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Nuclear Power Plant Generic Aging Lessons Learned (GALL)

Main Report and Appendix A

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Nuclear Power Plant Generic Aging Lessons Learned:
- Mechanical, Structural, and Thermal-Hydraulic Components and Systems
- Electrical Components and Systems

by

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Abstract

The purpose of this generic aging lessons learned (GALL) review is to provide a systematic review of plant aging information in order to assess materials and component aging issues related to continued operation and license renewal of operating reactors. Literature on mechanical, structural, and thermal-hydraulic components and systems reviewed consisted of 97 Nuclear Plant Aging Research (NPAR) reports, 23 NRC Generic Letters, 154 Information Notices, 29 Licensee Event Reports (LERs), 4 Bulletins, and 9 Nuclear Management and Resources Council Industry Reports (NUMARC IRs) and literature on electrical components and systems reviewed consisted of 66 NPAR reports, 8 NRC Generic Letters, 111 Information Notices, 53 LERs, 1 Bulletin, and 1 NUMARC IR. More than 550 documents were reviewed. The results of these reviews were systematized using a standardized GALL tabular format and standardized definitions of aging-related degradation mechanisms and effects. The tables are included in volumes 1 and 2 of this report. A computerized data base has also been developed for all review tables and can be used to expedite the search for desired information on structures, components, and relevant aging effects. A survey of the GALL tables reveals that all ongoing significant component aging issues are currently being addressed by the regulatory process. However, the aging of what are termed passive components has been highlighted for continued scrutiny.

Contents

Tables

Tables 2-7 are separated into two parts depending on whether reviewed material pertains to Mechanical, Structural, and Thermal-Hydraulic Components and Systems or to Electrical Components and Systems.

Table 8 is a composite of all Age-Related Degradation mechanisms used in reviewing both categories of material.

Executive Summary

It is well established that many of the critical components in nuclear power plants are subject to time-dependent degradation, or aging, as a result of normal plant operations. In a joint effort by Argonne National Laboratory (ANL) and Idaho National Engineering Laboratory (INEL) in support of the License Renewal Project Directorate (PDLR) of the U.S. Nuclear Regulatory Commission (NRC), we have conducted a comprehensive review and assessment of the results of the Nuclear Plant Aging Research Program (NPAR) and related information pertaining to nuclear power plant aging effects and plant impact. The results of this review, called the Generic Aging Lessons Learned (GALL) program, are presented in this report and will be used by NRC as resource material to update nuclear power plant operation and license renewal guidance and as background material for assisting NRC staff in license renewal reviews and establishing positions.

More than 550 documents containing nuclear power plant aging information were reviewed in this program. The PDLR staff performed searches for current operating experience documents covering the 5-year period, 1989-1994, using the NRC's Nuclear Documents Management System (NUDOCS). Searches used the following terms: aging, degradation, and failures. All generic communications (Bulletins, Generic Letters, and Information Notices) and Licensee Event Reports that were included in the searches were reviewed for aging information by ANL/INEL.

The literature on mechanical, structural, and thermal-hydraulic components and systems reviewed consisted of 97 NPAR reports, 23 NRC Generic Letters, 154 Information Notices, 29 LERs, 4 Bulletins, and 9 NUMARC IRs. The literature on electrical components and systems reviewed consisted of 66 NPAR reports, 8 NRC Generic Letters, 111 Information Notices, 53 LERs, 1 Bulletin, and 1 NUMARC IR.

The results of these reviews were compiled by using a standardized tabular format and standardized definitions of aging-related degradation effects. The GALL tables are presented in volumes 1 and 2 of this report. A computerized data base has also been generated for all GALL review tables. The data base/electronic library will provide the NRC staff, nuclear industry, and public with a comprehensive source of information about aging mechanisms and the resultant effects for nuclear systems, structures, and components and current information on relevant programs. The data base can be readily expanded to include relevant information from future NRC programs as they are completed. Copies of the data base are available in the NRC's Public Document Room located in Washington, DC.

A preliminary assessment of the GALL tables reveals that all significant issues with respect to component aging are currently being addressed by the regulatory process. However, the aging of certain components and the resulting aging effects, particularly in the category of what is termed passive components, have been highlighted for continued scrutiny and evaluation.

Acknowledgments

The authors are grateful to NRC program managers Deborah A. Jackson, Paul C. Shemanski, P. T. Kuo, and Christopher M. Regan for their support in providing guidance and reviewing information given in this report.

List of Acronyms

ACI	American Concrete Institute
ANL	Argonne National Laboratory
ARD	Age-Related Degradation
ASME	American Society of Mechanical Engineers
BL	Bulletin
ESFAS	Engineered Safety Features Actuation System
GALL	Generic Aging Lessons Learned
GC	Generic Communications
GL	Generic Letter
I&C	Instrumentation and Control
INEL	Idaho National Engineering Laboratory
IN	Information Notice
IR	Industry Report (submitted by NUMARC to address license renewal)
LER	Licensee Event Report
NEI	Nuclear Energy Institute
NPAR	Nuclear Plant Aging Research
NRC	Nuclear Regulatory Commission
NUDOCS	Nuclear Documents (NRC's Document Management System)
NUMARC	Nuclear Management and Resources Council
PDLR	License Renewal Project Directorate
PS	Plant-Specific
RG	Regulatory Guide
RPS	Reactor Protection System
S&T Req.	Surveillance and Test Requirements
SR	Safety Related
TS Req.	Technical Specification Requirements

1 Introduction

Approximately 110 nuclear electrical power generating plants operating in the United States in 1993 generated 20% of the nation's electrical demand.[1] It is well established that many of the critical components in nuclear power plants are subject to time-dependent degradation, or aging, as a result of normal plant operations. In recognition of the potentially adverse effects of the aging process on plant safety, the U.S. Nuclear Regulatory Commission's (NRC's) Office of Nuclear Regulatory Research established the Nuclear Plant Aging Research (NPAR) Program. The principal objective of this program was to develop a basic understanding of age-related degradation (ARD) processes and their effect on nuclear power plant systems, structures, and components. In addition, the Nuclear Energy Institute (NEI), formerly the Nuclear Management and Resources Council (NUMARC), has developed a series of industry reports describing their assessment of plant aging issues and management strategies.

The NRC's License Renewal Project Directorate (PDLR) has been charged with the responsibility for developing appropriate technical criteria for addressing the aging issues related to nuclear power plant license renewal. In order to carry out this responsibility, the PDLR initiated an activity to assess and integrate the age-related information from all available sources, including NPAR reports, generic communications, and Licensee Event Reports (LERs) and to use the results of this assessment to supplement and update license renewal guidance previously developed. This activity was called the Generic Aging Lessons Learned (GALL) program.

This report presents the results of the GALL review program. This was a joint effort involving 12 technical experts from Argonne National Laboratory (ANL) and Idaho National Engineering Laboratory (INEL). ANL also had the responsibility for coordinating and combining the results from the program into a single report. The ANL effort reviewed information on mechanical, structural, and thermal-hydraulic components and systems. The INEL effort reviewed information on electrical components and systems. The results of these reviews were compiled by using a standardized tabular format and standardized definitions of ARD effects. All tabulated review information is contained in Appendices A (Vol. 1) and B (Vol. 2) of this report. This information is also available in a computerized data base format based on the software program FoxPro, and this data base is available upon request from the NRC's Public Document Room located in Washington, DC. This data base allows rapid queries and sorts of the large amount of information generated in this review.

2 Description of Review Process

More than 550 documents containing nuclear power plant information were reviewed for GALL information. The PDLR staff performed searches for current operating experience documents covering the 5-year period, 1989-1994, using the NRC's Nuclear Documents Management System (NUDOCS). The searches used the following terms: aging, degradation, and failures. All generic communications (Bulletins, Generic Letters, and Information Notices) and Licensee Event Reports which were included in the searches were reviewed by ANL and INEL for aging information.

The review process was a joint effort involving Argonne National Laboratory (ANL) and Idaho National Engineering Laboratory (INEL), with ANL having the role of coordinating and combining the results from the program into a single report. ANL reviewed literature on mechanical, structural, and thermal-hydraulic components and systems, which consisted of 97 NPAR reports, 23 NRC Generic Letters, 154 Information Notices, 29 Licensee Event Reports (LERs), 4 Bulletins, and 9 NUMARC IRs. INEL reviewed literature on electrical components and systems, which consisted of 66 NPAR reports, 8 NRC Generic Letters, 111 Information Notices, 53 LERs, 1 Bulletin, and 1 NUMARC IR. A total of 163 NPAR reports, 31 NRC Generic Letters, 265 Information Notices, 82 LERs, 5 Bulletins, and 10 NUMARC Industry Reports (IRs) were reviewed under the GALL program. The results of these reviews were compiled by using a standardized tabular format and standardized definitions of ARD and effects.

Early in the review process, it was apparent that the terminology used in the various documents describing aging mechanisms and the resulting effects was often inconsistent and confusing. For example, an identified resulting effect was often used interchangeably with or in place of the mechanism responsible for aging. This problem can lead to difficulty in systematizing the literature and to technical misunderstandings between researchers. Therefore, a standardized and consistent set of definitions and descriptors for all aging mechanisms encountered during the review was developed based on the input of the 12 reviewers performing the review. Individual aging mechanisms and effects were identified and defined, and these are listed and described in Table 8. This list should also help focus and systematize future reactor aging studies.

The reports, notices, letters, and bulletins reviewed are listed in Tables 2-7. The results from each reviewed document are summarized in the Generic Aging Lessons Learned (GALL) tables contained in Appendices A (Vol. 1) and B (Vol. 2) of this two volume report. A separate table was prepared for each of the NPAR reports and NUMARC IRs; findings from the Generic Letters, Information Notices, Bulletins, and LERs are tabulated by year. All of the GALL table information has also been entered into a FoxPro data base software program that can be used on IBM PC-compatible systems to retrieve and categorize information on structures and components and their related aging effects. A number of custom programs were developed to automate entry of the data into the 19 data base fields containing up to 254 characters. The final data base was carefully edited to ensure the accuracy of the data. Testing of the data base involved searching for key words in one or more of the various data base fields (e.g., system, component, subcomponent or ARD mechanism). To facilitate searching on structure/component and subcomponent names, a three-digit code was added to identify similar items that appear with slightly different names throughout the data base. This code will enable a searcher to quickly locate all of the relevant information on a particular structure/component. Hard copy of the entire data base contained in the Appendices was produced with R&R ReportWriter software, which permits publication of tables that span two pages. This software enhances the normal output capability of commercially available data base programs. Electronic file copies of the data base are in xbase format, which is a generic dbase file that can be read by most data base software packages.

The information contained in the GALL tables is a summary of that provided in the reports. No attempt was made to supplement the contents of the reports with information available from other sources or from the reviewer's personal knowledge or experience, *except for the contents of two table columns titled "Relevant Program" and "Report Recommendations" as discussed below.* Furthermore, we found that not all of the reports, notices, and bulletins reviewed contained relevant information on Age-Related Degradation (ARD) processes. A number of the NPAR reports described programs, methodologies, computer codes, etc., for studying and analyzing aging processes in nuclear components, but did not provide detailed information on the processes themselves. The tables for these reports contain a standard statement indicating this fact. Almost all of the Generic Letters, Information Notices, LERs, and Bulletins reviewed contained detailed information on the failure of specific components, but the failures were sometimes judged not to be aging-related by the reviewer or by the author of the reviewed document. For example, failures caused by improper heat treatment, preexisting defects introduced during manufacturing, or overloads or other abuse during operation were not considered aging-related by the reviewer, even though the failure might not have occurred until the component had been in service for some time. GALL table entries are not provided for Generic Letters, Information Notices, LERs, and Bulletins judged not to contain detailed information on specific aging effects and impact on specific plant components.

Most of the information contained in the tables of the Appendices is self-explanatory, but some of the columns require additional explanation. The entries in the "ARD Mechanism" column are taken from the standard set of abbreviations listed and defined in Table 8 along with their associated "ARD Effects" shown in the next column. The effect of the ARD process is then explained more fully in the column headed "Effect of Aging on Component Function." The "Relative Contribution to Component Failure" is a measure of the contribution of the ARD mechanism listed to the failure of given component as compared to all causes of failure for that component. Some of the reviewed reports provided numerical data on relative contribution to failure, though most either gave qualitative assessments or said nothing. A standard set of semiquantitative terms was used in this column where information was available, namely "frequent," "moderate," "occasional," "infrequent," and "rare." These terms relate only to the "Relative Contribution to Component Failure" and do not in any way quantify the actual failure rate of a given component or its impact on plant safety.

The "Reported Programs" column lists existing programs, standards, or other guidance referred to in the reviewed document that addresses the particular ARD process or aging issue in question. The "Relevant Programs" column lists some programs currently in use by licensees in addressing issues that affect the stated system, structure, or component. There was no need to address the Relevant Programs column for the industry report tables, because the information given in the IRs is current with respect to discussions between NEI and the NRC staff. The "Report Recommendations" column summarizes any recommendations contained in the reviewed report for remedial actions or follow-on work with respect to a particular ARD process. These recommendations were not reviewed by the NRC staff for adequacy or endorsement. Finally, the number in brackets assesses the current relevance of the recommendation based on the reviewer's judgment. One of four possible standard entries is used: (1) obsolete or outdated, (2) safety enhancements, (3) may potentially need further evaluation, or (4) issue is presently being addressed. This numerical code was not used for the industry report tables, because the information given in these reports is current with respect to discussions between NEI and the NRC staff. Several industry report table entries under the Report Recommendations column heading have the word "More" appearing. This entry tells the reader that more information can be found in NUREG-1557 (Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal). The Relevant Programs and Report Recommendations columns for the industrial report tables contain details of the discussions between the NEI and the NRC staff.

3 Summary and Observations

More than 550 documents comprising 163 NPAR reports, 31 NRC Generic Letters, 265 Information Notices, 82 Licensee Event Reports, 5 Bulletins, and 10 NUMARC Industry Reports were reviewed under the GALL program. The results of these reviews were systematically summarized in a tabular format, using standardized definitions of ARD mechanisms and effects developed for this study. The review reveals (1) no new issues with respect to the components subject to ARD and the degradation mechanisms responsible and (2) that all ongoing significant issues are currently being addressed by the regulatory process. However, (3) the aging of passive components has been highlighted for continued scrutiny. The information contained in the column headed "Report Recommendations" in the GALL tables contained in the Appendices clearly reflects this position. Four possible aging issue current relevance categorization indicators were possible in this column. The all-important indicator "may potentially need further evaluation," which indicates the possibility of emerging aging issues, appears only a few times.

A few general observations concerning specific aging issues and the components affected are presented below.

3.1 Mechanical, Structural, and Thermal-Hydraulic Components and Systems

As expected, corrosion and corrosion-related processes were the dominant mechanisms of ARD in coolant piping and steam generators. Where high-velocity fluids were present in piping, erosion/corrosion was also a significant mechanism. Additionally for piping, feedwater nozzles, and interfacing tanks and other components, nonuniform water temperature fields aggravated by thermal bucyancy can cause large induced structural thermal stresses of either quasi-steady, low-cycle, or thermal shock nature and can lead to cracking or significant structural distortion. These thermal stresses are usually not accounted for in component design and are highly plant- and mode-of-operation-dependent. They can occur under normal or intermittent operation of plant systems and tend to be worse under low flow conditions. For reactor internals, irradiation-assisted stress corrosion cracking was an important source of degradation where high radiation fields were present. Other forms of corrosion, as well as vibrational fatigue, also contributed to internals degradation.

Pump and valve casings were likewise found to be subject to corrosion and erosion/corrosion related degradation. Thermal embrittlement was an important mechanism in cast stainless steel pump and valve components. Moving parts in pumps and valves suffered from ARD produced by wear, vibration, fatigue, and erosion/corrosion. Valve and pump seals and other elastomer components were subject to degradation by physical and chemical degradation at elevated temperature and/or prolonged exposure to the service environment.

The principal degradation mechanisms affecting concrete structures were leaching and breakdown of cement phases under the action of aggressive chemicals, degradation due to freeze-thaw cycles, and corrosive attack of the embedded rebar. The responsible mechanism(s) for some concrete wall cracking was found to be not well understood.

Diesel generators, air compressors, and ventilating and air conditioning equipment suffered principally from wear, vibration, and fatigue associated with reciprocating motion, as well as corrosion and wear induced by contamination. Heat exchangers and steam generators were subject to contamination and corrosion, as well as biofouling, thermal fatigue, and vibrational fatigue. Vibrational fatigue, wear, and elevated temperature degradation of damping fluids commonly caused degradation in snubbers.

Table 1 lists aging issues found to occur almost equally in BWR and PWR plants and tend to center on various forms of corrosion and fatigue. Another important commonality of the components listed in this table is that they are all what are termed passive components as described in 10 CFR 54. This may be of considerable significance because the literature reviewed seems to indicate that passive components are not as extensively or thoroughly covered by current plant maintenance procedures. Furthermore, surveillance and monitoring methods and instrumentation and procedures have not been as extensively developed or employed for passive components subjected to the highlighted aging mechanisms, nor are some of the passive component aging mechanisms as well understood. Thus, plant life extension by employing component replacement and maintenance could be more tenuous for the passive components. Furthermore, passive components tend to be some of the most costly in a plant and are frequently not as easy to replace. For these reasons, the knowledge base for predicting relevant aging effects behavior and significance, which is essential to the development of robust plans for aging reduction, monitoring procedures, and maintenance, is very important for passive components.

Table 1. Selected Examples of Aging Issues Significant to Passive Components

Reactor Type	Component	Material	Degradation Process	References
PWR	Instrumentation and CRD housing nozzles	Low-alloy steel (A533B, A508) with Type 308 or 309 SS clad	Environmentally assisted fatigue. Appropriate design rules do not yet exist in the ASME Boiler & Pressure Vessel Code.	NUREG/CR-5490
BWR and PWR	Closure studs	A-540, B22, B2, or B24	Environmentally assisted fatigue, fretting, and boric acid corrosion if leakage present	NUREG/CR-5490
PWR	CRD system components	Various	Dropped or stuck rod due to failure by fatigue, mechanical wear, or stress corrosion cracking	NUREG/CR-5555
BWR	Jet pump and holddown beams	Inconel X-750	Cracking and possible failure from vibrational and/or environmentally assisted fatigue and stress corrosion cracking	NUREG/CR-5754
BWR	Reactor internals	Various	Crack initiation, growth, and possible failure from irradiation-assisted stress corrosion cracking (IASCC)	NUREG/CR-5754

Table 1. Selected Examples of Aging Issues Significant to Passive Components (Cont'd)

Reactor Type	Component	Material	Degradation Process	References
PWR	Lower core support structure components	Type 304 SS, A-286, Inconel X-750, and others	Cracking and possible failure from vibrational fatigue and IASCC	NUREG/CR-6048
BWR	Pressure vessel upper head	Low-alloy steel (A533B, A508) with Type 308 or 309 SS clad	Cracking (possibly SCC) of weld clad, with cracks penetrating into underlying base metal	IN 90-29
BWR	Core shroud	Type 304 SS	SCC (or IASCC) leads to circumferential cracking of core shroud and concerns about possible structural failure in an accident or seismic event	IN 93-79, IN 94-42
BWR	Recirculating coolant pump seals	Cemented WC in Ni binder	Preferential corrosive dissolution of Ni binder under certain undefined conditions leads to excessive seal leakage and possible eventual pump failure	
BWR and PWR	All piping and feedwater nozzles and interfacing tanks and components	Commonly used materials, low-alloy steels	Large thermally induced stresses, either quasi-steady or low-cycle transient, thermal fatigue, induced by nonuniform coolant temperature fields aggravated by thermal-buoyancy-caused stratification under no-flow or low-flow levels, cause wall cracking or gross abnormal component distortion, usually not accounted for in component design, highly plant- and mode-of-operation dependent	NUREG/CR-4731 Vols. 1&2
BWR and PWR	Shielding wall concrete and other locations	Reinforced concrete	Actual process and mechanisms unclear; shows up as large surface cracks not caused by structural loading	NUREG/CR-4652

3.2 Electrical Components and Systems

Breakers and relays were usually covered together in the same report; the predominant aging-related failure mechanisms were contact wear, sticking linkage, loss of lubrication, or elevated temperature. Normally energized relay coils were frequently mentioned as high-failure-rate items because of the insulation breakdown caused by elevated temperature due to self-heating from the continuous current. Breakers are routinely refurbished on periodic schedules.

Degradation of cable insulation and jackets is the major effect of cable aging, due primarily to radiation and elevated temperature. Despite sizable efforts to develop electrical and mechanical methods of detecting cable insulation degradation, there are no reliable methods of detecting degradation of electrical cable insulation in a reactor containment. Electrical parameters, while relatively easy to measure, were found not to give a good indication of mechanical degradation. The mechanical indentor method was successful only for some insulation and jacket types.

Instrumentation and control (I&C) systems, including breakers and sensors, are made up of many small components that are routinely replaced after a number of years of service, as determined by qualification programs. Thus, aging is controlled by scheduled maintenance and periodic replacement. Redundancy in the Reactor Protection System and Engineered Safety Features Actuation Systems allows for taking a channel out of service for maintenance.

Motors and generators occasionally fail due to bearing wear caused by vibration and winding insulation breakdown from elevated temperatures. Brushes also age due to wear.

Battery chargers and inverters are small electrical systems made up of many electronic components that, like the I&C system, can be taken out of service for maintenance because of redundancy. Many of the electrical I&C components are included in plant QA programs that require periodic replacement. Inverter failures have caused numerous problems.

Many of the electrical I&C components are included in plant quality assurance programs that require periodic replacement. A more detailed analysis may be carried out at a later date to assess the significance of these mitigative practices and the aging processes.

Table 2a. NPAR Reports Reviewed
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
No report no. (May 1987)	Tech. Integration Review Group for Aging and Life Extension	Plan for Integration of Aging and Life-Extension Activities
BNL Tech. Report A-3270-11-26-84	Miller	Scoping Test on Containment Purge and Vent Seal Material
BNL Tech. Report A-3270-12-85	Silver, Vasudevan, and Subudhi	Pilot Assessment: Impact of Aging on the Seismic Performance of Selected Equipment Types
BNL Tech. Report A-3270-12-86	Fullwood, Higgins, Subudhi, and Taylor	Aging and Life Extension Assessment Program (ALEAP) Systems Level Plan
BNL Tech. Report A-3270R-2-90	Fresco and Subudhi	Interim Report—Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
BNL Tech. Report TR-3270-6-90	Gunther	Maintenance Team Inspection Results: Insights Related to Plant Aging
BNL Tech. Report TR-3270-9-90	Grove and Gunther	An Operational Assessment of the Babcock & Wilcox and Combustion Engineering Control Rod Drives
BNL Tech. Report A-3270-6-21-91	Hsu, Vesely, Grove, Subudhi, and Samanta	Degradation Modeling: Extensions and Applications
EGG-SSRE-8972	Atwood	Estimating Hazard Functions for Repairable Components
EGG-SSRE-9017	Atwood	User's Guide to PHAZE, a Computer Program for Parametric Hazard Function Estimation
EGG-SSRE-9777	Watkins, Steele, and DeWall	Isolation Valve Assessment (IVA) Software Version 3.10, User's Manual
EGG-SSRE-9926	Steele, Watkins, and DeWall	Evaluation of EPRI Draft Report NP-7065-Review of NRC/INEL Gate Valve Test Program
EGG-SSRE-10039	Hunt and Nitzel	An Evaluation of the Effects of Valve Body Erosion on Motor-Operated Valve Operability
Letter Report	Subudhi	Review of Aging-Seismic Studies on Nuclear Plant Equipment
Letter Report	Rib	Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Nuclear Safety 31:484-489	Hoopingarner and Zaloudek	Safety Implications of Diesel Generator Aging

Table 2a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
NUREG/CP-0036 (SAND-82-2264C)	Bader and Hanchey	Proceedings of the Workshop on Nuclear Plant Aging
NUREG-1144,V1	Morris and Vora	Nuclear Plant Aging Research (NPAR) Program Plan
NUREG-1144,V2	Vora	Nuclear Plant Aging Research (NPAR) Program Plan, Rev. 1
NUREG-1144,V3		Nuclear Plant Aging Research (NPAR) Program Plan, Status, and Accomplishments, Rev. 2
NUREG/CP-0100	Beranek	Proceedings of the International Nuclear Power Plant Aging Symposium
NUREG/CP-0105	Christensen	Proceedings of the Seventeenth Water Reactor Safety Information Meeting (aging session only)
NUREG/CR-2641 (ORNL/TM 8271)	Drago, Borkowski, Pike, and Goldberg,	The In-Plant Reliability Data Base for Nuclear Power Plant Components: Data Collection and Methodology Report
NUREG/CR-3154 (ORNL/TM 8647)	Borkowski, Kahl, Hebble, Frangola, and Johnson	The In-Plant Reliability Data Base for Nuclear Plant Components: Interim Report—The Valve Component
NUREG/CR-3543 (ORNL/TM 3543)	Murphy, Gallaher, Casada, and Hoy	Survey of Operating Experiences from LERs to Identify Aging Trends
NUREG/CR-3818 (SAND-84-0374)	Clark and Berry	Report of Results of Nuclear Power Plant Aging Workshop
NUREG/CR-3819 (EGG-2317)	Rose, Steele, DeWall, and Cornwell	Survey of Aged Power Plant Facilities
NUREG/CR-4144 (PNL-5389)	Davis, Shafaghi, Kurth, and Leverenz	Importance Ranking Based on Aging Consideration of Components Included in Probabilistic Risk Assessments
NUREG/CR-4279 (PNL-5479, V1)	Bush, Heasler, and Dodge	Aging and Service Wear of Hydraulic and Mechanical Snubbers used on Safety-Related Piping and Components of Nuclear Power Plants
NUREG/CR-4302 (ORNL-6193, V1)	Greenstreet, Murphy, Gallaher, and Eissenberg	Aging and Service Wear of Check Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants, Vol. 1
NUREG/CR-4302 (ORNL-6193, V2)	Haynes	Aging and Service Wear of Check Valves Used in Engineered Safety Feature Systems of Nuclear Power Plants, Vol. 2
NUREG/CR-4380 (ORNL-6226)	Crowley and Eissenberg	Evaluation of the Motor-Operated Valve Analysis and Test System (MOVATS) to Detect Degradation, Incorrect Adjustments, and Other Abnormalities in Motor-Operated Valves

Table 2a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
NUREG/CR-4597 (ORNL-6282, V1)	Adams and Makay	Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants, Vol. 1: Operating Experience and Failure Identification
NUREG/CR-4597 (ORNL-6282, V2)	Kitch, Schlonski, Sowatskey, and Cesarski	Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants, Vol. 2: Aging Assessment and Monitoring Method Evaluations
NUREG/CR-4652 (ORNL/TM-10059)	Naus	Concrete Component Aging and its Significance Relative to Life Extension of Nuclear Power Plants
NUREG/CR-4692 (ORNL/NOAC-233)	Murphy and Cletcher	Operating Experience Review of Failures of Power Operated Relief Valves and Block Valves in Nuclear Power Plants
NUREG/CR-4731 (EGG-2469), V1	Shah and MacDonald	Residual Life Assessment of Major Light Water Reactor Components, Vol. 1
NUREG/CR-4731 (EGG-2469), V2	Shah and MacDonald	Residual Life Assessment of Major Light Water Reactor Components—Overview, Vol. 2
NUREG/CR-4747 (EGG-2473, Vol. 1)	Meale and Satterwhite	An Aging Failure Survey of Light Water Reactor Safety Systems and Components, Vol. 1
NUREG/CR-4747 (EGG-2473, Vol. 2)	Meale and Satterwhite	An Aging Failure Survey of Light Water Reactor Safety Systems and Components, Vol. 2
NUREG/CR-4769 (EGG-2476)	Vesely	Risk Evaluations of Aging Phenomena: The Linear Aging Reliability Model and its Extensions
NUREG/CR-4967 (EGG-2514)	Meyer	Nuclear Plant Aging Research on High Pressure Injection Systems
NUREG/CR-4977 (EGG-2505, V1)	Steele and Arendts	SHAG Test Series: Seismic Research on an Aged United States Gate Valve and on a Piping System in the Decommissioned Heissdampfreaktor (HDR): Summary, Vol. 1
NUREG/CR-4977 (EGG-2505, V2)	Steele and Arendts	SHAG Test Series: Seismic Research on an Aged United States Gate Valve and on a Piping System in the Decommissioned Heissdampfreaktor (HDR): Appendices, Vol. 2
NUREG/CR-4985 (BNL/NUREG-52095)	Subudhi, Taylor, Clinton, Czajkowski, and Weeks	Indian Point 2 Reactor Coolant Pump Seal Evaluations
NUREG/CR-5052 (BNL-NUREG-52117)	Higgins, Lofaro, Subudhi, Fullwood, and Taylor	Operating Experience and Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors

Table 2a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
NUREG/CR-5057 (PNL-6397)	Hoopingarner and Zaloudek	Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
NUREG/CR-5159 (KEI-1559)	Kalsi, Horst, and Wang	Prediction of Check Valve Performance and Degradation in Nuclear Power Plant Systems
NUREG/CR-5248 (PNL-6701)	Levy, Wreathall, DeMoss, Wolford, Collins, and Jarrell	Prioritization of TIRGALEX—Recommended Components for Further Aging Research
NUREG/CR-5268 (BNL-NUREG-52177)	Lofaro, Subudhi, Gunther, Shier, Fullwood, and Taylor	Aging Study of Boiling Water Reactor Residual Heat Removal System
NUREG/CR-5314, V3	Jaske and Shah	Life Assessment Procedures for Major LWR Components; Cast Stainless Steel Components
NUREG/CR-5378	Wolford, Atwood, and Roesener	Aging Data Analysis and Risk Assessment-Development and Demonstration Study
NUREG/CR-5379 (PNL-6560), V1	Jarrell, Johnson, Zimmerman, and Gore	Nuclear Plant Service Water System Aging Degradation Assessment: Phase 1, Vol. 1
NUREG/CR-5379 (PNL-6560), V2	Jarrell, Larson, Stratton, Bohn, and Gore	Nuclear Plant Service Water System Aging Degradation Assessment, Vol. 2
NUREG/CR-5386 (PNL-6911)	Brown, Palmer, Werry, and Blahnik	Basis for Snubber Aging Research: Nuclear Plant Aging Research Program
NUREG/CR-5404 (ORNL-6566, V1)	Casada	Auxiliary Feedwater System Aging Study, Vol. 1
NUREG/CR-5404 (ORNL-6566, V2)	Kueck	Auxiliary Feedwater System Aging, Phase I: Follow-on Study
NUREG/CR-5406 (EGG-2569, V1)	DeWall and Steele	BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption Test, Vol 1: Analysis and Conclusions
NUREG/CR-5406 (EGG-2569, V2)	DeWall and Steele	BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption Test, Vol 2: Data Report
NUREG/CR-5406 (EGG-2569, V3)	DeWall and Steele	BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption Test, Vol 3: Review of Issues Associated with the BWR Containment Isolation Valve Closure

Table 2a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
NUREG/CR-5419 (BNL-NUREG-5221)	Villaran, Fullwood, and Subudhi	Aging Assessment of Instrument Air Systems in Nuclear Power Plants
NUREG/CR-5479 (ORNL/CR/5479)	Damiano and Kryter	Current Applications of Vibration Monitoring and Neutron Noise Analysis: Detection and Analysis of Structural Degradation of Reactor Vessel Internals from Operational Aging
NUREG/CR-5490	Werry	Regulatory Instrument Review: Management of Aging of LWR Major Safety Components
NUREG/CR-5491 (PNL-7191)	Allen and Johnson	Shippingport Station Aging Evaluation
NUREG/CR-5507	Gunther and Taylor	Results from the Nuclear Plant Aging Research Program: Their Use in Inspection Activities
NUREG/CR-5510	Vesely, Kurth, and Scalzo	Evaluations of Core Melt Frequency Effects due to Component Aging and Maintenance
NUREG/CR-5515	Neely, Jeanmougin, and Corugedo	Light Water Reactor Pressure Isolation Valve Performance Testing
NUREG/CR-5519	Moyers	Aging of Control and Service Air Compressors and Dryers used in Nuclear Power Plants
NUREG/CR-5555	Gunther and Sullivan	Aging Assessment of the Westinghouse PWR Control Rod Drive System
NUREG/CR-5558	Steele, DeWall, and Watkins	Generic Issue 87: Flexible Wedge Gate Valve Test Program: Phase II Results and Analysis
NUREG/CR-5583	Kalsi, Horst, Wang, and Sharma	Prediction of Check Valve Performance and Degradation in Nuclear Power Plant Systems-Wear and Impact Tests
NUREG/CR-5587	Vesely	Approaches for Age-Dependent Probabilistic Safety Assessments with Emphasis on Prioritization and Sensitivity Studies
NUREG/CR-5612	Samanta, Vesely, Hsu, and Subudhi	Degradation Modeling with Applications to Aging and Maintenance Effectiveness Evaluation
NUREG/CR-5643	Blahnik, Casada, Edson, Fineman	Insights Gained from Aging Research
NUREG/CR-5646	Steele and Nitzel	Piping System Response During High Level Simulated Seismic Tests at the Heissdampfreaktor Facility (SHAM Test Series)
NUREG/CR-5693	Lofaro, Gunther, Subudhi and Lee	Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors-Phase II

Table 2a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
NUREG/CR-5699	Greene	Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants—Vol. 1
NUREG/CR-5706	Casada	NRC Bulletin 88-04: Potential Safety-Related Pump Loss-An Assessment of Industry Data
NUREG/CR-5720	Steele, Watkins, DeWall, and Russell	Motor-Operated Valve Research Update
NUREG/CR-5754	Luk	Boiling-Water Reactor Internals Aging Degradation Study—Phase I
NUREG/CR-5779	Moyers	Aging of Non-Power-Cycle Heat Exchangers Used in Nuclear Power Plants
NUREG/CR-5783	Grove and Gunther	Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
NUREG/CR-5807	Wang and Kalsi	Improvements in Motor Operated Gate Valve Design and Prediction Models for Nuclear Power Plant Systems
NUREG/CR-5848	Dukelow	Recordkeeping Needs to Mitigate the Impact of Aging Degradation
NUREG/CR-5870	Brown, Werry, and Blahnik	Results of LWR Snubber Aging Research
NUREG/CR-5944	Casada and Todd	A Characterization of Check Valve Degradation and Failure Experience in the Nuclear Power Industry
NUREG/CR-6001	Buckley, Orton, Johnson, and Larson	Aging Assessment of BWR Standby Liquid Control Systems
NUREG/CR-6029	Winegardner	Aging Assessment of Nuclear Air Treatment System HEPA Filters and Adsorbers—Phase 1
NUREG/CR-6043	Blahnik and Klein	Phase I Aging Assessment of Essential HVAC Chillers Used in Nuclear Power Plants
NUREG/CR-6048	Luk	Pressurized-Water Reactor Internals Aging Degradation Study--A Phase I Report
ORNL/NRC/LTR-91/25	Casada	Throttled Valve Cavitation and Erosion
PNL-5722	Blahnik and Goodman	Operating Experience and Aging Assessment of ECCS Pump Room Coolers
PNL-6287	Hoopingarner, Kirkwood, and Lounzecky	Study Group Review of Nuclear Service Diesel Generator Testing and Aging Mitigation

Table 2a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Author	Title
PNL-7516	Hoopingarner	Emergency Diesel Generator Technical Specifications Study Results
PNL-7823	Chockie, Bjorkelo, Fleming, Scott, and Enderlin	Maintenance Practices to Manage Aging: A Review of Several Technologies
PNL-SA-18407	Johnson, Jarrell, Sinha, and Shah	Understanding and Managing Corrosion in Nuclear Power Plants
PNL-SA-20219	Brown and Blahnik	ASME Subsection ISTD Recommendations Based upon NPAR Snubber Aging Research Results

Table 2b. NPAR Reports Reviewed
Electrical Components and Systems

Report No.	Title
BNL A-3270-11-85	Seismic Endurance Tests Of Naturally Aged Small Electric Motors
BNL A-3270-3-86	Testing Program For The Monitoring Of Degradation In A Continuous Duty 460 Volt Class "B", 10 Hp Electric Motor
CHAPTER 24 CABLES	Aging And Life Extension Of Major Light Water Reactor Components, Edited By V. N. Shah And P. E. Macdonald, Elsevier Science Publishers B.V., 1993
NISTIR 4485	Annotated Bibliography: Diagnostic Methods And Measurement Approaches To Detect Incipient Defects Due To Aging Of Cables
NISTIR 4487	Detection Of Incipient Defects In Cables By Partial Discharge Signal Analysis
NISTIR 4787	The Use Of Time-Domain Dielectric Spectroscopy To Evaluate The Lifetime Of Nuclear Power Station Cables
NUREG-1377 R3	NRC Research Program On Plant Aging: Listing And Summaries Of Reports Issued Through July 1992
NUREG/CP-0100	Proceedings Of The International Nuclear Aging Symposium, Session 3 (Pgs 125-126 & 363-366)
NUREG/CP-0105	Seventeenth Water Reactor Safety Information Meeting (Electrical Parts)
NUREG/CR-3956	In Situ Testing Of The Shippingport Atomic Power Station Electrical Circuits
NUREG/CR-4156	Operating Experience And Aging-Seismic Assessment Of Electric Motors
NUREG/CR-4234 V2	Aging And Service Wear Of Electric Motor-Operated Valves Used In Engineered Safety-Feature Systems Of Nuclear Power Plants
NUREG/CR-4257	Inspection, Surveillance, And Monitoring Of Electrical Equipment Inside Containment Of Nuclear Power Plants - With Applications To Electrical Cables
NUREG/CR-4257 V2	Inspection, Surveillance, And Monitoring Of Electrical Equipment In Nuclear Power Plants - Pressure Transmitters
NUREG/CR-4457	Aging Of Class 1e Batteries In Safety Systems Of Nuclear Power Plants
NUREG/CR-4564	Operating Experience And Aging-Seismic Assessment Of Battery Chargers And Inverters
NUREG/CR-4715	An Aging Assessment Of Relays And Circuit Breakers And System Interactions
NUREG/CR-4740	Nuclear Plant-Aging Research On Reactor Protection Systems
NUREG/CR-4747 V1	An Aging Failure Survey Of LWR Safety Systems And Components

Table 2b. (Cont'd)
Electrical Components and Systems

Report No.	Title
NUREG/CR-4747 V2	An Aging Failure Survey Of Light Water Reactor Safety Systems And Components (Electrical)
NUREG/CR-4819 V1	Aging And Service Wear Of Solenoid-Operated Valves Used In Safety Systems Of Nuclear Power Plants
NUREG/CR-4819 V2	Aging And Service Wear Of Solenoid-Operated Valves Used In Safety Systems Of Nuclear Power Plants, Vol 2
NUREG/CR-4928	Degradation Of Nuclear Plant Temperature Sensors
NUREG/CR-4939 V1	Improving Motor Reliability In Nuclear Power Plants - Performance Evaluation And Maintenance Practices
NUREG/CR-4939 V2	Improving Motor Reliability In Nuclear Power Plants
NUREG/CR-4939 V3	Failure Analysis And Diagnostic Tests On A Naturally Aged Large Electric Motor
NUREG/CR-4967	Nuclear Plant Aging Research On High Pressure Injection Systems
NUREG/CR-4992 V1	Aging And Service Wear Of Multistage Switches Used In Safety Systems Of Nuclear Power Plants
NUREG/CR-5008	Development Of A Testing And Analysis Methodology To Determine The Functional Condition Of Solenoid Operated Valves
NUREG/CR-5051	Detecting And Mitigating Battery Charger And Inverter Aging
NUREG/CR-5053	Operating Experience And Aging Assessment Of Motor Control Centers
NUREG/CR-5141	Aging And Qualification Research On Solenoid Operated Valves
NUREG/CR-5181	Nuclear Plant Aging Research: The 1e Power System
NUREG/CR-5192	Testing Of A Naturally Aged Nuclear Power Plant Inverter And Battery Charger
NUREG/CR-5280 V1	Age-Related Degradation Of Westinghouse 480-Volt Circuit Breakers
NUREG/CR-5280 V2	Age-Related Degradation Of Westinghouse 480-Volt Circuit Breakers (Mechanical Cycling)
NUREG/CR-5334	Severe Accident Testing Of Electrical Penetration Assemblies
NUREG/CR-5383	Effect Of Aging On Response Time Of Nuclear Plant Pressure Sensors
NUREG/CR-5448	Aging Evaluation Of Class 1e Batteries: Seismic Testing
NUREG/CR-5461	Aging Of Cables, Connections, And Electrical Penetration Assemblies Used In Nuclear Power Plants
NUREG/CR-5546	An Investigation Of The Effects Of Thermal Aging On The Fire Damageability Of Electric Cables
NUREG/CR-5560	Aging Of Nuclear Plant Resistance Temperature Detectors

Table 2b. (Cont'd)
Electrical Components and Systems

Report No.	Title
NUREG/CR-5619	The Impact Of Thermal Aging On The Flammability Of Electric Cables
NUREG/CR-5643	Insights Gained From Aging Research
NUREG/CR-5655	Submergence And High Temperature Steam Testing Of Class 1e Electrical Cables
NUREG/CR-5700	Aging Assessment Of Reactor Instrumentation And Protection System Components
NUREG/CR-5762	Comprehensive Aging Assessment Of Circuit Breakers And Relays
NUREG/CR-5772 V1	Aging, Condition Monitoring, And Loss-Of-Coolant Accident (LOCA) Tests Of Class 1e Electrical Cables
NUREG/CR-5772 V2	Aging, Condition Monitoring, And Loss-Of-Coolant Accident (LOCA) Tests Of Class 1e Electrical Cables
NUREG/CR-5772 V3	Aging, Condition Monitoring, And Loss-Of-Coolant Accident (LOCA) Tests Of Class 1e Electrical Cables
NUREG/CR-6095	Aging, Loss-Of-Coolant Accident (LOCA), And High Potential Testing Of Damaged Cables
NUREG/CR-9XXX	Summaries Of Research Reports Submitted In Connection With The Nuclear Aging Research (NPAR) Program
SAND--88-0754	Time-Temperature-Dose Rate Superpositions: A Methodology For Predicting Cable Degradation Under Ambient Nuclear Power Plant Aging Conditions
TIRGALEX	Plan For Integration Of Aging And Life-Extension Activities
WYLE 60103-1	Test Plan Of Molded Case Circuit Breakers For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For Nuclear Plant Aging Research (NPAR)
WYLE 60103-2	Test Plan Of Metal Clad Circuit Breakers For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For ------ NPAR Program, Phase Ii
WYLE 60103-3	Test Plan Of Auxiliary Relays For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For ---- (NPAR) Program, Phase Ii
WYLE 60103-4	Test Plan Of Control Relays For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For ------ (NPAR) Program, Phase Ii
WYLE 60103-5	Test Plan Of Protective Relays For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For Nuclear Plant Aging Research (NPAR), Phase Ii

Table 2b. (Cont'd)
Electrical Components and Systems

Report No.	Title
WYLE 60103-6	Test Plan Of Timing Relays For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For Nuclear Plant Aging Research (NPAR), Phase Ii
WYLE 60103-7	Test Plan Of Electronic Relays For The Comprehensive Aging Assessment Of Circuit Breakers And Relays For Nuclear Plant Aging Research (NPAR), Phase Ii
SAND93-7027	Aging Management Guideline for Commercial Nuclear Power Plants-Electrical Switchgear
SAND93-7046	Aging Management Guideline for Commercial Nuclear Power Plants-Battery Chargers, Inverters and Uninterruptible Power Supplies
SAND93-7068	Aging Management Guideline for Commercial Nuclear Power Plants-Power and Distribution Transformers
SAND93-7069	Aging Management Guideline for Commercial Nuclear Power Plants-Motor Control Centers
SAND93-7071	Aging Management Guideline for Commercial Nuclear Power Plants-Stationary Batteries

Table 3a. NRC Generic Letters Reviewed
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Letter No.	Title
GL 89-04	Guidance on Developing Acceptable Inservice Testing Programs
GL 89–08	Erosion/Corrosion–Induced Pipe Wall Thinning
GL 89-10	Safety-Related (1) Motor-Operated Valve Testing and Surveillance
GL 89–10b, Suppl. 2	Availability of Program Descriptions
GL 89–10c, Suppl. 3	Consideration of the Results of NRC–Sponsored Tests of Motor–Operated Valves
GL 89–10d, Suppl. 4	Consideration of Valve Mispositioning in Boiling Water Reactors
GL 89-10, Suppl. 6	Information on Schedule Grouping, and Staff Responses to Additional Public Questions
GL 89–11	Resolution of Generic Issue 101, "Boiling Water Reactor Water Level Redundancy"
GL 89-13	Service Water System Problems Affecting Safety-Related Equipment
GL 89-13, Suppl. 1	Service Water System Problems Affecting Safety-Related Equipment, Suppl. 1
GL 89–21, Encl. 1	Request for Information Concerning Status of Implementation of Unresolved Safety Issue (USI) Requirements
GL 90-05	Guidance for Performing Temporary Non-Code Repair of ASME Code Class 1, 2, and 3 Piping
GL 90–06	Resolution of Generic Issue 70, "Power–Operated Relief Valve and Block Valve Reliability," and Generic Issue 94, "Additional Low–Temperature Overpressure Protection for Light–Water Reactors"
GL 90–09	Alternative Requirements for Snubber Visual Inspection Intervals and Corrective Actions
GL 91–07	GI–23, "Reactor Coolant Pump Seal Failures" and its Possible Effect on Station Blackout
GL 91–13	Request for Information Related to the Resolution of Generic Issue 130, "Essential Service Water System Failures at Multi–Unit Sites," Pursuant to 10 CFR 50.54(f)
GL 91-17	Generic Safety Issue 29, "Bolting Degradation or Failure in Nuclear Power Plants"
GL 91–18	Information to Licensees Regarding Two NRC Inspection Manual Sections on Resolution of Degraded and Nonconforming Conditions and on Operability
GL 92–01, Rev. 1	Reactor Vessel Structural Integrity, 10 CFR 50.54(f)

Table 3a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Letter No.	Title
GL 92-02	Resolution of Generic Issue 79, "Unanalyzed Reactor Vessel (PWR) Thermal Stress During Natural Convection Cooldown"
GL 92-04	Resolution of the Issues Related to Reactor Vessel Water Level Instrumentation in BWRs Pursuant to 10 CFR 50.54(F)
GL 93-04	Rod Control System Failure and Withdrawal of Rod Control Cluster Assemblies, 10 CFR 50.54(f)
GL 94-01	Removal of Accelerated Testing and Special Reporting Requirements for Emergency Diesel Generators

*Table 3b. NRC Generic Letters Reviewed
Electrical Components and Systems*

Letter No.	Title	Age Related
GL 89-19	Request For Action Related To Resolution Of Unresolved Safety Issue "Safety Implication Of Control Systems In LWR Nuclear Power Plants," Pursuant To 10 CFR 50.54(F)	No
GL 91-06	Resolution Of Generic Issue A-30, "Adequacy Of Safety-Related DC Power Supplies," Pursuant To 10 CFR 50.54(F)	No
GL 91-11	Resolution Of Generic Issue 48, "LCOS For Class 1e Vital Instrument Buses," And 49, "Interlocks And LCOS For Class 1e Tie Breakers," Pursuant To 10 CFR 50.54(F)	No
GL 91-15	Operating Experience Feedback Report, Solenoid-Operated Valve Problems At U.S. Reactors	Yes
GL 92-04	Resolution Of The Issues Related To Reactor Vessel Water Level Instrumentation In BWRs Pursuant To 10 CFR 50.54(F)	No
GL 92-08	Thermo-Lag 330-1 Fire Barriers	No
GL 93-04	Rod Control System Failure And Withdrawal Of Rod Control Cluster Assemblies, 10 CFR 50.54(F)	No
GL 94-01	Removal Of Accelerated Testing And Special Reporting Requirements For Emergency Diesel Generators	No

Table 4a. NRC Information Notices Reviewed
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 89–01	Valve Body Erosion
IN 89-04	Potential Problems from the Use of Space Heaters
IN 89–06	Bent Anchor Bolts in Boiling Water Reactor Torus Supports
IN 89-08	Pump Damage Caused by Low-Flow Operation
IN 89–15	Second Reactor Coolant Pump Shaft Failure at Crystal River
IN 89–20	Weld Failures in a Pump of Byron–Jackson Design
IN 89–26	Instrument Air Supply to Safety–Related Equipment
IN 89–30	High-Temperature Environments at Nuclear Power Plants
IN 89–32	Surveillance Testing of Low–Temperature Overpressure–Protection Systems
IN 89–32, Suppl. 1	Surveillance Testing of Low–Temperature Overpressure–Protection Systems
IN 89–33	Potential Failure of Westinghouse Steam Generator Tube Mechanical Plugs
IN 89–36	Excessive Temperatures in Emergency Core Cooling System Piping Located Outside Containment
IN 89–38	Atmospheric Dump Valve Failures at Palo Verde Units 1, 2, and 3
IN 89–48	Design Deficiency in the Turbine–Driven Auxiliary Feedwater Pump Cooling Water System
IN 89–49	Failure to Close Service Water Cross–Connect Isolation Valves
IN 89-53	Rupture of Extraction Steam Line on High Pressure Turbine
IN 89-55	Degradation of Containment Isolation Capability by a High-Energy Line Break
IN 89–58	Disablement of Turbine–Driven Auxiliary Feedwater Pump Due to Closure of One of the Parallel Steam Supply Valves
IN 89–61	Failure of Borg–Warner Gate Valves to Close Against Differential Pressure
IN 89–62	Malfunction of Borg–Warner Pressure Seal Bonnet Check Valves Caused by Vertical Misalignment of Disk
IN 89–65	Potential for Stress Corrosion Cracking in Steam Generator Tube Plugs Supplied by Babcock and Wilcox
IN 89–67	Loss of Residual Heat Removal Caused by Accumulator Nitrogen Injection
IN 89–69	Loss of Thermal Margin Caused by Channel Box Bow
IN 89–71	Diversion of the Residual Heat Removal Pump Seal Cooling Water Flow During Recirculation Operation Following a Loss–of–Coolant Accident
IN 89–73	Potential Overpressurization of Low Pressure Systems
IN 89–77	Debris in Containment Emergency Sumps and Incorrect Screen Configurations

Table 4a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 89–77, Suppl. 1	Debris in Containment Emergency Sumps and Incorrect Screen Configurations
IN 89–79	Degraded Coatings and Corrosion of Steel Containment Vessels
IN 89–79, Suppl. 1	Degraded Coatings and Corrosion of Steel Containment Vessels
IN 89–80	Potential for Water Hammer, Thermal Stratification, and Steam Binding in High–Pressure Coolant Injection Piping
IN 89–81	Inadequate Control of Temporary Modifications to Safety–Related Systems
IN 89–90	Pressurizer Safety Valve Lift Setpoint Shift
IN 89–90, Suppl. 1	Pressurizer Safety Valve Lift Setpoint Shift
IN 89–90, Suppl. 2	Pressurizer Safety Valve Lift Setpoint Shift
IN 90-02	Potential Degradation of Secondary Containment
IN 90–03	Malfunction of Borg–Warner Bolted Bonnet Check Valves Caused by Failure of the Swing Arm
IN 90–04	Cracking of the Upper Shell–To–Transition Cone Girth Welds in Steam Generators
IN 90–10	Primary Water Stress Corrosion Cracking (PWSCC) of Inconel 600
IN 90–17	Weight and Center of Gravity Discrepancies for Copes–Vulcan Valves
IN 90–18	Potential Problems with Crosby Safety Relief Valves used on Diesel Generator Air Start Receiver Tanks
IN 90–19	Potential Loss of Effective Volume for Containment Recirculation Spray at PWR Facilities
IN 90–21	Potential Failure of Motor–Operated Butterfly Valves to Operate Because Valve Seat Friction Was Underestimated
IN 90–29	Cracking of Cladding and Its Heat–Affected Zone in the Base Metal of a Reactor Vessel Head
IN 90–30	Ultrasonic Inspection Techniques for Dissimilar Metal Welds
IN 90–32	Surface Crack and Subsurface Indications in the Weld of a Reactor Vessel Head
IN 90–32, Suppl. 1	Surface Crack and Subsurface Indications in the Weld of a Reactor Vessel Head
IN 90–37	Sheared Pinion Gear–To–Shaft Keys in Limitorque Motor Actuators
IN 90–39	Recent Problems with Service Water Systems

Table 4a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 90–40	Results of NRC–Sponsored Testing of Motor–Operated Valves
IN 90–45	Overspeed of the Turbine–Driven Auxiliary Feedwater Pumps and Overpressurization of the Associated Piping Systems
IN 90-49	Stress Corrosion Cracking in PWR Steam Generator Tubes
IN 90-53	Potential Failures of Auxiliary Steam Piping and the Possible Effects on the Operability of Vital Equipment
IN 90–60	Availability of Failure Data in the Government–Industry Data Exchange Program
IN 90–64	Potential for Common–Mode Failure of High Pressure Safety Injection Pumps or Release of Reactor Coolant Outside Containment During a Loss–of–Coolant Accident
IN 90–65	Recent Orifice Plate Problems
IN 90–68	Stress Corrosion Cracking of Reactor Coolant Pump Bolts
IN 90–68, Suppl. 1	Stress Corrosion Cracking of Reactor Coolant Pump Bolts
IN 90–73	Corrosion of Valve–to–Torque Tube Keys in Spray Pond Cross Connect Valves
IN 90–74	Information on Precursors to Severe Accidents
IN 90–76	Failure of Turbine Overspeed Trip Mechanism Because of Inadequate Spring Tension
IN 90–78	Previously Unidentified Release Path from Boiling Water Reactor Control Rod Hydraulic Units
IN 90-79	Failures of Main Steam Isolation Check Valves Resulting in Disc Separation
IN-91-12	Potential Loss of Net Positive Suction Head (NPSH) of Standby Liquid Control System Pumps
IN 91-18	High-Energy Piping Failures Caused by Wall Thinning
IN 91-18, Suppl. 1	High Energy Piping Failures Caused by Wall Thinning
IN 91-19	Steam Generator Feedwater Distribution Piping Damage
IN 91-27	Incorrect Rotation of Positive Displacement Pump
IN 91-28	Cracking in Feedwater System Piping
IN 91-32	Possible Flaws in Certain Piping Systems Fabricated by Associated Piping and Engineering
IN 91-38	Thermal Stratification in Feedwater System Piping
IN 91-41	Potential Problems with the Use of Freeze Seals
IN 91-43	Recent Incidents Involving Rapid Increases in Primary-to-Secondary Leak Rate

Table 4a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 91-50	A Review of Water Hammer Events After 1985
IN 91-56	Potential Radioactive Leakage to Tank Vented to Atmosphere
IN 91-58	Dependency of Offset Disc Butterfly Valve's Operation Orientation with Respect to Flow
IN 91-61	Preliminary Results of Validation Testing of Motor-Operated Valve Diagnostic Equipment
IN 91-67	Problems with the Reliable Detection of Intergranular Attack (IGA) of Steam Generator Tubing
IN 91-69	Errors in Main Steam Line Break Analyses for Determining Containment Parameters
IN 91-73	Loss of Shutdown Cooling During Disassembly of High-Pressure Safety Injection System Check Valve
IN 91-80	Failure of Anchor Head Threads on Post-Tensioning System During Surveillance Inspection
IN 91-82	Problems with Diaphragms in Safety-Related Tanks
IN 92–07	Rapid Flow–Induced Erosion/Corrosion of Feedwater Piping
IN 92–16	Loss of Flow from the Residual Heat Removal Pump during Refueling Cavity Draindown
IN 92–16, Suppl. 1	Loss of Flow from the Residual Heat Removal Pump during Refueling Cavity Draindown
IN 92–16, Suppl. 2	Loss of Flow from the Residual Heat Removal Pump during Refueling Cavity Draindown
IN 92–19	Misapplication of Potter & Brumfield MDR Rotary Relays
IN 92–20	Inadequate Local Leak Rate Testing
IN 92–32	Problems Identified with Emergency Ventilation Systems for Near–Site (Within 10 miles) Emergency Operations Facilities and Technical Support Centers
IN 92–35	Higher Than Predicted Erosion/Corrosion in Unisolable Reactor Coolant Pressure Boundary Piping Inside Containment at a Boiling Water Reactor
IN 92–36	Intersystem LOCA Outside Containment
IN 92–41	Consideration of the Stem Rejection Load in Calculation of Required Valve Thrust
IN 92–50	Cracking of Valves in the Condensate Return Lines of a BWR Emergency Condenser System
IN 92–57	Radial Cracking of Shroud Support Access Hole Cover Welds
IN 92–59	Horizontally–Installed Motor–Operated Gate Valves

