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UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

October 18, 2000

MEMORANDUM TO: Mario V. Bonaca, Chairman
Plant License Renewal Subcommittee

Noel Dudley

FROM: Noel Dudley, Senior Staff Engineer

SUBJECT: CONSULTANT REPORT CONCERNING THE ELECTRICAL EQUIPMENT PORTIONS OF THE LICENSE RENEWAL GUIDANCE DOCUMENTS

Dr. Salvatore Carfagno provided the attached report concerning his review of the adequacy of staff guidance for reviewing license renewal applications related to electrical equipment. The introduction to his report includes a well reasoned discussion comparing the requirement to strictly adhere to regulatory guidance and the approach of allowing applicants complete responsibility for ensuring compliance. Some conclusions contained in the report are:

- additional guidance is needed for assessing components built or designed prior to the present IEEE criteria,
- state of technology (condition monitoring) is not consistent with satisfying the criteria for acceptability of aging management programs,
- condition monitoring does not increase the predictive capabilities of applicants,
- existing requirements are adequate but subject to difficulty in complying with them,
- PERT charts and checklists should be provided to the reviewers, and
- the frequency of acceptance tests should be increased.

Attachment: Consultant Report

cc: ACRS Members

cc att via e-mail:
J. Larkins
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REVIEW of ADEQUACY of STAFF GUIDANCE for REVIEWING LICENSE RENEWAL APPLICATIONS

October 12, 2000

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1. INTRODUCTION

This report was prepared in fulfillment of a task to conduct an independent review, for the Advisory Committee on Reactor Safeguards (ACRS), of the adequacy of staff guidance for reviewing license renewal application sections associated with electrical and instrumentation and control components and the time limited aging analyses (TLAAs) for environmental qualification of electrical equipment. The scope of the review is summarized in Section 2, and a copy of it is included in Appendix A.

Conclusions reached in response to the questions implied by the scope of the task are in Section 3, immediately following the section on scope.

To make it easier to understand the concepts involved in the regulatory documents, a summary of condition monitoring options that may be included in a license renewal application are included in Section 4. Section 5, the main body of this report contains the review, which was focused on the technical content of the documents, without commenting on matters of documentation, format, and schedules. For some of the documents the format is to provide a summary of the relevant sections of the documents, followed by review comments. This format was chosen to facilitate identification of the context of the review comments and to make it possible to omit background information from each review comment. In other cases, it was more convenient to intermix summary and comment statements.

A review of this type depends a great deal on the approach taken. At one extreme the approach is to take a strict interpretation of the regulatory documents and to require scientific justification for the applicant's compliance, making no allowance for engineering judgment. Adherence to this extreme approach would make this review impossible; and its adoption by regulators could lead to the closing of nuclear power plants. At the other extreme, the entire responsibility for compliance could be placed on the applicant, without requiring extensive documentation and justification of the positions taken in the license renewal application. This extreme approach is likewise unacceptable. Over the years a middle ground approach has developed naturally, in which the regulators and the utilities reach an accommodation: the utilities comply as best possible within the limits of the state of applicable technology, and the regulators make judgments consistent with reasonable assurance of public safety. The safety record of the nuclear power industry in the United States tends to confirm the adequacy of this middle ground approach. However, in reviewing applications for extended periods of operation, the degradation accompanying aging dictates a closer scrutiny of the regulations and compliance therewith. If anything, the middle ground accommodation should move in the direction of stricter compliance.

An example is useful in illustrating the accommodation discussed above. It is known that thermal aging analysis depends critically on the choice of activation energy, and that activation energies depend critically on the specific formulation of an insulating material, and possibly on the manufacturing process as well. In Section 4.3, an instance is reported from recent cable research in which the coloration of conductors with the same insulating material had significantly different degrees of degradation. Accordingly, strict compliance with aging requirements would lead to the need to measure the activation energy for the critical material in the component being evaluated; however, it is common practice to use values of activation energy found in tables of generic values, thereby saving considerable time and cost in thermal aging analyses. In view of the conservatism and other uncertainties in the qualification process, this is probably an acceptable accommodation.

An ideal situation would be to have consistency between the wording of regulations and the compliance therewith. This report notes a few instances in which improvement of the accommodation should be considered. Improvements can take the form of making regulatory requirements more consistent with the state of technology as well as more careful scrutiny of compliance.

2. SCOPE of REPORT

This report documents a review conducted in accordance with the requirement "to review and report on the adequacy of the staff guidance in the SRP and the GALL report for reviewing license renewal applications associated with electrical and I&C components and the TLAAs for environmental qualification of electrical equipment." The Scope of Work and specific requirements are included in Appendix A. The documents reviewed are listed in Section 6.

Key elements of the scope are:

- evaluation of relevant sections of the SRP (Ref. 5) to determine if it provides adequate guidance and direction for
    - determining that an applicant's aging management programs are acceptable
    - referencing applicable chapters of the GALL Report (Ref. 6)
    - assessing the adequacy of time-limited aging analyses
    - reviewing electrical and I&C systems that were designed and built prior to the present design criteria and inspection programs
- review of Chapters I and VI of the GALL report and other referenced documents (NRC, IEEE standards, and EPRI: Refs. 3, 4, and 8 - 16) to determine
    - whether existing programs will adequately manage age related degradation of the passive long-lived components over the extended life of the plant
    - adequacy of the technical basis for the aging management programs
    - whether older referenced IEEE standards are adequate for justifying continued operation of nuclear power plants for 60 years

3. CONCLUSIONS

The following conclusions are based on the review of Chapters 3.6 and 4.4 of the Standard Review Plan (SRP), Ref. 5, and Chapters I and VI of the GALL Report (Ref. 6) which are those covered by the scope of work. They apply to electrical and instrumentation and control components and environmental qualification of electrical equipment. These components fall within the scope of the 10CFR54 for license renewal in accordance with the criteria summarized in Section 5.1 of this report.

The Standard Review Plan and the GALL Report provide adequate guidance and direction for fulfilling the requirements of license renewal, subject to a few cautions. Reviews would be facilitated by the preparation of pert charts for the review process, guiding staff reviewers through the sequence of steps in the review of a license renewal application. In addition, check lists for selected elements of the review process, such as determination that the list of components within the scope of license renewal is complete, review of aging analyses, and evaluation of condition monitoring techniques, would also facilitate the review process.

Clearer language would be helpful in eliminating potential confusion as to the definition of components within the scope of license renewal. On the one hand, components with an active function are excluded and passive components are included, the rationale being that performance monitoring makes aging management easier for active components. Similarly, components whose replacement is based on a qualified life or a specific replacement interval are excluded. On the other hand, EQ components, most of which have active functions and do have a qualified life, are included; but their evaluation is essentially limited to the review of TLAAs and any aging monitoring programs that may be used to justify operation beyond their qualified life.

The document review conducted in the preparation of this report highlighted several references that would be particularly helpful in the training of staff members to undertake license renewal reviews. The version of 10CFR54 (Ref. 3b) that includes a discussion of public comments, and the Commission's response to them, provides an excellent appreciation for the rationale of the requirements, which is not always obvious from the regulation alone. In addition to the regulatory documents (Refs. 3, 5, 6, 7, 14, 15, and 16), familiarity with the referenced industry standards (Refs. 13, 17, and 18) is required. Particular attention may be drawn to the Branch Technical Position in Appendix A.1 of Ref. 5. Familiarity with some supporting documents is helpful: Ref. 10 provides a compendium of information on aging effects and condition monitoring techniques; and Ref. 8 shows how applicants plan to respond to the license renewal requirements. Pert charts in Ref. 8, designed to aid applicants, would also aid the staff in understanding the compliance process. Finally, attention is directed to Ref. 19 as a source of information on localized adverse environments that affect equipment performance.

Ample guidance and direction is provided in the SRP and the GALL Report for the review of aging management programs; difficulties arise where the current state of technology, particularly condition monitoring methods, is not consistent with satisfying the criteria for determining the acceptability of aging management programs. This potential conflict is described in several sections of this report, including Sections 4.1, 4.3, 5.4, and 5.10. The critical areas of review are discussed in the following paragraphs.

One critical area of review concerns condition monitoring (CM) programs that may be used for EQ components with a QL less than 60 years. While the documents reviewed contain a wealth of information on the criteria that must be met for CM programs to be acceptable, the fact remains that practical CM techniques probably do not exist that meet the key criterion, i.e., that the method be capable of predicting with reasonable assurance the remaining period during which the intended function can be performed. The regulatory documents state specifically that simply verifying that equipment is functional in the normal service environment is not sufficient. This is an area in which the type of accommodation discussed in the Introduction of this report is undoubtedly required.

The reason for excluding from review those components that have active functions, i.e., because it is easier to monitor such equipment than to monitor passive components, may be qualitatively true, but the fact remains that performance monitoring does not significantly increase the predictive capability of CM techniques.

Another area of review that may present difficulty concerns components designed and built prior to the existence of the present criteria and inspection programs; this area is also related to the question of whether equipment qualified in accordance with older regulations and IEEE standards are adequate for use during the period of continued operation. The first fact to be established is whether any currently installed equipment falls within this description; the list is probably limited to a very small number of components, if any. If no components fall into this category, the question is moot; if there any components that do fall into this category, the discussion given in Section 5.10 of this report may be summarized as follows.

