
Cost of Corrective Actions	0	$25 M
Averted Public Dose	3,200 PR	12,000 PR
Averted Occupational Dose	128 PR	480 PR
Averted Cleanup Costs	$1.6 M	$6 M
Averted Power Replacement	$2.5 M	$9.6 M

5.6 Comparison of Alternative B with the Alternative A

The Alternative B net impact-to-value ratio was compared with those developed for Alternative A. The net impact to value ratios were determined from the previously discussed attributes.

Tables 5-10 and 5-11 summarize the net impact to value ratios for the more cost effective scenario and less cost effective scenario for one reactor operating for 20 years after the implementation of the maintenance rule. The values in the tables have been rounded off, as appropriate.

Table 5-10

Net Impact to Value Ratio for the Less Cost Effective Scenario

(Without License Renewal)

	A
Incremental Cost of B	$11.2 M
Incremental Averted PR of B	1,944 PR
Net Impact Ratio of B	**$5.7 K/PR**

Table 5-11

Net Impact to Value Ratio for the More Cost Effective Scenario

(Without License Renewal)

	A
Incremental Cost of B	$18.9 M
Incremental Averted PR of B	4,736 PR
Net Impact Ratio of B	**$3.9 K/PR**

Tables 5-12 and 5-13 summarize the net impact to value ratios for the more cost effective scenario and less cost effective scenario for one reactor operating for 40 years after the implementation of the maintenance rule. The values in the tables have been rounded off, as appropriate.

Table 5-12

Net Impact to Value Ratio for the Less Cost Effective Scenario

(With License Renewal)

	A
Incremental Cost of B	\$11.5 M
Incremental Averted PR of B	3,948 PR
Net Impact Ratio of B	**\$2.9 K/PR**

Table 5-13

Net Impact to Value Ratio for the More Cost Effective Scenario

(With License Renewal)

	A
Incremental Cost of B	\$21.7 M
Incremental Averted PR of B	9,492 PR
Net Impact Ratio of B	**\$2.2 K/PR**

The net impact to value ratio comparison indicates that Alternative B is a cost effective alternative when compared to Alternative A. The most unfavorable comparison between B and A was for the less cost effective scen[illegible]o without license renewal. Even in this comparison the net impact ratio of B relative to A resulted in a cost of about \$5,700 per person-rem which compares very favorably with licensee estimates ranging upwards of \$10,000 per person-rem.

6.0 DECISION RATIONALE

6.1 REGULATORY ANALYSIS

A clear and consistent set of guidance acceptable to the NRC staff for implementing the §50.65 rule is the major goal of a Regulatory Guide. The NRC Draft Regulatory Guide will clearly achieve this goal in a cost effective manner. The NRC Draft Regulatory Guide basically relies on accepted current practices generally followed by both the NRC and industry. Since many of the elements of the NRC Draft Regulatory Guide are currently implemented by the nuclear power industry and none of the elements require state-of-the-art advancements in a technical discipline, there are no barriers to its timely implementation.

6.2 ENVIRONMENTAL IMPACT

As part of the §50.65 rulemaking effort, the Commission has determined that, under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in subpart A of 10 CFR Part 51, that issuance of the rule would not significantly affect the quality of the environment. Therefore, an environmental impact statement was not required for the §50.65 rule. Since the proposed Regulatory Guide provides one acceptable method of implementing the provisions of §50.65, neither an environmental impact statement nor an environmental assessment has been prepared for the proposed Regulatory Guide.

7.0 COMPARISON TO OTHER RULES AFFECTING STRUCTURES, SYSTEMS, AND COMPONENTS

The Maintenance Rule was compared with the following seven rules:

(1) License Renewal (10 CFR 54)

(2) Environmental Qualification (10 CFR 50.49)

(3) Fire Protection (10 CFR 50.48)

(4) Anticipated Transit Without Scram (10 CFR 50.62)

(5) Pressurized Thermal Shock (10 CFR 50.61)

(6) Station Blackout (10 CFR 50.63)

(7) Quality Assurance (10 CFR Part 50--Appendix B).

The attached Table 7-1, "Maintenance Rule Interrelationships with Rules Affecting SSCs," was developed to illustrate in a concise manner that, in many cases, the maintenance rule merely reiterates and reinforces requirements from these other seven rules. The primary thrust of this matrix is to show that the scope, requirements, and documentation needed to fully implement the maintenance rule does not significantly expand similar items beyond that set forth in the other seven rules selected for comparison. Within the matrix, similar items are aligned horizontally. It should be noted that the appearance of a corresponding scope or requirement does not necessarily mean that the items are identical, it merely shows there is some similarity in the scope or requirements. Blank spaces in the matrix are significant because they indicated a lack of similarity in the scope or requirements between the maintenance rule and the other rules.

Table 7-1. Maintenance Rule Interr

Title/Subject	Maintenance Rule 10 CFR 50.65 Draft NRC Reg Guide	License Renewal 10 CFR 54	Environment Qualification 10 CFR 50.49 Reg Guide 1.89	Fir 10 C Reg Branch T C
Scope	Safety-Related SSCs relied upon to remain functional during and following design basis events to ensure	Safety-Related SSCs relied upon to remain functional during and following design basis events to ensure	Safety-Related SSCs relied upon to remain functional during and following design basis events to ensure	Safety-Relat relied upon during and f events to ens
	a) the integrity of the reactor coolant pressure boundary, b) the capability to shut down the reactor and maintain it in a safe shutdown condition, and c) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10 CFR 100 guidelines.	a) the integrity of the reactor coolant pressure boundary, b) the capability to shut down the reactor and maintain it in a safe shutdown condition, and c) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10 CFR 100 guidelines.	a) the integrity of the reactor coolant pressure boundary, b) the capability to shut down the reactor and maintain it in a safe shutdown condition, and c) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10 CFR 100 guidelines.	a) the integ coolant b) the capa the react a safe sh and c) the capa mitigate accident potentia compara guidelin
	Non-Safety-Related SSCs			Non-Safety-
	d) that are relied upon to mitigate accidents or are used in plant emergency opera-ting procedures (EOPs),			
	e) whose failure could prevent safety-related SSCs from fulfilling their safety-related functions, or f) whose failure could cause a reactor scram or actuation of a safety-related system.	e) Non-Safety-Related SSCs whose failure could directly prevent any of the above safety functions.	e) Non-Safety-Related electrical equipment whose failure could prevent satisfactory accomplishment of the above safety functions.	e) containi could ad operatio SSCs.
		All SSCs relied on in safety analyses or plant evaluations to demon-strate compliance with the Commission's regulations for: - Fire Protection - Environmental Qualification - Pressurized Thermal Shock - Anticipated Transient w/o scram - Station Blackout All SSCs subject to operability requirements contained in the facility technical specification limiting conditions for operation.	Certain post-accident monitoring equipment.	

elationsh ps with Rules Affecting SSCs

e Protection CFR 50,§50.48 Guide 1.120 echnical Position MEB 9.5-1	Anticipated Transient without SCRAM 10 CFR 50 §50.62 Generic Letter 83-28	Presurized Therma Shock 10 CFR 50, §50.61 Reg Guide 1.154	Station Blackout 10 CFR 50 §63 Reg Guide 1.156	Appendix B Part 50
d SSCs which are o remain functional ollowing design basis ure rity of the reactor pressure boundary, bility to shut down or and maintain it in utdown condition, bility to prevent or the consequences of s that could result in offsite exposure ble to the 10 CFR 100 es. Related SSCs ng fire hazards that versely affect the n of safety-related	Safety-Related SSCs associated with the reactor protection system which are relied upon to remain functional during and following design basis events to ensure a) the integrity of the reactor coolant pressure boundary, b) the capability to shut down the reactor and maintain it in a safe shutdown condition, and c) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10 CFR 100 guidelines.	Safety-Related SSCs of pressurized water reactors relied upon for containment, i.e., the reactor vessel.	Safety-Related SSCs relied upon to remain functional during and following a station blackout. Note: A rule containing diesel generator requirements is pending.	Safety-Related Functions of SSCs SSCs that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

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Table 7-1. Maintenance Rule Interrelationship

Title/Subject	Maintenance Rule 10 CFR 50.65 Draft NRC Reg Guide	License Renewal 10 CFR 54	Environment Qualification 10 CFR 50.49 Reg Guide 1.89	Fire Prote 10 CFR 50, Reg Guide Branch Technic OMEB 9
Requirements	1) Determine which SSCs are within the scope of the rule. 2) Determine which SSCs will be addressed by the requirements of 50.65(a)(1) and those that will be addressed under 50.65(a)(2).	1) Determine which SSCs are within the scope of the rule.	1) Prepare a list of electric equipment important to safety in a harsh environment	1) Prepare a list of within scope of (These will be u auspices of the program.) For the fire protecti establish QA/maint program
	For SSCs covered by the provisions of 50.65(a)(1): 3) Establish appropriate goals for plants, systems, trains, and certain components,	(3,4,5) Demonstrate age-related degradation unique to license renewal is addressed through an effective program.		3) Establi h perfor
	4) Monitor the performance, condition, and availability of the SSCs, 5) Evaluate and trend the results of the monitoring efforts in order to ensure that the established goals are being achieved,			4) Monitor perfor inspection and 5) Evaluation com criteria. Record
	6) Determine the root cause or causes of inability to meet an established goal, unacceptable failure of a SSC, or unacceptable degradation of a SSC, 7) Take appropriate corrective action when goals are not met.	6) Identify SSCs that contribute to the performance of a required function or if they fail, prevent an SSC important to license renewal from performing its function.		
	For SSCs covered by the provisions of 50.65(a)(2): 8) Establish the basis for the determination that the performance or condition of the SSC is being effectively controlled through the performance of appropriate preventive maintenance, 9) Perform preventative maintenance activities such that unacceptable degradation of performance, condition, or availability is prevented to the extent necessary, and promptly detected if it should occur, 10) If failures or unacceptable degradations of SSCs occur, take appropriate goal setting monitoring, or corrective actions.	8) Describe and justify methods for SSC identification including specific criteria for determining and evaluating age-related degradation unique to license renewal.		

s with Rules Affecting SSCs (Continued)

tion §50.48 3.120 l Position 5-1	Anticipated Transient without SCRAM 10 CFR 50 §50.62 Generic Letter 83-28	Presurized Thermal Shock 10 CFR 50, §50.61 Reg Guide 1.154	Station Blackout 10 CFR 50 §63 Reg Guide 1.156	Appendix B Part 50
all SSCs this rule. nder the ire protection	1) Determine the SSCs that are within scope of this rule.	1) Determine all SSCs within scope of this rule.	1) Determine all SSCs within scope of this rule.	1) Identify SSCs covered by the QA program.
on system enance	Establish a reliability program for the reactor trip system (RTS)		Establish a reliability program for the emergency diesel generators.	Establish a QA program with written policies, procedures, and instructions
mance goals	3) Develop numerical performance standards including unavailability analysis	3) Establish screening criteria, i.e., a RTNDT (reference temperature for nil ductility transition) for the reactor vessels.	3) Establish reliability goals	3) Develop goals and acceptance criteria
nance through testing	4) Monitor performance and condition of RTS by maintenance, testing, and surveillance	4) Monitor RTPTS for changes in projected values	4) Monitor performance through testing and surveillance.	4) Monitor through inspections and test programs
pliance with results.	5) Evaluate trend results.	5) Evaluate projected RTPTS to ensure compliance with screening criteria		5) Establish control measures to verify the adequacy of designs such as performing design reviews.
	6) Determine the cause of challenges to the SSCs of the RTS		6) Use root cause investigations and root cause analysis to guide maintenance program.	6) Determine the cause of significant conditions.
	7) Take appropriate corrective measures to reduce challenges to the RTS			7) Take appropriate corrective actions.
	8) Establish criteria for determining acceptability of restart			
	9) Establish a preventative maintenance and surveillance program			
				10) For a condition adverse to quality, take corrective action

Table 7-1. Maintenance Rule Interrelation

Title/Subject	Maintenance Rule 10 CFR 50.65 Draft NRC Reg Guide	License Renewal 10 CFR 54	Environment Qualification 10 CFR 50.49 Reg Guide 1.89	Fire 10 C Reg Branch T O
Requirements (Continued)	For all SSCs within the scope of the Rule: 11) Assess total plant equipment out of service when performing maintenance and monitoring activities to determine the effect on performance of safety functions. 12) At-least-annual assessment of the results of monitoring and maintenance activities. 13) Evaluate available industry operating experience and [illegible]ely incorporate the [illegible] into the maintenance and monitoring efforts.	12) List of SSCs within the scope must be updated at lea.. annually. • Identify SSCs that could have age-related degradation unique to license renewal.		

...ships with Rules Affecting SSCs (Continued)

...Protection ...FR 50,§50.48 ...Guide 1.120 ...chnical Position ...MEB 9.5-1	Anticipated Transient without SCRAM 10 CFR 50 §50.62 Generic Letter 83-28	Presurized Thermal Shock 10 CFR 50, §50.61 Reg Guide 1.154	Station Blackout 10 CFR 50 §63 Reg Guide 1.156	Appendix B Part 50
			11) Perform maintenance while the reactor is down to minimize unavailability of the emergency diesel generators.	
	13) Develop plant specific and industry wide operating experience.			Appendix B contains 18 subsections. However, for brevity those that did not correlate closely with the maintenance rule were not included.

