① Spent fuel storage degradation capacity.

② A-40 shut down path

NUCLEAR MANAGEMENT AND RESOURCES COUNCIL, INC.

METHODOLOGY TO EVALUATE PLANT EQUIPMENT FOR LICENSE RENEWAL

October 6, 1989

PREPARED

FOR

UNITED STATES DEPARTMENT OF ENERGY

BY

SANDIA NATIONAL LABORATORIES

9001050205

47pp XA

ACKNOWLEDGMENTS

Preparation of this document was performed under the guidance of the NUMARC NUPLEX Working Group in cooperation with the United States Department of Energy, Electric Power Research Institute and Lead Plant Program utilities; Yankee Atomic Electric Company and Northern States Power Company. Funding for development of the document was provided by the United States Department of Energy. The document was prepared by Sandia National Laboratories.

NOTICE

TABLE OF CONTENTS

LIST OF FIGURES

METHODOLOGY TO EVALUATE PLANT EQUIPMENT FOR LICENSE RENEWAL

EXECUTIVE SUMMARY

This document presents a methodology with criteria for evaluating plant equipment for license renewal. The focus of review for such equipment is its ability to perform throughout the license renewal period. Plant equipment dispositioned during the licensing renewal evaluation will continue to be maintained in accordance with established plant practice to assure reliable operation.

The methodology presented is based upon the following precepts:

1. License renewal focuses on ensuring continued safe operation for the license renewal period.

2. License renewal is based upon continuation of the plant's current licensing basis.

3. Some equipment contributes to safety more than other equipment.

4. Existing plant programs contribute to ensuring continued safe operation.

5. Both deterministic and probabilistic approaches exist for evaluating equipment for license renewal, and subsequently for identifying plant equipment requiring further evaluation.

6. A variety of options are available to address equipment requiring further license renewal evaluation.

These precepts form the basis for the following step-by-step methodology for revaluating plant equipment for license renewal. License renewal evaluation focuses on those systems, structures, and components that are relied upon to operate the plant safely, are subject to potentially

significant age-related degradation, and are not subject to established effective replacement, refurbishment, or inspection programs.

The methodology begins with a systematic evaluation of all plant systems and structures, followed by a more focused evaluation on the component level. At each step, the evaluation focuses upon a decreasing subset of equipment, and the basis for sufficiency of review is documented and subject to regulatory review. The steps include:

- o Identification of systems and structures which will be relied upon to ensure continued safe plant operation.
- o Within these systems and structures, identification of components important to the system's or structure's safety function.
- o Review of existing replacement, refurbishment, and inspection programs for these components.
- o For the remaining components, assessment of the potential for significant age-related degradation.
- o Application of options for preventing or mitigating such degradation.

Although both deterministic and probabilistic approaches are presented in some steps, this document does not suggest development of a Probabilistic Risk Assessment (PRA), if one does not already exist, nor does it require the use of an existing PRA if a utility chooses to base its license renewal review on deterministic criteria only. Rather, it simply provides criteria for using an existing PRA to further focus the review.

This report presents a description of the methodology with both deterministic and probabilistic means of applying it. Specific criteria for each step are provided along with accompanying rationale; these criteria may be found in Appendix A. Application of the methodology should result in an effective and efficient review of the plant and should serve as a technical basis for license renewal, a focus for license renewal evaluations, and a foundation for the license renewal process and regulations.

1.0 INTRODUCTION

Currently licensed nuclear power plants represent a substantial capital investment and constitute a significant percentage of the installed electrical generating capacity in the U.S. The present regulatory process provides for a nuclear plant operating license term of 40 years. A nuclear plant license renewal program encompasses those activities that will be required to secure regulatory approval for plant operation beyond the 40-year initial operating license term.

The ability to operate a nuclear power plant beyond its initial license term may require a greater understanding of the impacts of aging mechanisms on plant safety and performance. Many plant components are already subject to a variety of programs to detect and prevent or mitigate potentially significant age-related degradation. The objective is to ensure that the proper activities are in place to manage age-related degradation in such a manner that plant safety is not adversely impacted during the license renewal period.

1.1 Background

Based on industry studies to date, there are three categories of components found in the plant: (1) those components that are routinely inspected, refurbished, or replaced, (2) those that have lifetimes in excess of the range of license renewal, and (3) those that have lifetimes within the range of license renewal. The latter category is the primary focus of license renewal.

Nuclear power plant owners have the ultimate responsibility for safe plant operation. Part of this responsibility is fulfilled through programs which detect and mitigate the effects of age-related degradation. In parallel with these efforts, there are programs under way to enhance the performance of a plant which offsets any adverse effects of age-related degradation. These programs are the principal means of maintaining a plant in a condition that will ensure safe operation.

A broader, more systematic assessment of plant systems, structures, and components is necessary to ensure the ability to operate safely during the license renewal period. To accomplish this objective, it is necessary to determine what plant equipment contributes to safe plant operation and is subject to age-related degradation. The methodology described in this report for evaluation of plant equipment will serve as industry's technical basis for license renewal review.

1.2 Purpose

The purpose of this report is to define a methodology with criteria for evaluating systems, structures, and components for license renewal.

1.3 Scope

This document contains a methodology to be used by applicants and the Nuclear Regulatory Commission (NRC) for evaluating systems, structures, and components for license renewal.