The DOR guidelines (Ref. 16) and Category II of NUREG-0588 (Ref. 15) - the earlier regulations - do not, as often thought, dispense with the aging requirement of later regulations: RG 1.89 (Ref. 14) and Category I of NUREG-0588.+ The key difference is that the later regulations require preaging of equipment samples to simulate the effects of aging degradation on functional capability prior to accident simulation testing, while the earlier regulations (DOR) required that "Ongoing programs should exist at the plant to review surveillance and maintenance records to assure that equipment which is exhibiting age related degradation will be identified and replaced as necessary," or that (NUREG-0588 Category II) for equipment other than valve actuators and motors, "the qualification programs should address aging only to the extent that equipment that is composed, in part, of materials susceptible to aging effects should be identified, and a schedule for periodically replacing the equipment and/or materials be established." Valve actuators and motors were required by NUREG-0588 to account for the effect of aging the same way as required for Category I equipment. In short, equipment qualified in accordance with older standards that did not require preaging of samples were not required to be requalified to establish a qualified life, but such equipment was required to be evaluated for aging effects and for programs to be established to assure that the equipment remained capable of performing its intended function.

If there are any components still in service that were qualified on the basis of the older standards, any weakness in a claim that there is reasonable assurance that their intended function(s) can be performed is not due to any weakness in the regulations, but in a possible deficiency in their implementation. Here again, one faces the dilemma caused by a gap between the requirements and the ability to fulfill them within the limits of existing technology. Condition monitoring methods with reliable predictive capability are still rare, so it is not surprising if utilities had difficulty 20 or so years ago complying with the letter of the aging surveillance requirement. In other words, it was necessary to reach an accommodation between the requirement and the ability to comply with it.

A simple way to distinguish between components qualified in accordance with the older requirements and those that complied with the later requirements is that the former did not require a qualified life (QL) and the latter did. One can have more confidence in the safety assurance of equipment that had to be subjected to accelerated aging prior to a LOCA test (with QL) than equipment that passed a LOCA test without prior aging (no QL); but this does not necessarily mean that the latter are unacceptable.

Any components still dependent on the older standards are nearly in the same situation as equipment with a QL less than 60 years, and they could be evaluated in a similar way. Thus, the license renewal process provides an opportunity to correct any deficiencies that may still exist in

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+ In NUREG-0588, Category I refers to equipment qualified in accordance with later standards (IEEE Std 323-74 and RG 1.89), and Category II refers to equipment qualified in accordance with older standards (IEEE Std 323-71 and DOR Guidelines).

the acceptance of components without a QL. It must be borne in mind that all of this discussion applies to components expected to perform intended function(s) in harsh environments; the interpretation of current standards is that a qualified life is not required for equipment that does not undergo a change in environment when a design basis event occurs.

The question concerning the adequacy of the technical basis for aging management programs has essentially been answered by the foregoing discussion: the technical requirements are adequate, any weakness exists in the ability to comply with any requirement that demands prediction of future functional capability.

The question as to whether existing programs will adequately manage age related degradation of passive long-lived components over the extended life of the plant can be answered from two points of view. If by "existing programs" is meant those that have been defined in the license renewal regulations, the answer is that the requirements are adequate but are subject to difficulty in complying with them. If "existing programs" refers to programs actually implemented in operating plants, it is not feasible to answer the question simply on the basis of having reviewed the documents in the list of references. At best, any programs that have been implemented, and which are required to have predictive capability, must suffer from the fact that existing condition monitoring methods do not have reliable predictive capability.

The guidance available for evaluating time-limited aging analyses is adequate. The only caution applies to the choice of activation energy, which is known to depend critically on the specific composition of materials analyzed - making the use of generic values of activation energy questionable. However, it may be reasonable to reach an accommodation on this matter in view of all the other uncertainties - as well as conservatisms - that exist in the evaluation of component acceptability.

As to a final question concerning the adequacy of guidance in the SRP in referring to applicable chapters of the GALL Report, the answer is that the guidance is certainly adequate.

A final comment stems from the observation on reviewing Ref. 10 that a large fraction of failures (among cables and penetrations) in normal service occur in connectors and hookup and panel wire, coupled with the observation in Ref. 19 of the many types of adverse conditions that exist in plants (although statistically minimal): one is led to ask whether these observations should not be reflected in the priorities applied to actions taken to assure safety. When one considers the resources that have been devoted to the study of cable aging and condition monitoring during the last two decades, one wonders whether a better distribution of resources isn't indicated.

4 DESCRIPTION of AGING MANAGEMENT OPTIONS

To evaluate the aging management guidelines, it is essential to understand the different types of aging management programs available; therefore, this section is devoted to a description of the options and comments on their positive and negative features.

4.1 Qualification to Extend Qualified Life*

One option for aging management for license renewal is to conduct a traditional qualification test, as outlined below, and establish a qualified life equal to the extended plant life. Several variations may be considered: for example, for a new plant and new equipment, the accelerated aging program may be designed to reproduce the degradation of 60 years of service; while for an existing plant and existing equipment, the testing may be limited to whatever is necessary to extend the qualified life to 60 years. While this option is included here, mainly for completeness and to comment on certain concerns about the traditional qualification, other aging management options described in Sections 4.2 to 4.6 are usually considered preferable. From a practical point of view, the traditional qualification testing is very expensive and time consuming.

The traditional method of qualifying safety-related electrical equipment is testing to establish a qualified life. In a typical program, the following sequence of major steps are entailed if the equipment is required to function in an accident environment. The applicable accident may be a loss-of-coolant accident (LOCA) or a high energy line break (HELB); but for simplicity, this description mentions only the loss of coolant accident (LOCA). Where a specific equipment makes the description clearer, electrical cables are used as the example.

selection of the service temperature, normal service radiation dose, accident dose, and accident temperature/pressure profile for which the equipment is to be qualified

definition of the safety function and acceptance criteria for satisfactory performance of the function

choice of a qualified life goal

establishment of the activation energy of the critical material or part of the equipment (for cables this is almost always the insulation material)

calculation of accelerated thermal aging conditions using the Arrhenius equation, using the activation energy, the selected service temperature, and qualified life goal as inputs. The outputs will be the oven temperature and duration of the accelerated thermal aging

for present purposes, the elements of the test program may be limited to the following

accelerated thermal aging

radiation aging to the normal service dose+

irradiation to the accident dose+

simulation of the LOCA

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* Review of components with a qualified life or specified replacement interval are explicitly excluded from license renewal reviews; however, if the qualified life is less than 60 years, applicants may choose to re-evaluate the existing qualified life to extend it to 60 years.

+ In practice, the aging and accident doses are usually combined into a single radiation exposure.

If the sample tested satisfies the acceptance criteria, the equipment is given a qualified life equal to the goal selected at the start of the program

The main technical concern with the traditional qualification is that accelerated aging is subject to major uncertainties resulting from the following considerations: small uncertainties in the value of activation energy produce major uncertainties in the qualified life; since it is not feasible to age each material and part separately, any material or part with an activation energy higher than the one used to calculate thermal aging conditions, will be over-aged (for example, cable jackets are usually over-aged); the use of high stress levels (high temperature and high dose rates) to abbreviate aging by a factor of 100 or more can result in degradation differing from that which occurs in normal service; in the case of cables, the use of short specimens (about 3 m long) makes it difficult to define functional testing and acceptance criteria.

Sometimes, equipment subjected to accelerated aging appears to be degraded in excess of what has been observed in long-term industrial applications, in which case the excessive aging contributes to the conservatism of the qualification process. It must be cautioned that radiation aging and accident irradiation are usually combined in qualification programs, so that equipment is observed not at the conclusion of accelerated aging but after part of the accident simulation has been completed, i.e., the accident radiation exposure may contribute additional degradation to the aging degradation.

When extensive review of this type of EQ program was undertaken in the 1980s, adequate guidelines were established for the staff; these included a check list, a copy of which is included in Appendix B.

4.2 REANALYSIS of EXISTING QUALIFICATION

If it is found that the service temperature assumed in an existing qualification is excessive, or that the activation energy used in calculating thermal aging conditions was too low, or both, then a recalculation of the qualified life yields a longer life which may meet the need for license renewal. Of course, it is also possible that a re-examination of the original assumptions may force a reduction of the existing qualified life.

A dramatic example can be found in Ref. 12 (Table 2.3) in which the qualified life of cables qualifed by five manufacturers between 1975 and 1981 were recalculated. In all cases the original qualified life was 40 years, but the assumed service temperature varied between 50 °C and 90 °C among the manufacturers. When the qualified lives were normalized to a service temperature of 60 °C, the recalculated qualified lives varied between 11 years and 2,847 years.

Although it is not feasible to conduct a similar recalculation of radiation aging, the original aging dose was usually chosen as 50 Mrd, which was conservative for most applications and is probably adequate even if the service life is extended to 60 years, except in localized plant areas with high radiation levels. Equipment in these areas can degrade unacceptably in less time than the qualified life, and it is necessary to periodically replace such equipment. For example, some cables located near the reactor vessel are replaced at intervals of a few years, a fraction of the qualified life for other areas of the plant.