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Table 7-1. Maintenance Rule Interrelatio

Title/Subject	Maintenance Rule 10 CFR 50.65 Draft NRC Reg Guide	License Renewal 10 CFR 54	Environment Qualification 10 CFR 50.49 Reg Guide 1.89	F 10 R Branch
Documentation	Although there is no specific documentation requirement in the Maintenance Rule, the Draft NRC Reg. Guide lists the following documentation requirements: 1) Process for: • setting goals and monitoring; • immediate evaluation; • feedback. 2) Identification of SSCs within the scope of the rule and basis for placing in (a)(1) or (a)(2) 3) Identification of goals including rationale 4) Monitoring results and root cause analysis 5) Results of at-least-annual assessments.	• Integrated Plant Assessment • Justification of methods used to determine the identity of all SSCs important to license renewal and those that could be subjected to age related degradation unique to license renewal. • Identification and justification of any changes in the current licensing basis associated with age-related degradation unique to license renewal. • A description of proposed plant modification or administrative control procedures necessary to ensure age related degradation unique to license renewal is adequately managed during the renewal term. • Changes to technical specifications including technical basis for these changes that will account for the modifications to plant design, or limitations on plant operations during the renewal term due to age-related degradation concerns.	• Maintain a Qualifications File in auditable form which contains – Performance specifications under conditions during and following basic accidents – Voltage, frequency, load, and other electrical characteristics – Environmental conditions (temperature, pressure, humidity, radiation, chemical, and submergence) at locations where the equipment must perform • Record of qualification including documentation must be maintained in auditable form for the entire period for which the item is installed or stored for future use • Implement an electric equipment qualification program which must include and be based on – Temperature and pressure – Humidity – Chemical effects – Radiation – Aging – Synergistic Effects – Margins • Prepare a list of electric equipment important to safety covered by this rule. • Information concerning performance specs, voltage, and electrical characteristics and environmental conditions shall be kept current and the file shall be in auditable form. • A record of the qualification including documentation must be maintained in an auditable form for the entire period for which the item is installed or stored for future use.	• A Fire maint descri protec facility descri necess progr • Traini brigad maint

nships with Rules Affecting SSCs (Continued)

ire Protection CFR 50,§50.48 g Guide 1.120 Technical Position OMEB 9.5-1	Anticipated Transient without SCRAM 10 CFR 50 §50.62 Generic Letter 83-28	Presurized Thermal Shock 10 CFR 50, §50.61 Reg Guide 1.154	Station Blackout 10 CFR 50 §63 Reg Guide 1.156	Appendix B Part 50
Protection Plan shall be ined. This plan shall be the overall fire tion program for the The plan must also be specific features ary to implement the m ng records for each fire e member must be ined for 3 years.	• The following reports must be submitted to the NRC: – Post-Trip Review Program – Vendor Interface Program – Equipment classification and Vendor Interface Program – Reactor Trip System Reliability Program – Data and information capability for unscheduled reactor shutdowns	• Projected values of RTPTS of reactor bessel belt line materials shall be updated whenever there are significant changes in these projected values. • When RTPTS is projected to exceed the PTS screening criteria an analysis and schedule for implementing flux reduction programs shall be submitted. • To operate above the screening criteria a safety analysis must be submitted.	• The capability for coping with a station blackout of specified duration shall be determined by an appropriate coping analysis. The baseline assumptions, analyses, and related information must be available for NRC review. • Justification for the proposed station blackout duration. • A description of the procedures that will be implemented for station blackout events. • A list of modifications to equipment and procedures, if any, necessary to meet the requirements of this rule.	• QA program must be established [illegible] execute [illegible] program shall be documented by written policies, procedures, and instructions. • Identify the SSCs covered by the QA program and the major organizations participating in the program. • Test results shall be documented and evaluated to assure that requirements have been satisfied. • Sufficient records shall be maintained to furnish evidence of activities affecting quality. Records shall be identifiable and retrievable.

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REFERENCES

1. "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," 10 CFR Part 50.65 RIN 3150-AD00, Federal Register, Vol. 56, No. 132, Wednesday, July 10, 1991.

2. "Regulatory Analysis for Rule on Nuclear Power Plant Maintenance," Division of Safety Issue Resolution, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, June 1991.

3. "Status of Maintenance in the U.S. Nuclear Power Industry, 1985," NUREG-1212, Vols. 1 and 2, June 1986.

4. "Draft Regulatory Guide, Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," U.S. Nuclear Regulatory Commission, August 1992, (included as Appendix C).

5. "Regulatory Analysis for Final Rule on Nuclear Power Plant License Renewal," U.S. Nuclear Regulatory Commission, December 1991.

APPENDIX A

FINAL MAINTENANCE RULE

APPENDIX A: FINAL MAINTENANCE RULE

§ 50.65 Requirements for monitoring the effectiveness of maintenance at nuclear power plants

(a) (1) Each holder of an operating license under §§50.21(b) or 50.22 shall monitor the performance or condition of structures, systems, or components, against licensee--established goals, in a manner sufficient to provide reasonable assurance that such structures, systems, and components, as defined in paragraph (b), are capable of fulfilling their intended functions. Such goals shall be established commensurate with safety and, where practical, take into account industry-wide operating experience. When the performance or condition of a structure, system, of component does not meet established goals, appropriate corrective actions shall be taken.

(2) Monitoring as specified in paragraph (a)(1) of this section is not required where it has been demonstrated that the performance or condition of a structure, system, or component is being effectively controlled through the performance of appropriate preventive maintenance, such that the structure, system, or component remains capable of performing its intended function.

(3) Performance and condition monitoring activities and associated goals and preventive maintenance activities shall be evaluated at least annually, taking into account, where practical, industry-wide operating experience. Adjustments be made where necessary to ensure that the objective of preventing failures of structures, systems, and components through maintenance is appropriately balanced against the objective of minimizing unavailability of structures, systems, and components due to monitoring or preventive maintenance. In performing monitoring and preventive maintenance activities, an assessment of the total plant equipment that is out of service should be taken into account to determine the overall effect on performance of safety functions.

(b) The scope of the monitoring program specified in paragraph (a)(1) of this section shall include safety-related and nonsafety-related structures, systems, and components, as follows:

(1) Safety related structures, systems, or components that are relied upon to remain functional during and following design basis events to ensure the integrity of the reactor coolant

pressure boundary, the capability to shut down the reactor and maintain it in a safe shutdown condition, and the capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposure comparable to the 10 CFR Part 100 guidelines.

(2) Nonsafety-related structures, systems, or components:

(i) That are relied upon to mitigate accidents or transients or are used in plant emergency operating procedures (EOPs); or

(ii) Whose failure could prevent safety-related structures, systems, and components from fulfilling their safety-related functions; or

(iii) Whose failure could cause a reactor scram or actuation of a safety-related system.

(c) The requirements of this section shall be implemented by each licensee no later than July 10, 1996.

APPENDIX B
GUIDANCE REQUIRED BY LICENSEES

APPENDIX B: GUIDANCE REQUIRED BY LICENSEES

SCOPE

- Is the scope of the monitoring program required to include those nonsafety-related SSCs whose failures could cause actuation of a safety-related system, even if they are not relied upon to mitigate accidents or transients, are not used in plant EOPs, and their failures could not prevent safety-related SSCs from fulfilling their safety-related functions, could not cause a reactor scram, and could not initiate or adversely affect a transient?
- For what SSCs must the monitoring program provide reasonable assurance of capability of fulfilling intended functions?
- At what level must SSCs be monitored pursuant to (a)(1), if not excluded under (a)(2)?
- If a SSC is included in the scope of monitoring only because it has a failure mode that could cause actuation of a safety-related system, must it be monitored in a manner sufficient to provide reasonable assurance that it is capable of fulfilling its intended functions?
- Is the licensee required to monitor the overall effectiveness of maintenance?

GOALS

- Must the licensee establish goals for the performance or condition of each SSC being monitored pursuant to (a)(1)?
- Would a goal that is the same as a current criterion for performing corrective maintenance meet the requirements of the rule?
- Would a goal that corresponds to a current level of performance or condition meet the requirements of the rule?
- What criterion or criteria must the goals for performance or condition of a SSC satisfy to meet the requirements of the rule?
- What determines whether the goals for a SSC are commensurate with safety?
- Under what circumstance is it possible to monitor the condition of a SSC against goals that are commensurate with safety?
- Can a single goal for the performance or condition of a SSC satisfy all of the criteria?

Must the licensee establish goals that are related to the risk of failures that could prevent safety-related structures, systems, and components from fulfilling their safety-related function or whose failure could cause a reactor scram or actuation of a safety-related system?

- Must goals be based on PRAs?
- Must the licensee identify the current licensing basis of each SSC within the scope of the rule?
- In what respect or respects must goals take into account industry-wide operating experience?
- May the parameters monitored against goals be the same as those monitored against criteria for performing corrective maintenance?

MONITORING

- Does periodic surveillance meet the requirement for monitoring a SSC?
- What criterion or criteria must the frequency of periodic surveillance satisfy to meet the requirements of the rule?
- Can monitoring provide reasonable assurance that the SSC is capable of fulfilling its intended functions even if established goals are not met?
- Can established goals be met without the SSC being capable of fulfilling its intended function?
- For how much normal operating time must an operating SSC continue to operate in order to fulfill its intended function?
- For how much time during and following a design basis event must a standby SSC continue to operate in order to fulfill its intended function?
- Can an operating SSC be capable of fulfilling its intended function and yet fail to complete its intended function solely because of one or more internal failures?
- For how much normal operating time must a standby SSC remain capable of operation in order to fulfill its intended function?
- May the requirement for monitoring a component be met by monitoring the system that contains the component?

CORRECTIVE ACTION

- Does repairing a SSC satisfy the requirement for corrective action when its performance or condition does not meet established goals?
- What criterion or criteria must corrective action meet to be appropriate when the performance or condition of a SSC does not meet established goals?

- Would making goals less challenging be appropriate corrective action when a SSC does not meet established goals?
- How soon must corrective action be taken?

PREVENTIVE MAINTENANCE

- For monitoring not to be required, how recently must it have been demonstrated that the performance or condition of a SSC is being effectively controlled?
- Can an operating SSC have its performance or condition effectively controlled such that it is capable of performing its intended function and yet fail to perform its intended function solely because of one or more internal failures?
- Does the licensee avoid the necessity of monitoring SSCs for which it has demonstrated effective control of performance or condition such that the SSC remains capable of performing its intended function?
- What does the licensee save by demonstrating effective control of performance or condition?

EVALUATION

- Must the required at-least-annual evaluation include comparison of latest monitoring results with goals?
- Must the required evaluation include redemonstration of effective control through preventive maintenance?
- Against what criteria must goals be evaluated at least annually?
- Against what criteria must performance and condition monitoring activities be evaluated at least annually?
- Against what criteria must preventive maintenance activities be evaluated at least annually?
- Must the required evaluation of monitoring activities include monitoring activities for predictive maintenance that are not pursuant to (a)(1)?
- Must the required evaluation of preventive maintenance activities include activities on SSCs for which the licensee is not claiming to demonstrate effective control?
- Is the licensee required to summarize the overall effectiveness of maintenance?

BALANCING OBJECTIVES

- Must adjustments be made at least annually where necessary to balance the objective of preventing failures against the objective of minimizing unavailability?
- Must adjustments be made where necessary to balance the objective of preventing failures during all plant states against the objective of minimizing unavailability during all plant states, including low power and shutdown states?
- Is the licensee required to ensure that the objective of preventing failures through maintenance is appropriately balanced against the objective of minimizing unavailability due to monitoring, even if the monitoring is not pursuant to (a)(1)?
- Is the licensee required to ensure that the objective of preventing failures through maintenance is appropriately balanced against the objective of minimizing unavailability due to preventive maintenance, even if the preventive maintenance is not pursuant to (a)(2)?
- Is the licensee required to evaluate the effectiveness of performance and condition monitoring activities and associated goals and preventive maintenance activities with respect to preventing failures?
- Must the basis for balancing of the objective of preventing failures against the objective of minimizing unavailability be a PRA?
- If evaluation demonstrates that the objective of minimizing unavailability due to a monitoring activity that is integrated with technical specification surveillance requirements has been inappropriately emphasized relative to the objective of preventing failures through maintenance, is the licensee required to adjust the frequency of surveillance above that required by technical specifications?
- If evaluation demonstrates that the objective of preventing failures through maintenance has been inappropriately emphasized relative to the objective of minimizing unavailability due to a monitoring activity that is integrated with technical specification surveillance requirements, is the licensee required to adjust the frequency of surveillance below that required by technical specifications?
- If evaluation demonstrates that the objective of minimizing unavailability due to a preventive maintenance activity that is both pursuant to (a)(2) and a technical specification surveillance requirement has been inappropriately emphasized relative to the objective of preventing failures through maintenance, is the licensee required to adjust the frequency of preventive maintenance above that required by technical specifications?

- If evaluation demonstrates that the objective of preventing failures through maintenance has been inappropriately emphasized relative to the objective of minimizing unavailability due to a preventive maintenance activity that is both pursuant to (a)(2) and a technical specification surveillance requirement, is the licensee required to adjust the frequency of preventive maintenance below that required by technical specifications?

ASSESSMENT OF EQUIPMENT OUT OF SERVICE

- Is the licensee ever required to take into account an assessment of the total plant equipment that is out of service?
- Does the rule say that an assessment of total plant equipment out of service should be taken into account in performing monitoring activities that are not pursuant to (a)(1)?
- Does the rule say that an assessment of total plant equipment out of service should be taken into account in performing preventive maintenance activities that are not pursuant to (a)(2)?
- Does the rule say that an assessment of total plant equipment out of service should be taken into account in performing monitoring and preventive maintenance activities, even when the plant is in a low power or shutdown state?
- Does the rule say that the assessment of total plant equipment out of service should be performed at least annually?
- Must an assessment of total plant equipment out of service be based on a PRA?