Table 4a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 92-60	Valve Stem Failure Caused by Embrittlement
IN 92–61	Loss of High Head Safety Injection
IN 92–63	Cracked Insulators in ASL Dry Type Transformers Manufactured by Westinghouse Electric Corporation
IN 92–64	Nozzle Ring Settings on Low Pressure Water–Relief Valves
IN 92–65	Safety System Problems Caused by Modifications that Were Not Adequately Reviewed and Tested
IN 92–70	Westinghouse Motor–Operated Valve Performance Data Supplied to Nuclear Power Plant Licensees
IN 92–80	Operation with Steam Generator Tubes Seriously Degraded
IN 92–85	Potential Failures of Emergency Core Cooling Systems Caused by Foreign Material Blockage
IN 92–86	Unexpected Restriction to Thermal Growth of Reactor Coolant Piping
IN 93–02	Malfunction of a Pressurizer Code Safety Valve
IN 93-06	Potential Bypass Leakage Paths Around Filters Installed in Ventilation Systems
IN 93–08	Failure of Residual Heat Removal Pump Bearings Due to High Thrust Loading
IN 93–16	Failures of Nut–Locking Devices in Check Valves
IN 93–20	Thermal Fatigue Cracking of Feedwater Piping to Steam Generators
IN 93–21	Summary of NRC Staff Observations Compiled during Engineering Audits or Inspections of Licensee Erosion/Corrosion Programs
IN 93–34	Potential for Loss of Emergency Cooling Function due to a Combination of Operational and Post–LOCA Debris in Containment
IN 93–34, Suppl. 1	Potential for Loss of Emergency Cooling Function due to a Combination of Operational and Post–LOCA Debris in Containment
IN 93–37	Eyebolts with Indeterminate Properties Installed in Limitorque Valve Operator Housing Covers
IN 93–42	Failure of Anti–Rotation Keys in Motor–Operated Valves Manufactured by Velan
IN 93–43	Use of Inappropriate Lubrication Oils in Safety–Related Applications
IN 93-45	Degradation of Shutdown Cooling System Performance
IN 93–48	Failure of Turbine–Driven Main Feedwater Pump to Trip Because of Contaminated Oil
IN 93–51	Repetitive Overspeed Tripping of Turbine–Driven Auxiliary Feedwater Pumps
IN 93–54	Motor–Operated Valve Actuator Thrust Variations Measured with a Torque Thrust Cell and a Strain Gage

Table 4a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 93–55	Potential Problem with Main Steamline Break Analysis for Main Steam Vaults/Tunnels
IN 93–59	Unexpected Opening of Both Doors in an Airlock
IN 93-61	Excessive Reactor Coolant Leakage Following a Seal Failure in a Reactor Coolant Pump or Reactor Recirculation Pump
IN 93–62	Thermal Stratification of Water in BWR Reactor
IN 93–66	Switchover to Hot-Leg Injection Following a Loss-of-Coolant Accident in Pressurized Water Reactors
IN 93-67	Bursting of High-Pressure Coolant Injection Steam Line Rupture Discs Injures Plant Personnel
IN 93–68	Failure of Pump Shaft Coupling Caused by Temper Embrittlement during Manufacture
IN 93–70	Degradation of Boraflex Neutron Absorber Coupons
IN 93–79	Core Shroud Cracking at Beltline Region Welds in Boiling-Water Reactors
IN 93–82	Recent Fuel and Core Performance Problems in Operating Reactors
IN 93–83	Potential Loss of Spent Fuel Pool Cooling Following a Loss of Coolant Accident (LOCA)
IN 93–87	Fuse Problems with Westinghouse 7300 Printed Circuit Cards
IN 93–92	Plant Improvements to Mitigate Common Dependencies in Component Cooling Water
IN 93–97	Failures of Yokes Installed on Walworth Gate
IN 93-101	Jet Pump Hold-Down Beam Failure
IN 94–01	Turbine Blade Failures Caused by Torsional Excitation from Electrical System Disturbance
IN 94–03	Deficiencies Identified During Service Water System Operational Performance Inspections
IN 94–05	Potential Failure of Steam Generator Tubes with Kinetically Welded Sleeves
IN 94–06	Potential Failure of Long-Term Emergency Nitrogen Supply for the Automatic Depressurization System Valves
IN 94–08	Potential for Surveillance Testing to Fail to Detect an Inoperable Main Steam Isolation Valve
IN 94–11	Turbine Overspeed and Reactor Cooldown During Shutdown Evolution
IN 94–13	Assemblies and Other Components Due to Improper Operation of Refueling Equipment
IN 94–18	Accuracy of Motor-Operated Valve Diagnostic Equipment (Responses to Supplement 5 to Generic Letter 89-10)

Table 4a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Notice No.	Title
IN 94–25	Failure of Containment Spray Header Valve to Open Due to Excessive Pressure from Inertial Effects of Water
IN 94–27	Facility Operating Concerns Resulting from Local Area Flooding
IN 94–29	Charging Pump Trip During a Loss–of–Coolant Event Caused by Low Suction Pressure
IN 94–30	Leaking Shutdown Cooling Isolation Valves at Cooper Nuclear Station
IN 94–34	Thermo–Lag 330–660 Flexi–Blanket Ampacity Derating Concerns
IN 94–36	Undetected Accumulation of Gas in Reactor Coolant System
IN 94–38	Results of a Special NRC Inspection at Dresden Nuclear Power Station Unit 1 Following a Rupture of Service Water Inside Containment
IN 94–42	Cracking in the Lower Region of the Core Shroud in Boiling–Water Reactors
IN 94–43	Determination of Primary–to–Secondary Steam Generator Leak Rate
IN 94–44	Main Steam Isolation Valve Failure to Close on Demand Because of Inadequate Maintenance and Testing
IN 94–45	Potential Common-Mode Failure Mechanism for Large Vertical Pumps
IN 94–48	Snubber Lubricant Degradation in High–Temperature Environments
IN 94–49	Failure of Torque Switch Roll Pins

Table 4b. NRC Information Notices Reviewed Electrical Components and Systems

Notice No.	Title	Age Related
IN 89-03	Potential Electrical Equipment Problems	No
IN 89-07	Failures Of Small-Diameter Tubing In Control Air, Fuel Oil, And Lube Oil Systems Which Render Emergency Diesel Generators Inoperable	Yes
IN 89-11	Failure Of DC Motor-Operated Valves To Develop Rated Torque Because Of Improper Cable Sizing	No
IN 89-16	Excessive Voltage Drop In DC Systems	No
IN 89-17	Contamination And Degradation Of Safety-Related Battery Cells	Yes
IN 89-20	Weld Failures In A Pump Of Byron-Jackson Design	Yes
IN 89-21	Changes In Performance Characteristics Of Molded-Case Breakers	No
IN 89-23	Environmental Qualification Of Litton-Veam CIR Series Electrical Connectors	No
IN 89-30	High Temperature Environments At Nuclear Power Plants	No
IN 89-30-01	High Temperature Environments At Nuclear Power Plants	No
IN 89-42	Failure Of Rosemount Models 1153 And 1154 Transmitters	Yes
IN 89-43	Permanent Deformation Of Torque Switch Helical Springs In Limitorque SMA-Type Motor Operators	Yes
IN 89-50	Inadequate Emergency Diesel Generator Fuel Supply	No
IN 89-63	Possible Submergence Of Electrical Circuits Located Above The Flood Level Because Of Water Intrusion And Lack Of Drainage	No
IN 89-64	Electrical Bus Bar Failures	Yes
IN 89-66	Qualification Life Of Solenoid Valves	Yes
IN 89-68	Evaluation Of Instrument Setpoints During Modifications	No
IN 89-79	Degraded Coatings And Corrosion Of Steel Containment Vessels	Yes
IN 89-79-01	Sustained Degraded Voltage On The Offsite Electrical Grid And Loss Of Other Generating Stations As A Result Of A Plant Trip	No
IN 89-84	Failure Of Ingersoll Rand Air Start Motors As A Result Of Pinion Gear Assembly Fitting Problems	Yes
IN 89-87	Disabling Of Emergency Diesel Generators By Their Neutral Ground-Fault Protection Circuitry	No
IN 90-18	Potential Problems With Crosby Safety Relief Valves Used On Diesel Generator Air Start Receiver Tanks	No
IN 90-22	Unanticipated Equipment Actuations Following Restoration Of Power To Rosemount Transmitter Trip Units	No

Table 4b. (Cont'd)
Electrical Components and Systems

Notice No.	Title	Age Related
IN 90-23	Improper Installation Of Patel Conduit Seals	No
IN 90-25	Loss Of Vital AC Power With Subsequent Reactor Coolant System Heat-Up	No
IN 90-41	Potential Failure Of General Electric Magne-Blast Circuit Breakers And AK Circuit Breakers	Yes
IN 90-42	Failure Of Electrical Power Equipment Due To Solar Magnetic Disturbances	No
IN 90-43	Mechanical Interference With Thermal Trip Function In GE Molded-Case Circuit Breakers	No
IN 90-51	Failures Of Voltage-Dropping Resistors In The Power Supply Circuitry Of Electric Governor Systems	Yes
IN 90-51-01	Failure Of Voltage-Dropping Resistors In The Power Supply Circuitry Of Electric Governor Systems	Yes
IN 90-60	Availability Of Failure Data In The Government-Industry Data Exchange Program	No
IN 90-74	Information On Precursors To Severe Accidents	No
IN 90-80	Sand Intrusion Resulting In Two Diesel Generators Becoming Inoperable	Yes
IN 91-06	Lockup Of Emergency Diesel Generator And Load Sequencer Control Circuits Preventing Restart Of Tripped Emergency Diesel Generator	No
IN 91-11	Inadequate Physical Separation And Electrical Isolation Of Non-Safety-Related Circuits From Reactor Protection System Circuits	No
IN 91-20	Electric Wire Insulation Degradation Caused Failure In A Safety-Related Motor Control Center	Yes
IN 91-29	Deficiencies Identified During Electrical Distribution System Functional Inspections	No
IN 91-29-02	Potential Deficiencies Found During Electrical Distribution System Functional Inspections	No
IN 91-34	Potential Problems In Identifying Causes Of Emergency Diesel Generator Malfunctions	No
IN 91-45	Possible Malfunction Of Westinghouse ARD, BFD, And NBFD Relays, And A 200 DC And DPC 250 Magnetic Contactors	Yes
IN 91-46	Degradation Of Emergency Diesel Generator Fuel Oil Delivery Systems	Yes
IN 91-47	Failure Of Thermo-Lag Fire Barrier Material To Pass Fire Endurance Test	No

Table 4b. (Cont'd)
Electrical Components and Systems

Notice No.	Title	Age Related
IN 91-53	Failure Of Remote Shutdown System Instrumentation Because Of Incorrectly Installed Components	No
IN 91-57	Operational Experience On Bus Transfers	No
IN 91-62	Diesel Engine Damage Caused By Hydraulic Lockup Resulting From Fluid Leakage Into Cylinders	Yes
IN 91-74	Changes In Pressurizer Safety Valve Setpoints Before Installation	No
IN 91-78	Status Indication Of Control Power For Circuit Breakers Used In Safety-Related Applications	Yes
IN 91-79	Deficiencies In The Procedures For Installing Thermo-Lag Fire Barrier Materials	No
IN 91-81	Switchyard Problems That Contribute To Loss Of Offsite Power	Yes
IN 91-83	Solenoid-Operated Valve Failures Resulted In Turbine Overspeed	Yes
IN 91-85	Potential Failures Of Thermostatic Control Valves For Diesel Generator Jacket Cooling Water	Yes
IN 91-87	Hydrogen Embrittlement Of Raychem Cryofit Couplings	Yes
IN 92-03	Remote Functions In General Electric F-Frame Molded-Case Circuit Breakers	No
IN 92-04	Potter & Brumfield Model MDR Rotary Relay Failures	Yes
IN 92-05	Potential Coil Insulation Breakdown In ABB RXMH2 Relays	No
IN 92-06	Reliability Of ATWS Mitigation System And Other NRC Required Equipment Not Controlled By Plant Technical Specifications	No
IN 92-09	Overloading And Subsequent Lock Out Of Electrical Buses During Accident Conditions	No
IN 92-12	Effects Of Cable Leakage Currents On Instrument Settings And Indications	No
IN 92-23	Results Of Validation Testing Of Motor-Operated Valve Diagnostic Equipment	No
IN 92-27	Thermally Induce Accelerated Aging And Failure Of Ite/Gould A.C. Relays Used In Safety-Related Applications	Yes
IN 92-29	Potential Breaker Miscoordination Caused By Instantaneous Trip Circuitry	No
IN 92-31	Electrical Connection Problem In Johnson Yokogawa Corporation YS-80 Programmable Indicating Controllers	No
IN 92-33	Increased Instrument Response Time When Pressure Dampening Devices Are Installed	No

Table 4b. (Cont'd)
Electrical Components and Systems

Report	Title	Age Related
IN 92-40	Inadequate Testing Of Emergency Bus Undervoltage Logic Circuitry	No
IN 92-43	Defective Molded Phenolic Armature Carriers Found On Elmwood Contactors	No
IN 92-44	Problems With Westinghouse DS-206 Type Circuit Breakers	Yes
IN 92-45	Incorrect Relay Used In Emergency Diesel Generator Output Breaker Control Circuitry	No
IN 92-46	Thermo-Lag Fire Barrier Material Special Review Team Final Report Findings, Current Fire Endurance Tests, And Ampacity	No
IN 92-47	Intentional Bypassing Of Automatic Actuation Of Plant Protective Features	No
IN 92-48	Failure Of Exide Batteries	Yes
IN 92-51	Misapplication And Inadequate Testing Of Molded-Case Circuit Breakers	No
IN 92-53	Potential Failure Of Emergency Diesel Generators Due To Excessive Rate Of Loading	No
IN 92-54	Level Instrumentation Inaccuracies Caused By Rapid Depressurization	No
IN 92-55	Current Fire Endurance Test Results For Thermo-Lag Fire Barrier Material	No
IN 92-67	Deficiency Of Design Modifications To Address Failures Of Hiller Actuators Upon A Gradual Loss Of Air Pressure	No
IN 92-69	Water Leakage Yard Through Conduits Into Building	No
IN 92-78	Piston To Cylinder Liner Tin Smearing On Cooper-Bessemer KSV Diesel Engines	Yes
IN 92-81	Potential Deficiency Of Electrical Cables With Bonded Hypalon Jackets	No
IN 92-82	Results Of Thermo-Lag 330-1 Combustibility Testing	No
IN 92-83	Thrust Limits For Limitorque Actuators And Potential Overstressing Of Motor-Operated Valves	No
IN 93-05	Storm-Related Loss Of Offsite Power Events Due To Salt Buildup On Switchyard Insulators	Yes
IN 93-09	Failure Of Undervoltage Trip Attachment On Westinghouse Model DB-50 Reactor Trip Breaker	No
IN 93-11	Single Failure Vulnerability Of Engineered Safety Features Actuation Systems	No

Table 4b. (Cont'd)
Electrical Components and Systems

Report	Title	Age Related
IN 93-15	Failure To Verify The Continuity Of Shunt Trip Attachment Contacts In Manual Safety Injection And Reactor Trip Switches	No
IN 93-22	Tripping Of Klockner-Moeller Molded-Case Circuit Breakers Due To Support Lever Failure	Yes
IN 93-23	Weschler Instruments Model 252 Switchboard Meters	Yes
IN 93-25	Electrical Penetration Assembly Degradation	No
IN 93-26	Grease Solidification Causes Molded-Case Circuit Breaker Failure To Close	Yes
IN 93-27	Level Instrumentation Inaccuracies Observed During Normal Plant Depressurization	No
IN 93-33	Potential Deficiency Of Certain Class 1e Instrumentation And Control Cables	Yes
IN 93-37	Eyebolts With Indeterminate Properties Installed In Limitorque Valve Operator Housing Covers	No
IN 93-46	Potential Problem With Westinghouse Rod Control System And Inadvertent Withdrawal Of A Single Rod Control Cluster Assembly	No
IN 93-47	Unrecognized Loss Of Control Room Annunciators	No
IN 93-49	Improper Integration Of Software Into Operating Practices	No
IN 93-64	Periodic Testing And Preventive Maintenance Of Molded Case Circuit Breakers	Yes
IN 93-65	Reactor Trips Caused By Breaker Testing With Fault Protection Bypassed	No
IN 93-74	High Temperatures Reduce Limitorque AC Motor Operator Torque	No
IN 93-75	Spurious Tripping Of Low-Voltage Power Circuit Breakers With GE RMS-9 Digital Trip Units	No
IN 93-87	Fire Problems With Westinghouse 7300 Printed Circuit Cards	No
IN 93-89	Potential Problems With BWR Level Instrumentation Backfill Modifications	No
IN 93-91	Misadjustment Between General Electric 4.16-LV Circuit Breakers And Their Associated Cubicles	No
IN 93-99	Undervoltage Relay And Thermal Overload Setpoint Problems	No
IN 94-02	Inoperability Of General Electric Magne-Blast Breaker Because Of Misalignment Of Close-Latch Spring	No
IN 94-04	Digital Integrated Circuit Sockets With Intermittent Contact	Yes

Table 4b. (Cont'd)
Electrical Components and Systems

Report	Title	Age Related
IN 94-10	Failure Of Motor-Operated Valve Electric Power Train Due To Sheared Of Dislodged Motor Pinion Gear Key	No
IN 94-19	Emergency Diesel Generator Vulnerability To Failure From Cold Fuel Oil	No
IN 94-20	Common-Cause Failures Due To Inadequate Design Control And Dedication	No
IN 94-33	Capacitor Failures In Westinghouse Eagle 21 Plant Protection Systems	Yes
IN 94-34	Thermo-Lag 330-660 Flexi-Blanket Ampacity Derating Concerns	No
IN 94-40	Failure Of A Rod Control Cluster Assembly To Fully Insert Following A Reactor Trip At Braidwood Unit 2	No
IN 94-41	Problems With General Electric Type Cr124 Overload Relay Ambient Compensation	No

Table 5a. NRC Licensee Event Reports Reviewed
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Title
LER 86-008, Rev. 1	Main Coolant Pump Suction Valve Stem Failure
LER 86-017, Rev. 1	Local Leak Rate Test Results of App. J Related Valves in Excess of Limits
LER 88–014 Rev. 1	Primary Containment Penetration Local Leak Rate Test Failures
LER 89-001	Oxidation of Division 2 Fuel Oil Resulted in Division 2 Diesel Generator Being Inoperable when Division 1 Generator was Out for Planned Maintenance
LER 89-001, Rev. 1	Oxidation of Division 2 Fuel Oil Resulted in Division 2 Diesel Generator Being Inoperable when Division 1 Generator was Out for Planned Maintenance
LER 89–005	Containment Vent Valve Seal Degradation Discovered
LER 89–011	Turbine Stop Valve Closure Due to Auto Stop Oil Line Break
LER 89–016– Rev. 2	Auxiliary Feedwater Pump FW–10 Outside Design Basis
LER 90–021	Containment Spray Header Clogged Nozzles Due to Pipe Wall Coating Material Aging
LER 90–022	Degraded Fire Penetration Seals as Result of Inadequate Construction Technique
LER 91–011 Rev. 2	Discussion of Additional Design Features & Required Functions of Containment Electrical Penetration Assembly Seals not Included in Revs. 0 & 1 of LER
LER 92–001	ESF Component Actuation: 12GB4 (Cont. Isol. Valve) Failed–Closed Twice Due to Equipment Failure
LER 92–003	Manual Reactor and Main Turbine Trip Due to Failed Expansion Joint in 21 Main Condenser
LER 92–006	Reactor Shutdown to Modify and Test Emergency Core Cooling and Containment Spray Minimum Flow Isolation Valves
LER 92–007	Reactor Trip Due to Failure of the Low Pressure Turbine Exhaust Boot Seal
LER 92–008	Spent Fuel Pool Exhaust Ventilation System Inoperable Due to Unacceptable Leakage Around the Charcoal Absorber
LER 92-009	Analyzer Failed with the Redundant Monitor Having Its Emergency Power Source Inoperable
LER 92–010	Reactor Trip Due to Low Pressure Turbine Exhaust Boot Seal Failure
LER 92–013 Rev. 1	Local Leak Rate Test Results in Excess of Limits Due to Valve Degradation
LER 92–026	Breach of Containment Integrity Due to Failure of Personnel Airlock Door

Table 5a. (Cont'd)
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Title
LER 93–001	Technical Specification 3.0 Implementation Due to Excessive PPS Leakage
LER 93–001 Rev. 2	Manual Reactor Trip Following a Steam Generator Tube Rupture
LER 93–005	Failure of the Drywell Vent Valve 3–1601–63 Due to a Degraded O–Ring on the Two-Way Versa Valve
LER 93–003 Rev. 1	Main Steam Isolation Valve Local Leak Rate Exceeded
LER 93–003 Rev. 2	Main Steam Isolation Valve Local Leak Rate Exceeded
LER 93–007	Discovery That Certain Valves Should be Subject to ASME Section XI Testing
LER 93-010	Failure of an Essential Cooling Water Traveling Screen Coupling
LER 94–005	Failure of Control Rod to Scram Due to Degradation of Pilot Valve Elastomers Caused by In–Service Aging
LER 94–005 Rev. 1	Failure of Control Rod to Scram Due to Degradation of Pilot Valve Elastomers Caused by In–Service Aging

Table 5b. NRC Licensee Event Reports Reviewed Electrical Components and Systems

Report	Title
LER 88-011-282	Auto-Start Of Train A Of Auxiliary Building Special Ventilation System As A Result Of A Radiation Monitor Spike
LER 88-033-02-327	Unplanned Reactor Trip Signal Due To A Reactor Protection System (RPS) Channel 1 Instrument Failure During RPS Channel 2 Calibration
LER 89-001-280	Unplanned Auto Start Of #3 EDG Due To Failed Diode
LER 89-002-331	Age-Related Failure Of A Governor Printed Circuit Board Results In High Pressure Coolant Injection System Inoperability
LER 89-003-263	Isolation Of Reactor Water Cleanup System Due To Capacitor Failure In Filter/Demineralizer Inlet Temperature Indication Switch
LER 89-006-261	Reactor Trip Due To Loss Of Turbine E-H Control Power Supplies
LER 89-010-362	Fuel Handling Isolation System Train "A" Actuation Due To Power Supply Failure
LER 89-014-271	Reactor Core Isolation Cooling System Inoperable Due To Motor Burn Out
LER 89-015-327	Control Room Isolation Resulting From A Worn Set Of Contacts In The 480 V Motor Starter For A Main Control Room Ventilation Intake Radiation Monitor
LER 89-019-01-325	Failure Of Service Water System To Meet Design Requirements
LER 89-020-01-528	Apparent Ground Causes Control Element Assembly Slip
LER 89-031-01-302	Failure Of "A" 480 V Engineered Safeguards Transformer Causes Temporary Interruption Of Decay Heat Cooling And A Plant Operational Mode Change
LER 90-007-01-388	ESF Actuations Due To RPS EPA Breaker Spurious Trip
LER 90-018-244	Dropped Control Rod During Rod Control Exercise Causes Automatic Actuation Of RPS
LER 90-022-01-344	Degraded Fire Penetration Seals As A Result Of Inadequate Construction Technique
LER 90-023-325	Partial Group 6 Isolation Resulting From Failure Of Relay I-Cac-3a
LER 90-023-424	Transformer Failure Results In Loss Of Steam Generator Level And Manual Reactor Trip
LER 90-029-01-325	Cbeaf System Actuation Resulting From The Failure Of The 1-D22a-K2 Relay Coil.
LER 91-001-293	Automatic Closing Of The Primary Containment System Group 5 Isolation Valves During Surveillance Testing
LER 91-002-01-327	EGTS Inoperable Because Of A Train EGTS Being Out Of Service For Filter Testing And B Train Diesel Generator Being Declared Inoperable Resulting ---

Table 5b. (Cont'd)
Electrical Components and Systems

Report	Title
LER 91-006-530	ESF Actuation Due To Loss Of Power To 4.16 kV Bus
LER 91-007-456	Rod Control System Failure Causes Shutdown Bank Control Rods To Be In A Condition Prohibited By Technical Specifications
LER 91-008-260	Unplanned Engineered Safety Features Actuation Due To A Failed PCIS Relay
LER 91-010-01-155	Reactor Protection System Pressure Switches Experiencing Setpoint Drift; Revision 1
LER 91-014-01-498	Erratic Containment Extended Range Pressure Channel Output
LER 91-016-260	Unplanned Engineered Safety Features Actuation Due To A Blown Fuse Caused By A Failed Relay
LER 91-016-424	Failure To Complete Technical Specification Required Action For Battery Cell Low Voltage
LER 91-020-237	Reactor Building Ventilation Isolation And Automatic Standby Gas Treatment Initiation Due To Radiation Monitor Power Supply Failure
LER 91-021-254	RCIC Declared Inoperable Due To High Pump Flow In ISI Required Action Range
LER 91-028-325	Component Failure Of A Reactor Water Cleanup System Isolation Logic Relay Resulted In An Unplanned Engineered Safety Feature Actuation
LER 91-028-254	Loss Of Power To 1a RPS Bus Caused By EPA 1a-1 Tripping On Undervoltage Due To Low M-G Set Output
LER 91-030-423	Motor Control Center Auxiliary Control Relay Failure Due To Thermal Aging
LER 92-001-263	Shutdown Required By Technical Specification Due To Inoperable Bellows Leak Detection System For Safety Relief Valves
LER 92-001-155	Brittle Motor Lead Wires Discovered In Vop-7050 (Main Steam Isolation Valve-MSIV)
LER 92-001-296	Engineered Safety Feature Actuation Caused By A Failed Relay Coil
LER 92-001-339	Reactor Trip Caused By MFRV Closure Upon Failure Of Driver Card
LER 92-002-247	Reactor Trip Due To Main Feedwater Regulating Valve Going Closed
LER 92-004-389	Manual Reactor Trip Due To Low Steam Generator Water Level Caused By A Failed Circuit In The 2a Feedwater Regulating Control System.
LER 92-006-331	Emergency Safety Feature Actuation During Modification Acceptance Testing Due To Damaged Switchyard Cable

Table 5b. (Cont'd)
Electrical Components and Systems

Report	Title
LER 92-006-354	Reactor Shutdown To Comply With Technical Specification 3.6.1.1, Due To Failure Of Suppression Chamber To Drywell Vacuum Breakers
LER 92-007-01-333	Failure Of Analog Transmitter Trip System (ATTS) Trip Relays Due To Thermal Aging
LER 92-009-01-499	Missed Technical Specification Required Surveillance Due To A Faulty Toxic Gas Monitoring System Modem
LER 92-011-325	Primary Containment Monitoring System Inoperability Due To Relay Failure
LER 92-021-237	Automatic Isolation Of Reactor Building Ventilation Due To Radiation Monitor Trip Relay Failure
LER 92-034-01-333	Engineered Safety Feature Actuations Due To Transformer Failure
LER 92-038-255	Reactor Trip Caused By A Loss Of The Preferred AC Bus Y-20 Coincident With A Blown Fuse In A Second Channel Of The Reactor Protective System
LER 93-002-249	Control Valve Fast Closure Half-Scram Pressure Switches Out-Of Calibration Due To Setpoint Drift
LER 93-003-530	Emergency Diesel Generator Unable To Start And Run In Manual Test Mode
LER 93-005-01-305	Annual Transmitter Calibration Finds A Shift In The Pressurizer High Pressure Reactor Trip Signal Initiation Due To Instrument Drift.
LER 93-005-01-275	Medium Voltage Cable Failures Due To Chemical Degradation And Unknown Causes
LER 93-009-498	Technical Specification 3.0.3 Entry Due To Potentially Undersized Fuses In The Solid State Protection System
LER 93-007-249	Yarway Reactor Water Level Switch Failure
LER 93-008-237	Yarway Reactor Water Level Switch Failure