The guidelines for this aging management option should include documented justification for any changes in the service conditions and activation energies used in the original qualification.

4.3 CONDITION MONITORING

This option requires that there exist condition indicators, i.e., measurable properties of the equipment or its materials or parts, correlated with the functional capability of the equipment. (An example is the elongation-at-break (EAB) of the insulation of electrical cables, which is indicative of the degradation of the insulation.) The scheme requires that the indicator be trendable in time and that there exist criteria for deciding when the equipment is approaching the point at which it will no longer be capable of performing its intended function. A key feature of this method is that it must be predictive, i.e., it is not sufficient that measurement of an indicator reveal the current functional capability in normal service: it is essential to predict how much longer the equipment can be depended upon to perform its intended function in case of an applicable accident. This is a heavy demand, and one which is not commonly within the capability of current condition monitoring technology.

Condition monitoring has been the subject of considerable research by government and industry, including the NRC's Nuclear Plant Aging Research (NPAR) program (Ref. 11), the nearly completed NRC study of condition monitoring techniques for low-voltage electric cables (Ref. 12), and a DOE study of aging management for electrical cable and terminations (Ref. 10), among others. The results of much of this research is reflected in an IEEE guide for assessing, monitoring and mitigating aging effects (Ref. 13). A common feature of the information in the cited references is that it is qualitative, i.e., aging mechanisms, their effects, and monitoring techniques are presented, but decision criteria are not available; these criteria must be established for the specific installed equipment.

The results of an NRC cable research program nearing completion (Ref. 12) do not appear very promising for condition monitoring as a method of predicting LOCA survivability of electric cables. The condition monitoring measurements studied included elongation-at-break (EAB), oxygen induction time, oxygen induction temperature, Fourier transform infrared spectroscopy (FTIR), compressive modulus, hardness, power factor (PF), insulation resistance (IR), and polarization index (PI). For cables with XLPE insulation, Ref. 12 suggests that a limiting EAB value of 50% might be a reasonable criterion for LOCA survivability. However, it was cautioned that one of the cables failed the final testing following LOCA simulation in spite of the fact that the values of EAB at the end of aging were as high as 312%. Criteria mentioned for other CM measurements include PF>0.3 for XLPE, PF>0.4 for EPR, and PI< approx. 2 for XLPE. It was concluded that FTIR may not be an appropriate CM method; and hardness measurements were inconclusive because of an inappropriate instrument. For the other CM methods studied, it was not feasible within the limits of the program to establish acceptance criteria. Because of variations in CM measurements for cables with the same generic insulation material but made by different manufacturers, it was concluded that trending data and acceptance criteria would be needed for the specific installed cables. To illustrate the difficulty of finding generic criteria, it is interesting to observe that in a case involving a multiconductor cable with conductors that differed only in color, CM measurements on conductors with different colors were significantly different.

Although the CM measurements made in this study were made under laboratory conditions, using the same instruments, and presumably by the same persons, considerable data scatter was observed. Making CM measurements under varying plant conditions over periods of 40 to 60 years, probably with different personnel and different testing equipment, data scatter would undoubtedly be worse than was observed in the research program. In some cases there was no significant trend in measurements with age, and when trends were observed, they were not of major magnitude except for EAB. Furthermore, it was emphasized it is difficult to establish generic criteria not only because they depend on specific cable formulations, but also because of the effect of the environmental conditions in plants: e.g., temperature, humidity, cable length, and adjacent operating equipment. Accessibility is another difficulty. For EAB, the method that seemed to be superior to all the others, the main problem is that it is a destructive measurement and would require the installation of sacrificial cables in strategic locations of the plant.

A major point of the foregoing discussion is that research into condition monitoring methods over the last two decades has not produced results that can be put to immediate use for specific equipment. Therefore, guidelines for evaluating this option must not only assure that applicants understand what is incurred in any commitment to the use of CM (i.e., the need for testing to establish trends, the finding of useful trends, and establishing criteria for accident survivability), but a reasonable time must be agreed upon for obtaining all the necessary ingredients for a successful CM program: in an extreme example, it would not be acceptable if the effort required to establish an acceptable CM method were to take the entire period of extended plant operation.

If trending data and acceptance criteria do not exist for an installed equipment, the following testing may be required. The accelerated aging would have to be repeated on a representative sample, with the process interrupted at intervals to permit condition monitoring measurements to obtain the trending data. The critical measurement is the one made at the conclusion of accelerated aging, i.e., under pre-LOCA-test conditions. Note that this requires that the critical CM measurement be made after thermal and radiation aging; and this requires that the radiation process be interrupted for CM measurements at the completion of the normal service dose exposure, i.e., before the accident dose is applied. Alternatively, the critical CM measurement can be chosen to be the one made at the conclusion of thermal aging, which is a conservative choice because it ignores any additional degradation that might occur during radiation aging. This procedure constitutes a repetition of a considerable portion of the original qualification testing, an expensive and time-consuming undertaking which conflicts with any desire to pursue aging management by methods that are adequate but not unnecessarily burdensome.

While the foregoing discussion has emphasized the difficulty of obtaining predictive information from CM techniques, condition monitoring is still the most effective way to manage aging. In contrast to qualification based on establishing a qualified life, condition monitoring looks at real equipment in the real service environment; consequently, it is capable of uncovering significant aging mechanisms that may not be reproduced by the accelerated aging used in the qualified life approach. While CM methods may not meet the ideal of providing a dependable criterion for predicting how much longer after a CM measurement the equipment can remain capable of performing its intended function, it is the best way to observe the condition of the equipment in service.

Evaluation of CM measurements can provide a basis for corrective actions such as recalibration, repair, refurbishment, and replacement independently of its weakness as a predictive method.

4.4 ROOT CAUSE ANALYSIS

Equipment designed and qualified for operation during an accident may sometimes fail even in normal service. In such cases there was a tendency in the past to regard such failures as random and not due to a common cause; consequently, the equipment may simply have been repaired or replaced, without any re-evaluation of the qualification status. It has become increasingly clear that root cause analyses of failures that occur in normal service are essential. The corrective action depends on the outcome of the failure analysis. If the failure is found to be due to a factor common to all samples of the equipment, re-examination of the qualification status is required. If the cause is found to be due to service conditions more severe than those for which the equipment was qualified, examples of corrective steps include relocation, shielding, and replacement with superior equipment.

4.5 RECALIBRATION, REPAIR, REFURBISHMENT, and REPLACEMENT

Decisions concerning recalibration, repair, refurbishment, and replacement must be based on failure analysis and engineering evaluation of surveillance activities in the plant, including periodic testing, inspection, and condition monitoring. Because of the variety of equipment and the types of observations that may be made, it is not feasible to provide specific guidelines except that the evaluations must be done by qualified personnel and the decisions must be justified and documented in auditable form.

4.6 MITIGATION of AGING EFFECTS

Various procedures can be taken to mitigate aging effects when they are found to exceed those assumed when the equipment was qualified. These include relocating equipment to areas with less severe environmental conditions, shielding equipment from undesirable service conditions, and adding means to reduce the severity of the service conditions. When none of these approaches is feasible, it may be necessary to replace the equipment with superior types or to replace it at intervals when its condition becomes unacceptable.

5. DOCUMENT REVIEW

5.1 U.S. CODE of FEDERAL REGULATIONS 10CFR Part 54, REQUIREMENTS for RENEWAL of OPERATING LICENSES for NUCLEAR POWER PLANTS, (Ref. 3)

This Part of the Code defines the scope of systems, structures, and components (SSC) included in the review of applications for license renewal. Section 54.21 defines the technical information that must be included in the application.

Two criteria define the attributes of structures and components that are within its scope:

> perform an intended function without moving parts or without a change in configuration or properties; these are termed passive components
>
> are not subject to replacement based on a qualified life or specified time period

The second criterion does not apply generically to passive components "that are replaced based on performance or condition from an aging management review." On page 22478 of Ref. 3b, it is reasoned that, "Absent the specific nature of the performance or condition replacement criteria... [and considering that] components with "passive" functions are not as easily monitorable as components with active functions, such generic exclusion is not appropriate." The main requirement to comply with this section of the Code is demonstration "that the effects of aging will be adequately managed so that the intended function(s) will be maintained...for the period of extended operation."

The other main requirement is the evaluation of time-limited aging analyses, for which it must be demonstrated that:

> "i. The analyses remain valid for the period of extended operation;
>
> ii. The analyses have been projected to the end of the period of extended operation; or
>
> iii. The effects of aging on the intended function(s) will be adequately managed for the period of extended operation."

Electrical equipment subject to environmental qualification (EQ equipment) is captured by the TLAA criterion because EQ includes time limited aging analyses.

5.2 PROPOSED RULEMAKING FOR U.S. CODE OF FEDERAL REGULATIONS 10CFR PART 54, REQUIREMENTS FOR RENEWAL OF OPERATING LICENSES FOR NUCLEAR POWER PLANTS (REF. 4)* and

NUCLEAR POWER PLANT LICENSE RENEWAL; REVISIONS (In APPENDIX A of Ref. 8)

The proposed rule documents proposed changes to the requirements adopted in the license renewal rule published in 1991. Although the statement "Comment period expires 6/14/93" appears under the title, an entry under the heading "DATES" indicates that comments were to be submitted by December 8, 1994. A copy of the final rule published in the Federal Register on May 8, 1995, was found in the appendix of Ref. 8; and this review is limited to some comments on the technical content of the final rule. While the reader is referred to the appendix of Ref. 8, the page numbers in the following comments are those of the publication in the Federal Register.