APPENDIX C

NRC DRAFT REGULATORY GUIDE FOR MONITORING THE EFFECTIVENESS OF MAINTENANCE AT NUCLEAR POWER PLANTS

NRC Draft Regulatory Guide for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

August 1992

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TABLE OF CONTENTS

LIST OF FIGURES

C.1 INTRODUCTION

The Nuclear Regulatory Commission amended its regulations in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," to add section 50.65, entitled "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants." (Hereafter, 10 CFR 50.65 may be referred to as the "maintenance rule" or the "rule.") The purpose of the maintenance rule is to require commercial nuclear power plant licensees to monitor the effectiveness of maintenance activities for safety-related and certain non-safety-related structures, systems, and components in order to minimize the likelihood of failures and events caused by the lack of effective maintenance.

Regulatory guides are issued to describe and make available to the public methods acceptable to the NRC staff of implementing specific parts of the Commissions regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission.

This regulatory guide generally describes methods that are acceptable to the NRC staff for implementing the requirements of the maintenance rule. It must be emphasized that the methods described herein are not the only acceptable methods for implementing these requirements. Other methods are acceptable if the staff finds that they meet the requirements of the maintenance rule. Licensees are afforded flexibility in establishing and managing their efforts to meet the requirements of the maintenance rule. A variety of approaches to goal setting, monitoring, and preventive maintenance may be used by licensees.

Comments on this draft regulatory guide that are received after November 30, 1992, may not be fully addressed by the NRC staff because of the time constraints imposed by the commitment of the NRC staff to issue the final Regulatory Guide by June 30, 1993.

C.2 DISCUSSION

C.2.1 Background

The regulatory analysis and the backfit analysis for the maintenance rule both indicate that there is a clear link between effective maintenance and safety as it relates to such factors as the frequency of events, challenges to safety systems and the associated need for availability and reliability of safety equipment. Effective maintenance helps to ensure that failures are minimized in non-safety-related structures, systems and components (SSCs)[1] that could lead to an event or an accident, or that could adversely affect safety system performance. Minimizing challenges to safety systems is consistent with a defense-in-depth philosophy. Effective maintenance is also important to ensure that design assumptions and margins in the licensee's design basis are either maintained or are not unacceptably degraded. Effective nuclear power plant maintenance is therefore clearly important in protecting the public health and safety.

The necessity for ongoing results-oriented assessments of maintenance effectiveness is indicated by the fact that, despite significant industry accomplishment in the areas of maintenance program content and implementation, plant events caused by the degradation or failure of plant equipment continue to occur as a result of instances of ineffective maintenance. Operational events have been exacerbated by or have resulted from plant equipment being unacceptably degraded because of poor maintenance practices or because plant equipment was unavailable because of maintenance activities.

C.2.2 Objective

The objective of this regulatory guide is to describe an acceptable method for licensees to comply with the maintenance rule by monitoring the overall, continuing effectiveness of their maintenance activities to ensure that:

1. Safety-related and certain non-safety-related SSCs remain capable of performing their intended functions,
2. Assumptions about equipment reliability used in safety analyses, plant probabilistic risk assessments, individual plant examinations, specific studies of SSCs, or other studies used to confirm that a plant can continue to operate safely, continue to be valid,

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[1] The term SSCs will sometimes denote structures, systems, or components.

3. Equipment failures that prevent the fulfillment of safety-related functions or cause faults that result in SCRAMs or TRIPs or unnecessary challenges to safety-related systems will be minimized,

4. The reliability benefits gained from performing preventive maintenance are appropriately balanced against the increase in risk resulting from removing equipment from service to perform maintenance, and

5. The design margins that exist because of the availability and reliability of redundant trains and components are not reduced by maintenance activities or lack of maintenance.

C.2.3 Additional Discussion

The details of a licensee's efforts regarding goal setting, monitoring, preventive maintenance, and periodic assessments are not prescribed in this regulatory guide. Attachment 1 provides a glossary of terms used in this guide, and illustrations are provided in the Attachments 2, 3 and 4 for optional methods to meet the requirements of the maintenance rule.

The guidance in this regulatory guide is intended to focus on the effectiveness of the results of each licensee's maintenance activities rather than on the specific processes. Effective maintenance does not necessarily equate to additional maintenance or continuation of maintenance activities that are not effective. Licensees should regard their efforts toward goal setting and monitoring, that are described in the following regulatory position, as potentially effective tools that can be used to adjust their maintenance activities and focus on those items that actually need continued or augmented maintenance. The intent is to encourage licensees to optimize maintenance activities with respect to safety performance of SSCs, even if that means performing less maintenance on some SSCs.

Licensees are expected to find that their efforts to implement the provisions of the maintenance rule will also be useful in meeting at least some of the requirements of the license renewal rule (10 CFR 54). Aging concerns, which are a central focus of the license renewal rule, are routinely addressed through the performance of maintenance activities. Therefore, the efforts of licensees to determine that their maintenance efforts are effective should also be useful in their efforts toward showing that an established effective program exists for managing aging concerns. For example, goals could be established that would show that degradation (aging) of SSCs is controlled at an acceptable level. Thus, monitoring efforts associated with particular goals, performed in response to the maintenance rule, would be directly applicable to showing that license renewal concerns are being properly addressed.

Licensees are not required, either by the rule or this regulatory guidance, to perform alternative or additional surveillance or testing beyond that required by the regulations or by licensee commitments unless results indicate that current surveillance or testing is inadequate. Typical examples of such regulations or licensee commitments include:

1. Surveillance test and inspections performed in accordance with Section XI of the ASME code as required by 10 CFR 50.55a.
2. Reactor pressure vessel material surveillance tests conducted in accordance with Appendix H of 10 CFR 50.
3. Containment leakage tests performed in accordance with Appendix J of 10 CFR 50.
4. Surveillance or testing required by plant technical specifications.
5. Tests and inspections performed in response to NRC bulletins, generic letters, or information notices.

If the licensee's root cause analysis of a failure or unacceptable degradation[1] of an SSC or the licensee's inability to meet a goal indicates that current surveillance or testing is inadequate, additional efforts may be necessary. Also, temporarily enhanced testing or surveillance may be needed to determine the effectiveness of corrective actions previously taken, in order to prevent recurrence of a failure or unacceptable degradation of a SSC.

The activities described in the maintenance rule are schematically depicted in Figure 1.

1 The term "unacceptable degradation" is used throughout this document and is meant to convey that degradation of SSCs is to be expected and that degradation may be acceptable. The adjective "unacceptable" was added to allow licensees flexibility in determining if and when any detected degradation needs to be addressed. The point at which degradation becomes unacceptable is left to licensees to determine based on their particular needs regarding the performance, condition and availability of SSCs.

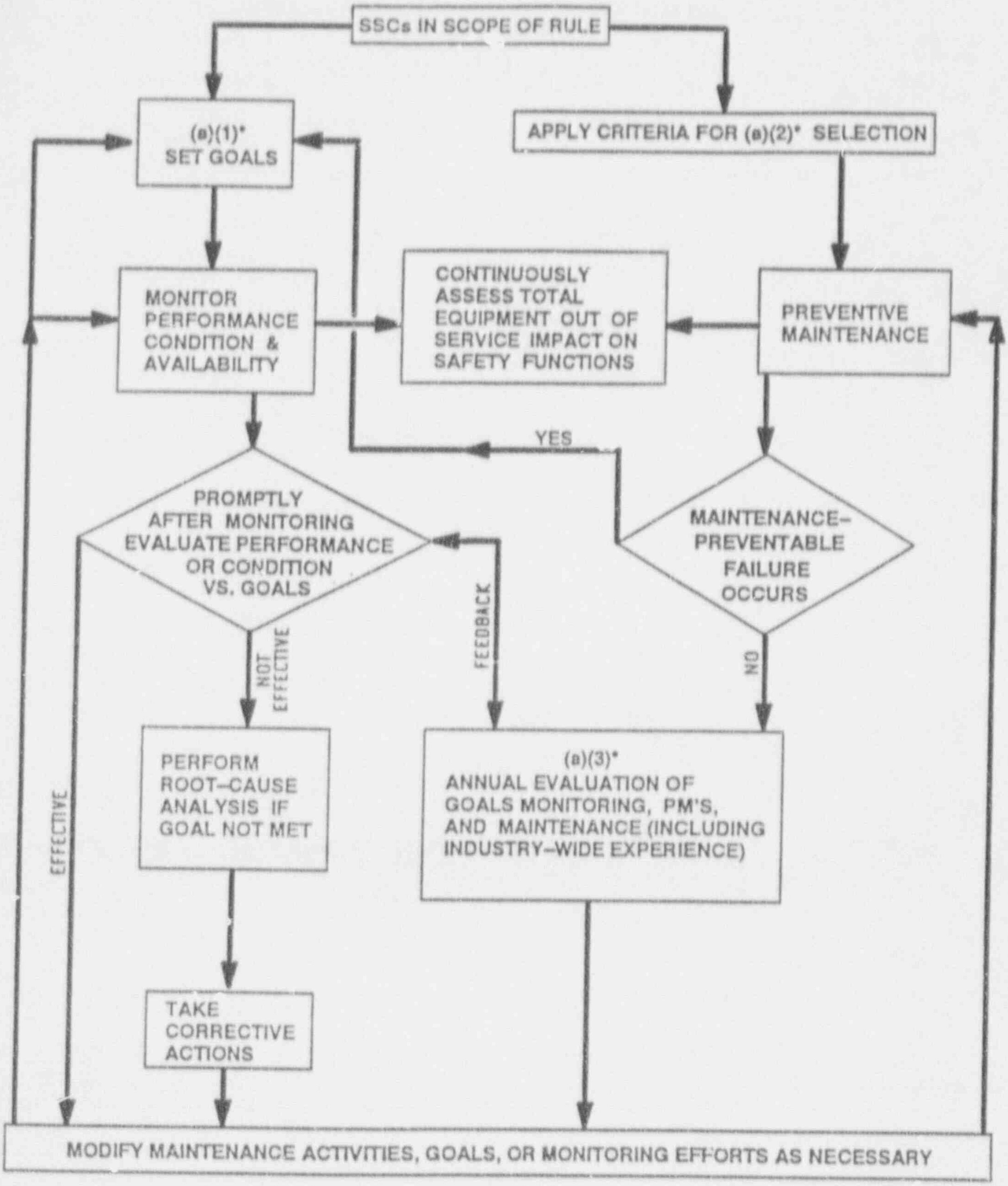

Figure 1. Effective Maintenance Flow Chart

C.3 REGULATORY POSITION

C.3.1. General Description and Summary of Regulatory Position

The approach described in this regulatory guide represents one method acceptable to the NRC staff for complying with the requirements specified in the maintenance rule. Other approaches may also be found to be acceptable. The approach described in this regulatory guide is intended to offer licensees flexibility in establishing and modifying their goal setting, monitoring, and preventive maintenance activities.

The actions taken to comply with the maintenance rule need not conflict with current testing and surveillance activities (e.g., surveillance testing under technical specification requirements). Many existing activities may be integrated with goal setting, monitoring, and assessment activities. These existing activities can also provide a basis for establishing goals and monitoring SSC performance, condition, and availability.

In general, each licensee is responsible for taking the following actions:

1. Determine which SSCs at each nuclear power plant are within the scope of the maintenance rule.

2. Select those SSCs to be governed by the requirements of 50.65(a)(1) and those SSCs that will be considered except[illegible]s and addressed under the requirements of 50.65(a)(2).

3. For SSCs covered by the provisions of 50.65(a)(1):
   a) Establish appropriate goals for plant, systems, trains, and certain components.
   Monitor the performance, condition, and availability of the SSCs.
   c) Evaluate and trend the results of the monitoring efforts in order to ensure that the established goals are being achieved.
   d) Determine the cause or causes of inability to meet an established goal, and root cause of critical component failure or unacceptable degradation of a SSC. Particular attention should be paid to generic or common cause failures.
   e) Take appropriate corrective action when goals are not met.

4. For SSCs covered by the provisions of 50.65(a)(2):

a) Establish the bases for the determination that the performance or condition of the SSC is being effectively contr lled during the relevant service life or required period of operation, through the performance of appropriate preventive maintenance such that the SSC remains capable of performing its intended function.

b) Perform preventive maintenance activities such that maintenance preventable failures or unacceptable degradation of performance, condition, or availability are prevented to the extent necessary, and promptly detected if they should occur.

c) If failures or unacceptable degradations of SSCs occur, that could have been prevented by appropriate maintenance, take appropriate goal setting, monitoring, or corrective actions. Monitoring activities should continue until the root cause of the problem has been determined and the adequacy of the SSC's performance, condition, or availability has been confirmed.

d) Licensees should set goals and take subsequent monitoring actions, based on plant or industry experience with like or similar SSCs, if maintenance preventable failures could be reasonably expected to occur.

5. For all SSCs within the scope of the maintenance rule, the provisions of 50.65(a)(3) require that licensees:

a) Evaluate, at least annually, monitoring activities, goals, unacceptable degradation and failures of SSCs, along with corresponding corrective actions, and make adjustments as appropriate.

b) Evaluate, at least annually, the effectiveness of preventive and corrective maintenance activities, and make adjustments as appropriate.

c) Evaluate, at least annually, the balance between unavailability of SSCs due to maintenance and the reliability gained from performing maintenance actions, and make adjustments as necessary.

d) When scheduling maintenance or monitoring activities, assess the cumulative effect of equipment that is out of service in order to determine the effect on performance of safety functions.

e) Evaluate applicable industry operating experience and effectively incorporate the results of this evaluation into the maintenance and monitoring efforts.

The at-least-annual assessment of the results of monitoring and maintenance activities, along with prompt evaluation of monitoring activity results, are considered particularly important to evaluate overall maintenance effectiveness.