1.4 Approach

The methodology provides both deterministic and probabilistic approaches to identifying plant systems and structures which contribute to plant safety and of those, identifying the ones for which degradation is potentially significant to plant safety. These systems and structures are established as the primary focus of further review. From this list of systems and structures, the methodology describes how to: (1) identify the subset of components that are important to the system's or structure's safety function; (2) identify those components which currently are subject to established effective replacement, refurbishment, or inspection programs; (3) review those remaining components to determine the impacts, if any, of potential age-related degradation. For those components where age-related degradation is a concern, options for resolving such degradation are identified. These options are described but not prescribed. While there may be generic strategies for continued operation of particular components, implementation of these options will be plant-specific.

2.0 METHODOLOGY

A methodology with criteria for evaluating systems, structures, and components for license renewal is presented in Sections 2.1 and 2.2. This methodology, is based on the following precepts:

1. License renewal focuses on ensuring continued safe operation for the license renewal period.

2. License renewal is based upon continuation of the plant's current licensing basis.

3. Some equipment contributes to safety more than other equipment.

4. Existing plant programs contribute to ensuring continued safe operation.

5. Both deterministic and probabilistic approaches exist for evaluating equipment for license renewal, and subsequently for identifying equipment requiring further evaluation.

6. A variety of options are available to address equipment requiring further license renewal evaluation.

These precepts form the foundation for the method consisting of two major steps with a series of substeps that progressively focus the license renewal evaluation. Figure 1 summarizes the method, Appendix A summarizes the criteria.

Step 1, "Evaluation of All Plant Systems and Structures," reviews all plant systems and structures to determine those that require component-level license renewal evaluation. First, Substep 1a develops a list of systems and structures potentially requiring further license renewal evaluation based upon the system or structure having a role, whether major or minor, in plant safety. Second, Substep 1b determines if degradation of the systems and structure identified in Substep 1a could potentially affect plant safety. Such systems and structures require component-level evaluation for license renewal. The net result, after Substeps 1a and 1b are completed, is the development of a list of systems and structures requiring further component-level evaluation for license renewal.

Step 2, "Evaluation of Components Within Systems and Structures," addresses plant systems and structures that have been determined by Step 1 to require component-level evaluation for license renewal. Each such system and structure is reviewed: (1) to identify components that are important to performance of the system's or structure's safety function; (2) of these, to identify components that are not routinely replaced, refurbished, or subject to detailed inspection; (3) to determine if these remaining components are susceptible to age-related degradation which may significantly affect plant safety; and (4) to suggest options which can be used to resolve potentially-significant age-related degradation.

Application of this methodology will result in a systematic evaluation of all plant systems, structures, and components. The detail of the review increases while progressing through the successive steps. At each step, some equipment not requiring further detailed evaluation is likely to be identified. The bases for such a conclusion would be documented and available for regulatory review.

2.1 Step 1: Evaluation of All Plant Systems and Structures

The methodology begins with a systematic review of all plant systems and structures. The review consists of addressing two major questions:

o Does the plant system or structure contribute to plant safety?

- o Is degradation of the system or structure potentially significant to plant safety?

Each is discussed in more detail below.

2.1.1 Substep 1a: Does the Plant System or Structure Contribute to Plant Safety

As an initial step, all systems and structures that contribute to plant safety are identified from the list of all plant systems and structures.[1] These will be subject to further license renewal review. The intent of Substep 1a is to be all-inclusive and not exclude any system or structure which may contribute to safety.

To implement this step, criteria have been developed and are described below:

- o Systems or structures which contribute to plant safety are those which perform one or more safety functions. These systems and structures are defined as:

  1a.1 Systems or structures that are identified as being safety-related in a licensing basis document,

  OR

  1a.2 Systems relied upon or structures identified in a licensing basis safety analysis or evluation

  OR

  1a.3.a Systems utilized in plant emergency operating procedures,

---

[1] For the purposes of this document, a "system" is a collection of components working together to perform a given function. Structures are composed of components in a similar manner. A component is a piece of equipment, such as a vessel, pipe, pump, valve, beam, or support, which is combined with other components into a system or structure. For example, the PWR reactor coolant system includes, among its components, the reactor vessel, primary system piping, reactor coolant pumps, steam generators, and associated instrumentation and controls.

A-XC shutdown path

or

1a.3.b Systems taken credit for in a risk assessment if a plant unique risk assessment is available and used.

These criteria are shown schematically in Figure 2.

accident mitigation? Grant fire

Criteria 1a.1 and 1a.2 above, identify those systems and structures relied upon to fulfill the requirements of the plant's current licensing basis. Among the safety functions performed by this equipment are reactor criticality control; control of reactor coolant system integrity, inventory, and heat removal; and containment integrity control and heat removal. Performance of these functions during design basis events will ensure the integrity of the reactor coolant pressure boundary; the capability to shut down the reactor and maintain safe shutdown; and the capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposures comparable to the guidelines of 10 CFR Part 100. Criterion 1a.3 identifies those systems and structures, not traditionally classified as safety-related, which may be used in responding to plant transients or accidents along with the traditional safety-related systems or structures. Systems or structures identified by these Criteria (1a.1 through 1a.3) contribute to plant safety and require further license renewal evaluation.

Criteria 1a.3.a and 1a.3.b provides the option of either deterministically or probabilistically identifying those systems or structures which may be used in responding to plant transients or accidents. In the deterministic approach (Criterion 1a.3.a), the plant's Emergency Operating Procedures (EOPs) are reviewed to identify systems called upon by the EOPs in responding to the various plant transients and accidents. Some systems so identified will have also been identified by Criteria 1a.1 and 1a.2, while the remainder not so identified represent those additional systems, not traditionally classified safety related, which contribute to plant safety.

In criterion 1a.3.b, a plant unique risk assessment, if available, may be used to augment the list of traditional safety-related systems and

structures with those systems and structures, not traditionally classified as safety related, which may be used in responding to plant transients and accidents.