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* This is the version that was provided for review; a later version was found in the appendix of Ref. 8.

p 22469. Under the heading Aging Mechanisms and Effects of Aging, it is pointed out that the focus must be on the effects of aging on functional capability, and it is not essential to understand how aging mechanisms produce such effects. It is recognized that the causes of functional degradation can include "faulty manufacturing processes, faulty maintenance, improper operation, or personnel errors" in addition to aging. It is interesting that attention is drawn to the potential contribution of faulty manufacturing to functional degradation because of the claim sometimes made, in the area of equipment qualification, that qualification pertains to design and that the manufacturing process is not part of what is qualified. However, it is well known that products produced by different manufacturers from the same design and specifications will not be identical.

p 22472. Under the heading Excluding Structures and Components With Active Functions, it is explained that "structures and components associated only with active functions can be generically excluded from a license renewal aging management review [because] the effects of aging on active functions can be more readily determinable, and existing programs and requirements are expected to directly detect the effects of aging."

The question remains that any intended function required when components are exposed to the severe conditions produced by an accident cannot be easily detected by surveillance activities in normal service. The position that active components can be excluded appears to take an optimistic view of the status of performance and condition monitoring, especially as applied to components required to function in accident environments.

p 22477. Under the heading "Passive" Structures and Components, it is concluded "that an aging management review is required for structures and components...that perform passive intended functions." It is explained that "structures and components that have passive functions generally do not have performance and condition characteristics that are as readily monitorable as those that perform active functions." It is explained that "passive structures and components for which aging degradation is not readily monitored are those that perform an intended function without moving parts or without a change in configuration or properties," which is clarified to encompass "a change in state."

The inclusion of electrical cables among passive components is justified because "there is no single method or combination of methods that can provide the necessary information about the condition of electrical cable...regarding the extent of aging degradation or remaining qualified life." It is emphasized that "these components are relied on to remain functional during and following design basis events...and there are no known effective methods for continuous monitoring of cable systems..."

Preliminary review of cable condition monitoring research (e.g., Ref. 12) that has taken place in the last five years does not seem to justify any significant change in these statements. There are many methods of monitoring cable condition, but - in view of their present state of development - it is unlikely that a utility would be willing to stake a decision on replacing cable solely on the basis of condition monitoring criteria currently feasible.

p 22478. Under the heading "Long-Lived" Structures and Components, it is recognized that replacement of a structure or component either "(i) on a specified interval based upon the qualified life...or (ii) periodically in accordance with a specified time period..." can effectively mitigate the effects of aging. All structures and components that do not meet these two criteria are deemed to be "long-lived."

This position is reasonable provided qualification programs and the technical basis for periodic replacement account adequately for aging effects. See also comment for p 22472, above. Note, too, that criterion iii (see Section 5.1) nonetheless captures EQ equipment.

p 22479. Under the heading The IPA Process, the Commission agrees with a DOE comment that "the IPA process serves to demonstrate that a structure or component will perform in a manner consistent with the CLB rather than to provide "absolute" assurance that the structure or component will not fail.

This position is consistent with the fact that no degree of aging management can "guarantee" the future functional capability of structures and components.

5.3 ACRS REVIEW of LICENSE RENEWAL APPLICATIONS for CALVERT CLIFFS NUCLEAR POWER PLANT and OCONEE NUCLEAR STATION

The ACRS has reviewed the license renewal applications for the Calvert Cliffs Nuclear Power Plant and the Oconee Nuclear Station (Refs. 1 and 2) and concluded in both cases that the plants "can be operated in accordance with their current licensing basis for the period of the extended license without undue risk to the health and safety of the public."

This conclusion implies that the ACRS considers adequate the NRC and industry guidelines used for the preparation and review of license renewal applications. This report constitutes an independent assessment of the adequacy of the guidelines in accordance with the Scope of Work (Section 2).

5.4 GENERIC AGING LESSONS LEARNED (GALL) REPORT (Ref. 6)
Vol. 1 Summary (Draft for Public Comment)

5.4.1 Summary

This report was prepared in response to the issue, "To what extent should the staff review existing programs relied on for license renewal in determining whether an applicant has demonstrated reasonable assurance that such programs will be effective in managing effects of aging on the functionality of structures and components in the period of extended operation?" The results of the staff evaluation of existing aging management programs are presented in tables that list, in part:

component

aging effect/mechanism

aging management programs

whether further evaluation is recommended

In those cases where further evaluation is recommended, the aging management program(s) that require further evaluation are identified.

The only components within the scope of this independent review are non-environmentally qualified electrical cables and connections and environmentally qualified equipment; structures are outside the scope of this review. Accordingly, the chapters that fall within the scope of this report are Chapter VI.A - Non-environmentally Qualified (Non-EQ) Electrical Cables and Connections, and Chapter VI.B - Environmentally qualified (EQ) Equipment. Applicable sections of Chapters X and XI, which are referenced in Chapter VI, were also reviewed.

"The staff's evaluation of the adequacy of each generic aging management program ... [was] based on the review of...10 program...elements:" 1. Scope of program, 2. Preventive actions, 3. Parameters monitored or inspected, 4. Detection of aging effects, 5. Monitoring and trending, 6. Acceptance criteria, 7. Corrective actions, 8. Confirmation process, 9. Administrative controls, and 10. Operating experience.

5.4.2 Comments

The description of the aging management program elements is considered acceptable; however, the following comments apply to elements 4 and 5.

The description of element 4 states, "Detection of aging effects should occur before there is a loss of any...component intended function." It must be kept in mind that the most important 'intended function' is the one required when an accident occurs. For non-environmentally qualified electrical cables and connections this point is relatively less important than it is for environmentally qualified equipment, because the environment of non-EQ cables and connections is not likely to change from the normal environment when an accident occurs. However, for EQ equipment the environment will be more severe than normal when an accident occurs; therefore, it is difficult to determine whether the intended function can be performed based on inspection and testing conducted under normal service conditions.

For EQ equipment, although components with a QL or specified replacement interval are excluded from license renewal review, EQ equipment is included because it involves TLAAs. This concern also applies if CM is depended upon to accommodate a QL (now usually 40 years) which is less than the desired life, e.g., 60 years. Consequently, while it is possible to detect aging effects, it is usually not feasible to determine when the aging effects have progressed to the level that there remains reasonable assurance that the intended function can be performed during the period before the next surveillance is scheduled to take place. This dilemma is described more fully in Section 4.3 of this report, on Condition Monitoring. Since decision criteria are generally not available, it is inconsistent to imply that the evaluation of aging programs has demonstrated that element 4 is satisfied.

The description of element 5 states, in part, "Monitoring and trending should provide for prediction of the extent of the effects of aging and timely corrective or mitigating actions." The comments concerning element 4 apply even more strongly here, because element 5 emphasizes the requirement for predicting future intended function capability.

It is recommended that elements 4 and 5 be reworded to be consistent with existing technology. If utilities are put in the position of complying with an impractical requirement, the staff is placed in the position of accepting responses that do not satisfy the requirements as stated.

These comments are not intended to discourage the monitoring of aging effects. In fact, such monitoring is highly recommended because it is in the plant that the real equipment and environments exist. This contrasts favorably with the equipment qualification process in which a representative sample of equipment is tested and plant conditions are simulated. In the important case of electrical cables, for example, a 3-m sample may be tested to qualify cable for the long runs that are installed in plants.

It is suggested that a check list be prepared, similar to the one (see Appendix B) for the review of equipment qualification programs.

5.5 GENERIC AGING LESSONS LEARNED (GALL) REPORT (Ref. 6)

Vol. 2 Tabulation of Results (Draft for Public Comment)

Chapter VI. Electrical Components

Chapter X.E1 Time-Limited Aging Analyses: Environmental Qualification (EQ) of Electrical Components

Chapter XI. Aging Management Programs: XI.E1 Non-EQ Electrical cables and Connections, XI.E2 Non-EQ Electrical Cables Used in Instrumentation Circuits, and XI.E3 Non-EQ Inaccessible Medium-Voltage Cables

5.5.1 Summary

In Vol. 2 of the GALL report, Tables VI.A, for non-EQ equipment, and VI.B, for EQ equipment, list the material, environment, aging effect, aging mechanisms, the aging management program, and the evaluation and technical basis for the conclusion that further evaluation or no further evaluation is recommended. Based on its evaluation of aging management programs, no further evaluation is recommended for any of the non-EQ items; but further evaluation is recommended for EQ items subject to 10CFR50.49, because time limited aging analysis (TLAA) is involved in the qualification. Table VI refers to Chapter XI for a discussion of the evaluation and technical basis.