The above described actions are discussed in the following sections of the regulatory position.

Much of the material that follows may be regarded as instructional rather the prescriptive. The examples should be regarded as illustrative. The NRC will be concerned with results, in terms of maintaining or improving performance, condition, and availability of SSCs within the scope of the rule. The specific details of each licensees program for goal setting, monitoring and feedback are not particularly important if the results are satisfactory.

C.3.2 Scope

As stated in 50.65(b), the scope of the monitoring activities specified in 50.65(a)(1) includes safety-related and non-safety-related SSCs, as follows:

1. "Safety-related structures, systems, or components that are relied upon to remain functional during and following design basis events to ensure the integrity of the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in a safe shutdown condition, and the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10 CFR part 100 guidelines."

2. "Non-safety-related structures, systems, or components:"
   a) "That are relied upon to mitigate accidents or transients or are used in plant emergency operating procedures (EOPs); or"
   b) "Whose failure could prevent safety-related SSCs from fulfilling their safety-related function; or"
   c) "Whose failure could cause a reactor scram or actuation of a safety-related system."

C.3.3 Criteria for Initial Application of 50.65(a)(1) or (a)(2)

In general, SSCs within the scope of the maintenance rule should be placed under the provisions of 50.65(a)(1) unless certain criteria are satisfied. These criteria are more stringent for systems and certain components, as described in the following paragraphs.

All systems within the scope of the maintenance rule should be placed under the provisions of 50.65(a)(1), except that systems that meet criterion 1 below may be placed under the provisions of 50.65(a)(2).

Safety-related components (50.65(b)(1)) and non-safety-related components whose failure could prevent safety-related SSCs from fulfilling their safety-related function (50.65(b)(2)(ii)) should be placed under the provisions of 50.65(a)(1), except that such of those components that meet criterion 1 below may be placed under the provisions of 50.65(a)(2).

Non-safety-related components that are relied upon to mitigate accidents or transients or are used in EOPs (50.65(b)(2)(i)) and non-safety-related components whose failure could cause a reactor scram or actuation of a safety-related system (50.65(b)(2)(iii)) should be placed under the provisions of 50.65(a)(1), except that such of those components that meet criterion 1 or 2 below may be placed under the provisions of 50.65(a)(2).

Structures and passive components (assuming that such passive components would not be included above) within the scope of the maintenance rule should be placed under the provisions of 50.65(a)(1), except that structures and passive components that meet criterion 1 or 2 below may be placed under the provisions of 50.65(a)(2). Examples of passive components include ventilation ducts, pipe supports, electrical cabinets, fire barriers, electrical cables, certain piping, and certain valves.

The following criteria are to be applied, as noted above, for initially placing SSCs under the provisions of 50.65(a)(2):

1. A history of effective maintenance exists for a period of at least three surveillance cycles or one evaluation cycle (50.56(a)(3)), whichever is longer.[1] Effective maintenance is demonstrated by acceptable performance, condition, and availability of the applicable SSCs.

   If failures, unacceptable degradation, or unacceptable unavailability of like or similar SSCs are noted or observed, acceptable performance, condition, and availability of the particular SSC might need to be demonstrated over a longer period, in order to ensure the necessary level of confidence.

2. Failure, unacceptable degradation, or unacceptable unavailability of a particular structure or component is determined to be of low risk significance. This determination should be made using a formal assessment method such as one of the two methods described in NUREG/CR-5695, dated March 1991, "A Process for Risk-Focused Maintenance." Other deterministic or risk based methods may also be found to be acceptable for such an evaluation.

C.3.4 Licensee Established Goals - 50.65(a)(1)

C.3.4.1 Goal Setting In General

Goals for SSCs and the plant are to be established and adjusted by licensees. Goals should be commensurate with the SSC's importance to safety.

Goals for SSCs should be established to ensure that:

1. The high degree of reliability and availability for risk-significant systems, as required by the NRC or assumed by the licensee in the design basis, is maintained, and the assumptic ..d in the plant-specific probabilistic risk analysis (PRA),

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[1] If surveillances of particular SSCs are performed at quarterly or more frequent intervals (monthly, weekly, etc.), the need to wait until the end of the evaluation cycle in order to make a determination that maintenance is effective could result in an unnecessary burden to licensees. In such cases, it is recommended that licensees make an initial determination of the number of surveillances needed to establish that maintenance is effective for the SSC. The licensee's decision would then be validated over time by the satisfactory performance, condition and availability of the SSC, or the number of surveillances previously chosen to establish maintenance effectiveness would be adjusted.

individual plant examination (IPE), or individual plant examination for external events (IPEEE) are maintained,

2. The design margin established through the use of redundant, reliable, and available components and trains is not significantly reduced, and
3. The frequency of challenges to safety systems is minimized.

Goals might be set as minimum values or as maximum values, depending on the application. Where appropriate, licensees should incorporate alert set points in their goals that provide an early warning that goals might not be met.

The maintenance history of SSCs may be helpful in developing goals. Such evaluations could include:

1. A review of plant-specific SSC failure, degradation, and unavailability data, and
2. A review of generic (industry-wide) SSC failure, degradation, and unavailability data.

Licensees may consider sources for goals based on SSC performance, condition and availability, as required by existing licensing commitme[illegible] [illegible]ical specification surveillance requirements.

Other sources for goals could include the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Sections III and XI, the Institute of Electrical and Electronic Engineers (IEEE) Criteria for "Protection Systems for Nuclear Generating Stations", IEEE-279, for applicable systems, American Nuclear Society (ANS) standards, and other applicable industry standards.

Upon failure to attain a goal that is dependent on subordinate system or component performance, appropriate goals might be established for the system or component that was found to have caused the failure to meet the higher level goal.

Goals may be limited to a specific SSC even if like or similar SSCs exist with similar functions. In such cases, an adequate basis should be established to support the choice of the particular SSC for monitoring and the exclusion of the others.

Goals should be established as appropriate and as discussed below for:

1. Overall plant performance,
2. Systems or trains, as appropriate,

3. Structures that, without monitoring, could degrade unacceptably or fail, and
4. Components, as described in section C.4.6.

C.3.4.2 Plant Performance Goals

Plant performance goals are expected to provide feedback to licensees concerning the overall effectiveness of their maintenance efforts. Some of these high level goals should be predicated on and related to the success of lower level goals. Plant PRAs, IPEs, or other risk analyses should be used in formulating plant performance goals.

Overall plant performance goals could provide a measure of plant risk due to initiating events. Goals related to maintaining low frequency of challenges to safety systems may be stated in terms of a goal for number of unplanned automatic SCRAMs or TRIPs and safety system challenges.

Goals may also be based on indicators of performance similar to those currently recognized by the NRC, insurance providers, public utility commissions, or industry organizations, as appropriate.

C.3.4.3 System or Train-Level Goals

These goals should be based on system or train performance, condition, and availability (or unavailability if desired).

Goals should be established for safety-related systems and trains, and for non-safety-related systems that are important contributors to, or causes of, safety-related system challenges, SCRAMs, or TRIPs. An unavailability or availability goal is a preferred approach for trains of safety-related systems. If a system goal is used, a method of analyzing the aggregated results should be established, so that the performance and availability of the individual trains can be evaluated. See the last paragraph of section C.7.1 for additional guidance.

System or train failure data, power generation system failure data, industry indicators of system performance, or other measurable quantities that express the goals of maintenance regarding system performance could be used in developing goals.

System or train goals should be consistent with the values for reliability and availability assumed in plant risk analyses.

Train level goals may be needed if there are variations in the reliability or availability of individual trains such that maintenance related problems in one train are masked by acceptable system reliability resulting from the presence of redundant trains. This situation may be especially applicable to systems with more than two trains. This issue is addressed in the example provided in Attachment 3.

At least one system-level goal should deal with results of surveillance of the integrity of the reactor coolant pressure boundary (RCPB). Such a goal should encompass all of the components that comprise the RCPB, such as the reactor vessel, piping, steam generator tubes, safety and/or relief valves, and the reactor coolant pump seals.

C.3.4.4 Goals For Structures

It would be expected that most plant structures would fall under 50.65(a)(2) (see section C.6), however, such may not always be the case. Goals for structures could reflect such situations as a maintenance preventable failure, or the discovery of an unacceptable condition, or the discovery of deterioration that could lead to an unacceptable condition. Such situations might be plant-specific or they may be based on industry experience.

The purpose of structure-related goals would be to ensure that the structure remains capable of performing its intended function for its remaining lifetime. Such goals might refer to such considerations as limits for settlement, deflection, or mechanical impact on other SSCs.

C.3.4.5 Goals for SSCs Used in Emergency Operating Procedures (EOPs)

Licensees should establish goals for SSCs identified in EOPs commensurate with their importance to safety. Goals need not be established for those SSCs that are identified in EOPs but that do not require any maintenance or for which the licensee is not responsible for maintenance.

SSCs identified in an an EOP may be associated with goals previously established to ensure that SSC's acceptable performance, condition, or availability. For example, a loss of off-site power EOP requires the use of emergency diesel generators. However, if the emergency diesel generators are already monitored against licensee established goals, additional goals might not be needed.

C.3.4.6 Goals for Components or Classes of Components

Normally, goals would be expected to be set at the plant, system, or train level because of the complexity that is involved in setting goals for large numbers of components. However, licensees should set goals for the following components (or classes of components):

1. Risk-significant components,
2. Components that have been the cause of SCRAMs or TRIPS, or have been directly associated with the causes of challenges to safety systems, and
3. Components that failed, unacceptably degraded, or had unacceptable availability such that another goal was not met.

Goals for components or classes of components should be based on performance, condition and availability relative to the intended function of the particular component.

C.3.5 Monitoring SSCs (50.65(a)(1))

C.3.5.1 Monitoring In General

Monitoring of performance, condition, and availability as applicable, should be performed for all SSCs identified as being within the scope of 50.65(a)(1).

If a failure or unacceptable degradation of an SSC is likely to result in the loss of an intended function, monitoring efforts should be predictive, to the extent practical, in order to provide timely warning. Review of plant and industry data might provide a mechanism for predicting failure, unacceptable degradation, generic failures, common cause failures, or unacceptable availability that could occur in the future. This information may be useful to licensees for the setting of goals as well as determining the extent and frequency of monitoring.

If practical, monitoring efforts should be designed so that licensees can recognize and correct generic or common cause maintenance related failures or unacceptable degradation of SSCs. Licensees should be aware of similarities between SSCs that could be affected by maintenance practices.

Monitoring results should be analyzed in a timely fashion to ensure that goals will be met. See section C.5.7.

The frequency of monitoring can vary. Monitoring frequency may be either time directed, or based on performance or condition. The frequency of monitoring may be initially established as that currently required by existing surveillance requirements currently being performed. Subsequently, monitoring frequency would be varied, based on the ability to meet goals.

Experience gained from monitoring efforts may form the basis for requests from licensees to modify their technical specifications or other documented obligations.

The extent of monitoring may vary depending upon the type of goals established, the expected availability of the SSC, its safety or functional importance, the quality of information, and previous trends.

Monitoring efforts should provide a means for determining the effectiveness of previous corrective actions.

C.3.5.2 Monitoring at the Plant Level

Monitoring efforts at the system and component level should be aggregated and analyzed to ensure that plant goals are met.

C.3.5.3 Monitoring of System or Train Performance, Condition and Availability

Licensees should monitor the performance, condition and availability of systems or trains within the scope of 50.65(a)(1) to ensure that applicable goals are met.

System or train performance and condition may be monitored by utilizing existing surveillance procedures providing that the data collected using these procedures addresses the specific system or train goals.

For systems where maintenance of pressure boundary integrity is important to safety, licensees should monitor the condition of system or train pressure boundary integrity, as well as performance and availability, to ensure that the licensee's established goals will be met.

Licensees should monitor system or train availability if applicable. Train availability should be monitored, as needed, to detect differences in individual train availability. This is particularly important for those risk-significant systems for which it is necessary to recognize declining availability (for example, systems whose trains are unavailable relatively often, such as auxiliary feed water and diesel generators).

C.3.5.4 Monitoring the Condition of Structures

Structures that fail to meet the criteria for inclusion under the provisions of 50.65(a)(2) should be monitored against licensee established goals for failure or unacceptable degradation in order to ensure that goals will be met.

Such condition based monitoring may include activities such as non-destructive examination, visual inspection, vibration monitoring, deflection monitoring, thickness monitoring, corrosion monitoring, or other monitoring methods that the licensee may choose.

The frequency of monitoring should be sufficient to provide adequate data to indicate trends of degradation and thus allow sufficient time to take corrective action.

C.3.5.5 Monitoring SSCs Used for Emergency Operating Procedures

EOP equipment within the scope of 50.65(a)(1) is expected to be monitored during normal operation, as applicable. The focus of monitoring should be to ensure that deficiencies that could be significant during emergency conditions are highlighted and corrected in a timely manner, prior to the SSCs being required to function, and such that the licensee's established goals are met.

Monitoring is expected to be commensurate with the significance of the equipment to accomplish the EOP function.

C.3.5.6 Monitoring Component Performance, Condition, and Availability

1. Early detection of maintenance preventable generic or common cause failures,
2. Performance characteristic data that describe the ability of the component relative to its design function e.g., flow data, pressure data, pump head data, temperatures, vibration data, current data, hysteresis data, and other parameters that can indicate incipient unacceptable degradation of a component,

3. Failure or degradation data on specific equipment, including consideration of industry-wide sources for generic failure or degradation data, feedback from other programs such as design studies, original equipment manufacturer's information, root cause analysis programs, reliability-centered maintenance (RCM) programs, and equipment inservice examinations,
4. Characteristics of degraded performance of equipment as measured through non-destructive examination, oil or grease analysis, vibration analysis, ultrasonic analysis, infrared analysis, thermographic analysis, eddy current and acoustic analysis, and electric continuity analysis, and
5. Unacceptable loss of availability due to tests, surveillance, repairs, or preventive maintenance activities.