Table 6a. NRC Bulletins Reviewed
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Bulletin No.	Title
BL 89–01	Failure of Westinghouse Steam Generator Tube Mechanical Plugs
BL 89–01. Suppl. 1	Failure of Westinghouse Steam Generator Tube Mechanical Plugs
BL 89–01. Suppl. 2	Failure of Westinghouse Steam Generator Tube Mechanical Plugs
BL 89–02	Stress Corrosion Cracking of High–Hardness Type 410 Stainless Steel Internal Preloaded Bolting in Anchor Darling Model S350W Swing Check Valves of Similar Design

Table 6b. NRC Bulletins Reviewed
Electrical Components and Systems

Bulletin No.	Title
BL 90-01	Loss of Fill-Oil in Transmitters Manufactured By Rosemount

Table 7a. NUMARC Industry Reports Reviewed
Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Report No.	Title
IR 90-01	PWR Containment Structures License Renewal Industry Report
IR 90-02	BWR Pressure Vessel License Renewal Industry Report
IR 90-03	BWR Vessel Internals License Renewal Industry Report
IR 90-04	PWR Vessel License Renewal Industry Report
IR 90-05	PWR Reactor Pressure Vessel Internals License Renewal Industry Report
IR 90-06	Class 1 Structures License Renewal Industry Report
IR 90-07	PWR Reactor Coolant System License Renewal Industry Report
IR 90-09	BWR Primary Coolant Pressure Boundary License Renewal Industry Report
IR 90-10	BWR Containments License Renewal Industry Report

Table 7b. NUMARC Industry Reports Reviewed
Electrical Components and Systems

Report No.	Title
IR 90-08	Low Voltage Environmentally-Qualified Cable License Renewal Industry Report

Table 8. Standardized ARD Mechanisms, Definitions, and Associated Effects

Abbreviation	ARD Mechanism	Definition	ARD Effect
ADH	Adhesion	Undesired adherence of intermittently contacting surfaces of moving parts, as in valves	Loss of movement
AGR-CHEM	Aggressive chemicals	Breakdown of cement phases in concrete caused by contact with aggressive chemical (e.g., acidic groundwaters)	Loss of integrity; Increase of porosity & permeability, cracking, & spalling
AGREAC	Reaction with Aggregates	Chemical reactions between aggregates & alkalies that are introduced by cement or may come from admixtures, salt-contaminated aggregates, or penetration by seawater or deicing salt solution	Expansion & cracking
BIO	Biofouling	Buildup of micro- or macro-organisms on component surfaces, resulting in flow constriction, reduced heat transfer, etc. See also CORR/MIC.	Buildup of deposits
CATH	Cathodic protection effects on bond strength	Softening of concrete at the reinforcing bar surface when exposed to direct current for extended period of time	Loss of bond strength
CLOG	Clogging	Buildup of foreign particles or contaminants leading to restricted flow of air or coolant	Blockage of flow passages
CONCAL	Concrete interaction with aluminum	Concrete strength can be reduced when it is pumped through aluminum piping during placement	Reduction of concrete strength
CONTAM	Contamination	Undesirable introduction of foreign materials such as dust, wear debris, etc. onto critical surfaces or into lubricant	Buildup of deposits; loss of desired surface properties; loss of lubricant properties
CORR	Corrosion	Chemical interaction with environment resulting in loss of material or buildup of corrosion products	Loss of material; corrosion product buildup
CORR/RE	Corrosion of embedded or reinforcing steel	Corrosion of embedded or reinforcing steel caused by a decrease in concrete's alkalinity ($pH < 11.5$) due to leaching of alkaline products, entry of acidic materials, or carbonation	Cracking, spalling, loss of bond, loss of material

Table 8. (Cont'd)

Abbreviation	ARD Mechanism	Definition	ARD Effect
CORR/ OX	Oxidation	Corrosive reaction resulting in the production of a surface oxide layer or internal oxidation of the material	Loss of material; corrosion product buildup; internal damage
CORR/ PIT	Pitting corrosion	Localized corrosion resulting in surface pits or holes	Local loss of material
CORR/ UA	Uniform corrosion (wastage)	Uniform corrosive loss of material over a finite area	Loss of material; corrosion product buildup
CORR/ IN	Intergranular corrosive attack	Corrosive attack and penetration of the material along the grain boundaries with negligible attack of the remaining material	Crack initiation and growth
CORR/ SCC	Stress corrosion cracking	Cracking produced by the simultaneous presence of a susceptible material, tensile stress, and a corrosive environment	Crack initiation and growth
CORR/ PWSCC	Primary water stress corrosion cracking	A form of stress corrosion cracking observed on the primary water side of PWR steam generators and related components	Crack initiation and growth
CORR/ IASCC	Irradiation assisted stress corrosion cracking	A form of stress corrosion cracking enhanced by the presence of a significant neutron irradiation field (fluence $>\approx 10^{20}$ n/cm^2)	Crack initiation and growth
CORR/ TGSCC	Transgranular stress corrosion cracking	The transgranular form of SCC	Crack initiation and growth
CORR/ IGSCC	Intergranular stress corrosion cracking	The intergranular form of SCC	Crack initiation and growth
CORR/ CREV	Crevice corrosion	Localized corrosion produced by the concentration of corrosive chemical species in crevices	Local loss of material; crack initiation and growth
CORR/ LEACH	Leaching corrosion	Selective dissolution of a specific phase or chemical species by service environment	Loss of material soundness

Table 8. (Cont'd)

Abbreviation	ARD Mechanism	Definition	ARD Effect
CORR/ MIC	Microbiologically influenced corrosion	Corrosion produced by micro- or macro-biological organisms, caused by the production of corrosive substances, deposition, etc.	Loss of material; corrosion product buildup
CORR/ SA	Saline water attack	Corrosion of reinforced concrete by salt water attack of reinforcing bars	Loss of strength
CORR/ BA	Boric acid corrosion	Corrosion of carbon and low-alloy steel produced by leakage of BWR primary coolant containing boric acid	Loss of material
CREEP	Creep	Progressive plastic deformation produced by exposure to elevated temperatures and/or irradiation under stress	Change in dimension
CURSTR	Current stress	Abnormal current exceeding limits or short circuit	Equipment temperature rise, equipment degradation, dielectric loss, insulation breakdown
DRIFT	Signal drift	Various stressors can cause electrical instrumentation or equipment set points or signals to drift	Loss of calibration or function
ELE-TEMP	Elevated-temperature degradation	Progressive physical or chemical degradation induced by prolonged exposures to elevated temperatures	Chemical or physical degradation; thermal distortion; loss of strength & modulus
EMBR	Embrittlement	Loss of material ductility resulting from chemical or microstructural changes induced by the operating environment	Loss of fracture toughness
EMBR/ IR	Irradiation embrittlement	Embrittlement induced by exposure to neutron irradiation	Loss of fracture toughness; loss of strength & modulus (of concrete)
EMBR/ TE	Thermal embrittlement	Embrittlement induced by microstructural changes induced by prolonged exposures to elevated temperatures	Loss of fracture toughness
EMBR/ HY	Hydrogen embrittlement	Embrittlement induced by absorption of hydrogen	Loss of fracture toughness

Table 8. (Cont'd)

Abbreviation	ARD Mechanism	Definition	ARD Effect
EMBR/SA	Strain aging embrittlement	Embrittlement caused by strain aging associated with the redistribution of carbon and nitrogen atoms in cold-worked carbon steel	Loss of fracture toughness
ENVIR	Environmental degradation	Progressive physical or chemical degradation induced by prolonged exposures to the service environment. See also ELETEMP.	Chemical or physical degradation
ERO	Erosion	Loss of surface material at locations impinged by high-velocity gas or liquid streams, sometimes containing solid particles	Wall thinning; loss of material
ERO/CORR	Erosion/corrosion	Accelerated form of corrosion caused by removal of surface oxide layer due to impingement of high-velocity stream	Wall thinning; loss of material
ERO/CAV	Cavitation erosion	Erosive attack associated with the alternate formation and collapse of bubbles, as in pumps, etc.	Wall thinning; loss of material
EXFORCE	Excessive force	Greater than expected force	Causes distortion or bending
FAT	Fatigue	Progressive loss of structural integrity associated with the initiation and growth of cracks under cyclic loading conditions	Cumulative fatigue damage
FAT/ENV	Environmentally assisted fatigue	Decreased fatigue life due to environment of LWR reactor coolants	Cumulative fatigue damage
FAT/FIV	Flow-induced vibrational fatigue	Fatigue resulting from flow-induced vibrations	Cumulative fatigue damage
FAT/THERM	Thermal fatigue	Fatigue resulting from cyclic thermal stresses	Cumulative fatigue damage
FRZ/THAW	Freeze-thaw cycles	Breakdown of concrete caused by expansion associated with repeated freeze-thaw cycles, especially when wet	Loss of integrity; Scaling, cracking, & spalling
GAS	Gassing, loss of material to battery plates	Battery outgassing and material plating out	Loss of battery capacity, won't hold charge

Table 8. (Cont'd)

Abbreviation	ARD Mechanism	Definition	ARD Effect
LEACH	Leaching	Degradation of concrete caused by contacting water leaching out the $Ca(OH)_2$ phase, resulting in disintegration	Loss of integrity; Increase of porosity & permeability
LOSLUB	Loss of lubricant	Loss of lubricity due to evaporation or contamination	Viscosity change, loss of lubricity, allows rapid metal wear
LOTEMP	Low temperature	Lower than normal range	Deterioration of normal function
MECHSTR	Mechanical stress	Exceeding normal stress range	Deterioration of mechanical function, cracks, distortion, creep
MASON-BLOC	Restraint, shrinkage, creep, & aggressive environment	Cracking of masonry block walls due to restraint against expansion or contraction caused by changes in temperature, moisture, or carbonation; or from shrinkage, creep, or aggressive environment	Cracking of masonry block walls
MOIST	Moisture retention	Accumulation of moisture in filter media	Increased pressure drop; reduced strength
MOIST-EL	High humidity, or moisture present	Moisture in dielectric material	Loss of dielectric properties, increase in conductivity, reduces life, & molecular breakdown
PART	Particle retention	Accumulation of foreign particles in filter media	Increased pressure drop
PRESS-CY	Pressure cycles	Repeated pressure changes through normal pressure range	Deterioration of spring function (spring becomes set)
RAD	Nuclear radiation	Gamma or neutron radiation causing degradation effects.	Both mechanical and electrical properties degrade resulting in embrittlement, cracking, discoloration, and disintegration

Table 8. (Cont'd)

Abbreviation	ARD Mechanism	Definition	ARD Effect
RATCH	Ratchetting	Progressive plastic deformation caused by cyclic loading with a superimposed tensile mean stress	Change in dimension
RELAX	Stress relaxation	Progressive reduction of intentional secondary stress produced by exposure to elevated temperatures and/or irradiation under stress	Loss of preload; reduction of design margin
RESID	Residual stresses	Internal stresses introduced during fabrication or prior deformation	Crack initiation
SETTLE	Settlement	Settlement of foundations & structures as they are constructed and during their early life	Cracking, distortion, increase in component stress level
SHRINK	Shrinkage	Reduction in one or more physical dimensions	Change in dimension
THERM-CY	Thermal cycles	Repeated temperature changes through normal temperature range	Deterioration of insulation, forms cracks.
VIBR	Vibration	Moderate-to-high-frequency periodic motion resulting in loosening of component and fittings, crack initiation, etc.	Loosening; crack initiation and growth
VOLSTR	Voltage stress	Over voltage (in excess of tolerance or design limit) may include freq., rate, duration, or magnitude	Corona or ionization discharge causing burnout or degradation of insulation and electronics
VOLSTR-CH	Chemical effects related to voltage stress	Chemical effects related to corona, forms nitrous oxide in presence of water molecules	Reddish or white deposits in insulation. degrades insulation
WEAR	Wear	Loss of surface material caused by relative motion between contacting surfaces	Attrition, lockup
WEAR/ FRET	Fretting wear	Form of wear produced by vibrational rubbing of adjacent surfaces, as from flow-induced vibration of steam generator tubes	Attrition
WEAR/ DENT	Denting	Constriction of steam generator tubes produced by formation of corrosion products between tubes and adjacent surfaces	Constriction

Table 8. (Cont'd)

Abbreviation	ARD Mechanism	Definition	ARD Effect
WEAR/ GALL	Galling	Form of rubbing wear characterized by excessive friction and localized welding at high spots, followed by tearing and surface roughening	Attrition
WEATH	Weathering	Saturation of adsorber medium by adsorbed species	Loss of capacity

References

1. "World Nuclear Industry Handbook," Nuclear Engineering International, Surrey, U.K. (1994).

Appendix A: GALL Literature Review Tables - NPAR Reports, NRC Generic Letters, Information Notices, Licensee Event Reports, and NRC Bulletins

A.1 Mechanical, Structural, and Thermal-Hydraulic Components and Systems

Document: BNL A-3270, 11-26-84, Scoping Tests on Containment Purge and Vent Valve Seal Material
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Containment	Purge and vent butterfly valves	Valve seal material	Ethylene propylene	Parker Seal Company	ENVIR	Chemical or physical degradation

Document: BNL A-3270, 12-85, Pilot Assessment: Impact of Aging on the Seismic Performance of Selected Equipment Types
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Electric motors	Bearings	Not stated	Allis-Chalmers (<100 hp), Fairbanks-Morse and General Electric (>= 100 hp)	VIBR	Loosening
2	Various	Motor-operated valves	Motor operators	Not stated	Limitorque	Not stated	Not stated
3	Various	Relays	Not stated	Not stated	General Electric Co.	Not stated	Not stated
4	Various	Circuit breakers	Not stated	Not stated	General Electric Co.	Not stated	Not stated
5	Various	Motor control centers	Not stated	Not stated	Square D, General Electric Co.	Not stated	Not stated

Document: BNL A-3270, 6-21-91, Degradation Modeling: Extensions and Applications
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various reactor systems, including the ECCS, service air, and service water.	Various, including residual heat removal (RHR), pumps, air compressors, and service water pumps	This report does not provide specific detailed information on age-ralated degradation processes for specific nuclear components or systems.				

Document: BNL A-3270R, 2-90, Interim Report - Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system (feedwater)	Regulating valves	Operator	Not stated	Not stated	VIBR; CONTAM	Loosening; loss of desired surface properties
2	Cooling system (feedwater)	Motor-driven pumps	Bearings and seals	Not stated	Not stated	VIBR; CONTAM	Loosening; loss of desired surface properties
3	Cooling system (feedwater)	Motor-driven pumps	Shaft or impeller	Not stated	Not stated	FAT	Cumulative fatigue damage
4	Cooling system (feedwater)	Motor-driven pumps	Casing	Not stated	Not stated	ERO/CORR	Wall thinning; loss of material
5	Cooling system (feedwater)	Turbine-driven pumps	Seals	Non stated	Not stated	CONTAM	Loss of desired surface properties

Table A.1 Gall Report for NPAR Reports

Document: BNL A-3270, 11-26-84, Scoping Tests on Containment Purge and Vent Valve Seal Material
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Exposure to a containment environment characteristic of a severe accident situation causes accelerated degradation and cracking of the valve seat material	Not stated	Not discussed in report	ASME Sec XI or PS S&T Req.	Not stated	3	1

Document: BNL A-3270, 12-85, Pilot Assessment: Impact of Aging on the Seismic Performance of Selected Equipment Types
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Misalignment induced by vibration causes burnout of bearings.	Frequent	Not discussed in report	PS S&T Req.	Aging was not found to affect the seismic capacity of the components considered as long as routine preventative maintenance is performed. [2]	2-7	1
Not stated	Not stated	Not discussed in report	ASME Sec XI & GL 89-10 & Suppl.	Aging was not found to affect the seismic capacity of the components considered as long as routine preventative maintenance is performed. [2]	2-14	2
Not stated	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Aging was not found to affect the seismic capacity of the components considered as long as routine preventative maintenance is performed. [2]	2-18	3
Not stated	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Aging was not found to affect the seismic capacity of the components considered as long as routine preventative maintenance is performed. [2]	2-16	4
Not stated	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Aging was not found to affect the seismic capacity of the components considered as long as routine preventative maintenance is performed. [2]	2-18	5

Document: BNL A-3270, 6-21-91, Degradation Modeling: Extensions and Applications
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: BNL A-3270R, 2-90, Interim Report - Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure caused by valve-induced vibration and contamination of the instrument air system by oil, moisture and/or rust, or other foreign particles.	Frequent	Not discussed in report	ASME Sec XI & PS TS Req.	Not stated	19	1
Loss of pump-to-motor alignment and consequent pump instability.	Frequent	Not discussed in report	ASME Sec XI-IWP & PS TS Req.	Not stated	19	2
Not stated	Occasional	Not discussed in report	ASME Sec XI-IWP & PS TS Req. & ASME Sec III a	Not stated	19	3
Not stated	Rare	Not discussed in report	ASME Sec XI IWB	Not stated	20	4
Failure of seals from contamination results in subsequent lubricant contamination from by steam leaking past seals.	Infrequent	Not discussed in report	ASME Sec XI-IWP & PS TS Req.	Not stated	20	5

Document: BNL A-3270R, 2-90, Interim Report - Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
6	Cooling system (feedwater)	Turbine-driven pumps	Governor	Not stated	Not stated	CONTAM	Loss of desired surface properties
7	Main turbine	Electrohydraulic control	The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				
8	Main generator		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				
9	Condensate system		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				
10	Electrical distribution system		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				
11	Circulating water system		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				

Document: BNL A-3270R, 2-90, Interim Report - Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Mechanical failure of governor results from contamination of control oil.	Occasional	Not discussed in report	ASME Sec XI-IWP & PS TS Req.	Not stated	20	6
			No input for current programs column			7
			No input for current programs column			8
		Not discussed in report	No input for current programs column	Not stated		9
		Not discussed in report	No input for current programs column	Not stated		10
			No input for current programs column			11

Document: BNL A-3270R, 2-90, Interim Report - Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
12	Service/instrument air system		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				
13	Fire protection system		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				
14	Heating, ventilating, and air conditioning system		The report does not discuss specific components and aging mechanisms for these systems. However, they are identified as important for considering aging degradation, since their failure can cause unplanned reactor scrams.				

Document: BNL A3270, 12-86, Aging and Life Extension Assessment Program (ALEAP) Systems Level Plan
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various reactor systems, including the ECCS and service water	Various, including residual heat removal (RHR) pumps and service water pumps	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: BNL TR-3270-6-90, Maintenance Team Inspection Results: Insights Related to Plant Aging
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Broad spectrum	This report does not provide specific detailed information on age-ralated degradation processes for specific nuclear components or systems.				

Document: BNL A-3270R, 2-90, Interim Report - Aging Effects of Important Balance of Plant Systems in Nuclear Power Plants
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
			No input for current programs column			12
			No input for current programs column			13
			No input for current programs column			14

Document: BNL A3270, 12-86, Aging and Life Extension Assessment Program (ALEAP) Systems Level Plan
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: BNL TR-3270-6-90, Maintenance Team Inspection Results: Insights Related to Plant Aging
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Table A.1 Gall Report for NPAR Reports

Document: EGG-SSRE-10039, An Evaluation of the Effects of Valve Body Erosion on Motor-Operated Valve Operability
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Emergency Cooling	Motor Operated Valve (16 in. Globe Valve)	Valve Body	A216, Grade WCB, Cast Carbon Steel	Anchor-Darling Industries	ERO	Wall thinning; Loss of Material
2	Emergency Cooling	Motor Operated Valve (16 in. Globe Valve)	Valve Body	A216, Grade WCB, Cast Carbon Steel	Anchor-Darling Industries	ERO/CAV	Wall thinning; Loss of Material

Document: EGG-SSRE-8972, Estimating Hazard Functions for Repairable Components
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Feedwater system	Motor-operated valves	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: EGG-SSRE-9017, User's Guide to PHAZE, a Computer Code for Parametric Hazard Function Estimation
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Feedwater system	Motor-operated valves	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: EGG-SSRE-9777, Isolation Valve Assessment (IVA) User's Manual Version 3.10
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR feedwater cleanup system	Motor-operated flexible wedge gate isolation valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: EGG-SSRE-9926, Evaluation of EPRI Draft Report NP-7065 Review of NRC/INEL Gate Valve Test Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR water cleanup system	Motor operated flexible wedge gate isolation valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: EGG-SSRE-10039, An Evaluation of the Effects of Valve Body Erosion on Motor-Operated Valve Operability
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The wall thinning could create undue stresses and deformations in the valve body, which could lead to relative displacements and induce disc or stem binding. Binding could prevent the valve from performing its safety function.	Infrequent	Not stated	ASME Sec XI IST & GL 89-10 & Suppl.	Not stated	1-2, C1-10	1
The wall thinning could create undue stresses and deformations in the valve body, which could lead to relative displacements and induce disc or stem binding. Binding could prevent the valve from performing its safety function.	Infrequent	Not stated	ASME Sec XI IST & GL 89-10 & Suppl.	Not stated	1-2, C1-10	2

Document: EGG-SSRE-8972, Estimating Hazard Functions for Repairable Components
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: EGG-SSRE-9017, User's Guide to PHAZE, a Computer Code for Parametric Hazard Function Estimation
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: EGG-SSRE-9777, Isolation Valve Assessment (IVA) User's Manual Version 3.10
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: EGG-SSRE-9926, Evaluation of EPRI Draft Report NP-7065 Review of NRC/INEL Gate Valve Test Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: Letter Report (auth. Subudhi), Review of Aging-Seismic Studies on Nuclear Plant Equipment
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various including RCS, ECCS, SW, CCW, and others	Electric Motors	Stator/ Rotor Windings	Not stated	Not stated	ENVIR; VIBR	Physical Degradation; Loosening
2	Various including RCS, ECCS, SW, CCW, and others	Electric Motors	Bearings and Lubrication	Not stated	Not stated	ENVIR; VIBR	Physical Degradation; Loosening
3	Various including RCS, ECCS, SW, CCW, and others	Electric Motors	Electrical Leads	Not stated	Not stated	CONTAM; CORR	Buildup of deposits
4	Various including RCS, ECCS, SW, CCW, and others	Electric Motors	Bolts and Fasteners	Not stated	Not stated	VIBR	Loosening
5	Various including RCS, ECCS, SW, CCW, and others	Electric Motors	Commutator Brushes	Not stated	Not stated	WEAR	Attrition
6	Electrical Power Distribution	Battery Chargers and Inverters	Referred to INEL for review.				
7	Electrical Power Distribution	Electrical Cable	Referred to INEL for review.				
8	Electrical Power Distribution	Pressure Transmitters	Referred to INEL for review.				
9	Electrical Power Distribution	Emergency Diesel Generator	Governor	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
10	Electrical Power Distribution	Emergency Diesel Generator	Sensors	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
11	Electrical Power Distribution	Emergency Diesel Generator	Relays	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition

Table A.1 Gall Report for NPAR Reports

Document: Letter Report (auth. Subudhi), Review of Aging-Seismic Studies on Nuclear Plant Equipment
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Winding degradation and loosening causes electrical shorts resulting in failure of the motor.	Frequent	IEEE-323, 344, 334; Reg. Guide 1.89; ASME-OM8	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Update codes and standards noted in previous column. [2]	4-5	1
Steam and water environments cause corrosion. Vibration induced loosening will lead to seal leakage. Both mechanisms will lead to cracking and splitting of the bearings, loss of alignment, and potential jamming or freezing of the motor.	Frequent	IEEE-323, 344, 334; Reg. Guide 1.89; ASME-OM8	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Update codes and standards noted in previous column. [2]	4-6	2
Improper electrical contacts.	Occasional	IEEE-323, 344, 334; Reg. Guide 1.89; ASME-OM8	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Update codes and standards noted in previous column. [2]	4-7	3
Bending and distortion of bolts and fasteners leading to loss of motor balance.	Occasional	IEEE-323, 344, 334; Reg. Guide 1.89; ASME-OM8	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Update codes and standards noted in previous column. [2]	4-7	4
Poor connections of brushes leads to motor failure.	Occasional	IEEE-323, 344, 334; Reg. Guide 1.89; ASME-OM8	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Update codes and standards noted in previous column. [2]	4-7	5
						6
						7
						8
Not stated.	Occasional	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	9
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	10
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	11

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
12	Electrical Power Distribution	Emergency Diesel Generator	Startup components	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
13	Electrical Power Distribution	Emergency Diesel Generator	Engine Piping	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
14	Electrical Power Distribution	Emergency Diesel Generator	Injector Pumps	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
15	Electrical Power Distribution	Emergency Diesel Generator	Controls	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
16	Electrical Power Distribution	Emergency Diesel Generator	Starting Air Valve	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
17	Electrical Power Distribution	Emergency Diesel Generator	Starting Motors	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
18	Electrical Power Distribution	Emergency Diesel Generator	Air Compressor	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	12
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	13
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	14
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	15
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	16
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	17
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	18

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19	Electrical Power Distribution	Emergency Diesel Generator	Breakers	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
20	Electrical Power Distribution	Emergency Diesel Generator	Cooling/Lubrication Pumps	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
21	Electrical Power Distribution	Emergency Diesel Generator	Heat Exchangers	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
22	Electrical Power Distribution	Emergency Diesel Generator	Cooling Piping	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
23	Electrical Power Distribution	Emergency Diesel Generator	Lube Oil	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
24	Electrical Power Distribution	Emergency Diesel Generator	Other Systems	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper Bessemer, Fairbanks Morse, Electro-Motive Division, Nordberg, Transamerica Delaval, Worthington	VIBR, ENVIR, and WEAR	Loosening, Physical Degradation and Attrition
25	Various	Motor Operated Valves	Not stated	Not stated	Not stated	Not stated	Not stated
26	Various	Check Valves	Bonnet	Stainless steel	Not stated	WEAR; ERO/CORR	Attrition, Loss of material, Wall thinning
27	Various	Check Valves	Fasteners	Stainless steel	Not stated	VIBR; CORR	Loosening; Loss of material and corrosion product buildup

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	19
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	20
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	21
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	22
Not stated.	Rare	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	23
Not stated.	Not stated	None stated	PS TS Req., RG 1.9, RG 1.108	None given	4-46	24
Not stated.	Not stated	Reg Guides: ASME XI, Div 1; Generic Issues: Task II.E.6.1, Item B-58, Item C-11, Issue 54, Issue 105	ASME Sec XI OM-GL 89-10 & Suppl.	None given	4-54	25
Change in bonnet dimensions and cracking.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	26
Vibration induced fracture of the fasteners. Corrosion will accelerate the process.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	27

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
28	Various	Check Valves	Seat	Stainless steel hardened alloy, resilient material	Not stated	WEAR; ERO/CORR	Attrition, Loss of material, Wall thinning
29	Various	Check Valves	Obturator	Stainless steel with hardened alloy seating	Not stated	WEAR; ERO/CORR	Attrition, Loss of material, Wall thinning
30	Various	Check Valves	Obturator Hanger	Stainless steel	Not stated	WEAR; FAT; ERO/CORR	Attrition, Loss of fracture toughness; Loss of material, Wall thinning
31	Various	Check Valves	Hanger Pin	Stainless steel	Not stated	WEAR; FAT; ERO/CORR	Attrition, Loss of fracture toughness; Loss of material, Wall thinning
32	Various	Check Valves	Hanger Pin Bearing	Hardened alloy	Not stated	WEAR; EMBR; ERO/CORR	Attrition, Loss of fracture toughness; Loss of material, Wall thinning
33	Various	Check Valves	Seal, Gaskets	Asbestos type, Stainless steel, Resilient material	Not stated	EMBR/TE, WEAR, CORR	Loss of fracture toughness; Attrition; Loss of material
34	RCS and ECCS	Auxiliary Feedwater Pumps	Thrust Bearings	Rolling contact elements (Specialty steels)	Not stated	WEAR	Attrition
35	RCS and ECCS	Auxiliary Feedwater Pumps	Thrust runners	400-series S.S.	Not stated	WEAR	Attrition
36	RCS and ECCS	Auxiliary Feedwater Pumps	Shaft seals	Stuffing-box or mechanical type	Not stated	WEAR	Attrition
37	RCS and ECCS	Auxiliary Feedwater Pumps	Stationary vanes	400-series S.S.	Not stated	VIBR	Loosening
38	RCS and ECCS	Auxiliary Feedwater Pumps	Wear rings	400-series S.S.	Not stated	WEAR; VIBR	Attrition, Loosening
39	RCS and ECCS	Auxiliary Feedwater Pumps	Thrust balancers	400-series S.S.	Not stated	WEAR	Attrition
40	RCS and ECCS	Auxiliary Feedwater Pumps	Radial bearings	Bearing white metal (typically tin-base babbitt)	Not stated	WEAR; ELE-TEMP	Attrition, thermal distortion
41	RCS and ECCS	Auxiliary Feedwater Pumps	Shaft and Fasteners	400-series S.S.	Not stated	WEAR; VIBR	Attrition, Loosening

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Seat damage leads to valve leakage.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	28
Change in obturator dimensions causes valve leakage due to improper seating of the valve.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	29
Change in dimensions.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	30
Fracture of the pin.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	31
Change in dimensions.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	32
Valve leakage, excessive force needed to seat valve.	Not stated	Reg Guides: 1.147, 1.148; Generic Issues: Task II.E.6.1, Item B-58, Item C-11	If SR ASME Sec XI IWB, IWC, or IWD	None given	4-60	33
Change in rotor axial position. Loss of transmitted torque.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	34
Loss of transmitted torque.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	35
Seal leakage. Rotor vibration.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	36
Pump vibration. Loss of delivered flow.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	37
Pump vibration. Loss of transmitted torque. Loss of delivered flow.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	38
Loss of transmitted torque.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	39
Rotor vibration. Bearing heatup.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	40
Pump vibration.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	41

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
42	RCS and ECCS	Auxiliary Feedwater Pumps	Impellers	CrNi alloy steels, 17-4Ph	Not stated	WEAR; VIBR	Attrition, Loosening
43	RCS and ECCS	Auxiliary Feedwater Pumps	Couplings	Gear type	Not stated	WEAR; VIBR	Attrition, Loosening
44	RCS	Hydraulic Snubbers	EP Seals	Not stated	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	WEAR	Attrition
45	RCS	Hydraulic Snubbers	Piston Seals	Polyurethane	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	WEAR	Attrition
46	RCS	Hydraulic Snubbers	Poppet	Not stated	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	Not stated	Not stated
47	RCS	Hydraulic Snubbers	Activation adjustment screw	Not stated	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	Not stated	Not stated
48	RCS	Hydraulic Snubbers	Piston/ cylinder	Not stated	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	WEAR	Attrition, scoring
49	RCS	Hydraulic Snubbers	Not given	Not stated	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	CLOG	Blockage of flow

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Rotor unbalance and vibration. Loss of delivered flow.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	42
Rotor vibration.	Not stated	Reg Guides: 1.147; Generic Issues: Item C-11; ASME Section XI, OM-2, OM-6, OM-14, OM-15	ASME Sec XI IST & PS TS Req.	None given	4-68	43
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	44
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	45
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	46
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	47
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	48
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	49

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
50	RCS	Mechanical Snubbers	Not given	Not stated	Bergen-Patterson; Blaw Knox; ITT-Grinnell Corp.; Pacific Scientific; Anchor-Holth; International Nuclear Safeguards Corp.; ITT Barton; McDowell Welmon; Power Piping Co.	CORR	Loss of material; buildup of corrosion products

Document: No report # (May 1987), Plan for Integration of Aging and Life-Extension Activities
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactors	Pressure Vessel	Not applicable	Pressure vessel steels	Not stated	EMBR/IR	Loss of fracture toughness
2	Reactors	Pressure Vessel	Not applicable	Pressure vessel steels	Not stated	ELE-TEMP, EMBR/TE	Physical Degradation, Loss of fracture toughness
3	Reactors	Pressure Vessel	Not applicable	Pressure vessel steels	Not stated	FAT/TE, FAT/ PRESS	Initiation and growth of cracks
4	PWR	Containment	Post-tensioning-systems	Steel	Not stated	EMBR/HY	Loss of fracture toughness
5	PWR	Containment	Post-tensioning-systems	Steel	Not stated	CORR	Loss of material
6	PWR	Containment	Post-tensioning-systems	Steel	Not stated	RELAX	Loss of preload
7	PWR	Containment	Reinforced Concrete	Concrete; Steel	Not stated	ELE-TEMP; AGRCHEM AGCREAC; LEACH; FRZTHAW	Cracking and spalling of concrete; Corrosion and fatigue of steel
8	PWR	Containment	Metal Containment Liners	Steel	Not stated	CORR; FAT	Loss of material; Cumulative fatigue damage
9	Reactor Coolant System	Piping and Safe Ends	Welds	Ferritic Steel	Not stated	FAT	Cumulative fatigue damage
10	Reactor Coolant System	Piping and Safe Ends	Cast Components - Hot Leg	Cast Austenitic Stainless Steel	Not stated	EMBR/TE	Loss of fracture toughness
11	Reactor Coolant System	Piping and Safe Ends	Wrought Components	Wrought Austenitic Stainless Steel	Not stated	CORR/IGSCC; FAT	Crack initiation and growth, Cumulative fatigue damage
12	ESF and RPS	Cables	Not applicable	Not stated	Not stated	ELE-TEMP; ENVIR; IR/GAM	Physical degradation
13	ESF and RPS	Connectors	Not applicable	Not stated	Not stated	ELE-TEMP; ENVIR; IR/GAM; CORR	Physical degradation; corrosion product buildup
14	ESF and RPS	Penetrations	Not applicable	Not stated	Not stated	Not stated	Not stated

Document: Letter Report/ANL, Summaries of Research Reports Submitted in Connection with the Nuclear Plant Aging Research (NPAR) Program
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Reg Guides: NRC SRP 3.9.3, Draft RG SC 708-4; Generic Issues GL 84-13; ASME XI, PVP-45	ASME Sec XI ISTD & PS TS Req.	Re-assess existing requirements regarding visual examination. This may not be adequate [2]	4-82	50

Document: No report # (May 1987), Plan for Integration of Aging and Life-Extension Activities
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Propagation of flaws and cracks leading to loss of pressure retaining capability of the component.	Not stated	Yes, too numerous to list	10CFR App. G, RG 1.99 & ASME Sec XI-IWB	Extend the irradiation damage curve to higher fluences, improve the accuracy of fracture toughness data, demonstrate engineering feasibility of annealing, evaluate feasibility of replacement.. (More) [4]	A.2	1
Propagation of flaws and cracks leading to loss of pressure retaining capability of the component.	Not stated	Yes, too numerous to list	ASME Sec XI-IWB,10CFR App. G & RG 1.99	Extend the irradiation damage curve to higher fluences, improve the accuracy of fracture toughness data, demonstrate engineering feasibility of annealing, evaluate feasibility of replacement.. (More) [4]	A.4	2
Propagation of flaws and cracks leading to loss of pressure retaining capability of the component.	Not stated	Yes, too numerous to list	ASME Sec III & XI-IWB,10CFR App. G & RG 1.99	Extend the irradiation damage curve to higher fluences, improve the accuracy of fracture toughness data, demonstrate engineering feasibility of annealing, evaluate feasibility of replacement.. (More) [4]	A.4	3
Loss of tension in tendon wire.	Not stated	None	ASME Sec XI-IWL	Develop methods of monitoring [2]	A.15	4
Loss of tension in tendon wire.	Not stated	None	ASME Sec XI-IWL	Develop methods of monitoring [2]	A.15	5
Loss of tension in tendon wire.	Not stated	None	ASME Sec XI-IWE	Develop methods of monitoring [2]	A.15	6
Deterioration of concrete shielding properties; decrease in containment function capability.	Not stated	None	ASME Sec XI-IWE	Develop inspection program; investigate potential chemical and irradiation interactions [4-ORNL]	A.16	7
Increased leakage rates.	Not stated	None	ASME Sec XI-IWE	Evaluate research results related to concrete-liner interactions; specify requirements for visual inspection 4-ASME 1[1]	A.18	8
Not stated.	Not stated	None	ASME Sec III & Sec XI	Synthesize available data on fatigue design life; Expand ASME III to expand design analysis to cover fatigue for plant life extension [4-ANL]	A.25	9
Not stated.	Not stated	None	ASME Sec XI-IWB	Develop methods to determine damage due to thermal aging and synthesize information [4-ANL]	A.25	10
Not stated.	Not stated	None	ASME Sec XI-IWB	Define better UT for overlay clad [4]	A.26	11
Signal drift.	Not stated	None	10CFR 50.49 & PS, S&T Req.	Improve methods for detection and mitigation; determine degradation rates, failure rates, and residual life predictions [2]	A.31	12
Signal drift.	Not stated	None	10CFR 50.49 & PS, S&T Req.	Improve methods for detection and mitigation; determine degradation rates, failure rates, and residual life predictions [2]	A.31	13
Not stated.	Not stated	None	10CFR 50.49 & PS, S&T Req.	Not stated	A.32	14

Document: No report # (May 1987), Plan for Integration of Aging and Life-Extension Activities
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15	Emergency Diesel Generator	Governor and Controls	Not stated	Not stated	Not stated	VIBR, ENVIR, CORR	Loosening; Physical Degradation; Buildup of corrosion products
16	Emergency Diesel Generator	Fuel System	Not stated	Not stated	Not stated	VIBR; ENVIR	Loosening; Physical Degradation
17	Emergency Diesel Generator	Cooling System	Not stated	Not stated	Not stated	ENVIR	Physical Degradation
18	Emergency Diesel Generator	Starting System	Not stated	Not stated	Not stated	ENVIR; CORR	Physical Degradation; Buildup of corrosion products
19	Emergency Diesel Generator	Lube System	Not stated	Not stated	Not stated	VIBR; CORR	Loosening; Buildup of corrosion products
20	Emergency Diesel Generator	Intake and Exhaust System	Not stated	Not stated	Not stated	VIBR	Loosening
21	Emergency Diesel Generator	Engine Body	Not stated	Not stated	Not stated	VIBR; ELE-TEMP; CORR	Loosening; Physical degradation; Loss of material
22	Emergency Diesel Generator	Drivetrain	Not stated	Not stated	Not stated	VIBR	Loosening
23	Emergency Diesel Generator	Switchgear	Not stated	Not stated	Not stated	ENVIR	Physical Degradation
24	ESF, RPS, EDG, and AC and DC Electrical Systems	Switchgear and Relays	Circuit Breakers	Not stated	Not stated	WEAR	Attrition
25	ESF, RPS, EDG, and AC and DC Electrical Systems	Switchgear and Relays	Relays	Not stated	Not stated	DRIFT; CORR	Loss of instrument calibration; Buildup of corrosion products
26	ESF	Electric Motor-operated Valves	Valve seal and seat	Not stated	Not stated	WEAR; ERO/ CORR	Attrition; Loss of material
27	ESF	Electric Motor-operated Valves	Fasteners	Not stated	Not stated	VIBR	Loosening

Document: No report # (May 1987), Plan for Integration of Aging and Life-Extension Activities
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.40	15
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.40	16
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.41	17
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.41	18
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.41	19
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.41	20
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.42	21
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.42	22
Not stated.	Not stated	None	PS TS Req., RG 1.9,RG 1.108	Reexamine regulatory policy requiring frequent testing. Consider benefit of qualified diesel operator/technician having regulated authority over maintenance [4]	A.42	23
Failure of trip latch mechanism function.	Not stated	None	If Class 1E 10CFR50.49 otherwise PS S&T Req.	Determine if aging mechanism found in reactor trip breakers extends to other breakers. Complete operating experience assessment. [2]	A.51	24
Coil burnout in logic relays. Set point drift in protective and timing relays.	Not stated	None	PS S&T Req.	Establish/develop a cost effective methodology for detecting relay coil degradation and a preventive maintenance program [2]	A.52	25
Failure to seal completely.	Not stated	None	ASME Sec XI & GL 89-10 & Suppl.	Identify and evaluate monitoring methods. Review, evaluate and develop methods for operational readiness determinations. Develop criteria for acceptance. Reexamine maintenance needs and practices. (More) [4-EPRI-MOV]	A.57	26
Breakage of fasteners.	Not stated	None	ASME Sec XI & GL 89-10 & Suppl.	Identify and evaluate monitoring methods. Review, evaluate and develop methods for operational readiness determinations. Develop criteria for acceptance. Reexamine maintenance needs and practices. (More) [4-EPRI-MOV]	A.58	27

Document: No report # (May 1987), Plan for Integration of Aging and Life-Extension Activities
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
28	ESF	Electric Motor-operated Valves	Stem	Not stated	Not stated	DIST	Dimensional distortion of part
29	ESF	Electric Motor-operated Valves	Motor Operators	Not stated	Not stated	WEAR; CORR; DIST; VIBR	Attrition; Buildup of Corrosion Products; Dimensional distortion of part; Loosening
30	ESF	Electric Motor-operated Valves	Contacts	Not stated	Not stated	CORR	Buildup of corrosion products
31	ESF	Electro-hydraulic Valves	Not stated	Not stated	Not stated	Not stated	Not stated
32	ESF	Electro-pneumatic Valves	Not stated	Not stated	Not stated	Not stated	Not stated
33	ESF	Check Valves	Not stated	Not stated	Not stated	Not stated	Not stated
34	ESF	Explosively-actuated Valves	Not stated	Not stated	Not stated	Not stated	Not stated

Document: Nuclear Safety 31:484-489, Safety Implications of Diesel Generator Aging
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Emergency Diesel Generator	Instruments and control	Governor, control air subsystem, wiring and terminations, sensors	Not stated	Not stated	VIBR	Loosening
2	Emergency Diesel Generator	Fuel system	Engine piping, injector pumps, injectors and nozzles	Not stated	Not stated	VIBR	Loosening
3	Emergency Diesel Generator	Starting system	Air admittance valves, controls, starting motors	Not stated	Not stated	CORR/ CONTAM	Corrosion product buildup/loss of desired surface properties

Document: NUREG-1144, Nuclear Plant Aging Research (NPAR) Program Plan
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Multiple	Multiple	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: No report # (May 1987), Plan for Integration of Aging and Life-Extension Activities
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Increase in stroke time.	Not stated	None	ASME Sec XI & GL 89-10 & Suppl.	Identify and evaluate monitoring methods. Review, evaluate and develop methods for operational readiness determinations. Develop criteria for acceptance. Reexamine maintenance needs and practices. (More) [4-EPRI-MOV]	A.58	28
Decrease in transmitted torque. Increase in stroke time.	Not stated	None	ASME Sec XI & GL 89-10 & Suppl.	Identify and evaluate monitoring methods. Review, evaluate and develop methods for operational readiness determinations. Develop criteria for acceptance. Reexamine maintenance needs and practices. (More) [4-EPRI-MOV]	A.59	29
Increase in contact resistance.	Not stated	None	ASME Sec XI & GL 89-10 & Suppl.	Identify and evaluate monitoring methods. Review, evaluate and develop methods for operational readiness determinations. Develop criteria for acceptance. Reexamine maintenance needs and practices. (More) [4-EPRI-MOV]	A.59	30
Not stated.	Not stated	None	ASME Sec XI IWV	Not stated	A.63	31
Not stated.	Not stated	None	ASME Sec XI IWV	Not stated	A.63	32
Not stated.	Not stated	None	ASME Sec XI IWV	Not stated	A.63	33
Not stated.	Not stated	None	ASME Sec XI IWV	Not stated	A.63	34

Document: Nuclear Safety 31:484-489, Safety Implications of Diesel Generator Aging
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Vibration and vibration-induced loosening of subcomponents were the most frequent causes of all failures.	Frequent	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Relaxation of fast-starting and fast-loading test requirement [4]	485	1
Loosening of subcomponents by vibration has been observed to cause component failure.	Frequent	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Relaxation of fast-starting and fast-loading test requirement [4]	485	2
Corrosion product buildup and contamination of subcomponents can lead to failure-to-start problems.	Occasional	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Not stated	485, 486	3

Document: NUREG-1144, Nuclear Plant Aging Research (NPAR) Program Plan
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG-1144, Rev. 1, Nuclear Plant Aging Research (NPAR) Program Plan, Rev. 1
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Multiple	Multiple	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG-1144, Rev. 2, Nuclear Plant Aging Research: (NPAR) Program Plan, Status, and Accomplishments, Rev. 2
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Emergency Power	Emergency Diesel Generators	Subsystems: I/C, Lube Oil, Exhaust, Exciter and Voltage Regulator, Starting, Intake/Combustion, Cooling, Fuel Oil	Not stated	Not stated	VIBR	Loosening
2	Cooling and Power Systems	Motors	Stator Insulating System, Bearing Assemblies	Not stated	Not stated	FAT/THERM, ENVIR	Cumulative fatigue damage, physical/chemical degradation
3	Emergency Power	Battery Chargers and Inverters	Electrolytic Capacitors, Transformer, Semi Conductors, Cable Connectors, Wiring, Structural Fasteners	Not stated	Not stated	FAT/THERM	Cumulative Fatigue Damage
4	Emergency Power	Batteries	Grids, Top Conductor	Lead Alloy	Not stated	CORR	Physical Degradation

Document: NUREG/CP-0036, Proceedings of the Workshop on Nuclear Power Plant Aging
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR cooling system	Steam generator	Tubing (primary side)	Inconel 600	Westinghouse, Combustion Engineering	CORR/PWSCC	Crack initiation and growth
2	PWR cooling system	Steam generator	Tubing (primary side)	Inconel 600	Westinghouse, Combustion Engineering	CORR/IN	Crack initiation and growth
3	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	CORR/CREV	Loss of material; corrosion product buildup
4	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	CORR/SCC	Crack initiation and growth

Document: NUREG-1144, Rev. 1, Nuclear Plant Aging Research (NPAR) Program Plan, Rev. 1
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG-1144, Rev. 2, Nuclear Plant Aging Research: (NPAR) Program Plan, Status, and Accomplishments, Rev. 2
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The highest failure rate is 12% of the governor in the I/C system due to vibration, vibration loosening, thermal and physical shock. Fuel oil, starting and cooling also have a high failure rate. Fast start testing contributes to aging.	Frequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Replace fast start testing by engine health check; permit slower starts and longer run times; monitor and trend engine condition monitor; conduct major engine overhaul based on need rather than elapsed time. [4]	6.15	1
The stator insulating system and bearing assemblies of small motors (<200 lbs) failed most frequently (>70%). Heating cycles of winding in starting and overload conditions cause degradation of insulating material. (More)	Frequent	Not stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Perform tests for stator/rotor wind ings on windings temperature, vibration signa ture, current signature, voltage gradient, corone, insulation resist ance, power factor/loss factor, polarization index; (More) [2]	6.156.16	2
Overheating, electrical transfers, and personnel errors are the most documented stressors. Electrolytic capacitors are thermal sensitive. Failure of electrolytic capacitors in a short circuit mode result in direct loss of the equipment availability	Frequent	Not stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Improve the vital bus reliability by using an auto matic transfer switch; use of equipment for detecting and suppressing electrical bus disturbances; use of higher voltage and temperature related compo nents and forced air cooling [2]	6.20	3
The dominant aging problem is the thermal induced oxidation of the grids and top conductors. The swelling of the lead alloy material causes poor contact and decreased battery capacity. Brittle lead due to oxidation also leads to decreased ruggedness.	Not stated	Not stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Maintain and operate in accordance with IEEEE Standard 450, Reg. Guide 1.129, and manufacturer's recommendations [2]	6.21	4

Document: NUREG/CP-0036, Proceedings of the Workshop on Nuclear Power Plant Aging
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
PWSCC generally occurs at points of high residual stress or in-service deformation (denting). PWSCC commonly leads to tube leakage and creates the potential for tube failure.	Occasional	EPRI Steam Generator Owners Group	ASME Sec XI IWB & TS Req.	In-situ stress relief of tubes near tube-sheets; heat treat Inconel to reduce susceptibility in new plants. [4]	96	1
Intergranular attack can occur during layup, particularly in the presence of impurities such as oxygen and thiosulfates, and can lead to tube leakage and possible tube failure.	Rare	Not discussed in report	ASME Sec XI IWB & TS Req.	Control environment during layup to reduce oxygen and thiosulfates. [4]	98	2
Typically caused by the presence or formation of caustics, acid phosphates, chloride ions, or acid sulfates. Effects are same as above.	Occasional	NRC Draft Branch Tech Position 5-3;EPRI Steam Generator Owner's Grp.	ASME Sec XI IWB & TS Req.	Not stated.	98	3
Caused by formation of NaOH by hydrolysis reactions between phosphate water treatment and corrosion product oxides at tube sheet. Effects are same as above.	Not stated	NRC Draft Branch Tech Position 5-3;EPRI Steam Generator Owner's Grp.	ASME Sec XI IWB & TS Req.	Control water chemistry to eliminate free caustic buildup; heat treat tubing [4]	98-100	4

Document: NUREG/CP-0036, Proceedings of the Workshop on Nuclear Power Plant Aging
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	CORR/IN	Crack initiation and growth
6	PWR cooling system	Steam generator	Tubing (secondary side)			CORR/UA	Loss of material
7	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	CORR/PIT	Local loss of materia
8	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	WEAR/FRET	Attrition
9	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	WEAR	Attrition
10	PWR cooling system	Steam generator	Tubing (secondary side)	Inconel 600	Westinghouse, Combustion Engineering	WEAR	Attrition
11	PWR cooling system	Steam generator	Tube support plates	Carbon steel; ferritic stainless steel	Westinghouse, Combustion Engineering	WEAR/DENT	Constriction
12	PWR cooling system	Steam generator	Feedwater lines	Not stated	Westinghouse, Combustion Engineering	FAT/THERM	Cumulative fatigue damage
13	PWR cooling system	Condensers		Not stated	Not stated	CORR/UA	Loss of material
14	BWR cooling system	Coolant piping	Condenser tubes	Type 304 stainless steel	General Electric Co.	CORR/IGSCC	Crack initiation and growth
15	PWR pressure boundary	Pressure vessels, pumps, etc.	Bolts	Ferritic stainless steel	Not stated	CORR	Loss of material and crack initiation
16	PWR pressure boundary	Pressure vessels, pumps, etc.	Bolts	Ferritic stainless steel	Not stated	CORR/SCC	Crack initiation and growth
17	PWR pressure boundary	Pressure vessels, pumps, etc.	Bolts	Austenitic stainless steel	Not stated	CORR/TGSCC	Crack initiation and growth
18	Electrical and control systems	Electrical components	Electrical insulation	Various organic polymers	Not stated	EMBR/IR; EMBR/TH	Loss of fracture toughness

Document: NUREG/CP-0036, Proceedings of the Workshop on Nuclear Power Plant Aging
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Caused by the formation of a caustic environment at the tube sheet crevice. Effects are same as above	Occasional	NRC Draft Branch Tech Position 5-3;EPRI Steam Generator Owner's Grp.	ASME Sec XI IWB & TS Req.	Thermally treat tubing, sleeve affected area with more resistant material, eliminate crevice in design. [4]	100	5
Occurs in creviced areas because of the formation of acid phosphates. Effects are same as above.	Rare	NRC Draft Branch Tech Position 5-3;EPRI Steam Generator Owner's Group	ASME Sec XI IWB & TS Req.	Eliminate phosphate water treatment; control sodium/phosphate ratio. [4]	100	6
Produced by chloride and air or oxygen inleakage plus Cu ions, resulting in local corrosion cells. Pits can lead to tube leakage, though rupture is considered unlikely.	Not stated	NRC Draft Branch Tech Position 5-3;EPRI Steam Generator Owner's Grp.	ASME Sec XI IWB & TS Req.	Improve condenser performance to eliminate chlorides and oxygen in system [4]	101	7
Produced by rubbing of tubes against supports and anti-vibration bars because of flow-induced vibration. Can lead to tube leakage and possible failure	Occasional	Not discussed in report	ASME Sec XI IWB & TS Req.	Change material and design of anti-vibration bars. [4]	101	8
Observed near uppermost tube support plates in once-through SG, and is thought to be caused by the erosive action of corrosion product oxides carried in the high-velocity stream.	Not stated	Not discussed in report	ASME Sec XI IWB & TS Req.	Not stated.	101	9
Caused by foreign objects inadvertently left in steam generators, which vibrate against tubes and can cause leakage and possible failure.	Occasional	Not discussed in report	ASME Sec XI IWB & TS Req.	Avoid introduction of foreign objects [4]	101-103	10
Caused by buildup of oxides (primarily magnetite) in the gap between the tubes and the support plates, resulting in deformation, constriction, and possible tube failure.	Moderate	NRC Draft Branch Tech Position 5-3;EPRI Steam Generator Owner's Grp.	ASME Sec XI IWB & TS Req.	Oxygen control or deaeration in condenser, feed-water lines, and steam generator plus monitoring of condenser leakage. [4]	103-104	11
Thermal fatigue associated with introduction of ambient temperature water during startup and shutdown, possibly accelerated by environmental effects, can cause cracking at the I.D. of feedwater lines, leading to leakage.	Occasional	Not discussed in report	ASME Sec XI IWB & TS Req.	Proper mixing of auxiliary and main feedwater. [4]	104	12
Corrosion produced by chlorides in salt-water-cooled PWRs can lead to leakage in condenser tubes and service water system components, allowing ingress of chlorides into the secondary water system	Not stated	Not discussed in report	PS S&T Req.	Monitor condenser leakage, protect damaged tubes with Ti sleeves, plug and replace leaking tubes, use Ti tubes in new units. [4]	245-255	13
Sensitized austenitic stainless steel under residual or applied tensile stresses (typically near welds) is subject to IGSCC in contact with oxygenated cooling water, resulting in pipe cracking and leakage.	Moderate	Not discussed in report	ASME Sec XI IWC	Deaeration, hydrogen water chemistry, material replacement, and inspection [4]	107-120	14
The nature of the corrosive attack (general, intergranular, etc.) is not identified, but boric acid corrosion can lead to failure of bolting materials in service.	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	230	15
SCC of ferritic stainless steel bolting materials can be caused by the nonjudicious use of lubricants, resulting in failure in service	Not stated	Not discussed in report	ASME Sec XI	Not stated	230	16
Chloride contamination can produce TGSCC of austenitic stainless steel bolting materials, resulting in failure in service.	Not stated	Not discussed in report	ASME Sec XI	Not stated	230	17
Long-term exposure to irradiation at elevated temperatures can produce embrittlement and loss of strength in organic insulation; the extent of the effect varies with the material.	Not stated	IEEE Std. 323-1974; ASTM Std. D2953-71	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Not stated	121-130	18

Document: NUREG/CP-0036, Proceedings of the Workshop on Nuclear Power Plant Aging
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19	Electrical and control systems	Electrical components	Electrical insulation	Polyimide, polyester, silicone, polyvinyl, teflon	Not stated	EMBR/IR; EMBR/TH	Loss of fracture toughness
20	Electrical and control systems	Various control and switching devices	Misc. sub-component parts	Various	Various	ELE-TEMP; EMBR/IR; FAT; VIBR	Chemical and physical breakdown

Document: NUREG/CP-0100, Proceedings of the International Nuclear Power Plant Aging Symposium
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Concrete structures			Concrete (typically steel reinforced)	Not stated	AGRCHEM	Loss of integrity
2	Concrete structures			Concrete (typically steel reinforced)	Not stated	LEACH	Loss of integrity
3	Concrete structures			Concrete (typically steel reinforced)	Not stated	CORR	Loss of material
4	Concrete structures			Concrete (typically steel reinforced)	Not stated	FRZ/THAW	Loss of integrity
5	Pressure boundary	Pressure vessel and coolant piping		Austenitic stainless steels and ferritic steels	Not stated	FAT	Cumulative fatigue damage
6	Pressure boundary	Pressure vessel		SA533, Gr. B, Class 1 steel	Not stated	EMBR/TE	Loss of fracture toughness
7	Pressure boundary	Pressure vessel		Not stated	Not stated	EMBR/TE	Loss of fracture toughness
8	Cooling system	Feedwater lines		Typically carbon or low-alloy steel	Not stated	ERO/CORR	Wall thinning
9	Cooling system	Coolant pumps	Pump impellers and blades	13Cr-4Ni-Mo cast martensitic stainless steel	Not stated	EMBR	Loss of fracture toughness
10	Cooling system	Coolant pumps	Pump body	CF8, CF8M, and CF8A cast duplex SS	Byron-Jackson; Westinghouse; Bingham-Willamette; CE/Klein, Schanzlin, and Becker	EMBR/TE	Loss of fracture toughness
11	Cooling system	Coolant pumps	Pump body	CF8, CF8M, and CF8A cast duplex SS	Byron-Jackson; Westinghouse; Bingham-Willamette; CE/Klein, Schanzlin, and Becker	FAT; FAT/THERM	Cumulative fatigue damage