5.5.2 Comments

Chapter X is considered an acceptable presentation of the evaluation and technical basis - with the minor comment that use of the word "will" on page X-10 is not appropriate. On this page, in items 9 and 10, it is stated that compliance with 10CFR50.49 demonstrates that "a component **will** perform required functions" and that "Compliance with CFR10.49 provides evidence that a component **will** perform its intended functions..." [Emphasis added]. It is more accurate to state that compliance with 10CFR 50.49 provides **reasonable assurance** that the component **can** perform its required functions. This comment is based on extensive past discussions among qualification standards writing groups, but it is also consistent with the statement in the first paragraph of Chapter XI.E1, "The purpose of the aging management program described herein is to provide **reasonable assurance** that the intended functions of electrical equipment will be maintained...," where, unfortunately, the word "will" is repeated. [Emphasis added.]

Chapter XI, which is limited to a discussion of aging management for non-EQ components, is considered generally acceptable - again subject to the following minor comments. It is suggested that moisture be added to heat and radiation as an environmental condition of interest in Chapters XI.E1 and XI.E2, for non-EQ electrical cables and connections and non-EQ electrical cables used in instrumentation circuits, respectively. In Chapters XI.E1 and XI.E3, the latter for non-EQ inaccessible medium-voltage cables, an inspection interval of "at least once every 10 years is an adequate period to preclude failures of the conductor insulation;" however, particularly with increasing age, a shorter interval would be more appropriate.

5.6 STANDARD REVIEW PLAN for the REVIEW of LICENSE RENEWAL APPLICATIONS for NUCLEAR POWER PLANTS (Ref. 5)

Chapter 3.6 Aging Management of Electrical and Instrumentation and Controls

5.6.1 Summary

The components specifically addressed in this chapter of Ref. 5 are:

1. Electrical equipment subject to environmental qualification (EQ) in accordance with 10CFR50.49.

2. Non-EQ electrical cables and connections exposed to an adverse localized environment caused by heat of radiation.

3. Non-EQ cables and connections used in instrumentation circuits sensitive to reduction in conductor insulation resistance.

4. Non-EQ inaccessible medium-voltage cables exposed to adverse localized environments caused by moisture and voltage exposure.

5. Non-EQ electrical connectors exposed to borated water leakage.

Table 3.6-1 of Ref. 5 gives general descriptions of aging management programs for each of the above categories of components. Further evaluation of aging management programs is recommended only for the first category, EQ components, because they are subject to time limited aging analyses (TLAAs). A somewhat more detailed description of the aging management programs for non-EQ components is given in Table 3.6-2. The GALL Report (Ref. 6), which is reviewed in Section 4.4 of this report, gives more detailed descriptions of the aging management programs listed in Tables 3.6-1 and 3.6-2, but the key elements are the same.

The EQ components are the only ones identified in the GALL report to require augmented evaluation. The aging management programs for this category should contain the following elements: corrective actions, confirmation process, and administrative controls, for which 10CFR50, Appendix B, provides adequate guidance. Although this code does not apply to non-EQ components, the applicant may choose to expand its scope to do so; otherwise, the aging management programs must be reviewed on a case-by-case basis.

For the non-EQ components, the GALL Report identifies generic aging management programs that are acceptable to the NRC. If an applicant demonstrates that the proposed aging management program is identical to one of the approved generic programs, the staff needs only to verify that such is the case, and no further review is required.

If the applicant chooses an aging management program which does not correspond to an approved generic program, the staff should review the program, referring to the Branch Technical Position in Appendix A.1 of the GALL Report, for acceptance criteria.

If the applicant discovers a component or aging effect that is not included in the GALL Report, the staff should likewise review the aging management program, referring to the Branch Technical Position in Appendix A.1 of the Gall Report, for acceptance criteria.

The applicant must document the aging management programs in a supplement to the FSAR, and these must ultimately be incorporated into an updated FSAR. Changes can be made without prior commission approval provided they are evaluated by the applicant to be in compliance with 10CFR50.59. All age management procedures must be completed before the period of extended operation.

Chapter 3.6 of Ref. 5 also provides sample statements of conclusions that may be reached by reviewers.

5.6.2 Comments

EQ components subject to environmental qualification in accordance with 10CFR50.49: The augmented review of TLAA analyses is documented in Chapter 4 of Ref. 5. and is reviewed in Section 5.8 of this report. The staff has extensive experience in the review of aging analyses for EQ components.

Non-EQ cables and connections exposed to adverse local environments: It is suggested that consideration be given to adding moisture to heat and radiation as the causes of adverse environments. It is also suggested that the inspection interval of "at least once every 10 years" be reduced after the age of the components reaches approximately 40 years, or after testing indicates that significant degradation has taken place. It is questioned whether visual inspection for surface anomalies is an adequate indicator of component degradation.

Non-EQ electrical cables used in circuits sensitive to reduction of conductor insulation resistance: The aging management program is adequate.

Non-EQ inaccessible medium-voltage cables exposed to localized moisture and voltage exposure: A weakness in the aging management program for this category is that the testing is defined only as to "be determined prior to each test," so that a reviewer has no specific guidance as to what constitutes an acceptable test. Here too, it is suggested that a testing interval shorter than "at least once every 10 years" would be more appropriate after the age of the components exceeds approximately 40 years, or after testing indicates that significant degradation has taken place.

Non-EQ connectors subject to borated water leakage: It is not obvious how visual inspection of connectors and enclosure external surfaces can provide a reliable determination of "the possible intrusion of borated water" into the components.

A flow chart guiding reviewers to the appropriate review category and check lists for each category could simplify the task of reviewers.

5.7 STANDARD REVIEW PLAN for the REVIEW of LICENSE RENEWAL APPLICATIONS for NUCLEAR POWER PLANTS (Ref. 5)

Chapter 4.1 Identification of Time-limited Aging Analyses

5.7.1 Summary

This chapter of Ref. 5 addresses the identification of TLAAs, which are defined in 10CFR54.3, in part, as licensee calculations and analyses that consider the effects of aging and involve time-limited assumptions defined by the current operating term. e.g., 40 years. Applicants for license renewal are required by 10CFR54.21(c)(1) to provide a list of TLAAs. The listing should provide sufficient detail to identify the type of calculation and include a summary of the results. The adequacy of TLAAs already included in the current licensing basis (CLB) are outside the scope of review for license renewal. Applicants are required to list exemptions from the requirement to list TLAAs; but Chapter 4.1 notes that no such exemptions were found in the license renewal applications already reviewed. Applicants have the option of listing TLAAs not required by CFR54.21(c)(1).

Chapter 4.1 directs the staff to focus its attention on confirming that no required TLAAs were omitted from the application. Six acceptance criteria are listed that are intended to provide "reasonable assurance" that no required TLAAs are omitted; these criteria are identical to the six attributes included in 10CFR54.3 for the definition of TLAAs. (Two key attributes are given in the first sentence of the preceding paragraph, above.) In addition to defining the acceptance criteria, Chapter 6 defines the review procedure, which consists essentially of selecting a TLAA likely to meet the six acceptance criteria, but which the applicant did include in its list, and verify that the TLAA selected does not meet at least one of the criteria. Examples of TLAAs that "need to be addressed" and that "need not be addressed" are described. It is mentioned that staff members of the Division of Engineering, without examining the identification of TLAAs, may nonetheless "question why the applicant did not identify certain analyses within their areas of review as TLAAs." The chapter concludes with a sample conclusion that the staff may include in its safety evaluation report, the key point of which is that the "staff concludes that the applicant has provided an acceptable list of TLAAs..."

Table 4.1-1 of Ref. 5 gives three examples of potential TLAAs that do not qualify as a required TLAA, and two examples of potential TLAAs that do qualify; however, none of the examples applies to electrical equipment. Table 4.1-2 lists additional potential TLAAs, without commenting on their applicability; this table includes environmental qualification of electrical equipment. Finally, Table 4.1-3 lists plant-specific TLAAs that were identified by the initial license renewal applicants.

5.7.2 Comments

This chapter of Ref. 5 appears to be concerned strictly with confirming that the applicant has included all required TLAAs in its license renewal application; and there appears to be a wealth of guidance on accomplishing this review task. The only puzzling feature is how a reviewer chooses a TLAA that was not listed by the applicant but which is likely to satisfy all six acceptance criteria. The applicant's listing is required to include sufficient detail to permit identification of the type of calculation, but there is evidently no requirement that the review covered by Chapter 4.1 include a technical review of the adequacy of the calculation.

5.8 STANDARD REVIEW PLAN for the REVIEW of LICENSE RENEWAL APPLICATIONS for NUCLEAR POWER PLANTS (Ref. 5)

Chapter 4.4 Environmental Qualification (EQ) of Electric Equipment

5.8.1 Summary

An equipment qualification (EQ) program is required by 10CFR50, App. A, Criterion 4 and 10CFR50.49 for electric components in harsh environments, which are plant areas subject to the consequences of Loss of Coolant Accidents (LOCAs), High Energy Line Breaks, or post-LOCA radiation. It is required that significant aging effects be addressed and that reasonable assurance be demonstrated that the intended function can be performed after aging. A key output of such programs is a qualified life (QL), which equals the normal service time simulated by an accelerated aging program that precedes a simulation of the applicable accident(s). The significant aging effects are those that can affect the functional capability of the equipment. 10CFR 50.49 requires replacement or refurbishment prior to the end of the QL unless the QL is extended by ongoing qualification. In addition to the CFRs, guidance for reviewing EQ programs is available in Regulatory Guide 1.89, Rev. 1, DOR Guidelines, NUREG-0588, and IEEE Standards 323-71 and 323-74.