C.3.5.7 Timely Evaluation of Monitoring Results

In addition to the at-least-annual evaluation of monitoring and maintenance activities, licensees should evaluate the results, after the performance of the monitoring tasks, in a timely fashion commensurate with safety and compare the results with established goals.

If it is discovered that any goal is not met, an evaluation should be performed and appropriate, prompt, and effective corrective action must be taken (see section C.8). Licensees should also look ahead and determine if, based on their evaluation of trends, a goal will not be met by the end of the next evaluation period. If such is the case, appropriate evaluation or corrective action should be planned.

For example, the need to trend data, in order to predict if goals will be met in the future, can be seen when one considers safety-related mitigating systems. Probabilistic risk assessments usually predict that these systems will have a train unavailability of somewhere between 0.02 and 0.1. Some equipment is tested only quarterly (e.g., ASME pump and valve tests). A failure of one component on a quarterly basis could, by itself, result in a calculated unavailability of about 0.17 for a particular train for the entire year. Therefore, if the train goal is to be met, individual component performance should be trended in order to identify problems before component failure occurs.

The licensees evaluation of monitoring results if a goal is not met or if it appears that a goal will not be met, should address the following:

1. The safety significance of failure. In particular, a prompt review should be undertaken if there is a failure of a component or a train that is expected to have a very high reliability (e.g., scram breaker, safety-related pipe, etc.).
2. The SSC's maintenance history including trends of previous failures, corrective actions, previous root cause determinations, pertinent industry data, surveillance information, original design and application data, availability and reliability data, as applicable.
3. The importance of the SSC's function, its relative risk associated with its removal from service during each mode of operation including shutdown, i.e., what is the best time to make the SSC inoperable.
4. Generic or common cause implications of similar or identical failures on other SSCs.
5. Preventive maintenance tasks that could address the most probable or risk-significant failure modes and generic or common cause considerations, as applicable.
6. Frequency of preventive maintenance, either time- directed or condition based, and the basis for the schedule.
7. Availability of the SSC.
8. Assessment of those actions that might be accomplished to increase the SSC's reliability while simultaneously maintaining or increasing it's availability, as applicable.

C.3.6 Activities Governing the SSCs Selected for Inclusion Under 50.65(a)(2) As An Alternate Approach to Goal Setting and Monitoring

SSCs may be maintained under the guidance provided in 50.65(a)(2) if:

1. The criteria of section C.3 of this regulatory guide have been satisfied, and
2. It is demonstrated that the performance, condition, and availability of a SSC is being effectively controlled through the performance of appropriate preventive maintenance such that the SSC remains capable of performing its intended function.

Licensees should determine that an acceptable history of satisfactory performance, condition, and availability exists for those SSCs that are to be maintained under the provisions of 50.65(a)(2).

Systems that have been selected for inclusion within the scope of 50.65(a)(2) but that experience unacceptable unavailability or unacceptable degradation at the system or train level should promptly be subjected to the provisions of 50.65(a)(1).

Safety-related components (50.65(b)(1)) and non-safety-related components whose failure could prevent safety-related SSCs from fulfilling their safety-related function (50.65(b)(2)(ii)) that have been selected for inclusion within the scope of 50.65(a)(2) but that experience unacceptable unavailability, unacceptable degradation or any maintenance preventable failures should promptly be subjected to the provisions of 50.65(a)(1).

Non-safety-related components that are relied upon to mitigate accidents or transients or are used in EOPs (50.65(b)(2)(i)) and non-safety-related components whose failure could cause a reactor scram or actuation of a safety-related system (50.65(b)(2)(iii)) that have been selected for inclusion within the scope of 50.65(a)(2) but that experience unacceptable unavailability, unacceptable degradation or any maintenance preventable failures should be subjected to root cause analysis as described in section C.8.2 and placed under the provisions of 50.65(a)(1) if the results of the root cause analysis so indicate.

Structures or passive components within the scope of the maintenance rule that have been selected for inclusion within the scope of 50.65(a)(2) but that experience unacceptable degradation or any maintenance preventable failures should be subjected to root cause analysis as described in section C.8.2 and placed under the provisions of 50.65(a)(1) if the results of the root cause analysis so indicate.

A SSC may be returned to the provisions of 50.65(a)(2) after having been subjected to the monitoring requirements of 50.65(a)(1) when:

1. A root cause analysis of failure, unacceptable degradation, or unacceptable unavailability has been completed, and corrective actions implemented, as necessary, and
2. A demonstrated history of effective maintenance has been established, for a period of at least three surveillance cycles or one evaluation cycle (50.65(a)(3)), whichever is longer.[1] Effective maintenance is demonstrated by acceptable performance, condition, and availability of SSCs. If failures, unacceptable degradation, or unacceptable unavailability of identical or similar SSCs is observed, or has been previously experienced, demonstration of acceptable performance, condition, and availability of the particular SSC over a longer period should be expected, in order to achieve a higher level of confidence.

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1 See footnote 4.

3. As an alternative to 1 and 2 above, a technical evaluation indicates that a structure or component is of low enough risk-significance such that failure, degradation, or unavailability can be tolerated. This evaluation should be made using a formal assessment method such as one of the two methods described in NUREG/CR-5695, dated March 1991, "A Process for Risk-Focused Maintenance." Other deterministic or risk based methods may also be found to be acceptable for such an evaluation.

   This alternative does not apply to systems within the scope of the maintenance rule, safety-related components, or non-safety-related components whose failure could prevent safety-related SSCs from fulfilling their safety-related functions.

Effectively controlled preventive maintenance should include, as applicable:

1. Periodic maintenance based on time or condition, replacing, servicing, inspection, and testing,
2. Predictive maintenance, inspection, and testing,
3. Root cause analysis and trending of failures or unacceptable degradation,
4. Evaluation and feedback of testing and surveillance results to the preventive maintenance activities,
5. Corrective maintenance, performed as part of normal periodic maintenance, repair, overhaul, or replacement, as necessary, and
6. Post-maintenance testing.

C.3.7 At-Least-Annual Evaluation of Maintenance Activities, Goals, and Monitoring Activities (50.65(a)(3))

C.3.7.1 At-Least-Annual Assessments In General

At least annually, each licensee should perform an integrated evaluation of the results of monitoring and maintenance activities. Licensees should consider plant maintenance and monitoring results of the previous 12 months, pertinent industry experience data during that same period, results from previous plant evaluation cycles, and pertinent historical industry data.

The scope of evaluation of the goals, monitoring, and maintenance activities includes SSCs under the provisions of both 50.65a(1) and 50.65(a)(2).

The purpose of the at-least-annual evaluation is to assess the effectiveness of maintenance, monitoring, and goal setting activities so that any necessary adjustments can be made.

Adjustments may need to be made to goals, and should be made to monitoring activities or maintenance activities if goals are not met, or if it can reasonably be expected that goals will not be met. Any modifications that are made to maintenance activities should be done within the constraints of existing regulations and licensee commitments.

Alternatively, in those cases where goals are met, licensees might choose to modify, expand, or eliminate goals, monitoring activities, or maintenance activities within the constraints of regulations or licensee commitments, in order to improve the efficiency and effectiveness of their maintenance efforts.

It is understood that many licensees do not complete a full cycle of maintenance activities in one year. Nevertheless, licensees must make the evaluation on a yearly basis as required by the maintenance rule. In such cases, licensees should consider previous cycles of evaluation as well as historical data in order to provide a complete picture of their monitoring and maintenance activities. It should not be inferred that licensees need to change the schedule of maintenance, surveillance, testing, or monitoring activities in order to complete their annual evaluations.

These at-least-annual assessments should address:

1. The success of monitoring activities in relation to meeting established goals,
2. The success in identifying and promptly correcting generic or common cause failures,
3. The maintenance preventable unavailability or unreliability, during the assessment period, of SSCs relative to that reliability and availability assumed in the plant risk analysis,
4. The effectiveness of maintenance activities in relation to meeting the licensee's established goals,
5. Monitoring and maintenance actions that can be taken to improve or ensure SSC reliability, while simultaneously balancing or even decreasing the unavailability if the SSC is removed from service for monitoring or maintenance,
6. SSC failures, and detected unacceptable degradations
7. Industry-wide operating experience related to failures or unacceptable degradations experienced by the licensee, and

8. The licensee's evaluations of monitoring results described in section C.5.7 of this regulatory guide.

Individual components of certain systems or trains may fall under the provisions of 50.65(a)(2) even though the system in which the component is installed is under the provisions of 50.65(a)(1). The licensee's evaluation of whether the system or train goals were met, in accordance with 50.65(a)(3), should consider the unavailability, failure, and unacceptable degradation of such components even if the components are under the provisions of 50.65(a)(2).

C.3.7.2 Balancing Reliability and Unavailability

The provisions of the maintenance rule require that adjustments be made to goals, monitoring activities or maintenance activities where necessary to ensure that the objective of preventing failures of SSCs is appropriately balanced against the objective of minimizing unavailability of SSCs because of monitoring or preventive maintenance.

This balance can be achieved by:

1. Ensuring reliability, as stated in plant risk analysis, Final Safety Analysis Report or other sources, by the use of effective maintenance practices,
2. Evaluating the reliability and availability (or unavailability) of SSCs,
3. Scheduling the amount, type, or frequency of preventive maintenance to ensure that the time out of service is acceptable, while maintaining reliability (for example, performing additional condition monitoring instead of removing SSCs from service for preventive maintenance), and
4. Focusing maintenance resources on those failure modes that are critical to SSC reliability.

In the annual assessment, licensees should consider two issues regarding the need for , and scheduling of, maintenance. One issue involves licensees looking back and assessing maintenance history to determine if maintenance, particularly preventive maintenance, is appropriate. The second issue, discussed in section C.9, involves licensees looking ahead when scheduling maintenance and assessing the merits of the strategy for scheduling multiple simultaneous equipment outages.

Assessing how much maintenance is appropriate involves considerations such as balancing the amount of time, as well as the schedule, that a SSC is out of service due to maintenance, against the likelihood that maintenance errors will cause SCRAMs or TRIPs, or challenges to safety systems.

Balancing reliability and unavailability could be enhanced by reviewing preventive maintenance tasks or monitoring activities, determining the bases for the type and frequency of maintenance, examining maintenance and failure rate history, and evaluating the results. Based on the results of such actions, maintenance tasks could be initiated, increased, adjusted, or deleted.

C.3.8 Corrective Actions

C.3.8.1 Corrective Actions In General

Timely corrective action is to be taken if goals are not met. Such action should include an appropriate root cause analysis to determine why the goal was not met.

The at-least-annual assessment of goals, monitoring, and preventive maintenance activities should provide indications of the appropriate corrective actions to be taken to preclude recurrence of failure to meet goals and actions to appropriately balance reliability and unavailability.

If significant deviations are noted from the assumptions used in or the expected results of plant risk analyses, such information should be reflected in the plant risk analysis and specifically addressed in the annual evaluation. In such cases, licensees should determine whether an assessment is needed to justify continued operation of the plant.

The at-least-annual evaluation of goals, monitoring activities, and maintenance activities is considered most important because it provides an indication of the overall effectiveness of maintenance at the facility. The annual assessment is central to the objective of monitoring the effectiveness of maintenance. The evaluation of the feedback from the evaluation of goals, monitoring activities, and maintenance activities provides an indication of where improvements should be made.

C.3.8.2 Root Cause Analysis

Root cause analysis should be performed promptly after any of the following:

1. Single occurrences of the following:

a) Failure to meet a goal,

b) A failure of a risk significant SSC,

c) A common cause failure of SSCs, or

d) A significant plant event.

2. Repetitive occurrences (within one year) of:

a) Generic or common cause failures of the same or like SSCs monitored under 50.65(a)(1),

b) Failures, unacceptable degradation, or adverse trends within the same system,

c) Failure to meet a goal,

d) Maintenance related human errors resulting in SSC failures,

e) Cumulative poor overall component, system, or train performance, condition, or availability, or

f) Plant events in a single area of performance, condition, or availability of SSCs.

Root cause analysis should be performed in sufficient detail commensurate with the safety significance of the SSC as well as the potential for common cause failures.

A detailed analysis should be performed if a failure was catastrophic or without warning. A more simplified analysis may be performed if warning of failure or signs of unacceptable degradation appear in advance of failure. However, the cause which allowed the degradation or failure signs to persist without timely corrective actions should be addressed in addition to the failure mechanism.

Root cause analysis is discussed and illustrated in Attachment 4.

C.3.8.3 Short Term Corrective Actions of Routine Evaluation Results

Corrective actions for the most apparent cause of failure or unacceptable degradation should be pursued in a timely fashion after the unacceptable condition is recognized. These actions should be documented and trended to ensure their effectiveness. Actions should be taken to restore the SSC to its required capabilities, including reliability and availability. The SSC should then be tested, if appropriate, to verify its function and characteristics.

If returning the SSC to its required capabilities is not economically justified or is not technically feasible, and a root cause analysis has not been performed, then compensatory measures (e.g., additional monitoring or testing) should be implemented. Compensatory measures should remain in effect until the licensee is confident that the corrective actions taken will be effective and the root cause or causes have been identified and corrected.

Actions that may have been taken for repetitive or reasonably similar failures and for which the previous corrective actions were not effective should be subjected to a management review to ensure that the correct root cause is adequately addressed prior to returning the SSC to service.