The approach used in a PRA consists of a functional analysis of each system to identify its safety function. Those systems which are necessary to prevent or mitigate the consequences of an accident are identified. These systems, generally termed "front-line systems," are those that perform safety functions in response to an initiating event. In addition, support systems are frequently necessary to the successful operation of the front-line systems and are modeled as well. PRA generally include a review of the plant emergency operating procedures. As such, the PRA provides an alternative way of identifying additional systems for license renewal review.

All plant systems and structures identified by any of the three criteria in Substep 1a pass to Substep 1b for further consideration. These systems and structures comprise the list of the plant systems and structures which have a role in ensuring safe plant operation. In addition to the traditional set of safety-related systems, these criteria recognize the role of selected non-safety systems in controlling plant response to off-normal events and identify such systems for fu[illegible] consideration. Support systems necessary for system operation are identifie[illegible]. Thus, the further license evaluation encompasses a broadly define[illegible] set [illegible]nt systems and structures.

2.1.2 <u>Substep 1b</u>: Is Degradation of the System or Structure Potentially Significant to Plant Safety?

All systems and structures are subject to age-related degradation. However, this may or may not be significant to plant safety. Criteria have been developed to ascertain the potential significance of such age-related degradation. These criteria are outlined below:

- o Age-related degradation of a system or structure will be considered potentially significant to plant safety unless failure of the system or structure would not significantly contribute to increased radiological health and safety risk to the public. The degradation of a system or structure is considered potentially significant to plant safety unless:

1b.1.a The system's or structure's failure could not directly result in off site releases exceeding FSAR or other plant-specific off-site release limits,

and

1b.1.b The system's or structure's failure could not result in reactor coolant pressure boundary or primary containment leakage in excess of technical specification limits,

and

1b.1.c.1 The system or structure is not otherwise required for the performance or control of:

(1) reactor criticality

(2) reactor coolant system integrity, inventory, or heat removal

(3) containment integrity or heat removal

or

1b.1.c.2 Although the system or structure may be required for these functions, the system's or structure's failure is detectable in a time frame which would allow shutdown prior to requiring a manual or automatic plant trip.

OR

1b.2 A plant-unique risk assessment, if available and used, demonstrates that:

1b.2.a The system's or structure's failure does not occur in a sequence that has a core damage frequency greater than or equal to 1×10^{-6} per year or in a sequence that contributes 5% or more to the total estimated core damage frequency,

and

1b.2.b When the system or structure is assumed to fail due to age-related degradation, the total estimated core damage frequency will not increase by more than a factor of 3 or will not exceed 1×10^{-4} per year.

These criteria are shown schematically in Figure 3.

Age-related degradation may not significantly impact plant safety for the systems and structures identified in Substep 1a. Substep 1b assesses the potential safety significance of age-related degradation and determines those systems and structures which require component-level review. The above criteria set forth deterministic requirements which must be met or, if a PRA is used, probabilistic requirements which must be met to make the determination that potential age-related degradation would not significantly impact plant safety. Rather than assess the potential for age-related degradation of system and structures per se, Substep 1b assumes the case of system or structural failure (the bounding assumption) and assesses the potential impact on plant safety. For the determination to be made that safety would not be significantly impacted, all conditions of either the deterministic or probabilistic criteria must be met. Such a determination constitutes sufficient basis for concluding that these systems or structures need not be further evaluated for license renewal. Those systems or

structures for which such a determination cannot be made require component-level review as outlined in Step 2 of the methodology.

The deterministic Criteria (1b.1.a, 1b.1.b, and 1b.1.c.1 or 1b.1.c.2) require that system or structural failure could not directly result in releases exceeding specified off-site limits, or result in excess leakage from the reactor coolant pressure boundary or primary containment, or compromise plant safety functions.

Criterion 1b.1.a ensures that any single system or structural failure which would lead directly to an off-site release in excess of existing plant-specific limits, will be evaluated further. Various licensing basis documents set forth limits for off-site releases. The FSAR may be used for this purpose or, alternately, other accepted licensing limits (Technical Specifications). Although it is recognized that plant design and safety features ensure with high confidence that off-site dose limits will not be reached, this criterion requires that those systems or structures containing sufficient radionuclide inventory such that off-site limits could be exceeded, if no mitigative actions occur, would require further evaluation.

Criterion 1b.1.b ensures that those system or structural failures which could lead to reactor coolant pressure boundary leakage or primary containment leakage in excess of Technical Specification limits require further evaluation.

For those systems and structures which cannot directly cause off-site releases, or which cannot cause excess leakage of the reactor coolant pressure boundary or primary containment in excess of Technical Specification limits (i.e., those systems and structures satisfying Criteria 1b.1.a and 1b.1.b), it must be also shown that the system or structure meets one of the two conditions set forth in Criterion 1b.1.c.1 and 1b.1.c.2.

The first condition, 1b.1.c.1, requires that the system or structure is not otherwise required to perform or control reactor criticality; reactor coolant system integrity, inventory, or heat removal; or integrity of and heat removal from the containment. All modes of plant operation are considered in applying this criterion. Systems and structures which perform or control these functions require further review. Examples include the major safety systems in the plant, such as the emergency core cooling systems and their actuation logic. Other systems or structures which support the equipment performing these safety functions, for example cooling water and power systems, are also subject to further review.

Some systems provide only information on system performance or status, but are not necessary for control of system performance. Failure of such systems, unless they preclude bringing the plant to safe shutdown, would not directly influence system or structural performance. The consequences of age-related failure of such systems would be apparent, and the plant would be brought to a safe shutdown. Because plant safety is not significantly affected by the failure of such systems, no further review for license renewal would be required. Of course, existing plant practices which assure their proper functioning will continue for the license renewal term.

Equipment redundancy is not considered a sufficient basis for satisfying Criterion 1b.1.c.1. Two diverse systems performing the same function, such as the Scram System and Standby Liquid Control System, still will require further review.

Systems or structures which are not otherwise required to perform or control these functions and which meet the off-site release and leakage criteria do not require further evaluation. Most safety-related systems would not be expected to meet these criteria and, hence, would require further evaluation. Some systems, such as the moveable incore monitoring system, may meet this condition.

Criterion 1b.1.c.2 acknowledges that the effects of some failures manifest themselves only over a long period of time, during which the failure can be detected and either the function restored or the plant shut down prior to requiring the plant to trip. In this case, the impact of system or structure failures on safety will be minimal. Systems or structures which meet this condition, as well as the off-site release and leakage criteria do not require further review for license renewal. Generally, standby systems will not meet this criterion because their failure may be detected only when the system is called upon to operate.

Criteria 1b.1 represent a deterministic approach in identifying those systems and structures for which age-related degradation is potentially significant to plant safety. Criteria 1b.2 give the utilities which have a plant-unique risk analysis the option to use it to assess the potential safety significance of age-related degradation.

Since all risk assessments estimate core damage frequency, the probabilistic criteria have been formulated in those terms. It may be demonstrated that system or structure failure does not significantly impact plant safety, as measured in terms of the system's or structure's contribution to core damage frequency. To make such a determination, two types of criteria must be satisfied. First, in Criteria 1b.2.a, it must be shown that the system or structure does not contribute to accident sequences identified as significant to the estimated core damage frequency. For the purposes of this document, all sequences of estimated core damage frequency greater than or equal to 1×10^{-6} per year or those sequences which contribute 5% or more to total core damage frequency have been considered to be significant. Systems or structures which contribute to sequences higher than these thresholds require further license renewal evaluation. Systems or structures contributing only to the sequences lower than these thresholds must meet the added criterion in Substep 1b.2.b before a disposition is made.

Second, because age-related degradation could increase a system's or structure's failure probability, the potential effects on estimated core damage frequency of reduced reliability are examined in Criterion 1b.2.b. In theory, by varying the estimate of reliability, calculation of the change in estimated core damage frequency can be made. In practice, however, it may be difficult to estimate how a system's or structure's reliability changes in response to age-related degradation. Therefore, criterion 1b.2.b examines the effect on total core damage frequency if the bounding assumption of failure (probability of failure equals one) is made. For systems or structures satisfying criterion 1b.2.a not to require further review, it must also be shown that, using this conservative assumption, the estimated total core damage frequency does not change significantly. Recognizing that some plants have higher core damage frequency estimates than others, an upper bound of the total core damage frequency must also be met.

There are currently no regulatory reference values for "risk increase significance." In criterion 1b.2.b an increase in total core damage frequency of less than a factor of three is deemed not significant. This factor is well within the uncertainty bounds of currently estimated core damage frequency. As an upper bound to the total core damage frequency, 10^{-4} per reactor year was chosen recognizing that the upper bound of core damage frequencies for most currently operating plants is approximately at this level. With the bounding assumption, (i.e., system or structure failure) demonstration that this level is not exceeded ensures that the plant risk would not exceed currently accepted levels.

The "risk increase" criterion considers the effects of single system or structural failures to assess the potential significance of age-related degradation. While degradation of multiple systems or structures is possible, differing environments, service conditions, and operating history among different systems make this unlikely. The conservative nature of the assumption made (i.e., system failure probability equals one) and the low likelihood of age-related common mode failures that could simultaneously result in failure of multiple systems or structures provides confidence in the consideration of single system or structural failure to assess the potential significance of age-related degradation.

Systems or structures meeting both probabilistic criteria in Substep 1b do not require further license renewal review. Examples of such systems will be plant-specific.

Preliminary application of the criteria in Substep 1b have identified plant systems and structures which will require component-level review. These systems and structures are generally those major plant systems and structures containing the core and spent fuel, those which have a direct impact on plant safety (e.g., safety-related systems), and those which indirectly influence safety (e.g., support systems). Those systems and structures for which degradation was not considered potentially significant were generally those which provide non-safety functions (e.g., the Administrative Building), or which provide specialized functions which do not impact public health and safety (e.g. Breathing Air Systems, Inert Gas Systems, Decontamination Rooms).

2.2 Step 2: Evaluation of Components Within Systems and Structures

At this point in the evaluation, systems and structures requiring component level review have been identified. This component-level evaluation involves several steps. For each component in a system or structure requiring component-level evaluation, these steps address:

- o Is the component important to system or structure safety function?
- o Is the component subject to established effective replacement, refurbishment, or inspection programs?
- o Is the component subject to potentially-significant age-related degradation?

Components that are important to system or structure safety function and are not subject to established effective replacement, refurbishment, or inspection programs, and are subject to potentially significant age-related degradation, require further evaluation for license renewal. There are various options available to resolve potentially-significant age-related degradation. Implementation of one or more of these options would support the continued safe operation of these components during the license renewal period. The methods in the following substeps address the above questions for each component in each of the systems and structures requiring component-level evaluation. A component list for each system and structure is required for the application of the following steps.

2.2.1 <u>Substep 2a</u>: Is the Component Important to System or Structure Safety Function?