The pertinent content of these documents is summarized and reviewed in Section 5.9.

Acceptance of TLAAs requires, for the period of extended operation, that one of the following criteria be demonstrated:

i the analyses remain valid

ii the analyses have been projected to the end of the period

iii the effects of aging on the intended function(s) will be adequately managed

For option i, no further evaluation is necessary if it is shown that the existing qualification already includes the period of extended operation. For option ii, a reanalysis of the aging evaluation is required; Table 4.4-1 includes the important attributes of such reanalysis. For option iii, the applicant is referred to the GALL Report for acceptable aging management programs. The applicant is required to provide the information necessary to show that the material in the GALL report is applicable to the specific plant for which license renewal is sought. The applicant is required to provide a summary description of TLAAs in a supplement to the FSAR.

The reanalysis attributes listed in Table 4.4-1 include information on analytical methods, data collection and reduction methods, and underlying assumptions that guide the applicant in producing acceptable TLAAs and the staff in reviewing them. The reanalysis should be performed in a timely manner, so that sufficient time is available to refurbish, replace, or requalify the component if the reanalysis is unsuccessful.

Table 4.4-2 gives the implementation schedule for each of the three options listed above: If either of the first two options is completed satisfactorily, the implementation is considered completed. In the case of option iii, compliance is ongoing.

Review procedures are given to guide the staff in conducting evaluations of EQ programs for extended operation, and a sample conclusion is included.

The Commission has decided that the adequacy of EQ is a potential safety issue, and it is being addressed separately as part of Generic Safety Issue (GSI) 168, "Environmental Qualification of Electrical Equipment." The resolution of this GSI, which depends partly on ongoing cable research including the investigation of condition monitoring techniques to predict the accident survivability of cables, is scheduled for December 2000.

Since the potential issues associated with GSI 168, and their scope, are still under review, the applicant cannot be expected to provide a description of one or more options for maintaining the current licensing basis for the period of extended operation. An "acceptable approach is to provide a technical rationale demonstrating that the current licensing basis for EQ will be maintained for the period of extended operation."

5.8.2 Comments

This chapter of Ref. 5 provides generally acceptable guidance for staff review of license renewal applications. A few minor comments follow.

Paragraph 4.4.1.1 on time-limited aging analysis includes the statement that, "Compliance with 10CFR50.49 provides evidence that the component will perform its intended functions..." While the wording "provides evidence" is relatively less objectionable than "provides assurance", it is suggested, as elsewhere in this report, that "provides reasonable assurance" is preferable wording.

Paragraph 4.4.1.1 states how the DOR Guidelines will be used for the review of equipment subject to significant degradation due to aging where a qualified life was previously established; it should also state how equipment for which a qualified life was not established will be reviewed.

Paragraph 4.4.1.1.2, covering NUREG-0588 Category II components, states that the qualification programs for valve actuators and motors committed to conform with IEEE Standards 382-72 and 334-71, respectively, will be reviewed against Category II requirements; it is not clear what is to be done with components other than valve actuators and motors that fall under Category II.

The comments in the two foregoing paragraphs may be irrelevant if there no Category II components that have not been requalified in accordance Category I requirements and IEEE Std 323-74. See Section 5.10.

In paragraph 4.4.3.1.2, referring to aging analyses, the meaning of the last phrase, "...and the period of time prior to the end of qualified life" is not clear. It seems to mean that the applicant should identify how long before the end of qualified life the analyses will be completed.

Paragraph 4.4.3.3, on the FSAR supplement, allows applicants to make program changes in the supplement, without prior Commission approval, "provided that the applicant evaluates each such change pursuant to the criteria set forth in 10CFR50.49." It is not clear at what point the staff is to review such changes.

5.9 STANDARD REVIEW PLAN for the REVIEW of LICENSE RENEWAL APPLICATIONS for NUCLEAR POWER PLANTS (Ref. 5)

Appendix A.1 Aging Management Review - Generic (Branch Technical Position RLSB-1)

This Branch Technical Position identifies four types of aging management programs: prevention, mitigation, condition monitoring, and performance monitoring. It introduces the consideration of the risk significance of a structure or component in evaluating the robustness of an aging management program. It also emphasizes the use of root cause determination in choosing corrective actions when acceptance criteria are not met. It includes Table A.1-1 that lists and describes 10 elements of an aging management program for license renewal.

The document provides excellent guidance for identifying applicable aging effects for license renewal and defining acceptable aging management programs; perhaps, it should be considered required reading for staff reviewers.

A few excerpts of the document merit being quoted:

> From A.1.1 Background. "The license renewal process is not intended to demonstrate absolute assurance that structures and components will not fail, but rather that there is reasonable assurance that they will perform such that their intended functions are maintained...during the period of extended operation."
>
> From Item 2 of paragraph A.1.2.3.4 on the detection of aging effects: "A program based solely on detecting structure and component failure should not be considered as an effective aging management program for license renewal."
>
> From Table A.1.1, which describes the 10 elements of an aging management program:
>
> > 5. "Monitoring and trending should provide predictability of the extent of degradation and timely corrective or mitigative actions. The monitoring, inspection, or testing frequency, and sample size should be appropriate for timely detection of aging effects."
> >
> > 6. "Acceptance criteria, against which the need for corrective action will be evaluated, should ensure that the structure and component intended function(s) are maintained...during the period of extended operation."

5.10 COMPARISON of OLDER and CURRENT QUALIFICATION REQUIREMENTS (Refs. 14, 15, and 16)

IEEE Std 323-74 has been the primary industry standard for equipment qualification for the last quarter century. Subsequent to its publication, several 'daughter' standards were published for specific components including cables, valve actuators, motors, motor control centers, lead storage batteries, and battery chargers and inverters. The requirements of IEEE Std 323-74 are essentially those outlined in Section 4.1 of this report. It introduced two significant new requirements of qualification. One is the requirement for margins "to account for normal variations in commercial production of equipment and reasonable errors in defining satisfactory performance." Margins were defined as "the difference between the most severe specified service conditions of the plant and the conditions used in type testing..." The other, even more significant change, is the requirement that test specimens be conditioned by accelerated aging to account for the degradation of functional capability that takes place in normal service. The main output of the qualification process has been a qualified life, defined in the standard as, "The period of time for which satisfactory performance can be demonstrated..."

The immediate consequence of the publication of IEEE Std 323-74, was the recognition that the technology simply did not exist for reproducing the condition of equipment at the end of a long period of normal service (typically 40 years). This prompted the publication of an Addendum making it clear that the intention of the standard was that existing technology be used; in other words, utilities and manufacturers were not expected to undertake research to advance the technology of accelerated aging before conducting qualification testing. In spite of much research during the last quarter century on accelerated aging techniques, the ability to reproduce aged conditions has not improved significantly; but in the spirit of the accommodation discussed in the Introduction of this report, procedures acceptable to both the regulators and industry have been identified.

Subsequent to its publication, it was found that some of the statements in IEEE Std 323-74 could be improved. For example, the definition of qualification as the "generation and maintenance of evidence to **assure** that the equipment **will** operate on demand, to meet system performance requirements" [emphasis added] could better read "provide **reasonable assurance** that the equipment **can** perform its intended functions" in recognition of the fact that the qualification program cannot **guarantee** the performance of intended functions. Another example is the statement that "the objective of aging is to put samples in a condition equivalent to the **end-of-life** condition" [emphasis added], which obviously would guarantee failure during an accident simulation test following such aging. The intent of aging is to put samples in a condition equivalent to the condition at the end of the qualified life goal, which becomes the qualified life if the sample passes the accident simulation test. This latter weakness was corrected and other changes, thought by industry to be improvements, were made in a 1983 revision of the standard; however, the NRC has not endorsed this later version of the standard.

Regulatory Guide 1.89 endorses IEEE Std 323-74 for qualifying Class 1E equipment (essentially equivalent to equipment described elsewhere as 'safety-related' or 'important to safety'). This Guide specifies that non-safety-related equipment must "be environmentally qualified if its failure...could prevent satisfactory accomplishment of safety functions by safety-related equipment." (Examples of such equipment are given in Appendix B of the guide.) It also requires that "certain postaccident monitoring equipment...be environmentally qualified." (Reference is made to Regulatory Guide 1.97 for these types of equipment.)

RG 1.89 includes extensive information amplifying the requirements of 10CFR50.49 and IEEE Std 323-74. In particular, it supplements the 'aging' requirements as follows: known synergistic effects are to be accounted for; the Arrhenius methodology is considered acceptable for addressing thermal aging; and it states that "Periodic surveillance and testing programs are acceptable to account for uncertainties regarding age-related degradation..."

IEEE Std 323-74 had been preceded by a trial use standard IEEE Std 323-71, which had not included the margin and aging requirements in the manner documented in the 1974 version. Consequently, the adequacy of qualification programs that had already been completed was placed into question. This potential deficiency was addressed in the DOR Guidelines and NUREG 0588, which are discussed below.