Document: NUREG/CP-0036, Proceedings of the Workshop on Nuclear Power Plant Aging
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Long-term exposure to irradiation at elevated temperatures is observed to dramatically decrease the life of teflon compared to thermal aging alone, but the life is significantly increased for the other materials tested.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Not stated	256-262	19
Various electrical control and switching devices were subjected to pre-conditioning (thermal aging, irradiation, and mechanical cycling) prior to seismic loading tests. The equipment showed little or no adverse effects from the preconditioning.	Not stated	IEEE Stds. 323-1974 & 344-1975, EPRI NP-2129, and NRC Reg. Guide 1.89, Rev. 1 (Feb. 1982)	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Not stated	155-164	20

Document: NUREG/CP-0100, Proceedings of the International Nuclear Power Plant Aging Symposium
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Acids, sulfates, and chlorides dissolved in groundwater react with and breakdown the cement phases in the concrete, resulting in loss of strength.	Not stated	Not discussed in report	ASME Sec XI IWL	Not stated	84-88	1
Water in contact with concrete with cracks or improper construction joints can leach out the Ca(OH)2 phase, resulting in disintegration.	Not stated	Not discussed in report	ASME Sec XI IWL	Not stated	84-88	2
Water, typically containing dissolved chlorides, seeps into cracks, reduces the pH, and causes corrosive attack of the embedded rebar, resulting in loss of strength.	Not stated	Not discussed in report	ASME Sec XI IWL	Repair of cracks [4]	84-88	3
Expansion associated with freezing of concrete while wet can cause spalling. Repeated freeze/thaw cycles can cause severe degradation.	Not stated	Not discussed in report	ASME Sec XI IWL	Not stated	84-88	4
Temperature and load cycles from operating transients, in combination with environmental effects, can cause crack initiation, growth, and component failure.	Not stated	Not discussed in report	ASME Sec XI IWB	Improved design rules under development. [4]	100-113	5
Specimens of A533, Gr. B, Cl. 1 steel are being subjected to accelerated thermal aging treatments to determine possible deleterious effects on fracture toughness and other mechanical properties.	Not stated	Not discussed in report	10CFR App. G & RG 1.99	Not stated	207-211	6
Long-term exposure to neutron irradiation causes a progressive decrease in fracture toughness of the RPV materials near the core, increasing their susceptibility to sub-sequent failure under severe transients.	Not stated	USNRC RG 1.99, Rev. 2 and 1.154; 10 CFR 50	10CFR App. G & RG 1.99	Multifaceted approach for managing embrittlement is described. [4]	338-341	7
Wall thinning through the combined effects of corrosion and the erosion of the resulting poorly adherent magnetite layer under high-velocity flow result in possible component failure.	Not stated	Chexal-Horowitz-Erosion-Corrosion (CHEC) computer code	ASME Sec XI	Change water chemistry; improve flow geometries of piping; use more resistant materials (e.g., higher Cr alloys) [4]	95-99	8
Extended service at LWR operating temperatures can lead to significant loss of fracture toughness, thereby increasing susceptibility to failure under impact loading.	Not stated	Not discussed in report	ASME Sec XI	Embrittlement can be reduced by proper heat treatment and chemistry [2]	89-94	9
Prolonged service at operating temperatures can produce microstructural changes in the ferrite phase of the duplex SSs that causes a progressive loss of fracture toughness.	Not stated	ASME Code Section XI	ASME Sec XI	Perform periodic volumetric and surface in-service inspection to characterize flaws. Second ref. describes three-phase monitoring program. [4-ANL]	212-219; 353-362	10
System operating transients and pump vibrations can cause cyclic loadings and possible growth of pre-existing flaws.	Not stated	ASME Code Section XI	ASME Sec III & XI	Perform periodic volumetric and surface in-service inspection to characterize flaws. [4]	212-219	11

Document: NUREG/CP-0100, Proceedings of the International Nuclear Power Plant Aging Symposium
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
12	Cooling system	Coolant pumps	Pump body	CF8, CF8M, and CF8A cast duplex SS	Byron-Jackson; Westinghouse; Bingham-Willamette; CE/Klein, Schanzlin, and Becker	CORR/SCC	Crack initiation and growth
13	Cooling system	Coolant pumps	Pump shaft	Cr-plated; underlying alloy not stated	Byron-Jackson; Westinghouse; Bingham-Willamette; CE/Klein, Schanzlin, and Becker	FAT; FAT/THERM	Cumulative fatigue damage
14	Cooling system	Coolant pumps	Closure studs	SA193, Gr. B7 or SA540, Gr. B23	Byron-Jackson; Westinghouse; Bingham-Willamette; CE/Klein, Schanzlin, and Becker	CORR/BA	Loss of material
15	Not stated	Not stated	Elastomers for seals, diaphragms, hoses, belts, valve seats	Natural or synthetic rubber or related polymers	Not stated	ENVIR	Loss of desired properties
16	Multiple	Multiple	Multiple	Various	Various	Various	Various

Document: NUREG/CP-0105, Proceedings of the U.S. Nuclear Regulatory Commission, 17th Water Reactor Safety Information Meeting
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Pressure boundary	Pressure vessel	Upper-shelf welds	High-copper weld material, LINDE-124	Combustion Engineering Inc.	EMBR/IR	Loss of fracture toughness
2	Pressure boundary	Pressure vessel	Upper head stainless-steel weld cladding	Austenitic stainless steels, Types: 308, 309,304	Combustion Engineering Inc.	EMBR/IR	Loss of fracture toughness
3	Cooling system	Coolant piping	Not stated	304 and 316 Stainless Steel	Not stated	CORR/ IGSCC	Crack initiation and growth
4	Pressure boundary	Pressure vessel	Not stated	SA533, Gr. B, Class 1 steel	Not stated	CORR/SCC	Crack initiation and growth
5	Pressure boundary	Recirculating cover plate	Not stated	CF-3, CF-8, and CF-8M, cast duplex SS	Georg Fischer Co., Switzerland; and Gundremmingen Reactor, Germany	EMBR	Loss of fracture toughness
6	Pressure boundary	Reactor internals	Core support plate, core shroud and top guide	Not stated	Not stated	CORR/SCC	Crack initiation and growth

Document: NUREG/CP-0100, Proceedings of the International Nuclear Power Plant Aging Symposium
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Very low levels of ferrite at repair and fabrication welds plus sensitization from welding procedure can leave these regions susceptible to crack initiation by SCC.	Not stated	ASME Code Section XI	ASME Sec XI	Perform periodic volumetric and surface in-service inspection to characterize flaws. [4]	212-219	12
Alternate bending stresses from asymmetric distribution of static pressure and cyclic thermal stresses from turbulent mixing of hot and cold reactor coolant can cause fatigue crack initiation and growth.	Not stated	ASME Code Section XI	ASME Sec III & XI	Perform periodic volumetric and surface in-service inspection to characterize flaws. Use monitors to detect vibrations caused by cracks in shaft. [4-EPRI]	212-219	13
Leakage of borated PWR primary coolant across pump casing-to-cover gasket can cause significant corrosion of closure studs, leading to possible breakage.	Not stated	Not discussed in report	ASME Sec XI or PS S&T Req.	Perform periodic visual and volumetric in-service inspection to detect corrosion. [4]	212-219	14
Elastomers break down during storage by breaking or crosslinking molecular bonds and evaporation, migration, or mutation of compound ingredients, causing loss of strength, ductility, and resilience.	Not stated	MIL-STD-1523A; MIL-HDBK-695C	PS S&T Req.	Shelf life may be greater than that given in MIL standards; more research is needed. [2]	118-124	15
Paper presents an overview of common aging processes for PWR pressure vessels, PWR reactor cooling system piping and nozzles, BWR Mark I containments, diesel generators, motor-operated valves, and cables, connections, and penetrations. No aging.					28-38	16

Document: NUREG/CP-0105, Proceedings of the U.S. Nuclear Regulatory Commission, 17th Water Reactor Safety Information Meeting
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Irradiation reduces fracture toughness, tearing modulus, and ductility of upper-shelf welds, thus increasing their susceptibility to crack initiation and growth.	Not stated	NRC-HSSI, ASME-185	10 CFR App. G	Not stated	31-39	1
Irradiation reduces fracture toughness and tearing modulus of the weld cladding. During an overcooling transient, this can lead to the growth of small surface flaws thus increasing the probability of pressure vessel failure.	Not stated	Not discussed in report	10 CFR App. G	Not stated	44-47	2
High concentration of ionic impurities, such as sulfates and chlorides, and oxidizing radiolysis products in BWR water together with high tensile stresses resulted in IGSCC of 304 and 316 pipes.	Not stated	EPRI-HWC	ASME Sec XI	Inject hydrogen into feedwater [4]	301-310	3
Susceptibility to SCC increases with increasing sulfur content and/or number of sulfide inclusions. A533B steel contains far fewer sulfide inclusions than other ferritic steels and is found to be less susceptible to SCC.	Not stated	Not discussed in report	10 CFR App. G	Control sulfur content [4]	310-311	4
Thermal aging decreases the fracture toughness and tearing modulus of cast stainless steels. Precipitation and/or growth of phase-boundary carbides or nitrides leads to brittle fracture and/or cleavage of ferrite phase due to particle cracking.	Not stated	ASTM E813-85, E1152	ASME Sec XI	Not stated.	332-342	5
Soluble corrosion products in reactor coolant systems undergo cathodic reduction, contributing to crack growth. At 289 C and 10 -6/s -1 strain rate, chromate (at 0.1 ppm level) is found to be more deleterious than nitrate, borate, carbonate, & chlorides.		Not discussed in report	ASME Sec XI & PS TS	Not stated	369-371	6

Document: NUREG/CP-0105, Proceedings of the U.S. Nuclear Regulatory Commission, 17th Water Reactor Safety Information Meeting
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	Cooling system	Piping	Not stated	Stainless steel, Type 304	Not stated	CORR/SCC	Crack initiation and growth
8	Power plant	Various	Various Class 1E cables		Not stated	ELE-TEMP	Chemical or physical degradation, thermal distortion
9	Cooling system	Steam Generator	Tubes	Inconel 600	Not stated	CORR/PWSCC	Crack initiation and growth
10	Not stated	Not stated	Circuit breakers and relays	Relays (protective, auxiliary, control, timing, electronic); breakers (molded-case and metal-clad)	Not stated	WEAR	Attrition
11	Auxiliary Feed Water System	Not stated	Pump drivers, valve operators, valves, pumps	Not stated	Not stated	WEAR	Loss of desired property or function, attrition
12	Compressed air system	Not stated	Compressors, valves, filters, dryers, pipes, silencers, moisture separators	Not stated	Not stated	WEAR	Loss of desired property or function. Attrition
13	Power operation and safety system	Inverters	Filter capacitors, thyristors, fuses	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation; thermal distortion

Document: NUREG/CR-2641, The In-Plant Reliability Data Base for Nuclear Power Plant Components: Data Collection and Methodology Report
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Safety-related	Safety-related	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-3154, The In Plant Reliability Data Base for Nuclear Plant Components: Interim Report - The Valve Component
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Nuclear power generating station	Valve	Seat	Not stated	Not stated	ERO/CORR, ERO/CAV	Loss of material

Document: NUREG/CP-0105, Proceedings of the U.S. Nuclear Regulatory Commission, 17th Water Reactor Safety Information Meeting
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Service-induced cracking of BWR reactor internal components were mainly attributed to SCC. BWR water environments contain ionic impurities and radiolysis products that can lead to SCC.	Not stated	Not discussed in report	ASME Sec XI or PS S&T Req.	Control hydrogen water chemistry [4]	372	7
After artificial aging at 100 C to a nominal lifetime of 60 years using an aging acceleration factor of ~80, many cables passed the loss of coolant accident steam exposure test indicating a good life extension potential for a number of cable prod.	Not stated	NRC/Long-Term Cable Aging Program	PS S&T Req.	Not stated	397	8
High-residual tensile stresses and low mill-annealing temp. contribute to PWSCC. Small increases in operating temp. can accelerate damage. Roll transitions, irregular transitions at U-bends, and dented tubes are susceptible sites for PWSCC.	Not stated	NRC/NPAR	ASME Sec XI IWB & PS S&T Req.	Eliminate high tensile stresses, reduce hot leg temperature. [4]	415-420	9
Aging, contact oxidation, and service-related wear of circuit breakers and relays can lead to loss of capacity and inadvertent actuation of safety related systems; and can cause significant damage to associated equipment, increase the chance of fires.	Not stated	NRC/NPAR	PS S&T Req.	Develop effective inspection, surveillance, and condition monitoring methods. [2]	434-435	10
Aging and service related degradation is responsible for a significant fraction of the AFW failures. The degradation of instrumentation and control devices, such as electrical contacts, relays, switches, circuits, etc. can result in component failure.	Not stated	NRC/NPAR	ASME Sec XI	Optimize surveillance and monitoring programs [4]	445-446	11
Aging-related degradation plays a significant role in compressed air system failures. In particular, wear, corrosion, fatigue, blocking/clogging, calibration setpoint drift are the dominant mechanisms for component failure.	Not stated	NRC/NPAR, 10CFR50.73	PS S&T Req.	Optimize preventive maintenance procedure. [4]	458-463	12
Overheating, electrical transients, and personnel errors are the leading causes of inverter failures. These failures can result in reactor trip, containment isolation, safety injection system actuation, and loss of feedwater.	Not stated	IEEE-650-1989	PS S&T Req.	Comprehensive inspection, testing and preventive/ corrective maintenance [2]	501-505	13

Document: NUREG/CR-2641, The In-Plant Reliability Data Base for Nuclear Power Plant Components: Data Collection and Methodology Report
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-3154, The In Plant Reliability Data Base for Nuclear Plant Components: Interim Report - The Valve Component
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Corrosion, erosion/cavitation (aggravated when valve is operated nearly closed) cause improper seating and fluid leakage past a "closed" valve.	Moderate	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	1

Document: NUREG/CR-3154, The In Plant Reliability Data Base for Nuclear Plant Components: Interim Report - The Valve Component
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2	Nuclear power generating station	Valve	Stem	Not stated	Not stated	WEAR	Attrition
3	Nuclear power generating station	Valve	Bonnet	Not stated	Not stated	WEAR	Attrition
4	Nuclear power generating station	Valve	Packing	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
5	Nuclear power generating station	Valve	Seals	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
6	Nuclear power generating station	Valve	Fasteners	Not stated	Not stated	FAT	Cumulative fatigue damage
7	Nuclear power generating station	Valve	Gate	Not stated	Not stated	FAT	Cumulative fatigue damage
8	Nuclear power generating station	Valve	Flange	Not stated	Not stated	CORR	Loss of material
9	Nuclear power generating station	Valve	Bushing	Not stated	Not stated	WEAR	Attrition
10	Nuclear power generating station	Valve	Linkages	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-3543, Survey of Operating Experience from LERs to Identify Aging Trends
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	All safety-related systems	Pipe	Pipe welds	Not stated	Not stated	FAT (Vibration-induced and thermal)	Cumulative fatigue damage
2	All safety-related systems	Pipe	Pipe welds	Not stated	Not stated	CORR/SCC	Crack initiation and growth
3	All safety-related systems	Pipe	Pipe threads and tube fittings	Not stated	Not stated	VIBR; FAT	Loosening; Cumulative fatigue damage
4	All safety-related systems	Pipe	Pipe walls	Not stated	Not stated	ERO/CORR	Wall thinning

Document: NUREG/CR-3154, The In Plant Reliability Data Base for Nuclear Plant Components: Interim Report - The Valve Component
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Worn stem can cause misalignment of stem travel, worn bushings, and faulty valve seating, leading to seat distortion and leaking.	Occasional	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	2
Not stated	Not stated	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	3
Elevated temperature distortion and chemical attack of packing can cause packing to deteriorate and loose sealing effectiveness, resulting in persistent fluid leakage.	Moderate	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	4
Elevated temperature distortion and chemical attack of seals can cause seals to deteriorate and loose sealing effectiveness, resulting in persistent fluid leakage.	Occasional	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	5
Fatigue resulting from vibration can cause loosening or breaking of fasteners, resulting in misalignment of parts and leakage.	Rare	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	6
Fatigue resulting from vibration can cause cracking or distortion of gate, leading to faulty seating and leakage or valve jamming.	Rare	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	7
Corrosion of flange faces can cause failure to seal and leakage.	Rare	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	8
Wear of bushing can cause improper stem travel and damage to seat, resulting in leakage.	Occasional	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	9
Wear can cause linkages to improperly control valve positioning, resulting in valve not being closed completely or jamming into the seat. Result is seat distortion and leakage.	Rare	ANSI FIRR Committee	ASME Sec XI IST & PS S&T Req.	Not stated	7-11, 39, 45	10

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Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Pipe welds are subject to loss of fatigue resistance, resulting in leakage.	Frequent	Not discussed in report	ASME Sec XI IWB, IWC or IWD	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	11,12,17, 18	1
Wall thinning due to corrosion or stress corrosion cracking can lead to pipe leakage.	Occasional	Not discussed in report	ASME Sec XI IWB, IWC or IWD	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	8,14	2
Subcomponents are subject to loosening and cracking, resulting in pipe leakage.	Moderate	Not discussed in report	ASME Sec XI IWB, IWC or IWD	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	11,12,13, 17,18	3
Pipe wall thinning resulting in pipe failure and tube crack or rupture, placing the steam generator in a degraded failure condition.	Occasional	Not discussed in report	ASME Sec XI IWB, IWC or IWD	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	8,9,17,18	4

Document: NUREG/CR-3543, Survey of Operating Experience from LERs to Identify Aging Trends
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5	All safety-related systems	Valve	Valve seats, housing, operators, and shafts	Not stated	Not stated	WEAR or CONTAM	Loss of material OR improper valve seating
6	All safety-related systems	Pump	Impellers, bearings, seals or packing	Not stated	Not stated	WEAR	Attrition
7	All safety-related systems	Pump	Strainers, housings, impellers	Not stated	Not stated	CONTAM	Blockage of flow passages
8	All safety-related systems	Heat exchangers	Coil	Not stated	Not stated	CONTAM	Coil blockage
9	Building atmosphere radiation monitors	Vane type air pumps	Not stated	Not stated	Not stated	WEAR caused by CONTAM	Attrition

Document: NUREG/CR-3818, Report of Results of Nuclear Power Plant Aging Workshops
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Pressure and temperature sensors		Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
2	Various	Pressure and temperature sensors		Not stated	Not stated	VIBR	Loosening
3	Various	Pressure and temperature sensors		Not stated	Not stated	WEAR	Attrition
4	Various	Electrical connectors		Not stated	Not stated	CONTAM	Buildup of deposits
5	Various	Electrical connectors		Not stated	Not stated	CORR	Corrosion product buildup
6	Various	Valve (solenoid)		Not stated	Not stated	CONTAM	Buildup of deposits
7	Various	Valve (solenoid)		Not stated	Not stated	WEAR	Attrition
8	Various	Valve operators		Not stated	Not stated	VIBR	Loosening
9	Various	Valve operators		Not stated	Not stated	ELE-TEMP	Chemical or physical degradation

Document: NUREG/CR-3543, Survey of Operating Experience from LERs to Identify Aging Trends
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Wear and foreign materials cause loss of material and improper seating, resulting in internal leakage and packing leakage.	Frequent	Not discussed in report	ASME Sec XI IST and GL 89-10 & suppl.	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	9,10,17,18	5
Wear of impellers, bearings, seals, or packing can lead to pump failures.	Frequent	Not discussed in report	ASME Sec XI IST	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	8,17,18	6
Blockage of passages, resulting in inadequate water flow.	Occasional	Not discussed in report	ASME Sec XI IST	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	10	7
Coil blockage due to silt and marine growth can lead to degraded heat exchanger performance.	Occasional	Not discussed in report	ASME Sec XI or PS S&T Req.	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	10	8
Wear caused by foreign material in the sampled air stream apparently can lead to air pump failure.	Frequent	Not discussed in report	PS S&T Req.	Most failure studies have concentrated on a generic component. Future work should include the environment for each component/ subcomponent,type of component, and material of construction. (More) [4]	10,18	9

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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Causes decalibration, set point drift, or failure of sensor.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Additional research and development [2]	10	1
Causes breakage of sensor.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Additional research and development [2]	10	2
Causes decalibration and set point drift.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Additional research and development [2]	10	3
Causes spurious response and open circuits, resulting from dirt and dust.	Not stated	Not discussed in report	PS S&T Req.	Additional research and development [2]	10	4
Causes spurious response and open circuits.	Not stated	Not discussed in report	PS S&T Req.	Additional research and development [2]	10	5
Contamination of fluids results in deposits on valve seats and failure to seat, resulting in leakage.	Not stated	Not discussed in report	ASME Sec XI-IWP	Additional research and development [2]	10	6
Wear of movable internals can cause hindered operation in the form of leakage or failure to open or close.	Not stated	Not discussed in report	ASME Sec XI-IWP	Additional research and development [2]	10	7
Loosening of fasteners can cause failure to operate or leakage.	Not stated	Not discussed in report	ASME Sec XI-IWV &GL 89-10 & Suppl.	Additional research and development [2]	11	8
Elevated temperatures can cause degradation of lubricants and packing, causing excessive torque.	Not stated	Not discussed in report	ASME Sec XI-IWV &GL 89-10 & Suppl.	Additional research and development [2]	11	9

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3	All BWR and PWR fluid-mechanical systems	Valves	Not stated	Not stated	Not stated	ERO	Wall thinning
4	All BWR and PWR fluid-mechanical systems	Valves	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
5	All BWR and PWR fluid-mechanical systems	Valves	Not stated	Not stated	Not stated	ELE-TEMP	Not stated
6	All BWR and PWR fluid-mechanical systems	Pumps	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material
7	All BWR and PWR fluid-mechanical systems	Pumps	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
8	All BWR and PWR fluid-mechanical systems	Pumps	Not stated	Not stated	Not stated	CORR	Loss of material
9	All BWR and PWR fluid-mechanical systems	Pumps	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
10	All BWR and PWR fluid-mechanical systems	Pumps	Not stated	Not stated	Not stated	ERO	Wall thinning

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Occasional	Not discussed in report	ASME Sec XI	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5	3
Vibrations may ultimately lead to component damage.	Occasional	Not discussed in report	ASME Sec XI	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5, 17	4
Not stated	Occasional	Not discussed in report	ASME Sec XI	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5	5
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI-IST	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5, 17	6
Vibrations may ultimately lead to component damage.	Frequent	Not discussed in report	ASME Sec XI-IST	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5, 17	7
Not stated	Moderate	Not discussed in report	ASME Sec XI-IST	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5	8
Not stated	Moderate	Not discussed in report	ASME Sec XI-IST	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5	9
Not stated	Occasional	Not discussed in report	ASME Sec XI-IST	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes [2]	5	10

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	All BWR and PWR fluid-mechanical systems	Pumps	Not stated	Not stated	Not stated	ELE-TEMP	Not stated
12	All BWR and PWR fluid-mechanical systems	Pipes	Not stated	Not stated	Not stated	CORR	Not stated
13	All BWR and PWR fluid-mechanical systems	Pipes	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material
14	All BWR and PWR fluid-mechanical systems	Pipes	Not stated	Not stated	Not stated	ERO	Wall thinning
15	All BWR and PWR fluid-mechanical systems	Pipes	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
16	All BWR and PWR fluid-mechanical systems	Pipes	Not stated	Not stated	Not stated	ELE-TEMP	Not stated
17	All BWR and PWR fluid-mechanical systems	Pipes	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
18	All BWR and PWR fluid-mechanical systems	All components (valves, pumps and pipes)	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5	11
Not stated	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [2]	5	12
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	5, 17	13
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	5	14
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	5	15
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	5	16
Vibrations may ultimately lead to component damage.	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	5, 17	17
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6, 17	18

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19	All BWR and PWR fluid-mechanical systems	All components (valves, pumps and pipes)	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
20	All BWR and PWR fluid-mechanical systems	All components (valves, pumps and pipes)	Not stated	Not stated	Not stated	CORR	Loss of material
21	All BWR and PWR fluid-mechanical systems	All components (valves, pumps and pipes)	Not stated	Not stated	Not stated	ERO	Wall thinning
22	All PWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
23	All PWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material
24	All PWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	CORR	Loss of material
25	All PWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	ERO	Wall thinning
26	All BWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Vibrations may ultimately lead to component damage.	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6, 17	19
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6	20
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6	21
Not stated	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6, 17	22
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6, 17	23
Not stated	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6	24
Not stated	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6	25
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6, 17	26

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
27	All BWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	CORR	Loss of material
28	All BWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	ERO	Wall thinning
29	All BWR fluid-mechanical systems	Valves, pumps and pipes	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
30	Residual heat removal systems for BWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
31	Residual heat removal systems for BWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material
32	Residual heat removal systems for BWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	CORR	Loss of material
33	Residual heat removal systems for BWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	ERO	Wall thinning
34	Safety injection system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6	27
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6	28
Vibrations may ultimately lead to component damage.	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	6, 17	29
Vibrations may ultimately lead to component damage.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11, 17	30
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11, 17	31
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11	32
Not stated	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11	33
Vibrations may ultimately lead to component damage.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11, 17	34

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
35	Safety injection system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material
36	Safety injection system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
37	Safety injection system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	ELE-TEMP	Not stated
38	Cooling water system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	CONTAM; ERO	Loss of desired surface properties; loss of material
39	Cooling water system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
40	Cooling water system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	ERO	Wall thinning
41	Cooling water system for PWRs	Valves, pumps and pipes	Not stated	Not stated	Not stated	CORR	Loss of material

Document: NUREG/CR-4144, Importance Ranking Based on Aging Considerations of Components Included in Probabilistic Risk Assessments
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Entire plant	Broad spectrum	This report does not provide specific detailed information on aging mechanisms for specific components.				