C.3.9 Assessment of Out-of-Service Equipment On Plant Safety Functions (50.65(a)(3))

Licensees are to assess the cumulative impact on plant safety functions prior to equipment being taken out of service for maintenance. Assessing the cumulative impact of out-of-service equipment on the performance of safety functions, is intended to minimize the amount of time that the plant is placed in risk-significant configurations. This assessment is to be performed routinely for each mode of operation, up until such time that all fuel is removed from the site.

Adjustments to surveillance, testing, and maintenance may be indicated by these assessments. These adjustments may be more demanding than current regulatory requirements or licensee commitments, or alternatively, may form the bases for modified or reduced maintenance activities or for requests for reduced regulatory requirements. In those instances when a current regulatory requirement or licensee commitment is not involved, licensees may decide to reschedule, modify, augment, or curtail maintenance activities, based on their assessments of the effect on plant safety. In those instances when a regulatory requirement or licensee commitment is in potential conflict with a desired adjustment, based on licensee assessments with regard to surveillance, testing, or maintenance, the NRC should be informed and a change requested.

The continuous assessment does not necessarily require that a quantitative assessment of probabilistic risk be performed. The level of detail and effort with which the assessment is performed is expected to vary, depending on the circumstances involved. The continuous assessment is initially expected to vary in the level of detail and complexity and then develop, along with industry experience.

Initially, the continuous assessment of the impact of out of service equipment on plant safety functions could take the form of one or more of the following options:

1. Guidelines for removing SSCs from service based upon previous evaluations of the potential effects of the out of service (OOS) condition of the SSC. Appropriate compensatory actions may be needed prior to removing the SSCs from service.

2. A deterministic judgement, based on a structured approach, such as a Management Oversight Risk Tree analysis, barrier or change analysis, or other analysis. The analysis should support the conclusion that safety functions (not limited to safety-related SSCs), both operating and shutdown, are not degraded.
3. An on-line, risk-based configuration management system, such as an ongoing and regularly updated PRA. Assumptions used in the PRA should be validated through the monitoring of SSC performance. The PRA should then be updated.

It is expected that assessments of this type will be refined by the licensee over time, based on technological improvement and feedback from both plant and industry experience.
Scheduling of preventive maintenance activities should be carefully considered by licensees as part of their monitoring efforts. The risk associated with maintenance activities and the availability of SSCs can depend on the plant mode, the cumulative effect of equipment out of service, and the success paths available to respond to potential accidents at the time when the maintenance activities are performed.

For example, scheduled maintenance of high pressure injection pumps may best be performed during periods of cold shutdown when these pumps are not needed. Similarly, diesel generator scheduled maintenance should be performed based on an evaluation of when emergency power would be needed least as well as on the availability of off-site power sources. The problem of when to take a PWR residual heat removal system out of service for maintenance is somewhat more complex because the system is potentially in demand during power operation and usually in service during shutdown. Consideration of the optimum times for preventive maintenance would be in order for such a system.

C.3.10 Data Collection and Documentation

Licensees should establish and maintain sufficient data and information so that they can consistently implement and determine the effectiveness of their maintenance and monitoring efforts. Documentation of data and information may be excluded from the licensee's quality assurance program unless the documentation used is already part of that program. Such data and information should include:

1. Process for:
   a) Setting goals and monitoring,
   b) Immediate evaluation of monitoring results as well as results of at-least-annual assessment of goals, monitoring efforts, and maintenance activities,
   c) Feedback and adjustment of goals, monitoring and maintenance activities,

2. Identification of plant-specific SSCs within the scope of the maintenance rule along with bases for selection and subsequent sorting of each SSC under 50.65(a)(1) or 50.65(a)(2),
3. Identification of goals, including the rationale for their selection,
4. Results of monitoring, along with root cause analyses if applicable, for plant specific SSCs covered by the rule, over the preceding 5 years or since the rule took effect, whichever is less,
5. Results of at-least-annual assessments, as appropriate, for plant specific SSCs within the scope of the maintenance rule, including:
    a. Evaluation of the effectiveness and applicability of goals that were met, as well as goals that were not met, along with corrective actions and root cause analyses,
    b. Performance monitoring, condition monitoring, and preventive maintenance activities,
    c. Feedback and corrective actions from monitoring and preventive maintenance assessments,
    d. Failure, unavailability, and unreliability data, as appropriate,
    e. Evaluations made of the balance between reliability and unavailability arising from maintenance activity,
    f. Adjustments to goals, performance monitoring activities, condition monitoring activities, and preventive maintenance activities made (or not made) in order to improve the results of maintenance as well as the reliability/unavailability balance for specific SSCs,
    g. Incorporation of industry operating experience and feedback into monitoring and maintenance activities, and
    h. Explanation of deviations from assumptions and results previously used in applicable plant risk analyses

The feedback of data that provides information concerning the performance, condition and availability of SSCs is an important part of any maintenance-effectiveness monitoring program that complies with the requirements of the maintenance rule. To this end, licensees should collect and analyze plant-specific data on failure, availability, and reliability for the SSCs within the scope of the rule. It is suggested that all licensees would benefit if the data has a structure and format suitable for use in an industry-wide database that could allow them to analyze and compare data from other facilities with their own.

C.4 IMPLEMENTATION

This section of the regulatory guide provides information to licensees regarding the NRC staff's plans for using this regulatory guide.

This draft regulatory guide has been released to encourage public participation in its development. The regulatory guide is to be published in final form, after consideration of public comments, by June 30, 1993.

The maintenance rule becomes effective in July 1996. The NRC plans to conduct public workshops, instructional audits, and trial inspections and to provide formal instruction programs for NRC personnel during the three years from July 1993 to July 1996. Supplements or modifications to this regulatory guide may be published during this period as a result of feedback from this process .

Except in those cases in which a licensee proposes an acceptable alternative method of complying with specified portions of the NRC's regulations, the method to be described in the final regulatory guide will be used for evaluating compliance with 10 CFR 50.65.

Licensees are not required to submit their maintenance programs to the NRC for review and approval. Licensees are not required to report implementation progress toward meeting the requirements of the rule directly to NRC. The NRC will conduct on-site inspections, within the scope of its normal inspection process, to determine if the individual efforts of licensees conform to the requirements of the rule.

The NRC staff's guidance in this regulatory guide does not authorize, endorse, or intend to recommend any action that would be in conflict with any regulation or any established licensee commitment. Licensees are encouraged to communicate with the NRC if such conflicts are encountered or anticipated.

Attachment 1

GLOSSARY

Active Component: A component that normally is operating or can and should change state under normal operating conditions or in response to accident conditions (e.g., pumps, valves, switches). (Source: NUREG/CR-5695.)

Alert Value: A pre-established value for equipment failure or unavailability rate to identify when systems, trains, or components are reasonably close to not achieving their availability or reliability goal or goals.

Analysis: A process of mathematical or other logical reasoning that leads from stated premises to the conclusion concerning specific capabilities of a SSC and its adequacy for a particular application.

Availability: The time that a SSC is capable of performing its intended function as a fraction of the total time that the intended function may be demanded. The numerical complement of unavailability. Note that availability includes reliability.

Capability: The ability of a SSC to perform its intended function. Capability includes availability .

Common Cause Failure: Multiple failures attributable to a common cause.

Condition: The state of readiness of a SSC to perform its intended function. Condition refers to passive properties of SSCs when they are subject to mechanisms that cause deterioration such as corrosion, erosion, wear, etc.

Critical Components: Components whose capability must be maintained in order to ensure that the system or train, of which the component is a part, will continue to perform its intended function.

Failure: Unintended cessation of function of a SSC. Failures can be classified as:

Immediate (Catastrophic): Failure of equipment that is both sudden and complete.

Degraded: A failure that is gradual, partial, or both; the equipment degrades to a level that, in effect, is a termination of the ability to perform its required function.

Incipient: An imperfection in the state or condition of equipment that could result in a degraded or immediate failure if corrective action is not taken.

Generic Failure: Failure of more than one identical component or part of a component due to the same or similar cause or causes. Generic failures may or may not be common mode failures.

Maintenance: The aggregate of those functions required to preserve or restore safety, reliability, and availability of plant s ctures, systems, and components. Maintenance includes not only activities traditionally associated with identifying and correcting actual or potential degraded conditions, i.e., repair, surveillance, diagnostic examinations, and preventive measures; but extends to all supporting functions for the conduct of these activities. (Source: Federal Register/ Vol. 53, No. 56/ Wednesday, March 23, 1988/ Rules and Regulations/ page 9340.)

Maintenance-Preventable Failure: A maintenance-preventable failure is an unintended event or condition such that a SSC is not capable of performing its intended function and that should have been prevented by the performance of appropriate maintenance actions by the licensee. Under certain conditions a SSC may be considered to be incapable of performing its intended function if it is out of specified adjustment or not within specified tolerances.

A failure of a SSC is not considered to be a maintenance-preventable failure if:

1. The state or condition of the failed SSC was evaluated, prior to failure, by the licensee and it was determined that its failure could be accepted because the failure would have insignificant impact on the objectives of this regulatory guide (see DISCUSSION section) and the requirements of the maintenance rule, or

2. The SSC failed because of "new component mortality," design deficiency (providing the deficiency was not previously identified and left uncorrected).

Monitoring: Periodically gathering, trending, and evaluating information pertinent to the performance, condition, and availability of SSCs, and comparing the results with previously established goals in order to verify that the goals have been met and that maintenance activities are effective.

As used in this regulatory guide, monitoring is specifically oriented toward gathering information so that it can be determined that a licensee's goals ((50.65(a)(1)) have been met. Thus, the surv or testing that is conducted as part of normal preventive maintenance, as described in documents such as technical specifications or ASME code requirements, is not considered monitoring in the context of this regulatory guide unless it is associated with meeting goals to establish the effectiveness of maintenance activities.

Passive Component: A component that cannot or should not change state under normal operating conditions or in response to accident conditions (e.g., piping, tanks, reactor vessel, heat exchangers). (Source: NUREG/CR-5695.)

Preventive Maintenance: The aggregate of all those actions necessary to maintain SSC intended function and reduce the probability of SSC failure in subsequent service by preventing their unacceptable degradation. Preventive maintenance activities are expected to include periodic or predictive maintenance activities, as well as diagnostic testing, trending of failures, or trending of unacceptable degradation, as appropriate.

Performance: The measured or assessed ability of an active SSC to accomplish its intended function. Performance compares how well a SSC carries out its function when measured against its designed or intended capability.

Reliability: A measure of the expectation (assuming that the SSC is available) that the SSC will perform its function upon demand at any future instant in time. For example, for an active system or component, reliability can be expressed as the probability that the system or component will start on demand, continue to run, and will perform its intended function (e.g., a pump will deliver the required flow at the required head). For a passive SSC, reliability can be expressed as the probability per unit time that the SSC will continue to fulfill its intended function. Note that reliability is a component of availability.

Reliability Centered Maintenance: A series of orderly steps for identifying system functions, sub-system functions, functional failures, and dominant failure modes, ranking them, and selecting applicable and effective preventive maintenance tasks to address the classified failure modes.

Root Cause: The root cause (of failure, unacceptable degradation, or unacceptable unavailability) is the most basic in depth cause of an occurrence, that when removed, will prevent recurrence and permit the return of the SSC to service.

System: A collection of components that is configured and operated to serve some specific plant function (e.g., The feedwater system provides water to the steam generators. The containment spray system sprays water into the containment. The high pressure coolant injection system injects water into the primary system.)

Unacceptable Degradation: The level of deteriorated performance, condition, or availability of a SSC that the licensee determines must be avoided in order for a SSC to continue to perform its intended function. Degradation of SSCs is expected in service and licensees must ensure that SSCs are maintained so that the level of degradation remains acceptable.

Unavailability: The numerical complement of availability. A SSC may become unavailable as a result of the item being maintained (inspected, tested or repaired, i.e., maintenance unavailability) or as a result of undetected malfunctions (i.e., unannounced unavailability). (Note: A system or component need not be considered unavailable during testing if appropriate compensatory measures have been taken to ensure that its required function will be performed during testing.)

Unidentified Failure Initiators: Those causes of failure or unacceptable degradation that exist within SSCs for which the root cause has not been determined. Unidentified failure initiators thus remain capable of causing additional failures or unacceptable degradation.

THE FOLLOWING ATTACHMENT IS PROVIDED FOR ILLUSTRATION ONLY.

Attachment 2

EXAMPLES FOR SETTING GOALS AND MONITORING

1. DESCRIPTION OF POSSIBLE GOALS

1.1 Overall Plant Goal

One overall plant goal could be to not exceed an estimated core melt frequency. This could be demonstrated, in part, by showing that the reliability and availability values used in the plant-specific PRA or IPE, for major accident mitigation systems, are valid. The plant-specific PRA should reflect actual system and component failure and unavailability data. The revised calculations of core melt frequency can then be compared to the previous PRA or IPE calculations. This approach may show that the overall plant goal is being met even if all the individual mitigating systems are not achieving their reliability and availability goals, because some SSCs are more reliable and available.

1.2 System Level Goal

Attachment 3 provides a quantitative example of using a plant-specific PRA to establish reliability/availability goals for an accident mitigation system.

Licensees might consider establishing goals based on the following three complementary indicators of safety system unavailability:

1. Unavailability Indicator. To recognize the degrading availability of risk-significant systems whose trains fail relatively often, such as AFW and diesels, the licensee may use an average train unavailability indicator.
2. Condition (or failures) of Highly Reliable Components. The licensee may trend the condition of risk-significant components that rarely fail.
3. Common Cause Failures. Failures of classes of components, such as pumps and valves can be statistically analyzed to determine if certain failures are not independent.

1.3 Component Level Goals

Component goals should be based on performance, condition, availability, or a combination of these. For active components, it is expected that the goals will include at least some performance-based elements, including reliability and availability. For passive components, it is expected that the goals would be largely condition oriented.

For example, goals for a heat exchanger might include:

- Minimum flow as specified in the FSAR
- Maximum outlet temperature
- Minimum delta temperature
- Rate of increase in marine growth/Bio-fouling
- Rate/numbers of tubes plugged
- Rate/numbers of tubes with eddy current indications
- Rate of erosion and/or corrosion of bell housing.

2. EXAMPLES

2.1 Goals and Monitoring for Risk-Significant Standby Safety System

The following is an example of goal setting for a safety system composed of redundant trains that can be expected to fail occasionally (e.g., electro-mechanical trains).

A licensee has found that the emergency core cooling system (ECCS) unavailability modeled in the PRA corresponds to an ECCS average train unavailability of one percent. Therefore, the licensee selects one percent average train unavailability as a goal for the ECCS system.

The licensee might compare ECCS performance with respect to these goals in the following ways:

The licensee might monitor the performance of ECCS components and use reliability analysis methods to aggregate the component performance to estimate average train unavailability. The licensee thereafter might use statistical analysis to evaluate whether this measure of average train unavailability meets the one percent goal.

The licensee could also evaluate the extent to which the failure rates of similar components are independent of each other. The extent to which the failure rates are dependent is analyzed to estimate whether the likelihood of common cause failure could be significantly greater than the one percent goal. If the goal is significantly exceeded, the licensee would be expected to determine the causes and take appropriate corrective action.

2.2 Goals and Monitoring for Very Risk-Significant Standby Safety System Composed of Highly Reliable Redundant Trains

A licensee has determined that the reactor trip system has always been available on demand. That is, its unavailability is too small to measure and trend. In fact, it has been an objective of the maintenance efforts at this plant to prevent failure of even one shutdown rod to drop on time. Therefore, the licensee decides to establish goals of no failures of reactor trip breakers and no failure of a rod to drop.

To ensure achieving these goals, the licensee decides (1) any failure of a scram breaker will be brought to management attention and (2) to monitor and trend the rod drop times in order to be able to recognize degradation before failure occurs. The alert level set here might be no degradation in rod drop time, so that if degradation does occur, it will be identified for the attention of management.

2.3 Goal and Monitoring for BOP System Whose Failure Can SCRAM or TRIP the Reactor or Challenge Safety Systems.

A licensee has found that main feedwater problems caused about half of the reactor trips. The licensee has taken corrective action for each of these main feedwater problems as part of a trip reduction program. The licensee estimates that if these corrective actions are successful, the reactor trip rate will be reduced to about 1 automatic trip per year. This trip rate is selected as a goal.

In addition, the licensee is concerned about erosion causing thinning of the main feedwater piping with age. The licensee has instituted a non-destructive examination program to periodically monitor and trend the condition of the high pressure feedwater piping. The licensee sets an alert value that thinning will not exceed 8 percent of the wall thickness, an action required value of 12 percent, and a goal of 15 percent. These goal, alert, and action-required values ensure that if the trend in pipe wall thinning is excessive, the causes can be found and time will be available for corrective actions to be taken prior to the pipe wall thickness being reduced below the minimum wall thickness specified by the ASME code (20 percent for this pipe).

2.4 Goal for Equipment Used in EOPs

A goal for equipment used in EOPs might be successful completion of all EOPs used during an emergency exercise with no more than one equipment failure, two "significant" component deficiencies, or three "minor" deficiencies. The attributes of "significant" and "minor" deficiencies would be defined by the licensee.

THE FOLLOWING ATTACHMENT IS PROVIDED FOR ILLUSTRATION.

Attachment 3

AN EXAMPLE OF MONITORING UNAVAILABILITY OF AUXILIARY FEEDWATER SYSTEM TO RECOGNIZE AND CORRECT PERFORMANCE DEGRADATION, UNDER 50.65(a)(1)

This example describes how a utility can monitor the performance of the auxiliary feedwater (AFW) system. The steps include: (1) identifying the risk-significant parts of the AFW, (2) setting appropriate performance goals, (3) selecting a performance monitoring program for the important parts of the system, (4) establishing alert levels to flag performance that deviates from these goals, and, where performance deviates from the goal, (5) finding the causes and correcting them.

1. Identification of Risk-Significant Equipment and Setting Overall AFW Goal

The AFW system at the utility's Plant A (a PWR) has three trains: two motor-driven and one turbine driven. Each train is designed to provide sufficient flow to remove heat from the reactor coolant system when main feedwater is unavailable and the reactor coolant pressure is too high to permit heat removal by the RHR system.

The utility had performed a probabilistic risk assessment (PRA) of Plant A.

The plant selected a goal that AFW performance should not degrade beyond the plant-specific PRA estimate of the mean value of AFW unavailability; that is 3×10^{-4}. This corresponds to the AFW function being unavailable about 3 hours per year.

In order to identify the risk-significant aspects of AFW, the utility examines the plant-specific PRA cutsets (combinations of failures) that result in AFW unavailability. These combinations of failures that can lead to loss of AFW function can be considered in three categories: single component failures, common cause failures, and multiple train failures. These three categories are considered separately, as described below.

2. Single, Non-Redundant Component Failures

The single-component cut sets are addressed as follows.

There are only a few single-component cut sets, i.e., where there is no redundancy. These failures are important to prevent.

In this example, one of these single-component cut sets is the inadvertent opening of a cross-connect valve to the other unit on the site. This accounts for half of the predicted AFW unavailability. The other single failure that can cause loss of AFW is insufficient water in the condensate storage tank. The utility can ensure that these two potential single failures are prevented through a combination of surveillance, condition monitoring, and training.

3. <u>Common Cause Failures</u>

The second most important causes of unavailability of AFW are predicted in Plant A's PRA to be common cause failures. The most risk-significant of these common cause failures consists of back-leakage of hot fluid from the feedwater line through certain check valves such that the water at the inlet of the AFW pumps exceeds a limiting temperature. Since all three AFW pumps are supplied from a common inlet pipe, back-leakage through two check valves can adversely affect all three pumps. In that event, the pumps would cavitate when started. Other important common cause failures are failures of both motor driven AFW pumps.

The utility can analyze these potential common causes, and can develop a combination of surveillance, condition monitoring, and training to prevent their occurrence. In addition, the utility can monitor the time between instances of degradation of these items to monitor the extent to which degradations are either random or else dependent (e.g., common cause).

To illustrate the risk importance of common cause failures, it should be noted that in the PRA for plant A, it was estimated that the contribution to AFW unavailability from common cause failures was about 1.2×10^{-4}. This value would be exceeded if all three trains were unavailable for more than about an hour during a one year period. Therefore, it is extremely important that the surveillance program and the frequency of surveillance be directed to detecting incipient problems (e.g., detecting back-leakage before all three AFW trains are adversely affected).

4. <u>Redundant Trains</u>

As described above, in this example, the utility management set a goal that AFW availability should not degrade below the performance postulated in the PRA. Since unavailability is expected to vary randomly, an alert level can be selected to flag when performance appears to be outside the expected range. One way to do this is to use a statistical control bound, or alert level, as outlined in this example.

5. Setting an Unavailability Goal for Redundant Trains

After both the single-component cut sets and the common cause cut sets are subtracted, the remaining cut sets that result in loss of AFW involve random unavailability of each of the three trains. The PRA predicts a mean frequency of 1.0×10^{-5} for the sum of these cut sets involving random unavailability of three trains. This corresponds approximately to an average train unavailability of 0.02, as shown below.

Thus the utility set the goal for average train unavailability as 0.02. The utility differentiates random variations in performance from significant deviations from this goal by setting alert levels, using methods from statistical process control.

This average train unavailability of 0.02 corresponds to about one train failure per year (for a three train system with a one month surveillance test interval). If some equipment in a train is only tested quarterly (e.g., ASME required pump or valve testing), a failure of one component could, by itself, represent an unavailability of about 0.12 for that train for the entire year. Therefore, to meet the train unavailability goal, the utility should monitor and trend the condition of selected components to recognize degradation and correct it before failures occur.

6. Method for Measuring Performance of Redundant Trains

Unavailability is the probability that, at a randomly selected time during any time period, the equipment will not function on demand. Unavailability can be estimated as the fraction of time when the equipment was unable to function. The utility estimates random unavailability of AFW trains as follows:

Q = Unavailability of AFW system

= (train #1 unavailability) x (train #2 unavailability)

x (train #3 unavailability).

q = Train unavailability

= Fraction of time train was unable to function

$$q = \frac{\text{(Out-of-service Time) + (Fault-Exposure Time)}}{\text{(Time)}}$$

The terms in this equation are defined as follows:

Fault-exposure Time	=	1/2 the time interval from last operation to discovery of malfunction or error that resulted in the train being unable to perform its function
Out-of-service Time	=	Hours that train was out of service for maintenance or other administrative reasons.
Time	=	Time period over which the unavailability is measured (for example, 1 quarter or 1 year).

Each quarter, the utility estimates the AFW unavailability experienced during a selected time period, such as the previous four quarters.

This measure of train unavailability can be smoothed by averaging the result from the three individual trains to give an average train unavailability. This approach is similar to the INPO indicator of safety system performance.

7. <u>Method for Setting Alert Level for Redundant Trains</u>.

This section describes how an alert level can be set to differentiate when the performance deviates from the goal.

The performance goal is envisioned as established by management. In this example, plant management set a goal that AFW performance should be consistent with the PRA. To determine whether random variations in AFW train unavailability are or are not consistent with this goal, a performance analyst can develop alert levels for train unavailability in the following way.

First the overall goal for AFW unavailability is adjusted to subtract out the contributions due to the single component failures and common cause failures addressed separately, above. As described above, the combinations of failures that involve loss of three trains without common cause failures corresponds to a system unavailability of 1.0×10^{-5}. The cube root of this corresponds approximately to an average train unavailability.

q = Target average train unavailability

$$q = \sqrt[3]{Q}$$

$$q = \sqrt[3]{10^{-5}}$$

$$q = 0.02$$

The target average train unavailability can also be expressed in terms of train failure rate (or, equivalently, repair frequency) and maintenance frequency as follows:

$$q = \lambda_f (T/2) + (\lambda_f + \lambda_m) t$$

where:

λ_m = Frequency (per hour) of outages for preventive maintenance or other administrative reasons.

λ_f = Frequency (per hour) of independent train failures

T = Surveillance test interval

= 720 hours.

t = Allowed outage time

= 72 hours.

Note: It is assumed that $\lambda_f T$, probability of failures during the test interval, is sufficiently small so that the probability of more than one failure can be neglected.

In this example, the utility's review of previous experience at plant A indicates that, on the average, AFW trains are taken out of service for preventive maintenance four times more frequently than they are taken out of service for repair. That is:

$$\lambda_m = 4 \lambda_f$$

Therefore, $q = \lambda_f (T/2) + (\lambda_f + \lambda_m) t$

$$q = \sqrt[3]{10^{-5}}$$

Thus, the expected train ...ure rate and maintenance rates corresponding to the goal are calculated as follows:

$$\lambda_f (T/2 + 5t) = \sqrt[3]{10^{-5}} = 0.02$$

$\lambda_f = 3.0 \times 10^{-5}$ per hour

$\lambda_m = 1.2 \times 10^{-4}$ per hour

This train failure rate and maintenance frequency are then used to calculate the probability of 0, 1, 2, 3, or more train failures during a year. With this information, the utility can set alert levels to differentiate random variations in train unavailability from significant deviations from the goal. The method the utility uses for setting an alert level for train unavailability is to set thresholds to compare with measured the measured values of train unavailability. In this example, the utility selects, as alert levels, significance levels of 90% and 95%.

The probability that 0, 1, 2, 3 or 4 train failures will occur during the observation period (one year in this example) is approximated by a Poisson distribution.

The Poisson distribution for the probability of n train failures during the observation period is:

$$P(n_f, T_{obs}) = \frac{(\lambda_f, T_{obs})^{n_f} e^{-T_{obs}}}{n_f!}$$

where:

T_{obs} = The observation period. In this example for a three-train system, the observation period used in the equation is three times the actual observation period: e.g., one year on each of three trains.

n_t = The number of failures among the three trains summed over the observation period.

For this example, the values calculated from this distribution of the total number of train failures among the three trains are listed in Table 1. Table 1 also lists the contribution of these failures, and subsequent repairs, to average train unavailability.

Table 1

Poisson Distribution of Number of Train Failures Expected (in This Example) in Aggregate of Three AFW Trains During One Year.

Number of Train Failures	Probability of This Number of Failures	Train Downtime Due to Failures and Repair Time (hours)	Train Unavailability Due to Failures and Repair Time
0	0.45	0	0
1	0.36	432	0.016
2	0.14	864	0.033
3	0.04	1296	0.049

The unavailability due to preventive maintenances, in this example, can be calculated from a Poisson distribution with a maintenance frequency four times larger than the failure rate used to calculate the entries in Table 1. (As discussed above, in this example, the frequency of train maintenance outages has historically been four times the frequency of train failures.) The values in this Poisson distribution are summarized in Table 2. Table 2 also list the contribution of these preventive maintenances to average train unavailability.

These two distributions for unavailability due to failures & repair and due to preventive maintenances (Tables 1 and 2) are combined in table 3. Thus, in Table 3, one can read down the cumulative probability column to .9075 to determine that an alert level corresponding to a 90% confidence level is an average train unavailability of 0.044.

In this example, the utility also selected a second level corresponding to a 95% significance level. The band between the two levels corresponds to a 90% to 95% chance that the average AFW train unavailability during the year is not meeting it's goal. This band also corresponds to a 5% to 10% false alarm rate.

Table 2

Poisson Distribution of Number of Preventive Maintenances Expected (in This Example) in Aggregate of Three AFW Trains During One Year.