The DOR Guidelines were produced after some qualification programs had already been conducted, some of which had not addressed degradation caused by aging in the normal service environment. In a critical paragraph on specimen aging, Ref. 14 states, "Tests which were successful using test specimens which had not been preaged may be considered acceptable provided the component does not contain materials which are known to be susceptible to significant degradation due to thermal and radiation aging. If the component contains such materials a qualified life for the component must be established on a case by case basis." After the publication of IEEE Std 323-74 and RG 1.89, which required an accounting for aging degradation, the foregoing statement was sometimes misinterpreted by using the first part to justify accepting prior qualification programs in which test specimens had not been aged. The second part of the statement makes it clear that such programs are not acceptable if significant aging mechanisms exist, which is the case for most safety-related equipment. Nonetheless, the document also includes a statement referring to "the staff's conclusion that the incremental improvement in safety from arbitrarily requiring that a specific qualified life be demonstrated for all Class IE equipment..." is not justified. However, any controversy that was generated over the correct interpretation of the DOR Guidelines is essentially moot, because practically all (if not all) equipment qualification programs now comply with the aging requirement.

NUREG-0588 established two categories of qualification: Category I (with QL) for equipment qualified in compliance with IEEE Std 323-74 and Category II (no QL) for equipment qualified in compliance with IEEE Std 323-71. While there are several differences between the requirements for these two categories of qualification, the one of major interest concerns aging. For Category I, the requirement is stated as, "Aging effects on all equipment, regardless of its location in the plant, should be considered and included in the qualification program." This statement is followed by nine additional paragraphs explaining how to meet the requirement. For Category II, the requirement is to consider aging effects in qualification programs for motors and valve actuators committed to IEEE Std 382-72 and IEEE Std 334-71, respectively; for other equipment, the aging requirement is somewhat less stringent than it is in Category I. The key statement is, "the qualification programs should address aging only to the extent that equipment that is composed, in part, of materials susceptible to aging effects should be identified, and a schedule for periodically replacing the equipment and/or materials be established." The practical effect is that the requirement to age samples before conducting an accident simulation test was eliminated. However, as stated at the end of the preceding paragraph, on the DOR Guidelines, the point is now essentially moot, because most (if not all) equipment qualification programs now comply with the aging requirement.

Paragraph 4.4.1.1.2 of Ref. 5, which refers to NUREG-0588 and IEEE Std 323-71, states that motor and valve actuator qualifications committed to IEEE Std 334-71 and IEEE Std 382-72, respectively, will be reviewed for the period of extended operation against Category II requirements. All equipment subject to the requirements of Category I will be reviewed for the period of extended operation.

5.11 INDUSTRY GUIDELINE for IMPLEMENTING the REQUIREMENTS of 10 CFR PART 54 - The LICENSE RENEWAL RULE (Ref. 8)

This document provides excellent guidance to applicants for compliance with the requirements of 10CFR54, and it could be used to advantage by the staff as well. Its format is to quote pertinent sections of the code and to follow each section with a detailed explanation of its meaning and how to comply with it. Figure 2.0-1, a chart on the "License Renewal Implementation Process" clearly illustrates that there are two sequences of procedures to follow: one starting with the identification of SSCs within the scope of license renewal and the other starting with the identification of TLAAs and exemptions. Pert charts that illustrate the flow of the compliance process, decision points, and compliance activities are a very useful feature. The regulatory documents would be enhanced by the addition of similar charts; alternatively, both applicants and the staff could be directed to the charts in Ref. 8.

Ref. 8 provides guidance in the text for fulfilling the action items. For example, in the chart on "Assuring That the Effects of Aging Will Be Managed" (Figure 4.2-1), a key action item is, "Identify and review aging management programs;" this activity is explained in several sections of the report, including sections titled: Demonstrate that the Effects of Aging are Managed, Reference Previous Reviews, Identify and Demonstrate Applicability of the Selected Reference, and Demonstrate that the Effects of Aging are Managed. The last of these includes attributes that can be used to review the adequacy of aging management programs, one of which highlights the need to provide "an adequate predictability and timely corrective or mitigative actions."

There is a phrase on page 20 referring to "structures or components in areas that are known to be benign and not requiring aging management" that could be worrisome if it is interpreted too broadly, thereby capturing components in mild environments that are nonetheless subject to functional degradation.

Section 4.3 of Ref. 8 describes the elements of an inspection program that may be adopted when an aging management program does not provide reasonable assurance of maintaining the intended function(s) of components; but it is not obvious that inspection programs can overcome the deficiencies of aging management programs.

Appendix A of Ref. 8 conveniently includes a complete copy of the version of 10CFR54 published in the Federal Register on May 8, 1995, which includes Section "V. Public Responses to Specific Questions," which is a follow-up of Section "V. Questions," of the version published on May 14, 1993 (Ref. 4). A few comments concerning this version of 10CFR54 are included in Section 5.2 of this report.

A table in Appendix B of Ref. 8 has a list of 129 structures, components, and commodity groupings with the designation that they are or are not passive. Item 79, one of many entries for the electrical and instrumentation & control category, applies to cables, connectors, splices, and terminal blocks among other components, which are designated "passive." All other structures, components, and commodity groupings in the electrical and instrumentation & control category are designated as "not passive," except for high-voltage insulators. Inconsistent with Item 79, Item 107 designates terminal blocks as "not passive."

5.12 AGING MANAGEMENT GUIDELINE for NUCLEAR POWER PLANTS - ELECTRICAL CABLE and PENETRATIONS, SAND96-0344 (Ref. 10)

This document is a compendium of information on failure data, stressors and aging mechanisms, and methods of managing the aging of electrical cables and their terminations. It is based on a review of more than 300 references, communication with engineers of "host" plants, and review of plant documents and records. The report was prepared for use by plant maintenance personnel and systems engineers whose responsibilities include aging management. The final chapter provides guidance for complying with the aging management requirements of 10CFR54 for cables and their terminations. Specifically, the components evaluated include low- and medium-voltage cables and their terminations, including terminal blocks, splices, and connectors.

The historical failure data are presented in tabular and pie-chart formats that display effectively the distribution of failures among the different components. For example, among low-voltage components, the largest fraction of failures occurred among hookup and panel wire (36%), followed by connectors (30%), cable (14.5%), compression fittings (12.5%), and smaller fractions for terminal blocks and splices. The major contributions to failure of low-voltage hookup and panel wire were insulation (55.5%) and conductor (38.5%).

A few notable conclusions reached from the review of historical failure data are:

> the number of failures in normal operation is extremely low in proportion to the amount of cables and terminations installed in nuclear plants (the report correctly cautions that the failures occurred in normal service and that few plants have reached 20 years of operation)
>
> failure occurred predominantly near end devices or connected loads
>
> thermal degradation is responsible for most low-voltage cable failures
>
> wetting concurrent with operating voltage stress is responsible for most medium-voltage cable failures
>
> thermal aging is most significant near hotspots
>
> factors other than thermal and radiation aging account for a significant fraction of failures of hookup and panel wire; these factors include design, installation, maintenance, modification, or testing activities

We may conclude from these observations that aging management programs should be focused on weak links (components with the highest probability of degradation affecting functional capability) and hotspots, where the rate of degradation is highest. If the aging of components that are in these categories can be managed, the aging management of components with lower failure probabilities and those located in benign environments may be encompassed by the programs applied to the more vulnerable situations.

Several thermal aging graphs show the thermal life calculated with the Arrhenius equation for nine insulation materials. For the materials in greatest use in nuclear power plants, these graphs show that the thermal life at 60 °C of EPR is several hundred years and for XLPE it is about 1000 years. Other graphs show that the life is substantially reduced for cables that are energized continuously. One table lists the maximum allowable environmental temperatures for the insulating materials to achieve a 60-year life, one list for un-energized cables and one with continuous energizing at 80% of rated ampacity. The values for EPR and XLPE/XLPO, are 75 °C and 83 °C, respectively, when the cables are not energized, but these numbers drop to 39 °C and 45 °C when the cables are energized at 80% of their ampacity at
30 °C.

In a discussion of material similarity, it is pointed out that, in addition to the base polymer, insulating materials include many other ingredients and that these sometimes account for more than half of the content. The implication is that the generic values of activation energies, a key factor in the calculation of thermal aging conditions, are not necessarily applicable to all insulating materials with the same base polymer.

The documentation of aging stressors, aging mechanisms, and condition monitoring methods confirms that the resources and efforts devoted to these topics have been focused on electrical cables, which may be weak links only in hotspots: such as locations near the reactor vessel, especially in neutron monitoring circuits, and near steam piping. Significantly less effort has been devoted to detection of the degradation of more vulnerable components, such as terminations and connectors.

The conclusions regarding condition monitoring techniques are the ones most relevant to compliance with the requirements of 10CFR54. Although many methods were thoroughly reviewed, the conclusions can do little more than point to "substantial progress," and the fact that some methods are "promising," "have significant potential," or "may be...viable." Even for elongation at break, one of the more promising condition monitoring techniques if sacrificial cables are installed in critical areas of the plant, it is difficult to establish criteria for predicting the remaining life of cables. No technique was identified as being effective for medium-voltage cables; however, since only 27 medium-voltage failures occurred in 1000 plant years of operation, there is little incentive to conduct condition monitoring on medium-voltage cables. The best approach to manage aging for medium-voltage cables is to concentrate on the prevention of conditions that cause degradation. The tentative conclusions of the cable research conducted during the several years since Ref. 10 was published do not appear to advance the condition monitoring technology significantly. There remains the dilemma that, while condition monitoring is required to fulfill some of the requirements of 10CFR54, it is doubtful that effective techniques fully ready to be implemented exist. The key problem is the requirement that condition monitoring techniques have the ability to predict the time during which components can be expected to remain capable of performing their intended function(s).