Document: NUREG/CR-3819, Survey of Aged Power Plant Facilities
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11, 17	35
Not stated	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11	36
Not stated	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11	37
The cumulative effects of corrosion due to FRMA buildup and erosion due to corrosion products can eventually lead to component failure.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11, 17	38
Vibrations may ultimately lead to component damage.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11, 17	39
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11	40
Not stated	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	The stressors that affect the component availability are due to system operation. Improve operating environments first and include such information as (a) vibration, (b) contamination, (c) corrosion, and (d) erosion to gain insight into root causes. [4]	7, 11	41

Document: NUREG/CR-4144, Importance Ranking Based on Aging Considerations of Components Included in Probabilistic Risk Assessments
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-4279, Aging and Service Wear of Hydraulic and Mechanical Snubbers Used on Safety-Related Piping and Components of Nuclear Powe
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Hydraulic Snubber	Control Valve	Not stated	Not stated	VIBR	Loosening
2	Various	Hydraulic Snubber	Reservoir	Not stated	Not stated	VIBR	Loosening
3	Various	Hydraulic Snubber	Reservoir	Not stated	Not stated	ELE-TEMP	Thermal Distortion
4	Various	Hydraulic Snubber	Cylinder	Not stated	Not stated	VIBR	Loosening
5	Various	Hydraulic Snubber	Cylinder	Not stated	Not stated	ELE-TEMP	Thermal Distortion
6	Various	Hydraulic Snubber	Seal	Polyurethane, Nitrile Rubber, Viton, Ethylene Propylene, Tefzel, and Metal O-rings	Not stated	ELE-TEMP	Thermal Distortion
7	Various	Hydraulic Snubber	Seal	Polyurethane, Nitrile Rubber, Viton, Ethylene Propylene, Tefzel, and Metal O-rings	Not stated	EMBR/IR	Loss of Fracture Toughness
8	Various	Hydraulic Snubber	Seal	Polyurethane, Nitrile Rubber, Viton, Ethylene Propylene, Tefzel, and Metal O-rings	Not stated	WEAR	Attrition
9	Various	Hydraulic Snubber	Hydraulic Fluid	Not stated	Not stated	CONTAM	Change in Viscosity
10	Various	Mechanical Snubber	Motion Sensor	Not stated	Not stated	VIBR	Loosening
11	Various	Mechanical Snubber	Motion Sensor	Not stated	Not stated	CORR/OX	Corrosion Product Buildup, Internal Damage
12	Various	Mechanical Snubber	Activation Rod	Not stated	Not stated	VIBR	Loosening
13	Various	Mechanical Snubber	Activation Rod	Not stated	Not stated	CORR/OX	Corrosion Product Buildup, Internal Damage
14	Various	Mechanical Snubber	Brake Mechanism	Not stated	Not stated	VIBR	Loosening
15	Various	Mechanical Snubber	Brake Mechanism	Not stated	Not stated	CORR/OX	Corrosion Product Buildup, Internal Damage

Document: NUREG/CR-4279, Aging and Service Wear of Hydraulic and Mechanical Snubbers Used on Safety-Related Piping and Components of Nuclear Power
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loosening of the Control Valve can cause the component to become inoperative.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 3.16, 5.5, 8.1	1
Loosening of the Reservoir can lead to loss of hydraulic fluid and cause the component to become inoperative.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 3.16, 5.5, 8.1	2
Thermal distortion of the Reservoir can lead to loss of hydraulic fluid and cause the component to become inoperative.	Rare	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	3
Loosening of the Cylinder can lead to loss of hydraulic fluid and cause the component to become inoperative.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	4
Thermal distortion of the Cylinder can lead to loss of hydraulic fluid and cause the component to become inoperative.	Rare	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	5
Thermal distortion of the Seal can lead to loss of hydraulic fluid and cause the component to become inoperative.	Occasional	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	6
Embrittlement of the Seal can lead to loss of hydraulic fluid and cause the component to become inoperative.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	7
Wear of the Seal can lead to loss of hydraulic fluid and cause the component to become inoperative.	Moderate	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	8
Viscosity change of the hydraulic fluid can cause the component to operate improperly.	Moderate	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.4, 5.5, 3.16, 8.1	9
Loosening of the Motion Sensor can lead to component failure and system lockup.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.6-2.8, 3.16, 8.1	10
Corrosion product buildup and internal damage of the Motion Sensor can lead to lockup.	Moderate	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.6-2.8, 3.16, 8.1	11
Loosening of the Activation Rod can lead to component failure and system lockup.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.6-2.8, 3.16, 8.1	12
Corrosion product buildup and internal damage of the Activation Rod can lead to lockup.	Moderate	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.6-2.8, 3.16, 8.1	13
Loosening of the Brake Mechanism can lead to component failure and system lockup.	Infrequent	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.6-2.8, 3.16, 8.1	14
Corrosion product buildup and internal damage of the Brake Mechanism can lead to lockup.	Moderate	ASME XI Std. ANSI/ASME OM4 Std.	ASME Sec XI OM Code ISTD	Determine if in-service testing can detect aging mechanisms. Perform periodic inspection, surveillance, and maintenance. [4-Maint rule]	2.6-2.8, 3.16, 8.1	15

Document: NUREG/CR-4302, Vol. 1, Aging and Service Wear of Check Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR and BWR safety systems	Swing check valve	Body assembly	Types 304 and 316 SS	Not stated	WEAR	Attrition
2	PWR and BWR safety systems	Swing check valve	Body assembly	Types 304 and 316 SS	Not stated	CORR	Loss of material
3	PWR and BWR safety systems	Swing check valve	Body assembly	Types 304 and 316 SS	Not stated	ERO	Wall thinning
4	PWR and BWR safety systems	Swing check valve	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	WEAR	Attrition
5	PWR and BWR safety systems	Swing check valve	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	CORR	Loss of material
6	PWR and BWR safety systems	Swing check valve	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	ERO	Loss of material
7	PWR and BWR safety systems	Swing check valve	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	FAT	Cumulative fatigue damage
8	PWR and BWR safety systems	Swing check valve	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	CONTAM	Loss of desired surface properties
9	PWR and BWR safety systems	Swing check valve	Seals	Welded seal, steel sealing ring, asbestos	Not stated	ELE-TEMP	Chemical degradation and thermal distortion
10	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Body assembly	Types 304 and 316 SS	Not stated	WEAR	Attrition
11	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Body assembly	Types 304 and 316 SS	Not stated	CORR	Loss of material
12	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Body assembly	Types 304 and 316 SS	Not stated	ERO	Wall thinning
13	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	WEAR	Attrition
14	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	CORR	Loss of material
15	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	ERO	Loss of material
16	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	FAT	Cumulative fatigue damage

Document: NUREG/CR-4302, Vol. 1, Aging and Service Wear of Check Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Causes obturator guide/holder to lose tolerance and obturator to fail to seat resulting in reverse leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Improve inspection techniques and surveillance at plants [2]	4, 5, 8, 9, 10, 14-18, 19, 21, 26, 37, 38	1
Causes wall thinning and through-wall external leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 26, 37, 38	2
Causes wall thinning and through-wall external leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 26, 37, 38	3
Causes hanger pin and bearing, obturator hanger, and obturator to lose tolerance resulting in valve failure to open or close or reverse leakage.	Frequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	4
Causes seat to lose tolerance and reverse leakage.	Moderate	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	5
Causes seat to lose tolerance and reverse leakage.	Moderate	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	6
Repetitive opening and closing of valve or vibration can cause breakage of obturator pin, arm, or obturator.	Moderate	Not discussed in report	ASME Sec XI IST and IWB & Sec III	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	7
Foreign material accumulation on seat or obturator surfaces can cause failure to seat and reverse leakage.	Moderate	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	8
Seal degradation can cause external leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	9
Causes obturator guide/holder to lose tolerance and obturator to fail to seat resulting in reverse leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 25, 37, 38, 49-52	10
Causes wall thinning and through wall external leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 25, 37, 38, 49-52	11
Causes wall thinning and through wall external leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 25, 37, 38, 49-52	12
Causes obturator to lose tolerance resulting in valve failure to open, close, or reverse leakage.	Frequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	13
Causes seat to lose tolerance and reverse leakage.	Moderate	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	14
Causes seat to lose tolerance and reverse leakage.	Moderate	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	15
Repetitive opening and closing of valve or fluid induced vibration can cause cracking of obturator or slot.	Moderate	Not discussed in report	ASME Sec XI IST and IWB & Sec III	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	16

Document: NUREG/CR-4302, Vol. 1, Aging and Service Wear of Check Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
17	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Internals	Stainless steel, Stellite and Hastelloy slots	Not stated	CONTAM	Loss of desired surface properties
18	PWR and BWR safety systems	Horizontal piston-lift, vertical-lift, and ball check valves	Seals	Welded seal, steel sealing ring, asbestos	Not stated	ELE-TEMP	Chemical degradation and thermal distortion

Document: NUREG/CR-4302, Vol. 2, Aging and Service Wear of Check Valves Used in Engineered Safety Feature Systems of Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Engineered safety-feature systems	Check valve (swing type)	Body assembly	Not stated	Not stated	WEAR	Attrition
2	Engineered safety-feature systems	Check valve (swing type)	Body assembly	Not stated	Not stated	FAT	Cumulative fatigue damage
3	Engineered safety-feature systems	Check valve (swing type)	Body assembly	Not stated	Not stated	ERO	Wall thinning
4	Engineered safety-feature systems	Check valve (swing type)	Body assembly	Not stated	Not stated	CORR	Loss of material
5	Engineered safety-feature systems	Check valve (swing type)	Hinge pin	Not stated	Not stated	WEAR	Attrition
6	Engineered safety-feature systems	Check valve (swing type)	Hinge pin	Not stated	Not stated	CORR	Corrosion product buildup
7	Engineered safety-feature systems	Check valve (swing type)	Hinge pin	Not stated	Not stated	FAT	Cumulative fatigue damage
8	Engineered safety-feature systems	Check valve (swing type)	Hinge arm	Not stated	Not stated	WEAR	Attrition
9	Engineered safety-feature systems	Check valve (swing type)	Hinge arm	Not stated	Not stated	FAT	Cumulative fatigue damage
10	Engineered safety-feature systems	Check valve (swing type)	Disc nut	Not stated	Not stated	VIBR	Loosening
11	Engineered safety-feature systems	Check valve (swing type)	Disc	Not stated	Not stated	WEAR	Attrition
12	Engineered safety-feature systems	Check valve (swing type)	Disc	Not stated	Not stated	ERO/ CORR	Wall thinning
13	Engineered safety-feature systems	Check valve (swing type)	Seat	Not stated	Not stated	WEAR	Attrition
14	Engineered safety-feature systems	Check valve (swing type)	Seat	Not stated	Not stated	ERO/ CORR	Wall thinning
15	Engineered safety-feature systems	Check valve (swing type)	Cap gasket	Not stated	Not stated	Not stated	Gasket deterioration

Document: NUREG/CR-4380, Evaluation of the Motor Operated Valve Analysis and Test System (MOVATS) to Detect Degradation, Incorrect Adjustments, and C
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Not stated	Motor operated valves	Gear	Not stated	Limitorque Corp.	WEAR	Attrition
2	Not stated	Motor operated valves	Stem	Not stated	Limitorque Corp.	Not stated	Change of dimension

Document: NUREG/CR-4302, Vol. 1, Aging and Service Wear of Check Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Foreign material accumulating on seat or obturator surfaces can cause failure to seat and reverse leakage.	Moderate	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	17
Seal degradation can cause external leakage.	Infrequent	Not discussed in report	ASME Sec XI IST and IWB	Not stated	4, 5, 8, 9, 10, 14-18, 19, 21, 49-52	18

Document: NUREG/CR-4302, Vol. 2, Aging and Service Wear of Check Valves Used in Engineered Safety Feature Systems of Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Movement of hinge pin in body mounting holes causes holes to enlarge, leading to improper tracking of valve hinge arm and potential impacting of swing valve with valve body, thereby weakening valve body.	Moderate	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	1
Repetitive swinging of arm and impacting of valve disc on body can cause cracking of body and external leakage.	Infrequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	2
Leakage past an improperly seated valve can cause erosion of valve body and wall thinning.	Moderate	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	3
Corrosion can lead to valve body leakage.	Infrequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	4
Flutter of valve causes wear of hinge pin, loss of hinge function, improper valve arm motion, and valve seating or sticking.	Frequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	2, 3, 4, 8	5
Corrosion of hinge pin causes resistance to motion of hinge arm and retarding of valve opening or closing.	Occasional	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	6
Rattling of hinge pin in enlarged valve body holes resulting from disc flutter can cause fatigue breakage of pin.	Occasional	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	2, 3, 8	7
Flutter of the arm caused by fluid/arm instabilities, prevalently occurring at low flows or caused by upstream flow disturbances, causes wear between arm and hinge pin, leading to impaired valve motion and flow control.	Frequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	2, 3, 8	8
Long term flutter of arm and cyclic loading or impacting of arm with other valve parts can cause arm breakage and complete loss of function.	Infrequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	2, 8	9
Flutter of hinge arm or impacting of arm can cause nut to loosen.	Occasional	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	10
Excessive wear of the hinge assembly can cause the disc to contact with other valve parts and wear, resulting in improper seating and leakage.	Infrequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	11
Erosion/corrosion can cause sealing surface irregularities and valve leakage.	Occasional	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	12
Disc/arm flutter instabilities can cause disc to rub or impact seat, producing seat wear and leakage.	Occasional	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	7, 8	13
Erosion/corrosion can cause sealing surface irregularities and valve leakage.	Frequent	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	14
Cap gasket deterioration can cause valve external leakage.	Not stated	Not stated	ASME Sec XI IWB or IST	Improve surveillance requirements and techniques [4]	8	15

Document: NUREG/CR-4380, Evaluation of the Motor Operated Valve Analysis and Test System (MOVATS) to Detect Degradation, Incorrect Adjustments, and Otl
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Wear and possible gear teeth breakage leads to failure of the valve to operate.	Occasional	Not discussed in report	ASME Sec XI & GL 89-10	Not stated	14, 32	1
Stem bent results in failure of the valve to complete its stroke because of premature torque switch grip.	Occasional	Not discussed in report	ASME Sec XI & GL 89-10	Not stated	14, 32	2

Document: NUREG/CR-4380, Evaluation of the Motor Operated Valve Analysis and Test System (MOVATS) to Detect Degradation, Incorrect Adjustments, and
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3	Not stated	Motor operated valves	Motor Pinion	Not stated	Limitorque Corp.	ADH	Loss of movement
4	Not stated	Motor operated valves	Stem	Not stated	Limitorque Corp.	WEAR	Attrition
5	Not stated	Motor operated valves	Stem/Spring	Not stated	Limitorque Corp.	ENVIR	Physical or chemical degradation
6	Not stated	Motor operated valves	Motor	Not stated	Limitorque Corp.	WEAR	Attrition

Document: NUREG/CR-4597, Vol. 1, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Rotor	400-series SS	Not stated	FAT	Cumulative fatigue damage
2	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Rotor	400-series SS	Not stated	WEAR	Attrition
3	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Shaft	Type 410, 414, or 416 SS	Not stated	FAT	Cumulative fatigue damage
4	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Shaft	Type 410, 414, or 416 SS	Not stated	WEAR	Attrition
5	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Impeller	Cast high-chromium alloy steels: 13-5, 15-5, and 17-4 PH	Not stated	FAT	Cumulative fatigue damage
6	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Impeller	Cast high-chromium alloy steels: 13-5, 15-5, and 17-4 PH	Not stated	WEAR	Attrition
7	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Impeller	Cast high-chromium alloy steels: 13-5, 15-5, and 17-4 PH	Not stated	ERO/CAV	Wall thinning: loss of material
8	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Thrust runner	Type 416, 420, or 420F SS	Not stated	FAT	Cumulative fatigue damage
9	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Thrust runner	Type 416, 420, or 420F SS	Not stated	WEAR	Attrition
10	Cooling system	Nonrotating internals	Stationary vanes (diffuser or volute)	Types 440A and 440B cast SS; 17-4 PH SS	Not stated	FAT	Cumulative fatigue damage

Document: NUREG/CR-4380, Evaluation of the Motor Operated Valve Analysis and Test System (MOVATS) to Detect Degradation, Incorrect Adjustments, and Otl
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Motor pinion binding can cause failure of the motor operator to operate because of motor burnout or actuation of the thermal overload switch.	Occasional	Not discussed in report	ASME Sec XI & GL 89-10	Not stated	14, 32	3
Stem wear in the form of worn threads or burrs can lead to failure to operate because of gear breakage or premature torque switch trip.	Occasional	Not discussed in report	ASME Sec XI & GL 89-10	Not stated	14, 32	4
Grease hardening results from extended exposure of the grease to elevated temperatures or radiation. The grease hardening between the motor and the worm gear can lead to a broken obturator or seat on a bent stem, resulting from the excess torque...	Occasional	Not discussed in report	ASME Sec XI & GL 89-10	Not stated	15, 32	5
Motor bearing wear and changes in the electrical resistance characteristics of either the conductor or insulation can lead to motor failure or actuation of the motor thermal overload switch.	Infrequent	Not discussed in report	ASME Sec XI & GL 89-10	Not stated	15, 32	6

Document: NUREG/CR-4597, Vol. 1, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Hydraulically induced transient loading and vibration of rotor at off normal conditions associated with low flow can cause component fatigue fracture and consequent reduced pump efficiency and possible seizure.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 14, 19, 29, 45, 64, 65	1
Wear of various rotor surfaces due to off-normal operation can cause progressive loss of efficiency.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	14, 19, 29, 45, 84	2
Hydraulic induced transient loading of shaft at far off-design flows can cause progressive loss of shaft integrity and possible pump seizure.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 50, 64, 65	3
Rubbing of shaft at wear surfaces due to hydraulic caused transient forces causes shaft play and possible seizure.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 50, 64, 65	4
Hydraulic induced transient loading of impeller at off-design power operation causes progressive loss of integrity.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 50, 64	5
Rubbing at wear surfaces results in loss of pump capacity to satisfy load requirements.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 50, 64	6
Insufficient NPSH and operating far from design point can cause wall thinning and structural failure of impeller.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 50	7
Hydraulic instabilities at low flow causes cyclic loading of component and cracking leading to failure of pump to operate.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	19, 47, 49, 50, 64	8
Transient loading of runners during startup and running at low flow causes excessive wear and reduced pump efficiency.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 47, 49, 50, 64	9
Hydraulic instabilities at low flow can cause excessive vane vibration, leading to vane breakage and pump stoppage.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 15, 34, 42, 64	10

Document: NUREG/CR-4597, Vol. 1, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	Cooling system	Nonrotating internals	Wear-surface	400-series SS	Not stated	WEAR	Attrition
12	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Fasteners	Cr-Mo steels	Not stated	FAT	Cumulative fatigue damage
13	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Pressure containment casing	Cast 416 SS (CA6NM)	Not stated	FAT	Cumulative fatigue damage
14	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Suction nozzle	Cast 416 SS (CA6NM)	Not stated	FAT	Cumulative fatigue damage
15	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Discharge nozzle	Cast 416 SS (CA6NM)	Not stated	FAT	Cumulative fatigue damage
16	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Bearing	Specialty steels	Not stated	FAT	Cumulative fatigue damage
17	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Bearing	Specialty steels	Not stated	CONTAM	Loss of lubricant properties and desired surface properties
18	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Shaft seal	Not stated	Not stated	WEAR	Attrition
19	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Thrust balancer	400-series SS	Not stated	WEAR	Attrition
20	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Thrust balancer	400-series SS	Not stated	FAT	Cumulative fatigue damage
21	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Coupling (gear type)	Not stated	Not stated	FAT	Cumulative fatigue damage
22	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Coupling (gear type)	Not stated	Not stated	WEAR	Attrition
23	Cooling system	Auxiliary feedwater multistage pumps (high-head centrifugal)	Fastener	400-series SS	Not stated	FAT	Cumulative fatigue damage

Document: NUREG/CR-4597, Vol. 1, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Excessive wear of the impeller wear surface rings is a result of excessive shaft flexibility and operation at hydraulically unstable conditions, resulting in reduced pump efficiency and capacity to deliver flow.	Frequent	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 41, 45, 50, 64, 87	11
Vibration can cause loosening or fatigue fracture of fasteners , resulting in loosening of parts and possible misalignment and pump seizure.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 20, 21, 45, 49, 64	12
Operation of pump at low flows produces hydraulic instabilities that cause large pressure oscillations and the potential for fatigue cracking of casing, resulting in leakage.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 20, 34, 47, 49, 50, 64	13
Operation of pump at low flows produces hydraulic instabilities that cause large pressure oscillations and the potential for fatigue cracking of casing, resulting in leakage.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 20, 34, 47, 49, 50, 64	14
Operation of pump at low flows produces hydraulic instabilities that cause large cyclic pressure fluctuations, possible fatigue cracking of discharge nozzles, failure of pump to operate at design flows, and leakage.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 20, 34, 47, 49, 50, 64	15
Operation of pump at low flows far from design point produces hydraulic instabilities, causing large cyclic bearing loads and possible bearing fracture and pump seizure.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 17, 29, 22, 34, 45, 64	16
Foreign material in lubricant and operation at excessive temperature can cause lubricant breakdown, resulting in bearing seizure and failure to operate.	Frequent	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 17, 19, 22, 29, 34, 45, 50, 64	17
Rotational rubbing between shaft and seal, often aggravated by inadequate injection water, causes wear and rapidly increasing leakage, decreasing pump delivered capacity.	Frequent	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 50, 83	18
Wear between close tolerance moving surfaces aggravated by unsteady thrust forces at part load causes loss of force balancing and reduced flow.	Moderate	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 45, 80, 81, 82, 83	19
Operation of pump at low flow and frequent startup cause wear surface wear and increased unbalance loads and vibrations, causing cracking of balancer and pump seizure.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 29, 50, 80-83	20
Frequent starting/stopping of pump produces large loads on gearing and fatigue cracking of gear, resulting in failure of pump to operate.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 47, 50, 64	21
Frequent starting and stopping of pump and poor lubrication causes gear wear and reduced pump efficiency.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	47, 50, 64, 65	22
Vibration can cause breakage of fasteners or loosening, resulting in leakage at a pressure containment boundary such as the casing.	Occasional	Not discussed in report	ASME Sec XI IST	Improve surveillance and monitoring of AUXFP. Improve the pump design to meet conditions [4]	9, 20, 21, 45, 49, 64, 65	23

Document: NUREG/CR-4597, Vol. 2, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Auxiliary feedwater system	High head centrifugal pumps	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-4652, Concrete Component Aging and Its Significance Relative to Life Extension of Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Concrete structures in LWR	Prestressed concrete containments	Tendon ducts and wires	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
2	Concrete structures in LWR	Prestressed concrete reactor vessels	Tendons and wires	Not stated	Not stated	CORR/SCC	Crack initiation and growth
3	Concrete structures in LWR	Biological shield walls and buildings	Various parts of walls and buildings	Not stated	Not stated	Not stated	Not stated

Document: NUREG/CR-4692, Operating Experience Review of Failures of Power Operated Relief Valves and Block Valves in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Power operated relief valves	Seat/plug interface	Not stated	Dresser, Garrett, Target Rock, Crosby	ERO	Wall thinning; loss of material
2	Various	Power operated relief valves	Packing	Not stated	Dresser, Garrett, Target Rock, Crosby	ELE-TEMP	Chemical or physical degradation
3	Various	Power operated relief valves	Moving parts	Not stated	Dresser, Garrett, Target Rock, Crosby	WEAR	Attrition
4	Various	Power operated relief valves	Controls	Not stated	Dresser, Garrett, Target Rock, Crosby	Not stated	Degradation
5	Various	Block valves	Packing	Not stated	Dresser, Garrett, Target Rock, Crosby	ELE-TEMP	Chemical or physical degradation
6	Various	Block valves	Torque and limit switches	Not stated	Dresser, Garrett, Target Rock, Crosby	Not stated	Not stated

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR primary pressure boundary	Reactor pressure vessel	Beltline region	Low alloy steels (SA302B, SA533B 1, SA508 2), Weld deposited SS clad (308, 309)	Combustion Engineering, B&W, Chicago Bridge and Iron, Rotterdam Dockyard Co.	EMBR/IR	Loss of fracture toughness

Document: NUREG/CR-4597, Vol. 2, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-4652, Concrete Component Aging and Its Significance Relative to Life Extension of Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The effects were so minor that component replacement was not required.	Not stated	Not discussed in report	ASME Sec XI IWL & RG 1.35	1. Existing facilities that have been shut down after an extended period of service should be used to obtain aging-related data for concrete materials.2. Accelerated aging techniques should be investigated... (More) [2]	33, 138, 139	1
Degraded tendons. However, the reactor vessel was capable of withstanding the operating pressures with the degraded tendons.	Not stated	Not discussed in report	ASME Sec XI IWL & RG 1.35	1. Existing facilities that have been shut down after an extended period of service should be used to obtain aging-related data for concrete materials.2. Accelerated aging techniques should be investigated... (More) [2]	35, 138, 139	2
Cracking of walls, which can be repaired with a procedure such as epoxy injection.	Not stated	Not discussed in report	ASME Sec XI IWL & RG 1.35	1. Existing facilities that have been shut down after an extended period of service should be used to obtain aging-related data for concrete materials.2. Accelerated aging techniques should be investigated... (More) [2]	36-37, 138, 139	3

Document: NUREG/CR-4692, Operating Experience Review of Failures of Power Operated Relief Valves and Block Valves in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High pressure steam/water impinging on surfaces causes material removal and leads to leakage.	Frequent	Not discussed in report	ASME Sec XI IST & PS S&T Req.	Improve design to withstand conditions [4]	1, 3, 24, 27, 67	1
Elevated temperature of packing causes degradation and leakage.	Occasional	Not discussed in report	ASME Sec XI IST & PS S&T Req.	Improve design to withstand conditions [4]	1, 3, 24, 27, 67	2
Wear of various moving parts causes failure of valves to seat or open as designed.	Occasional	Not discussed in report	ASME Sec XI IST & PS S&T Req.	Improve design to withstand conditions [4]	1, 3, 24, 27, 67	3
Degradation of the air or electrical actuation controls prevents valve operation.	Frequent	Not discussed in report	ASME Sec XI IST & PS S&T Req.	Improve design to withstand conditions [4]	1, 3, 24, 27, 67	4
Elevated temperature of packing causes degradation and leakage.	Occasional	Not discussed in report	ASME Sec XI IST & PS S&T Req.	Improve design to withstand conditions [4]	1, 3, 24, 27, 67	5
Causes valve to fail to close on demand.	Not stated	Not discussed in report	ASME Sec XI IST & PS S&T Req.	Improve design to withstand conditions [4]	1, 3, 24, 27, 67	6

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of toughness could lead to brittle fracture and failure of vessel especially under severe loads (pressurized thermal shock).	Frequent	USNRC Reg. Guide 1.99 Rev. 2ASME Sec. III Sect. GUSNCR Heavy Section Steel Program (HSST)EPRI (More)	10CFR App. G	Further study of embrittlement mechanisms and mitigation techniques (flux reduction, annealing, etc.) [4]	14-21 V1, 26-27 V1	1

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2	PWR primary pressure boundary	Reactor pressure vessel	Beltline region	Low alloy steels (SA302B, SA533B 1, SA508 2), Weld deposited SS clad (308, 309)	Combustion Engineering, B&W, Chicago Bridge and Iron, Rotterdam Dockyard Co.	FAT/ENV	Cumulative fatigue damage
3	PWR primary pressure boundary	Reactor pressure vessel	Beltline region	Low alloy steels (SA302B, SA533B 1, SA508 2), Weld deposited SS clad (308, 309)	Combustion Engineering, B&W, Chicago Bridge and Iron, Rotterdam Dockyard Co.	FAT/THERM	Cumulative fatigue damage
4	PWR primary pressure boundary	Reactor pressure vessel	Outlet/inlet nozzles	Low alloy steels	Combustion Engineering, B&W, Chicago Bridge and Iron, Rotterdam Dockyard Co.	FAT/ENV	Cumulative fatigue damage
5	PWR primary pressure boundary	Reactor pressure vessel	Outlet/inlet nozzles	Low alloy steels	Combustion Engineering, B&W, Chicago Bridge and Iron, Rotterdam Dockyard Co.	FAT/THERM	Cumulative fatigue damage
6	PWR primary pressure boundary	Reactor pressure vessel	In core instrumentation penetrations	Not identified	Not stated	FAT	Cumulative fatigue damage
7	PWR primary pressure boundary	Reactor pressure vessel	In core instrumentation penetrations	Not identified	Not stated	FAT/THERM	Cumulative fatigue damage
8	PWR primary pressure boundary	Reactor pressure vessel	Control rod drive housings	SS304 and CF-8 (W)	W, CE, B&W	FAT	Cumulative fatigue damage
9	PWR primary pressure boundary	Reactor pressure vessel	Control rod drive housings	SS304 and CF 8 (W)	W, CE, B&W	FAT/THERM	Cumulative fatigue damage
10	PWR primary pressure boundary	Reactor pressure vessel	Control rod drive housings	SS304 and CF 8 (W)	W, CE, B&W	EMBR/TE	Loss of fracture toughness
11	PWR primary pressure boundary	Reactor pressure vessel	Closure studs	Not identified	Not stated	FAT	Cumulative fatigue damage
12	PWR primary pressure boundary	Reactor coolant piping	Piping	SS304, CF8A, CF8M, A516 Gr 70, A106 Gr C, SS308L, 304L clad	W, CE, B&W	FAT	Cumulative fatigue damage
13	PWR primary pressure boundary	Reactor coolant piping	Piping	CF8A, CF8M	W	EMBR/TE	Loss of fracture toughness
14	PWR primary pressure boundary	Reactor coolant piping	Piping nozzles	Not identified	W, CE, B&W	FAT	Cumulative fatigue damage
15	PWR primary pressure boundary	Reactor coolant piping	Fittings	CF8A, A516 Gr 70, SS308L, 309L clad	Not stated	FAT	Cumulative fatigue damage
16	PWR primary pressure boundary	Reactor coolant piping	Dissimilar metal welds	Low alloy steels (SA302B, SA533B 1, SA50822), SS304, CF8A, CF8M, Alloy 600	W, CE, B&W	FAT	Cumulative fatigue damage
17	PWR primary pressure boundary	Pressurizer	Vessel	Low alloy steel (e.g., A516 Gr 70, A 533B 1, A533A 1) with 308, 308L 309 SS or Ni Cr Fe cladding	Not stated	FAT	Cumulative fatigue damage
18	PWR primary pressure boundary	Pressurizer	Vessel	Low alloy steel (e.g., A516 Gr 70, A 533B 1, A533A 1) with 308, 308L 309 SS or Ni Cr Fe cladding	Not stated	FAT/ THERM	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Crack initiation & propagation could result in leakage; possibility of brittle fracture failure.	Moderate	ASME Secs III & XIInternational Cyclic Crack Growth Group	10CFR App. G & ASME Sec III	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	2
Crack initiation & propagation could result in leakage; possibility of brittle fracture failure.	Moderate	ASME Secs III & XI	10CFR App. G & ASME Sec III	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	3
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XIInternational Cyclic Crack Growth Group	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	4
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	5
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	6
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to iprove predictions [4]	21-24 V1	7
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	8
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	21-24 V1	9
Increases susceptibility to leakage.	Moderate	EPRI, WOG, USNRC research programs	ASME Sec XI IWB	Judged not important V1. Judged potentially important V2 [2]	13, 17 V1, 108, 130, 131 V2	10
Crack initiation & propagation could result in stud failure and subsequent leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Should be replaced for life extension [3]	13, 16, 25, 26 V1	11
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Need in depth study of past operation to assess fraction of design life used [4]	55, 60-63, 64 V2	12
Increases susceptibility to leakage. Concludes brittle fracture not possible.	Moderate	USNRC research program	ASME Sec XI IWB	Need to monitor actual thermal embrittlement in plants [4]	60-64 V2	13
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Identified as highest fatigue usage in piping. Need in-depth study of past operation to assess fraction of design life used [4]	61, 63, 64 V2	14
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Need in-depth study of past operation to assess fraction of design life used [4]	59, 63, 64 V2	15
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Identified as important site for fatigue in primary piping system of Westinghouse PWRs [4]	55, 64 V2	16
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XIMIT ResearchPressure Vessel Research Committee	ASME Sec III & Sec XI IWB	Reanalyze fatigue life with better models of thermal history associated with transientsImplement transient logging programs [4]	19 24, 30, 32 35, 37, 40 42 V2	17
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XIMIT Research	ASME Sec III & Sec XI IWB	Reanalyze fatigue life with better models of thermal history associated with transients [4]	34,35, 40 42 V2	18