The first step of the component-level evaluation for license renewal is to identify all those components important to the system's or structure's safety function within each system or structure identified in Substep 1b as requiring component-level review. To implement Substep 2a, criteria have been developed and are described below:

- The component is important to system or structure safety function unless:

  2a.1 The component is normally isolated and does not perform an accident mitigating function.

  OR

  2a.2.a Component failure would not result in either the failure of any individual train within the system or the failure of the entire system to perform its required safety function,

  and

  2a.2.b Component failure would not reduce the structural support of any other component such that it would not perform its system safety function,

  and

  2a.2.c Component failure would not physically damage any other component such that it would not perform its system safety function,

  OR

2a.3 For components within the scope of a plant-unique risk assessment, if available and used, the component is not included in the risk assessment models.

These are shown schematically in Figure 4.

Systems and structures are comprised of components working together to perform a given function. While the systems and structures identified in Substep 1b perform a safety function, not all components within the system or structure may be important to that safety function. For example, systems often contain components which only provide information on system performance or status or which only facilitate testing or maintenance activities. Similarly, structures may contain components which are extraneous to the structure's safety function. For some systems and structures, only particular aspects of their performance are relevant to safety. For example, for BWRs, only the portion of the feedwater system providing core makeup may contribute to safety. Components not necessary for system or structure safety function, if they were to fail due to age-related degradation, would not adversely impact safety performance. Such components will continue to be addressed by existing plant practices, but require no further license renewal review. The criteria developed for this step provide the basis for identifying those components which are not important to the system's safety function. All others will be subject to further review.

Some components are normally isolated and are not important to the system's safety function. Examples include small valves and piping used in leakage tests. Failure of such components will not affect safety and, therefore, require no further review for license renewal. These components are addressed in Criterion 2a.1.

Other components are an integral part of the system, but are not important to the system's safety function. For such a determination to be made, <u>all</u> conditions given in Criteria 2a.2.a, 2a.2.b, and 2a.2.c must be satisfied. Because different components perform different roles, the criteria

capture a variety of perspectives. These include those components of the system required for functional operation and those which provide structural support. Because it is important to maintain redundancy in multi-train systems, the effect of failure on individual trains is considered. Consideration is also given to the potential for physical damage to other components as a result of failure. If failure of the component or structure would not cause system failure or reduce redundancy, would not compromise necessary structural support, and would not damage other important components such that they could not perform their safety function, further review for license renewal is not required. Components meeting Criteria 2a.1 and 2a.2.a, 2a.2.b, and 2a.2.c will be plant and system specific.

If a risk assessment is utilized in the license renewal review, the system modeling process for the PRA would have determined the components important to the system's safety function. Criterion 2a.3 addresses the components important from the PRA perspective. All components included in the risk assessment model would pass on to Substep 2b for further consideration unless they would have met one of the deterministic criteria, or the combination of Criteria 2a.1 or 2a.2.a, 2a.2.b, and 2a.2.c. Components within the scope of the risk assessment which were not included in the model do not require further review because the determination would have been made that such components are not necessary for the system safety function. Documentation would be provided to support this determination. Examples of components typically excluded from risk models because of their limited impact on system safety function include selected instrumentation providing parameter information and those components in normally isolated paths, such as test lines. Those passive components or other components which are not normally modeled as part of a risk assessment due to their low failure rates or those considered outside the scope of the PRA are addressed only by the deterministic Criteria, 2a.1, 2a.2.a, 2a.2.b, and 2a.2.c.

2.2.2 Substep 2b: Is the Component Subject to Established Effective Replacement, Refurbishment, or Inspection Programs?

Effective replacement, refurbishment, and inspection programs are important for managing age-related degradation, during both the initial licensing period and for the license renewal period. Continuation of these programs constitutes a basis for continued operation during the license renewal term. Therefore, the next step is to identify which of the components important to system or structure performance are subject to established effective replacement, refurbishment, or inspection programs.

To implement Substep 2b, criteria have been developed and are described below:

- A component is considered to be subject to an established effective replacement, refurbishment, or inspection program if:

  2b.1 The program is documented, approved, and routinely implemented in accordance with plant administrative procedures,

  AND

  2b.2 The program procedures ensure that all of the component's significant safety functions are properly addressed,

  AND

  2b.3 The program establishes specific criteria for determining the need for corrective action and requires such action be taken if these criteria are not met.

These criteria are shown schematically on Figure 5.

Many plant components are subject to established effective repair, replacement, or inspection programs during the initial operating term. Continuation of these established-effective plant programs constitutes a basis

for continued operation during the license renewal term provided that all of the component's significant safety functions (i.e. pressure boundary, valve alignment, proper-flow, etc.) are properly addressed. With this attention, these components will be capable of performing their safety function during the license renewal term. The criteria developed for Substep 2b require that these programs be formally established, approved, and routinely implemented in accordance with plant administrative procedures. To be effective, corrective actions must be required as part of the program if established acceptance criteria are not met. The existence of such programs and the acceptance of established corrective actions constitute the basis by which such programs are recognized as effective for current operation and will continue to be so for operation during the license renewal term as well.

It is recognized that many components are subject to a variety of replacement, refurbishment, or inspection programs to address diverse functional requirements and various degradation mechanisms. Therefore, several existing programs may be required to address all of a component's significant safety functions. Through a combination of such programs, as necessary, the basis for operation during the license renewal term is established.

Programs which could contribute to meeting the requirements of Substep 2b for a particular component include the following:

- o Programs which subject the component to periodic, routine replacement, or refurbishment.

- o Programs which qualify components for a specified life and require requalification or replacement at the end of the qualified life.