5.13 GUIDE for ASSESSING, MONITORING and MITIGATING AGING EFFECTS on CLASS 1E EQUIPMENT USED in NUCLEAR POWER GENERATING STATIONS (Ref. 13)

License renewal is only one of five reasons listed in this document for undertaking an aging assessment, but the Guide nonetheless gives very useful descriptions of the aging assessment process. The purpose of an aging assessment is described as establishing "the technical basis that demonstrates the continued safety and functional performance capability of Class 1E equipment." It includes much of the same type of information that is covered in greater detail in Ref. 10.

A flow chart illustrates the process for assessing, monitoring, and mitigating aging effects; and the accompanying text explains each of the elements of the process. The Guide states that an aging assessment should focus on weak-link materials or parts of the equipment to indicate the overall condition of the equipment.

Annex A of the Guide includes tables listing stressors, aging mechanisms, aging effects, and candidate monitoring methods for polymers, lubricants, and metals. Annex C lists the attributes that a trendable parameter or property (condition indicator) should have for the condition monitoring to be effective. A viable condition indicator must be measurable, reproducible, change uniformly with age, change enough so that differences in degree of aging can be established, and be capable of predicting with confidence the period during which the functional capability can be assured - not only for normal service but also for any applicable function during an accident. A table of condition monitoring methods for electric cable insulation lists essentially the same ones described in Ref. 10.

Annex D contains two examples of aging assessment relevant to this report, one for insulated cables and one for electrical penetration assemblies. These examples include information on bounding temperatures and radiation dose levels for the areas of the plant where the equipment might be located. The effect of self heating for energized cables is also included. With regard to condition monitoring, however, the examples do little more than to summarize the properties that a viable condition monitoring technique should have.

5.14 GUIDELINE for the MANAGEMENT of ADVERSE LOCALIZED EQUIPMENT ENVIRONMENTS (Ref. 19)

This EPRI document was "developed to provide a systematic approach for identifying and managing [adverse localized equipment environments] that can be applied to all types of equipment, including cables." An adverse localized environment is defined as a "condition in a limited plant area...that is significantly more severe than the specified service condition..." The document identifies localized equipment areas with adverse conditions of temperature, radiation, chemicals and contaminants, moisture, vibration, and ultraviolet radiation. It lists twelve basic actions, accompanied by a flow chart, for the management of the adverse environments. The primary activities are visual inspection, temperature monitoring, radiation hot spot detection, and trending of failures. The activities are described, and some check lists are provided. Twenty five photographs of potential adverse localized equipment environments are included, most of them in an appendix.

It is concluded that:

> "the number of adverse localized equipment environments is minimal and manageable
>
> localized environments can be managed without implementing new programs
>
> localized elevated temperature is the single most significant type of adverse localized environment
>
> walkdowns and temperature monitoring are important tools in identifying and managing localized environments
>
> adverse localized thermal environments for cables are also manageable"

An appendix documents two case studies of cable temperature evaluation: one for random-filled cable trays and one for the turbine building.

The document is directed at utilities, but staff members without experience in plant inspections, and therefore probably not familiar with the existence of adverse, would benefit from the insight this document provides into adverse conditions that exist in operating plants. Some of the adverse conditions appear to be the result of deficiencies in design, maintenance, and inspection. Although the report concludes that "the number of localized adverse environments is minimal and manageable," it is somewhat surprising to discover that some of the conditions exist at all.

The document is not intended to provide guidance for preparation of license renewal applications, but it does lead to a question about priorities. Without minimizing the importance of demonstrating that a plant is capable of managing equipment degradation for extended period of operation, it would seem that it is even more important to eliminate the adverse conditions described in the document. If a utility does not manage conditions are almost glaringly visible, one wonders about its ability to undertake the requirements of managing aging on the basis of detecting more subtle forms of functional degradation.

6. REFERENCES

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3a. U.S. Federal Code of Regulation 10CFR Part 54, Requirements for Renewal of Operating Licenses for Nuclear Power Plants, issued September 29, 1995.

3b. U.S. Federal Code of Regulation Parts 2, 51, and 54, Nuclear Power Plant License Renewal; Revisions, published in Federal Register May 8, 1995. (See Appendix A of Ref. 8 for a copy.)

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14. Regulatory Guide 1.89, Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants, Rev. 1, June 1984.

15. Staff Position on Environmental Qualification of Safety-Related Electrical Equipment, NUREG-0588, Rev. 1.

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17. IEEE Std 323-71, Trial Use Standard: General Guide for qualifying Class 1E Equipment for Nuclear Power Generating Stations, 1971.

18. IEEE Std 323-74, Standard for Qualifying Class 1E Electric Equipment for Nuclear Power Generating Stations, 1974.

19. Guideline for the Management of Adverse Localized Equipment Environments, Palo Alto, CA: 1999, TR-109619.

APPENDIX A

SCOPE of INDEPENDENT REVIEW TASK

STATEMENT OF WORK
TECHNICAL ASSISTANCE IN EVALUATING THE
GENERIC AGING LESSONS LEARNED REPORT

SCOPE OF WORK

The ACRS desires to have an independent expert to review and report on the adequacy of the staff guidance in the SRP and the GALL Report for reviewing license renewal application sections associated with electrical and I&C components and the TLAAs for environmental qualification of electrical equipment.

REQUIREMENTS

The contractor shall review Section ~~3.7~~ 3.6, "Aging Management of Electrical and Instrumentation and Controls," and Section 4.4, "Environmental Qualification (EQ) of Electrical Equipment," of the draft SRP for license renewal and evaluate whether the guidance provides adequate directions and criteria for a knowledgeable reviewer to determine that the applicant's aging management programs for electrical and I&C components are acceptable. The contractor shall evaluate whether the SRP provides acceptable guidance for referencing the applicable chapters of the GALL report. The contractor shall evaluate whether the guidance provides adequate directions for assessing the adequacy of time-limiting aging analyses. The contractor shall evaluate whether the SRP provides adequate guidance for reviewing electrical and I&C systems that were designed and built prior to the present design criteria and inspection programs.

The contractor shall review the draft GALL Report Chapter I, "Introduction," and Chapter VI, "Electrical Components," for completeness and for whether the existing programs identified in Chapter VI will adequately manage age related degradation of the passive long-lived components over the extended life of the plant. The contractor shall evaluate the adequacy of the technical basis for the aging management programs provided by the referenced NRC guidance documents. The contractor shall evaluate the Institute of Electrical and Electronics Engineers (IEEE) Standards and other industry documents referenced in Chapter VI of the GALL Report. The contractor shall consider whether the older IEEE Standards referenced in the GALL report are adequate for justifying continued operations of nuclear power plants for 60 years.

APPENDIX B

CHECKLIST for REVIEW of ENVIRONMENTAL QUALIFICATION of ELECTRICAL EQUIPMENT LOCATED in HARSH ENVIRONMENTS

CHECKLIST FOR REVIEW OF LICENSEE EQ DOCUMENTATION FILES (continued)

Component(s): ______________________________

EQ Issue	Cover in EQ Documentation Yes	Cover in EQ Documentation No
10. Radiation dose covers accident and normal service (DOR Guidelines permits analysis)	___	___
11. DBE exposure simulation meets plant requirements:	___	___
Steam Exposure	___	___
Temperature	___	___
Pressure	___	___
Humidity	___	___
(DOR Guidelines requires test for steam environment)		
12. Chemical or water spray simulation performed when required	___	___
13. Accident environment margins (N/A DOR Guidelines)	___	___
14. Submergence test (if required for application)	___	___
15. Test anomalies resolved	___	___
16. Applicable INs, etc. resolved	___	___
17. Maintenance/Surveillance Criteria and Life Defined	___	___
18. References clearly identified and attached or retrievable (including I.D. of plant equipment)	___	___

Issue Date:

CHECKLIST FOR REVIEW OF LICENSEE EQ DOCUMENTATION FILES

Plant/Docket No.: ____________ Reviewer: ____________

Component(s): ____________

Equipment Documentation File: ____________

Criteria: 10 CFR 50.49 ___ or DOR Guidelines ___ or Other ___

EQ Issue	Covered in EQ Documentation: Yes	No	Comments
1. Positive statement by the licensee that the equipment is qualified for its application.	___	___	
2. Full description of the equipment.	___	___	
3. If qualification sample is not identical to the installed device, a similarity analysis has been provided.	___	___	
4. Allowed mounting methods and orientations.	___	___	
5. Interfaces - conduit, housing seal, etc.	___	___	
6. A qualified life has been established based upon accelerated aging-thermal, radiation, cyclic as appropriate.	___	___	
7. All type tests performed on the same specimen (N/A DOR Guidelines).	___	___	
8. Performance/acceptance criteria (operating time, transmitter accuracy, etc. as applicable to component).	___	___	
9. Test sequence conforms to IEEE 323-74 or justification has been provided. (N/A DOR Guidelines)	___	___	

Issue Date: