Fitness-For-Service as the Technical Basis for Nuclear Plant Life Extension

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ABSTRACT

This paper presents the basis for implementation of a methodology to screen critical components in the form of a Fitness-For-Service (FFS) evaluation. The methodology integrates the current licensing base for a unit, operating experience observations and the safety significance of the component. Fitness-For-Service methods aim to define when degradation mechanisms become significant to safety. If bounding results indicate that functional integrity is unaffected, for a period of service years greater than the projected life of the plant, then degradation is not significant to safety.

The primary purposes of FFS evaluation are to insure diagnosis adequacy, in coverage and frequency, and to define the critical timing for selection of absolute risk avoidance options such as component replacements. The method for meeting these criteria is a two step process; selecting critical safety systems and then validating their performance. Historically, code development organizations have intentionally avoided codification of current operational issues because they could not identify a satisfactory methodology. The structure of FFS reflects and addresses this dilemma. However, standards are needed to make clear which factors need to be considered in a FFS evaluation of critical components.

INTRODUCTION

By the year 2515 the LWR experience base of nearly 4,000 reactor-operating years will include substantial information and data on primarily 35-50 year old units. This should readily facilitate extraction and development of technical guidance for renewal of licenses beyond 40 years. During this period, approximately half of the present LWRs are candidates for license renewal. It is, therefore, important to address the technical aspects of license renewal for these units. In doing this, useful information for codes and standards development, as well as the necessary data and records associated with license renewal can be established.

A utility request for license renewal will follow a series of evaluations of the economics and risks of sustaining present unit operation in comparison to available alternatives for meeting forecast load. These management analyses, are those of possible significance to public utility commissions and associated federal agencies, but they are of lesser, or perhaps negligible interest to the public safety concerns of the U.S. Nuclear Regulatory Commission (USNRC). Utilities, under the auspices of the Nuclear Management and Resources Council (NUMARC) Nuclear Utility Plant Life Extension (NUPLEX) Working Group are developing a methodology to address license renewal requirements for USNRC consideration. The method is a two step process. The first is selection of those systems which are significant to public safety; the second is validation that the current and projected performance of these systems is adequately understood for regulatory purposes. This paper deals primarily with the implementation of the second step.

METHODOLOGY DESCRIPTION

Figure 1 illustrates a selection methodology developed for the license renewal process (Carlson et al, 1988). The first step is to divide the unit or plant into safety and non-safety significant systems; the latter essentially being excluded from further license renewal review. Steps 1 and 2 are both aimed at assessing the impact of any form of operational degradation of a system significant to plant safety. Step 1b defines those systems for which there is already regulatory acceptance that all degradation effects of possible public safety consequence are adequately understood and managed by efforts conducted during the license term. That information is assumed to carry over into the renewal period and does not require further review.

Step 2, the more general case, recognizes that systems significant to safety contain a limited number of components that will affect the safety function. Step 2 is an examination of the selected systems, on a component by component basis, to determine which are of safety significance and how that deterioration can be managed to insure that the license renewal criteria are met.

A number of components of a nuclear unit were not intended for 40 year service and are routinely replaced based on either empirical experience or lifetime limitations specified in their Environmental Qualification File (EQF). This class of components need not be reconsidered in the renewal process. The same conclusion applies where the component is subject to detailed periodic inspection which assures effective detection and management of deteriorations. For the remainder, it is incumbent on the licensee to develop an assessment and management plan as part of the renewal process.

SELECTION METHODOLOGY IMPLEMENTATION

The adequacy and remaining life of systems and components have historically been addressed by a series of probabilistic and deterministic analyses as appropriate. Probabilistic risk assessment (PRA) is an example of the former; the flaw evaluation procedures of the ASME Boiler and Pressure Vessel Code, Section XI, Appendix A are an example of the latter. These deliberations are ultimately reflected in codes and standards or their equivalent as NRC regulatory guides. The implementation of the screening methodology is simply an extended use of both of these techniques with modifications introduced to reflect knowledge gained by operational experience. Plant specific data and records inputs are also utilized where they are clearly more pertinent than are generic assumptions.

The term Fittness-For-Service (FFS) represents a more diversified grouping of Section XI, Appendix A type analyses than now exist (e.g. only crack growth is now codified.) FFS is a formalized method of determining remaining life tied to the presence or absence of specific plant data. It describes a process rather than a singular answer that is used when it becomes evident that the original design criteria used to establish component design integrity were inadequate.

FFS methods differ from PRA methods in that they aim to define <u>when</u> degradation(s) become significant to safety. A typical FFS evaluation is conducted, whenever possible, as a two step process. The first step is a limiting case study in which bounding potential deterioration(s) are assumed. If bounding results indicate that functional integrity is unaffected, for a period of

service years greater than the projected life of the plant, then no further action is necessary and degradation is not significant to safety. The second step, a more detailed analysis, most often results in a time-based inspection, sampling or surveillance plan. Implementation of the plan or 'management of the deterioration' will determine the useful life of the component.
This two-step process is analogous to the NRC method for assessing the influence of radiation embrittlement of the operating life of reactor pressure vessels. A 'screening criteria' (10CFR50.61, 1986) is first applied. No action is required if the vessel 'passes.' If the vessel 'fails', an alternate deterioration management plan (Reg. Guide 1.154, 1987) must be developed to determine the actual margin applicable to the unit in question.