- o Programs which subject the component to routine inspections in accordance with ASME, ASTM, ANSI, IEEE, or similar NRC- or industry-recognized codes or standards.

- o Programs which subject the component to regular and thorough disassembly, inspection, overhaul, and testing and which require corrective action if unacceptable conditions are ascertained.

- o Programs which subject components to a failure trending program in which acceptance criteria for reliability are documented and corrective actions are specified.

- o Instrument calibration programs which require replacement or refurbishment if the component fails to meet specified acceptance criteria.

- o Other plant programs which can be shown to meet the above criteria.

Many components are routinely replaced or refurbished periodically as accepted practice during the initial licensing term. Operating experience, historic performance, component data bases, and component manufacturers' recommendations are used to arrive at a sound replacement and refurbishment strategy. Examples are plant unique, but may include refurbishment of safety relief valves, main steam isolation valves, and control rod drive hydraulic units. Continuation of these practices should be acceptable and suffice for the license renewal term.

Plant-specific programs, such as the Equipment Qualification Program, require periodic and scheduled replacement of items. During the license renewal term, these programs will specify replacement of selected components. Alternately, equipment may be requalified at the end of its qualified lifetime. Although it is important to continue to maintain and routinely replace or requalify these components, they need not be considered further in the license renewal review because the existence and continuation of such programs constitute an adequate basis for operation during the license renewal period.

Other components are subject to periodic inspections in accordance with established codes and standards. These standards provide the basis for detecting and managing degradation. Examples include the requirements of ASME Section XI, Subsections IWB, IWF, IWP, and IWV. Components covered by these subsections would include reactor vessels and piping (IWB), snubbers and pipe supports (IWF), pumps (IWP), and valves (IWV). Continued compliance with such standards for those aspects addressed by the code should be sufficient for the license renewal term. As codes and standards are modified over time, required compliance with the new requirements would be examined as it is currently on a case-specific basis.

Similarly, components regularly and thoroughly disassembled, inspected, overhauled, and tested under plant-specific programs do not require further detailed review as long as such programs continue during the license renewal term. Examples are plant specific, but might include an electric motor maintenance program that thoroughly disassembles, inspects, overhauls, and tests electric motors for various pumps, fans, and compressors.

Additional examples of effective programs include those associated with instrument calibration and those which explicitly track failure trends. Surveillance required to meet applicable Technical Specifications, when supplemented by other actions such as failure rate and performance trending or disassembly inspections, contributes to the management of age-related degradation.

The criteria for Substep 2b set forth requirements for established effective practices for managing age-related degradation. Programs which are effective for current operation have been detailed. Through a combination of these programs and the assurance that the programs address all of a component's significant safety functions the basis for continued operation is established. Components subject to such programs do not require further review for license renewal. Components not subject to such programs or which have functions that are not fully addressed by these programs will require further evaluation for license renewal in Substep 2c below.

2.2.3 Substep 2c: Is the Component Subject to Potentially Significant Age-Related Degradation?

At this point in the review process, components that are important to the system's or structure's safety function (i.e., not meeting the criteria of Substep 2a) and that are not routinely replaced, refurbished, or subject to detailed inspection (i.e., not meeting the criteria of Substep 2b) are assessed for potential age-related degradation and the impact such degradation has on system performance. Components that are not subject to age-related degradation or for which degradation does not impact system performance do not require further review for license renewal. Components subject to age-related degradation that is significant to the component's performing its intended function and, accordingly, impacts the system's performance and plant safety, require further evaluation for license renewal.

To implement Substep 2c, criteria have been developed and are described below:

- The component will be considered subject to potentially significant age-related degradation unless:

  2c.1 It is established and documented that potentially significant age-related degradation will not occur during the license renewal period.

  OR

  2c.2 A plant-unique risk assessment, if available and used, demonstrates that:

  a. When the component is assumed to fail due to age-related degradation, the total estimated core damage frequency will not increase by more than a factor of three or will not exceed 1×10^{-4} per year.

  and

b. When an age-related common-cause failure mechanism is postulated that may cause multiple components to fail (among those which have satisfied criterion 2c.2.a), those components meet Criterion 2c.2.a when their combined failures are considered as a single event.

These criteria are shown schematically in Figure 6.

Substep 2c provides both a deterministic and probabilistic option. The deterministic option, given in Criterion 2c.1, requires that the potential for significant component age-related degradation be assessed. The probabilistic option, given in Criterion 2c.2, assesses the potential significance to plant safety of component age-related degradation.

Assessments may be used to demonstrate the existence (or non-existence) of potentially significant age-related degradation in addressing Criterion 2c.1. Components not subject to age-related degradation do not require further review for license renewal. Components determined to be subject to potentially significant age-related degradation will require further evaluation for license renewal.

The intent of this substep is to use existing information rather than to conduct detailed aging-degradation evaluations. Further detailed, plant-specific age-related degradation studies of remaining components may be pursued under substep 2d, if necessary. Industry, DOE, and NRC-sponsored equipment evaluations may establish and document that aging does not contribute to component degradation during the license renewal term for selected components. These evaluations may be used as the basis for exclusion of such components from further consideration for license renewal. Such component-specific documentation should address the degradation mechanisms acting upon the particular type of component and assess their effect during the license renewal term. Should the analysis conclude that age-related degradation has no significant effect on the component's ability to perform its safety function or that age-related degradation occurs at a rate that is

of no significant concern to plant safety for the period of license renewal, then it may be concluded that the component is not subject to potentially significant age-related degradation.