Number of Maintenance Outages	Probability of This Number of Failures	Train Downtime Due to Preventive Maintenance (hours)	Train Unavailability Due to Preventive Maintenance Time
0	0.4	0	0
1	0.13	72	0.003
2	0.21	144	0.005
3	0.22	216	0.008
4	0.18	288	0.011
5	0.11	360	0.014
6	0.06	432	0.016
7	0.03	504	0.019
8	0.01	576	0.022

8. Example of Comparing Performance vs. Goal for Multiple Trains

The actual AFW average train unavailability experienced at plant A is shown in Table 4.

These data for average train unavailability averaged over a 4-quarter period are plotted in Figure 1, with alert levels at 90% and 95% significance levels. In this example, the average train unavailability was consistently higher than the goal for fandom failures. In addition, the data exceeded the 90% significance level for individual data points in the 4th quarter, and again starting in the 8th quarter. As a result, this portion of the system unavailability goal, due solely to redundant train unavailability, (i.e., excluding common cause and single-component failures) was being exceeded by about a factor of 40. For example, in the 9th quarter, the average train unavailability cubed is 4.2×10^{-4}, compared to the goal of 1.0×10^{-5} for redundant train failures. This also exceeds the goal of 3.0×10^{-4} for overall AFW unavailability.

In this example, two recurring problems had occurred with AFW, and their causes had been difficult to identify. One problem involved a valve in the service water system that cooled the motor driven pump bearings. The other problem involved a relief valve on the stear.. supply to the turbine train. The

Table 3

Combined Distribution of Number of Train Failures and Preventive Maintenances (in This Example) During One Year

Train Unavailability From Tables C-1 & C-2	Probability	Cumulative Probability
0 + 0 = 0	(.45)(.04) = .0180	.0180
0 + .003 = .003	(.45)(.13) = .0585	.0765
0 + .005 = .005	(.45)(.21) = .0945	.1710
0 + .008 = .008	(.45)(.22) = .0990	.2700
0 + .011 = .011	(.45)(.18) = .0810	.351
0 + .014 = .014	(.45)(.11) = .0495	.4005
0 + .016 = .016	(.45)(.06)+(.36)(.04) =.0414	.4419
0 + .019 = .019 .016 + .003 = .019	(.45)(.03)+(.36)(.13) = .0603	.5022
0 + .022 = .021 .016 + .005 = .021	(.45)(.01)+(.36)(.21) = .0801	.5823
.016 + .008 = .024	(.36)(.22) = .0792	.6615
.016 + .011 = .027	(.36)(.18) = .0643	.7263
.016 + .014 = .030	(.36)(.11) = .0396	.7659
.016 + .016 = .032 .033 + 0 = .032	(.36)(.06)+(.14)(.04) = .0272	.7931
.033 + .003 = .035 .016 + .019 = .035	(.14)(.13)+(.36)(.03) = .0290	.8221
.033 + .005 = .038	(.14)(.21) = .294	.8515
.033 + .008 = .041	(.14)(.22) = .0308	.8823
.033 + .011 = .044	(.14)(.18) = .0252	.9075 *
.033 + .016 = .049 .049 + 0 = .049	(.14)(.06)+(.04)(.04) = .0100	.9175
.033 + .019 = .052 .049 + .003 = .052	(.14)(.03)+(.04)(.13) = .0094	.9269
.049 + .005 = .054	(.04)(.21) = .0084	.9353
.049 + .008 = .057	(.04)(.22) = .0088	.9441
.049 + .011 = .060	(.04)(.18) = .0072	.9513 *
.049 + .014 = .063	(.04)(.11) = .0044	.9557

* Average train unavailabilities corresponding to approximately 90th and 95th percentiles.

Table 4

AFW Average Train Unavailability Experienced at Plant A

Quarter	Average Train Unavailability During the Quarter	Average Train Unavailability During the Last 4 Quarters
1	0.056	
2	0.028	
3	0.064	
4	0.047	0.048
5	0	0.035
6	0.049	0.040
7	0.0[illegible]	0.040
8	0.078	0.047
9	0.11	0.075
10	0.043	0.073
11	0	0.058
12	0.036	0.047

causes of these problems were identified and corrected, and AFW average train unavailability returned to normal.

9. Alternative Methods for Evaluating Alert Levels for Redundant Trains

There are other ways to analyze these performance data to differentiate systematic trends from random variations .

An alternative kind of statistics that addresses the cumulative sum of the data over time (cusum) would more rapidly flag long term trends. For example, in Figure 1, cusum could evaluate the consistently larger-than-expected unavailability much more efficiently than the single-point Poisson statistic used in this example.

Another very effective method is to use computer simulation to develop alert levels empirically. Simulation can evaluate tradeoffs between detection time and false alarm rate.

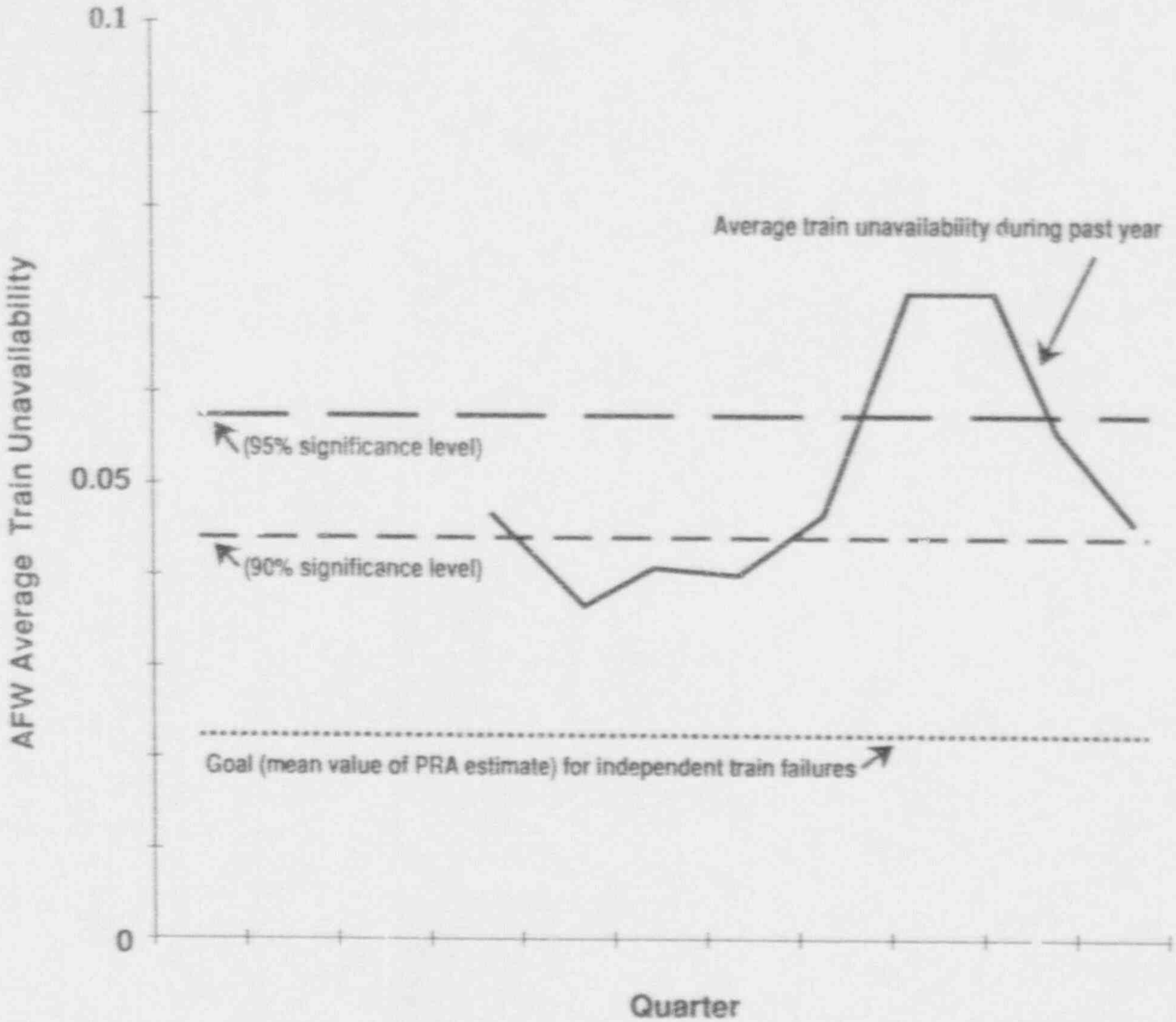

Figure 1. Example of Monitoring AFW Average Train Unavailability (4-quarter average)

THE FOLLOWING ATTACHMENT IS PROVIDED FOR ILLUSTRATION ONLY.

Attachment 4

ROOT CAUSE ANALYSIS

The economic and safety benefits associated with root cause determinations and evaluations are well known. However, the performance of the actual evaluation is complex. There are numerous root cause analysis techniques available, including Kempner-Tregoe Problem Analysis, Savannah River Plant Cause Code Tree, EG&G Intertech, Inc. Management Oversight and Risk Tree Analysis, (MORT), Barrier Analysis, and Change Analysis.

Root cause analysis is typically several levels in depth and the root cause is not usually the immediate or most apparent cause. For example, not only should the cause of a blown fuse be identified (for example, over-current), but what caused the over-current condition (for example, voltage regulator failure), and the cause of the voltage regulator failure (for example, weak springs in a faulty design).

Root cause cannot always be identified after a single failure. If such is the case, a highly probable cause should be determined. For significant occurrences (i.e. impact on plant safety equipment, TRIPs or SCRAMs), the probable cause should be agreed upon by the onsite safety review committee. When only a most probable cause is determined, monitoring equipment might be installed to capture additional data for future analysis. Compensatory measures should be taken to minimize effects of future failures. The hardware that was the most apparent immediate cause might be removed and tested prior to return to power operations.

1. Essential Elements of a Root Cause Analysis Program

Essential elements of an effective root cause analysis program include:

1.1 A comprehensive program of data collection, trending, inspection, surveillance, and analysis.

1.2 Feedback from root cause determinations is factored into the pertinent plant operations.

1.3 Emphasis is placed on learing from past experience.

1.4 Equipment performance, condition, and availability, as applicable, is trended to determine if root causes have been found.

1.5 Root cause efforts should be standardized for all departments so that the broadest foundation for trending and analysis is available and evaluators can utilize a common data base in order to identify major categories of causes.

1.6 Evaluators should be open minded, objective, creative individuals, trained in root cause analysis. The process should be independent. Recommended corrective action must be realistic and useable.

1.7 Generic recommendations should be factored into the preventive maintenance program to preclude similar occurrences on other systems.

1.8 The root cause of operational events should be:

(a) Identified in a timely manner. Where the root cause is either not identified or uncertain, an appropriate procedure for a highly probable cause should be followed.

(b) Verified to have been corrected before conditions are set which would allow recurrence.

1.9 A verification test should be conducted, as appropriate, that safely attempts to reproduce the occurrence without detrimental effects. Verification of root cause, if done thoroughly, consists of testing that effectively reproduces the symptoms that caused the original failure and meets a logic test as well. For example, a fuse was replaced and the component now functions. With the old fuse in place, the symptoms of failure were apparent (physical criteria reproduced). However, there is nothing wrong with the old fuse, which is not logical. Further investigation is warranted because the root cause is not verified. Verification should reproduce the symptoms of failure, fix the problem, and follow a common sense logical approach.

2. Problems Performing Root Cause Analysis

Failure to perform in-depth, root cause analyses can lead to failure initiators being left undetected. Failures then recur as operation continues. Further, an unrelated failure may be exacerbated by one or more unidentified failure initiators that are present as the result of past incomplete root cause analyses. The synergistic effect of these occurrences causes confused diagnosis of the event, possible multiple equipment failures, inoperability of equipment expected in use, personnel errors, and misdirection by management. Such occurrences place operators and the plant in an abnormal operating environment, possibly leading to unacceptable situations.

Typical traps that result in incorrect determinations of root cause are:

2.1 Assuming That Most Apparent Cause Is The Root Cause:

Root cause is often at the fourth or fifth level of sub- causes. Assuming that the most obvious cause is the root cause may lead to mis-identification.

Examples include:

(a) Assuming that the identified problem is the cause.

(b) Blaming circumstance on personnel error, when in fact the individual may have been set up to fail.

(c) Jumping to conclusions, as in the case where a cause is assumed based on limited information and then data is gathered to support that theory.

(d) Inadequate definition of the problem due to varied, contradictory, and complex data.

(e) "Overkill", where many actions are taken to address the issue, and it is never known what actually solved the problem, or even if the problem is indeed "solved".

2.2 Assuming That The Cost Of A Root Cause Analysis Is Unjustified:

Examples are:

(a) The root cause analysis has low priority because the component or system is not immediately needed for continued operation.

(b) A planned outage is within the time period that recurrence of the failure is estimated to occur (perhaps optimistically). The plant management postpones the resolution until the planned outage, and makes an interim fix as compensatory action in order to justify continued operation.

2.3 The Root Cause Program Is Set Up Without Sufficient Support:

The root cause program is destined to fail if support is lacking or perceived to be lacking, or analysts are not trained in root cause analysis, or supporting personnel are not knowledgeable in the required disciplines, or sufficient resources are not available, or plant personnel are unwilling to be the bearers or receivers of bad news. The root cause analysis is often pre-empted or brushed aside in such circumstances. Under such conditions neither plant management nor workers will support a root cause analysis program, nor will they have confidence in the root cause analysis results.

2.4 The Problem Is Complex:

The root cause may be (or is perceived to be) very complex, or there may no apparent indications of the cause.