IMPACTS ON LICENSE RENEWAL

Existing regulatory criteria requires that a potential safety risk be identified with sufficient lead time for a regulatory action. If a safety-related component is postulated to become inadequate in service year 32, the nominal licensee requirement is to insure that adequate inspection, surveillance sampling, or something similar is in hand to validate that any uncertainty in the assignment of year 32 is adequately monitored. The practical requirement is to insure that an appropriate option (e.g. replacement or refurbishment), has been planned and agreed upon with an appropriate lead time. Identification of the replacement or refurbishment option for resolution, however, is not required prior to that limiting lead time.

Although perhaps belabored, this 'timing' consideration is significant for renewal requirements. Specifically, the primary purposes of the FFS evaluation are to insure diagnosis adequacy in coverage and frequency and to define the critical timing for selection of absolute risk avoidance options such as component replacements. Selection of the latter is not an immediate requirement so long as options are known to exist.

FFS DISCUSSION

Figure 2 illustrates the general structure of a FFS evaluation in sufficient detail to indicate both its antecedents and prototypic inputs. The basis for Figure 2 is adapted from the ASME Section XI flaw evaluation procedures, which is an excellent example of an FFS evaluation.

Figure 3 illustrates the input factors and decisions involved in the FFS evaluation and suggests that a specific iterative format be used for evaluation. The reasoning is quite straightforward as has already been suggested. Note the progressive use of the FFS evaluation a) to determine the significance of known deteriorations, b) to focus inspections and c) to define data and records requirements.

APPLICATION TO CODES AND STANDARDS

The license renewal selection process (Figure 1) as described is a 'standard' for the safety-related issues of extended nuclear unit service. This covers the regulatory, safety and insurance-related factors that provide the rationale for most codes and standards activities. The more extensive efforts that a utility will perform, notably with non-safety systems, or for investment productivity need not be included in codes or standards.

Most codes and standards development organizations that have considered the issue agree that in general, their existing base does not preclude operation beyond 40 service years or it can be readily modified to accommodate it. The additional consensus is that what is needed is a methodology for life prediction together with application standards. This needed methodology is not unique to operation beyond 40 service years, but is instead a reflection of the status of codes and standards. Specifically, there is very high emphasis on design and test or inspection methods. There is substantially less on provision for operational feedback or adjudication.

What is specifically proposed is that standards be developed so that it is clearly understood what factors need to be considered in any FFS evaluation for any 'critical component' (Figure 1). Specifically:

- The general format illustrated should be accepted and/or as necessary expanded (Figure 2).

- Criteria that must be satisfied for each of the individual steps be identified on a critical component basis.

- Bounding conditions and data should be consolidated, again on a 'critical component' basis, which permit a screening evaluation. These could be standardized calculations in some cases.

- Guidelines for meeting acceptance criteria if components are beyond the bounds of the screening criteria should be developed.

Standards have been emphasized since it is really not clear how the classic codification process can practically be applied to the license renewal process, or to the more general process of component life estimating, until substantially after a number of those estimates have been formalized and tested. A somewhat more philosophical assessment is simply that codes work well when there is a large base of applicable experience, not while such base is being developed. In the context of license renewal, retrieval of data and records take on very specific meaning. With the passage of time any nuclear unit, even those which are nominally identical in design basis, take on a different character. A primary purpose of data and records retention is to demonstrate these differences to regulatory bodies. In general, data and records requirements are defined by outputs from a FFS evaluation. A staged FFS evaluation will include provision for the absence of some data. This absence will usually be reflected in a requirement to use 'worst case' assumptions.

SUMMARY

License renewal will likely be conducted by approximately half of the operating LWRs in the U.S. before the year 2015. However, the structure and process of license renewal must be addressed well before that time. The basic renewal criteria must provide assurance for aspects explicit in a 40 year design-life, the potential for new safety issues, and reliable performance of safety systems beyond 40 years.

The method for meeting these criteria is a two step process; selecting critical safety systems and then validating their performance. The basis for selecting critical safety systems is the screening methodology (Carlson et al, 1988). The two accepted methods of evaluating performance are PRA and FFS. PRA relies upon incident rate information obtained from operating experience. However, attempts to extract age-effects from the data are inconclusive at this time. Nevertheless, sensitivity studies can be used to simulate age degradation by conservatively increasing failure rates, and where appropriate, by modifying initiating events or accident sequences to determine the effect of risk.

FFS is a deterministic method of determining when safety is compromised. If after a bounding evaluation of potential degradation mechanisms functional integrity is unaffected and does not pose an undue risk to safety for the projected life of the plant, no further action is necessary. If not, a more detailed analysis may result in a time-based inspection, sampling or surveillance plan. The FFS approach permits the utilization of diverse

operational experience base and is in most cases the preferred method of evaluation.