If a plant-unique risk assessment is available, the probabilistic Criteria, 2c.2.a and 2c.2.b, also provide a basis for concluding that further evaluation for license renewal is not required. These criteria provide a probabilistic basis for evaluating the potential significance of age-related degradation.

If adequate data and techniques were available to quantitatively assess the effect of age-related degradation, a modification of the PRA for age-related degradation could be performed. Such data and techniques do not currently exist. Rather, the criteria for this step seek to bound the potential effects of age-related component degradation on plant performance.

Age-related degradation can impact component reliability which, in turn, could affect plant safety. Criterion 2c.2.a makes the bounding assumption that the component failure probability is 1.0 and calculates the resultant change in estimated total core damage frequency. Such a calculation bounds the effect of age-related degradation on a given component. For component failure to have a minimal impact on public health and safety, it must be shown that the estimated total core damage frequency does not change significantly. Recognizing that some plants have higher total core damage frequency estimates than others, an upper bound of the total core damage frequency, assuming that the component is failed, must also be met by this conservative bounding calculation.

There are currently no regulatory reference values for "risk increase significance." This criterion suggests, consistent with that applied on the system level (Substep 1b), that an increase in core damage frequency of less than a factor of 3 under the bounding assumption would not be significant. This factor is well within the uncertainty bounds of currently calculated estimates of core damage frequency. As an upper bound to the total core damage frequency, 1×10^{-4} per reactor year, was chosen recognizing that the upper bound of core damage frequencies for currently operating plants is approximately at this level.

At this point, consideration is given to the potential for age-related common-cause failures. Criterion 2c.2.b recognizes that age-related degradation may be a source of common-cause failures among multiple components. For this reason, components which satisfy criterion 2c.2.a must also meet the same numerical criterion when considered collectively in combination with others for which a potential age-related common-cause failure mechanism exists.

For those components meeting criterion 2c.2.a, potential age-related common-cause failure mechanisms should be sought. There is reason to expect that such failures will be infrequent, even for identical components, due to differences in environment, service conditions, and testing and maintenance. This would certainly be true among components in diverse systems. Several potential sources of common mode failure have been addressed in previous steps. Failures arising from shared equipment or dependence upon common supporting systems will have been considered for these particular components and systems in the previous substeps. Consideration should, however, be given to potential age-related common cause failures among components remaining under review, that is, those which are in systems and structures requiring component-level evaluation; those which are important to system or structure safety function; and those <u>not</u> periodically replaced, refurbished, or subject to detailed inspection. Not all components need to be considered in combination with all others for this criterion. Only those components subject to the same age-related degradation mechanism need be examined. Should any such mechanism be found, the potential significance can be evaluated using the bounding assumption of failure, accounting for dependence among the failures, and criterion 2c.2.a. For example, multiple motor-operated valves in a given system may be subject to common age-related degradation and, hence, should be considered under this criterion. However, combinations of electrical relays and manual valves would not be expected to be subject to common age-related degradation; as a result, they need not be considered under this criterion.

Components for which the above bounding calculations show that age-related degradation could not significantly impact plant safety would not require further review for license renewal. Components which do not meet these criteria require further evaluation for license renewal.

2.2.4 Substep 2d: Options to Resolve Potentially Significant Age-Related Degradation

At this point, components have been identified that are important to the safety of the plant, that are not routinely replaced or critically inspected during 40-year operation, and that are subject to potentially significant age-related degradation. A strategy for managing age-related degradation needs to be developed by each utility for each such component or group of components to justify continued operation of these components.

A variety of options to resolve potentially significant age-related degradation may be appropriate depending upon the component being addressed.

Among the options are:

1. Replace the component on a replacement schedule which precludes component age-related degradation from becoming a problem.

2. Demonstrate, by detailed investigation, that age-related degradation of the component will not be significant during the license renewal period.

3. Demonstrate, by a more rigorous analysis, that the potential age-related degradation of the component is not significant to safety.

4. Institute practices which manage component age-related degradation by diagnosing the age-related degradation processes and preventing or mitigating their effect.

Implementation of one or more of these options will complete the license renewal evaluation and provide the basis for continued operation of the remaining components for the license renewal term.

The most straight-forward resolution of the potential for age-related degradation may be to replace the aged component with a new one. Age-related degradation would not be of concern with the new component for the immediate future. Periodic replacement may obviate concern for age-related degradation altogether.

For other components, it may be desirable to conduct a detailed aging evaluation. This evaluation would supplement that which may have been performed under Substep 2c. The purpose of such an evaluation would be to identify the potential for and the effects of age-related degradation during the license renewal term. The evaluation may demonstrate that age-related degradation is not a concern during the license renewal term. If so, the evaluation would justify continued operation. If not, other options detailed in this step of the process would need to be pursued to justify continued operation.

The assessment of potential age-related degradation to this point in the review may well have been conservative. Improvements in the assessment can be made by improving analytical techniques for the evaluation, by more accurately assessing the environmental conditions giving rise to the degradation concern, or by implementing predictive monitoring techniques to better monitor the condition of the equipment. Examples include improved margin analysis, development of time-dependent component reliability data, water chemistry data collection, and performance trending. Updated codes and standards may provide improved criteria for assessing the acceptability of continued component operation. Research and development activities may improve our understanding of age-related degradation and its effects enabling more realistic assessments.

In making a decision to pursue license renewal prior to expiration of the initial license, after 20 years of operation, for example, a licensee has the option to implement preventive actions before the component reaches its natural life and thereby enhance life expectancy. Application of protective coatings, improved water chemistry, and cathodic protection are examples of such early actions.

The licensee also has options to mitigate the effects of age-related degradation. When degradation has been identified, actions can be taken to reduce the severity of the degradation and thereby enhance the service life. In some cases, corrective actions may be necessary to return degraded components to a condition acceptable for continued operation; this may be accomplished via overhaul, refurbishment, repair, replacement, or modification.

Improved maintenance and surveillance activities may also provide a basis for continued operation. Such activities would improve the assessment of the effects of age-related degradation and lead to actions to prevent or mitigate such degradation.

Life extension options depend largely on the timing of individual decisions and, most of all, on plant-unique assessments of components with due consideration of operational duty and historic performance. Through a combination of better assessment, prevention, and mitigation for those components with the potential for significant age-related degradation, continued safe, reliable, and economic performance can be assured.

3.0 CONCLUSION

This document describes a methodology with criteria for systematically evaluating plant equipment for license renewal. The methodology identifies plant systems and structures which require component level review. Among these systems and structures, (1) the subset of components that is important to the system's or structure's safety functions are identified; (2) those components which currently are subject to established effective replacement, refurbishment, or inspection programs are identified; (3) the remaining components are reviewed to determine the impacts, if any, of age-related degradation; and (4) for those components where age-related degradation is a concern, options for resolution are detailed. At each step, the review focuses upon a decreasing subset of equipment, and the basis for sufficiency of review is documented and subject to regulatory review. Application of the methodology should result in effective and efficient review of the plant and should serve as a technical basis for the scope of license renewal, a focus for license renewal evaluations, and a foundation for license renewal process and regulations.

1 APPENDIX A

Step 1. Evaluation of All Plant Systems and Structures

Substep 1a. Does the Plant System or Structure Contribute to Plant Safety?

1a.1. Systems or structures that are identified as being safety-related in a licensing basis document.

OR

1a.2. Systems relied upon or structures identified in a licensing basis safety analysis or evaluation.

OR

1a.3.a Systems utilized in plant emergency operating procedures.

or

1a.3.b Systems taken credit for in a risk assessment if a plant unique risk assessment is available and used.

Substep 1b. Is Degradation of the System or Structure Potentially Significant to Plant Safety?

1b.1.a The system's or structure's failure could not directly result in off-site releases exceeding FSAR or other plant-specific off-site release limits.

and

1b.1.b The system's or structure's failure could not result in reactor coolant pressure boundary or primary containment leakage in excess of technical specification limits.

and

1b.1.c.1 The system or structure is not otherwise required for the performance or control of:

(1) reactor criticality
(2) reactor coolant system integrity, inventory, or heat removal
(3) containment integrity or heat removal

or

1b.1.c.2 Although the system or structure may be required for these functions, the system's or structure's failure is detectable in a time frame which would allow shutdown prior to requiring a manual or automatic plant trip.

OR

1b.2. A plant-unique risk assessment, if available and used, demonstrates that:

1b.2.a The system's or structure's failure does not occur in a sequence that has a core damage frequency greater than or equal to 1×10^{-6} per year or in a sequence that contributes 5% or more to the total estimated core damage frequency.

and

1.b.2.b When the system or structure is assumed to due to age-related degradation, the total estimated core damage frequency will not increase by more than a factor of 3 or will not exceed 1×10^{-4} per year.

Step 2. Evaluation of Components Within Systems and Structures

Substep 2a. Is the Component Important to System or Structure Safety Function?

The component is important to system or structure safety function unless:

2a.1. The component is normally isolated and does not perform an accident mitigating function.

OR

2a.2.a Component failure would not result in either the failure of any individual train within the system or the failure of the entire system to perform its required safety function.

and

2a.2.b Component failure would not reduce the structural support of any other component such that it would not perform its system safety function and

and

2a.2.c Component failure would not physically damage any other component such that it would not perform its system safety function.

OR

2a.3. For components within the scope of a plant-unique risk assessment, if available and used, the component is not included in the risk assessment models.

Substep 2b. Is the Component Subject to Established Effective Replacementment, Refurbishment, or Inspection Programs?

A component is considered to be subject to an established effective replacement, refurbishment, or inspection program if:

2b.1. The program is documented, approved, and routinely implemented in accordance with plant administrative procedures,

AND

2b.2. The program procedures ensure that all of the component's significant safety functions are properly addressed,

AND

2b.3. The program establishes specific criteria for determining the need for corrective action and requires such action be taken if these criteria are not met.

Substep 2c. Is the Component Subject to Potentially Significant Age-Related Degradation?

The component will be considered subject to potentially significant age-related degradation unless:

2c.1 It is established and documented that potentially significant age-related degradation will not occur during the license renewal period.

OR

2c.2 A plant-unique risk assessment, if available and used, demonstrates that:

2c.2.a When the component is assumed to fail due to age-related degradation, the total core

estimated damage

frequency will not increase by more than a factor of three or will not exceed 1×10^{-4} per year.

and

2c.2.b When an age-related common-cause failure mechanism is postulated that may cause multiple components to fail (among those which have satisfied criterion 2c.2.a), those components meet Criterion 2c.2.a when their combined failures are considered as a single event.

Substep 2d. Options to Resolve Potentially Significant Age-Related Degradation.

A variety of options to resolve potentially significant age-related degradation may be appropriate depending upon the component being addressed. Among the options are:

1. Replace the component on a replacement schedule which precludes component age-related degradation from becoming a problem.
2. Demonstrate, by detailed investigation, that age-related degradation of the component will not be significant during the license renewal period.

3. Demonstrate, by a more rigorous analysis, that the potential age-related degradation of the component is not significant to safety.

4. Institute practices which manage component age-related degradation by diagnosing the age-related degradation processes and preventing or mitigating their effect.