Historically, code development organizations have intentionally avoided codification of current operational issues because they could not identify a satisfactory methodology. The structure of FFS reflects and addresses this dilemma. However, standards are needed to make clear which factors need to be considered in a FFS evaluation of critical components.

REFERENCES

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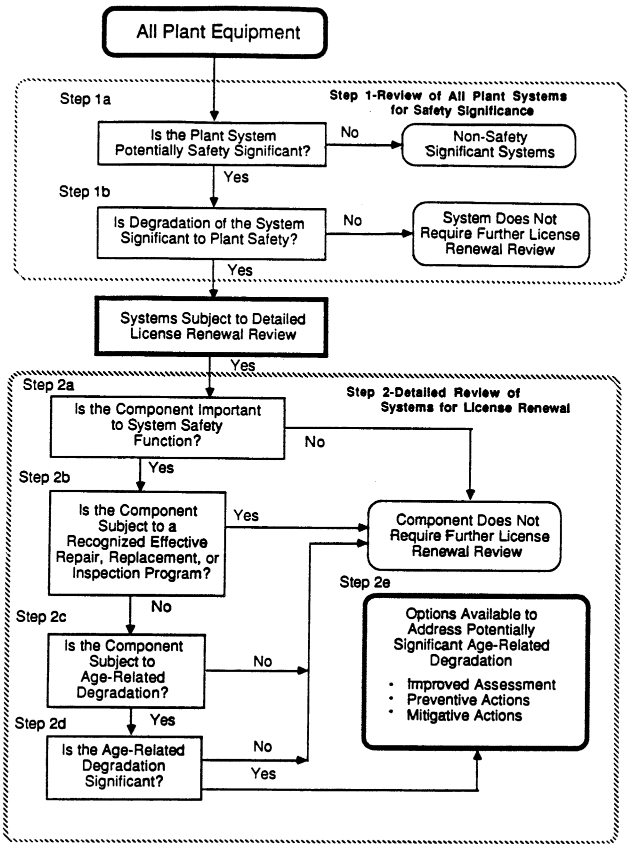

FIGURE 1: A Methodology to Identify and Evaluate Plant Equipment for License Renewal Review

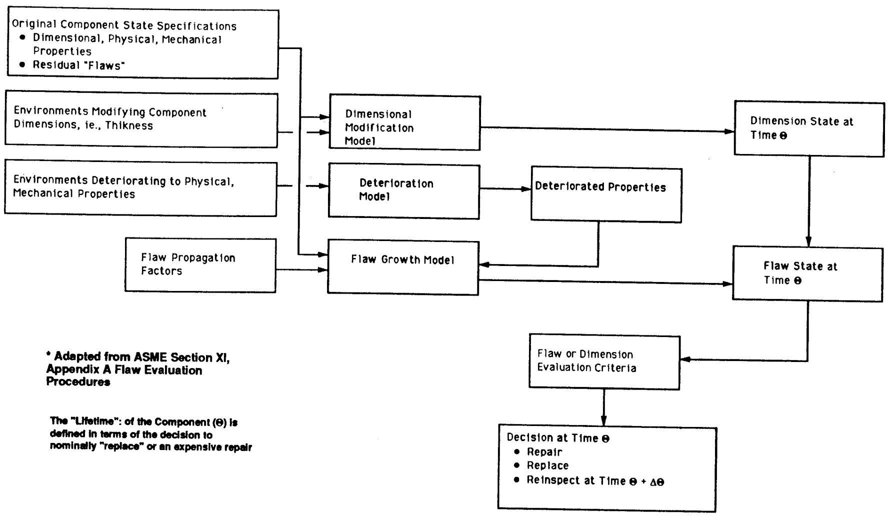

FIGURE 2 : Schematic of Component Longevity Evaluation Procedure (Fitness For Service)

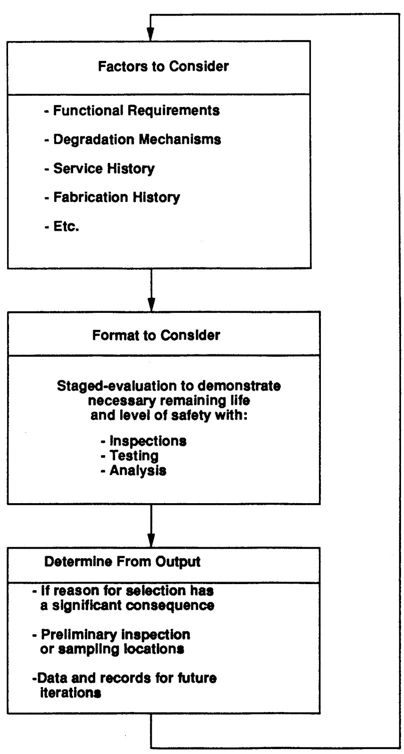

FIGURE 3: Iterative Nature of Fitness For Service Evaluation