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19	PWR primary pressure boundary	Pressurizer	Vessel	Low alloy steel (e.g., A516 Gr 70, A 533B 1, A533A 1) with 308, 308L 309 SS or Ni Cr Fe cladding	Not stated	FAT/ ENV	Cumulative fatigue damage
20	PWR primary pressure boundary	Pressurizer	Spray and surge nozzles	Carbon or low alloy steel forgings, SS clad	Not stated	FAT/ THERM	Cumulative fatigue damage
21	PWR primary pressure boundary	Pressurizer	Spray and surge nozzles	Carbon or low alloy steel forgings, SS clad	Not stated	FAT/ ENV	Cumulative fatigue damage
22	PWR primary pressure boundary	Pressurizer	Spray and surge nozzles	Carbon or low alloy steel forgings, SS clad	Not stated	FAT/ FIV	Cumulative fatigue damage
23	PWR primary pressure boundary	Pressurizer	Spray and surge nozzle thermal sleeves	Alloy 600 (CE)Not identified Westinghouse and B&W	Not stated	FAT/ THERM	Cumulative fatigue damage
24	PWR primary pressure boundary	Pressurizer	Spray and surge nozzle thermal sleeves	Alloy 600 (CE)Not identified Westinghouse and B&W	Not stated	FAT/ FIV	Cumulative fatigue damage
25	PWR primary pressure boundary	Pressurizer	Spray and surge lines	SS316, CF3M	Not stated	FAT/ THERM	Cumulative fatigue damage
26	PWR primary pressure boundary	Pressurizer	Spray and surge lines	SS316, CF3M	Not stated	EMBR/ TE	Loss of fracture toughness
27	PWR primary pressure boundary	Pressurizer	Spray line head	SS304, Alloy 600, Cast SS	Not stated	FAT/ THERM	Cumulative fatigue damage
28	PWR primary pressure boundary	Pressurizer	Spray line head	SS304, Alloy 600, Cast SS	Not stated	EMBR/ TE	Loss of fracture toughness
29	PWR primary pressure boundary	Pressurizer	Spray line head	SS304, Alloy 600, Cast SS	Not stated	ERO	Loss of material
30	PWR primary pressure boundary	Pressurizer	Heater sheaths and sleeves	SS304, SS316, Alloy 600	Not stated	WEAR	Attrition
31	PWR primary pressure boundary	Pressurizer	Heater sheaths and sleeves	SS304, SS316, Alloy 600	Not stated	CORR/ SCC	Crack initiation and growth
32	PWR primary pressure boundary	Pressurizer	Heater elements	Not identified	Not stated	CORR	Loss of material
33	PWR primary pressure boundary	Pressurizer	Manway cover bolts	Low alloy steel bolts A540 B24, A193 B7. A320 L43	Not stated	CORR/ SCC	Crack initiation and growth
34	PWR primary pressure boundary	Pressurizer	Supports (keys, skirts, lugs)	Not identified	Not stated	FAT	Cumulative fatigue damage
35	PWR primary pressure boundary	Pressurizer	Supports (keys, skirts, lugs)	Not identified	Not stated	FAT/ THERM	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Crack initiation & propagation could result in leakage.	Frequent	International Cyclic Crack Growth Group	ASME Sec III & Sec XI IWB	Need to consider environment for both initiation & growth [4]	35, 41 V2	19
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XIMIT Research	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Reanalyze fatigue life with better models of thermal history associated with transientsImplement transient logging programs [4]	34,35, 40 42 V2	20
Horizontal configuration of piping and low flow rates promote thermal stratification leading to high thermal loads.	Frequent	International Cyclic Crack Growth Group	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Need to consider environment for both initiation & growth [4]	35, 41 V2	21
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III, Sec XI IWB & Assoc. NRC GC	None	52, 55, 60 V2	22
Failure of sleeves could permit flow to directly impinge on nozzles and lead to higher fatigue loadings on nozzles. No loose part problem (pg V2). Potential to break loose (pg 57 V2).	Frequent	ASME Secs III & XIMIT Research	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Reanalyze fatigue life with better models of thermal history associated with transients [4]	34,35, 40 42 V2	23
Failure of sleeves could permit flow to directly impinge on nozzles and lead to higher fatigue loadings on nozzles. No loose part problem (pg V2). Potential to break loose (pg 57 V2).	Frequent	Not discussed in report	ASME Sec III, Sec XI IWB & Assoc. NRC GC	None	52, 55, 60 V2	24
Horizontal configuration of piping and low flow rates promote thermal stratification leading to high thermal loads. Crack initiation & propagation could result in leakage. Leak before break more difficult to demonstrate for these relatively small diame	Frequent	ASME Secs III & XI	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Analyze horizontal portions to determine whether leak before break is expected. Include base metal in inspections. Modify plant operating procedures to mimimize stratification. Develop acoustic emission monitoring for cracking. [4]	34,35, 40 42, 49 60 V2	25
Horizontal configuration of piping and low flow rates promote thermal stratification leading to high thermal loads. Leak before break more difficult to demonstrate for these relatively small diameter lines.	Frequent	Not discussed in report	ASME Sec XI IWB	None	57 V2	26
Change in spray pattern reduces effectiveness in controlling pressure surges and makes plant pressure control more difficult.	Frequent	ASME Secs III & XIMIT Research	ASME Sec III & Sec XI IWB	Reanalyze fatigue life with better models of thermal history associated with transients [4]	34,35, 40 42 V2	27
Not described.	Frequent	USNRC, EPRI, and WOG research programs	ASME Sec XI IWB	High temperature may make more susceptible than most [4]	37, 38, 41, 42 V2	28
Change in spray pattern could result in higher vessel stresses.	Infrequent	Not discussed in report	ASME Sec XI IWB	High probability spray head will have to be replaced [4]	37, 41, 42 V2	29
Crack initiation & propagation could result in unisolatable leakage.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	30, 32, 33, 37, 38, 40, 42 V2	30
Crack initiation & propagation could result in unisolatable leakage.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	33, 36, 38, 40 42 V2	31
Heaters have rated lifetimes of 5,000 cycles. Burnout is expected and replacement part of normal maintenance.	Frequent	Not discussed in report	ASME Sec XI IWB	None	37, 42 V2	32
Bolt failure would lead to leakage of primary cooolant. Could lead to boric acid corrosion of low alloy steel vessel.	Frequent	Not discussed in report	ASME Sec XI IWB	Plants need monitoring procedures to detect boric acid leakage [4]	30, 36, 37, 38, 40 42 V2	33
Cracking could lead to loss of support and overstress of piping.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	42 V2	34
Cracking could lead to loss of support and overstress of piping.	Frequent	ASME Secs III & XI	ASME Sec XI IWB	None	42 V2	35

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
36	PWR primary pressure boundary	Chemical and volume control system	Charging nozzle	Low alloy steel forging (CE, B&W), SS (W)	W, CE, B&W	FAT/ THERM	Cumulative fatigue damage
37	PWR primary pressure boundary	Chemical and volume control system	Charging nozzle	Low alloy steel forging (CE, B&W), SS (W)	W, CE, B&W	FAT/ FIV	Cumulative fatigue damage
38	PWR primary pressure boundary	Chemical and volume control system	Charging nozzle thermal sleeve	Alloy 600 (CE)	W, CE, B&W	FAT/ THERM	Cumulative fatigue damage
39	PWR primary pressure boundary	Chemical and volume control system	Charging nozzle thermal sleeve	Alloy 600 (CE)	W, CE, B&W	FAT/ FIV	Cumulative fatigue damage
40	PWR primary pressure boundary	Safety Injection System	Safety injection nozzle	Low alloy steel forging (CE, B&W), SS (W)	W, CE, B&W	FAT/THERM	Cumulative fatigue damage
41	PWR primary pressure boundary	Safety Injection System	Safety injection nozzle	Low alloy steel forging (CE, B&W), SS (W)	W, CE, B&W	FAT/FIV	Cumulative fatigue damage
42	PWR primary pressure boundary	Safety Injection System	Safety injection nozzle thermal sleeve	Alloy 600 (CE)	W, CE, B&W	FAT/THERM	Cumulative fatigue damage
43	PWR primary pressure boundary	Safety Injection System	Safety injection nozzle thermal sleeve	Alloy 600 (CE)	W, CE, B&W	FAT/FIV	Cumulative fatigue damage
44	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	CORR/SCC	Crack initiation and growth
45	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	CORR/IN	Crack initiation and growth
46	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	CORR/PIT	Local loss of materia
47	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	CORR/UA	Loss of material
48	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	CORR/OX	Corrosion product buildup
49	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	WEAR/FRET	Attrition

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Horizontal portions of charging line subject to stratified flows should be checked to verify leak before break behavior. Base metal should be inspected. Acoustic emission monitoring should be considered. On line monitoring of transients. [4]	64 71 V2	36
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	65, 67, 71 V2	37
Failure of sleeves could permit flow to directly impinge on nozzles and lead to higher fatigue loadings on nozzles. Potential to break loose.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	64 71 V2	38
Failure of sleeves could permit flow to directly impinge on nozzles and lead to higher fatigue loadings on nozzles. Potential to break loose.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	65, 67, 71 V2	39
Crack initiation & propagation could result in leakage. Local stratified flow may develop in horizontal portion of line because there is normally no flow leading to high thermal loads.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Horizontal portions of injection line subject to stratified flows should be checked to verify leak before break behavior. Base metal should be inspected. Acoustic emission monitoring should be considered. On-line monitoring of transients. [4]	67-71 V2	40
Crack initiation & propagation could result in leakage.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	68, 71 V2	41
Failure of sleeves could permit flow to directly impinge on nozzles and lead to higher fatigue loadings on nozzles. Potential to break loose.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	67-71 V2	42
Failure of sleeves could permit flow to directly impinge on nozzles and lead to higher fatigue loadings on nozzles. Potential to break loose.	Frequent	ASME Secs III & XI	ASME Sec III & Sec XI IWB	None	68, 71 V2	43
Crack initiation & propagation in tubesheet crevice region and tube support annuli.	Frequent	Vendor, EPRI, and European work on mitigation techniques; repair techniques; replacement	ASME Sec XI IWB & PS TS Req.	Highest priority given to preventing faulted water chemistries. Follow EPRI Secondary Water Chemistry Guidelines. Use boric acid and morpholine. Use Alloy 690. [4]	69, 72, 73, 76 V1; 145, 146, 149, 151 160, 163-165 V2	44
Crack initiation & propagation in tubesheet crevice region and tube support annuli.	Frequent	Vendor, EPRI, and European work on mitigation techniques; repair techniques; replacement	ASME Sec XI IWB & PS TS Req.	Highest priority given to preventing faulted water chemistries. Follow EPRI Secondary Water Chemistry Guidelines. Use boric acid and morpholine. Use Alloy 690. [4]	69, 72, 73, 76 V1; 145, 146, 149, 151 160, 163-165 V2	45
Local attack and tube thinning may eventually lead to leakage.	Frequent	Vendor, EPRI, and European work on mitigation techniques	ASME Sec XI IWB & PS TS Req.	Highest priority given to preventing faulted water chemistries. Eliminate copper alloys from feedwater system. [4]	69, 71, 75, 76 V1; 145, 146, 149, 151, 163, 164 V2	46
Wastage. Thinning of wall may eventually lead to rupture of tube.	Frequent	Vendor, EPRI, and European work on mitigation techniques	ASME Sec XI IWB & PS TS Req.	None	69, 70, 75, 76 V1; 145, 146, 155, 164 V2	47
Denting. Corrosion product buildup can cause excessive deformation of tubing and lead to cracking or blockage.	Frequent	Vendor and EPRI mitigation techniques	ASME Sec XI IWB & PS TS Req.	Control secondary water chemistry. Use ferritic SS support plates and designs which minimize crevices. No longer an important cause of tube failure. [4]	69, 70, 75, 76 V1; 145, 146, 149, 151 153, 162, 163, 164 V2	48
Thinning of wall may eventually lead to rupture of tube.	Moderate	Vendor mitigation techniques	ASME Sec XI IWB & PS TS Req.	Redesign antivibration bars to provide larger contact area. [4]	69, 73, 76 V1; 145, 147, 149 V2	49

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
50	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	FAT/FIV	Crack initiation and growth
51	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	FAT/THERM	Crack initiation and growth
52	PWR primary pressure boundary	Recirculating steam generators	Tubing	Alloy 600, 690	W, CE	CORR/PWSCC	Crack initiation and growth
53	PWR primary pressure boundary	Once-through steam generators	Tubing	Alloy 600	B&W	ERO/CORR	Wall thinning
54	PWR primary pressure boundary	Once-through steam generators	Tubing	Alloy 600	B&W	FAT/ENV	Cumulative fatigue damage
55	PWR reactor feedwater system	Feedwater piping	Piping	Carbon steel (A106-B, A-155, KC-65)	W, CE, B&W	ERO/CORR	Wall thinning; loss of material
56	PWR reactor feedwater system	Feedwater piping	Piping	Carbon steel (A106-B, A-155, KC-65)	W, CE, B&W	ERO/CAV	Wall thinning; loss of material
57	PWR reactor feedwater system	Feedwater piping	Piping	Carbon steel (A106-B, A-155, KC-65)	W, CE, B&W	FAT/THERM	Cumulative fatigue damage
58	PWR reactor feedwater system	Feedwater piping	Piping	Carbon steel (A106-B, A-155, KC-65)	W, CE, B&W	FAT	Cumulative fatigue damage
59	PWR reactor feedwater system	Feedwater piping	Piping	Carbon steel (A106-B, A-155, KC-65)	W, CE, B&W	WAT HAM	Cumulative fatigue damage
60	PWR reactor feedwater system	Feedwater piping	Elbows	Carbon steel (A234-WPB)	W, CE, B&W	ERO/CORR	Wall thinning; loss of material
61	PWR reactor feedwater system	Feedwater piping	Elbows	Carbon steel (A234-WPB)	W, CE, B&W	ERO/CAV	Wall thinning; loss of material
62	PWR reactor feedwater system	Feedwater piping	Elbows	Carbon steel (A234-WPB)	W, CE, B&W	FAT/THERM	Cumulative fatigue damage
63	PWR reactor feedwater system	Feedwater piping	Elbows	Carbon steel (A234-WPB)	W, CE, B&W	FAT	Cumulative fatigue damage
64	PWR reactor feedwater system	Feedwater piping	Elbows	Carbon steel (A234-WPB)	W, CE, B&W	WAT HAM	Cumulative fatigue damage
65	PWR reactor feedwater system	Feedwater piping	Nozzles	Not identified	W, CE, B&W	FAT/THERM	Cumulative fatigue damage
66	PWR reactor feedwater system	Feedwater piping	Thermal sleeves	Not identified	W, CE, B&W	FAT/THERM	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage or tube rupture.	Moderate	Vendor mitigation techniques	ASME Sec XI IWB & PS TS Req.	Reduce local fluid forces with flow resistance plates. [4]	145, 147, 150 V2	50
Can produce cracking or leakage especially in tubes with denting.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	145, 150 V2	51
Cracking and leakage in high stress areas such as U bends, rolled tubesheet joints, and dented regions.	Frequent	Vendor, EPRI, and European work on mitigation techniques; repair techniques	ASME Sec XI IWB & PS TS Req.	Use Alloy 690. Shot and rotopeening to induce favorable residual stresses. Consider nickel plating as repair technique. [4]	69, 72, 75, 76 V1; 147, 149, 154, 160, 162, 164, 165 V2	52
Fairly uniform wall thinning which could lead to leakage or rupture.	Frequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	73, 76, 77 V1; 148, 150, 164 V2	53
In upper portion of generator in free lane water droplets impinge and dry out. Chemical buildup combined with thermal cycling or vibration can cause cracking.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need to control chemistry and modify to preclude dryout [4]	73, 76, 77 V1; 148, 150, 164 V2	54
Leads to localized wall thinning especially near flow discontinuities or anywhere where high turbulence occurs (fittings, tees, elbows). If thinning is severe, even modest pressure pulse can produce rupture.	Frequent	EPRI, British, and French programs	ASME Sec XI IWC	Water chemistry changes to mitigate erosion corrosion can have other deleterious effects. Inside surfaces need to be kept as smooth as possible. Consider use of SS coatings. [4]	77, 82-86, 89-93, 97-103 V2	55
Feedwater system oeprates near saturation. Cavitiation can produce sever local damage in regions with velocity changes.	Infrequent	Not discussed in report	ASME Sec XI IWC	None	88, 89 V2	56
Most common in horizontal portions of system where thermal stratifications can occur. Crack initiation and propagation.	Frequent	Vendor programs	ASME Sec XI IWC & PS S&T Req.	Acoustic monitoring should be considered [2]	77-80, 85-88, 91, 93, 95, 99-101 V2	57
Crack initiation and propagation.	Infrequent	Not discussed in report	ASME Sec XI IWC & PS S&T Req.	None	82, 88, 100 V2	58
Crack initiation and propagation. Can produce final failure in structures weakened by other mechanisms.	Moderate	Vendor programs	ASME Sec XI IWC	None	81, 82, 94, 95, 100 V2	59
Leads to localized wall thinning especially near flow discontinuities or anywhere where high turbulence occurs (fittings, tees, elbows). If thinning is severe, even modest pressure pulse can produce rupture.	Frequent	EPRI, British, and French programs	ASME Sec XI IWC	Water chemistry changes to mitigate erosion corrosion can have other deleterious effects. Inside surfaces need to be kept as smooth as possible. Consider use of SS coatings. [4]	77, 82-86, 89-93, 97-103 V2	60
Feedwater system oeprates near saturation. Cavitiation can produce sever local damage in regions with velcotiy changes.	Infrequent	Not discussed in report	ASME Sec XI IWC	None	82, 88, 89 V2	61
Most common in horizontal portions of system where thermal stratifications can occur. Crack initiation and propagation.	Frequent	Vendor programs	ASME Sec XI IWC & PS S&T Req.	Acoustic monitoring should be considered [2]	77-80, 85-88, 91, 93, 95, 99-101 V2	62
Crack initiation and propagation.	Infrequent	Not discussed in report	ASME Sec XI IWC & PS S&T Req.	None	88, 100 V2	63
Crack initiation and propagation. Can produce final failure in structures weakened by other mechanisms.	Moderate	Vendor programs	ASME Sec XI IWC	None	81, 82, 94, 95, 100 V2	64
Most common in horizontal portions of system where thermal stratifications can occur. Crack initiation and propagation.	Frequent	Vendor programs	ASME Sec XI IWC & PS S&T Req.	None	77-80, 85-88, 91, 93, 95, 99-101 V2	65
Most common in horizontal portions of system where thermal stratifications can occur. Crack initiation and propagation.	Frequent	Vendor programs	ASME Sec XI IWC & PS S&T Req.	Acoustic monitoring should be considered [2]	77-80, 85-88, 91, 93, 95, 99-101 V2	66

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
67	PWR reactor feedwater system	Feedwater piping	Thermal sleeves	Not identified	W, CE, B&W	WAT HAM	Cumulative fatigue damage
68	PWR reactor feedwater system	Feedwater piping	Thermal sleeves	Not identified	W, CE, B&W	FAT/FIV	Cumulative fatigue damage
69	PWR Primary coolant system	Reactor coolant pumps	Body	CF-8, CF-8M, CF-8A, Carbon steel with SS clad (1 plant)	W, Byron Jackson, Bingham, CE, Klein	EMBR/TE	Loss of fracture toughness
70	PWR Primary coolant system	Reactor coolant pumps	Body	CF-8, CF-8M, CF-8A, Carbon steel with SS clad (1 plant)	W, Byron Jackson, Bingham, CE, Klein	FAT	Cumulative fatigue damage
71	PWR Primary coolant system	Reactor coolant pumps	Body	CF-8, CF-8M, CF-8A, Carbon steel with SS clad (1 plant)	W, Byron Jackson, Bingham, CE, Klein	FAT/THERM	Cumulative fatigue damage
72	PWR Primary coolant system	Reactor coolant pumps	Body	CF-8, CF-8M, CF-8A, Carbon steel with SS clad (1 plant)	W, Byron Jackson, Bingham, CE, Klein	CORR/SCC	Crack initiation and growth
73	PWR Primary coolant system	Reactor coolant pumps	Shaft	SS 304, 316	W, Byron Jackson, Bingham, CE, Klein	FAT	Cumulative fatigue damage
74	PWR Primary coolant system	Reactor coolant pumps	Shaft	SS 304, 316	W, Byron Jackson, Bingham, CE, Klein	FAT/THERM	Cumulative fatigue damage
75	PWR Primary coolant system	Reactor coolant pumps	Closure studs	Low alloy steel (A540-B23 or A193-B7)	W, Byron Jackson, Bingham, CE, Klein	CORR	Loss of material
76	PWR CRDMs and reactor internals	CRDMs	Pressure housing	SS 304 and CF-8 (W) Not identified CE and B&W	W, CE, B&W	EMBR/TE	Loss of fracture toughness
77	PWR CRDMs and reactor internals	CRDMs	Pressure housing	SS 304 and CF-8 (W) Not identified CE and B&W	W, CE, B&W	FAT	Cumulative fatigue damage
78	PWR CRDMs and reactor internals	CRDMs	Pressure housing	SS 304 and CF-8 (W) Not identified CE and B&W	W, CE, B&W	CORR/SCC	Crack initiation and growth
79	PWR CRDMs and reactor internals	CRDMs	Latch assembly	SS 304 with Stellite 6 and hard chrome plate bearing and wear surfaces (W) Not identified CE and B&W	W, CE, B&W	WEAR	Loss of material
80	PWR CRDMs and reactor internals	CRDMs	Latch assembly	SS 304 with Stellite 6 and hard chrome plate bearing and wear surfaces (W) Not identified CE and B&W	W, CE, B&W	WEAR/FRET	Loss of material
81	PWR CRDMs and reactor internals	CRDMs	Drive rod	SS 410 (W) Not identified CE and B&W	W, CE, B&W	FAT	Cumulative fatigue damage
82	PWR CRDMs and reactor internals	CRDMs	Drive rod	SS 410 (W) Not identified CE and B&W	W, CE, B&W	WEAR	Loss of material
83	PWR CRDMs and reactor internals	Reactor internals	Instrument guide tubes (Thimble tubes)	SS 304 (W) Not identified CE and B&W	W, CE, B&W	FAT/FIV	Cumulative fatigue damage
84	PWR CRDMs and reactor internals	Reactor internals	Instrument guide tubes (Thimble tubes)	SS 304 (W) Not identified CE and B&W	W, CE, B&W	WEAR/FRET	Loss of material
85	PWR CRDMs and reactor internals	Reactor internals	Thermal shield	SS 304	W, CE, B&W	FAT/FIV	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Crack initiation and propagation. Can produce final failure in structures weakened by other mechanisms.	Moderate	Vendor programs	ASME Sec XI IWC	None	81, 82, 94, 95, 100 V2	67
Crack initiation and propagation.	Infrequent	Not discussed in report	ASME Sec XI IWC & PS S&T Req.	None	82, 91, 101 V2	68
Loss of toughness would increase possibility of leakage, unstable ductile tearing.	Moderate	USNRC Research	ASME Sec XI IWB & PS TS Req.	Need model to predict embrittlement based on composition, microstructure. Need information on throughwall distribution of ferrite. [4]	10, 11, 13-16 V2	69
Crack initiation and growth.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	11, 12, 15, 16 V2	70
Crack initiation and growth.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	11, 12, 15, 16 V2	71
Crack initiation and growth. Most likely to affect low ferrite bodies and welds.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	12 V2	72
Crack initiation and growth.	Frequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need field demonstration of improved NDE [4-EPRI]	11-16 V2	73
Crack initiation and growth.	Frequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need field demonstration of improved NDE [4-EPRI]	11-16 V2	74
Gasket leakage could lead to boric acid attack of ferritic closure studs.	Moderate	USNRC IN 80-27	ASME Sec XI IWB & PS TS Req.	Improve gasket technology and inspection. Better inspection for studs. [2]	10, 12, 14-16 V2	75
Loss of toughness would increase possibility of leakage. Affects only cast housings.	Moderate	EPRI, WOG, and USNRC research programs	ASME Sec XI IWB & PS TS Req.	Evaluation of embrittlement is needed [4]	121, 130, 131 V2	76
Crack initiation and growth leading to leakage. Estimated usage factors are very low.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need to develop techniques to assure integrity of inaccessible welds [4]	133, 137 V2	77
Leakage in seal welds.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need to develop techniques to assure integrity of inaccessible welds [4]	122, 132 V2	78
Binding and sticking of control rod drive.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need life test to determine practical lifetimes [2]	129, 130, 137 V2	79
Binding and sticking of control rod drive.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Need life test to determine practical lifetimes [2]	129, 130, 137 V2	80
Crack initiation and growth leading to CRA uncoupling.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	137 V2	81
Loss of material leading to CRA uncoupling.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	137 V2	82
Crack initiation and growth leading to leakage. Loose parts.	Frequent	USNRC IN 87 44, USNRC Bulletin 88-09	ASME Sec XI IWB	Establish vibration monitoring programs using neutron noise detectors [4]	130, 136-138 V2	83
Wall Thinning. Leakage, loose parts.	Frequent	USNRC IN 87 44, USNRC Bulletin 88-09	ASME Sec XI IWB	None	130, 136-138 V2	84
Crack initiation and growth. Such problems have lead to removal of thermal shields in many CE plants.	Frequent	Not discussed in report	ASME Sec XI IWB	None	125, 138 V2	85

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
86	PWR CRDMs and reactor internals	Reactor internals	Thermal shield bolts	SS316, A-286, X-750	W, CE, B&W	CORR/SCC	Crack initiation and growth
87	PWR CRDMs and reactor internals	Reactor internals	Thermal shield bolts	SS316, A-286, X-750	W, CE, B&W	RELAX	Stress relaxation
88	PWR CRDMs and reactor internals	Reactor internals	Thermal shield bolts	SS 316, A-286, X-750	W, CE, B&W	FAT	Cumulative fatigue damage
89	PWR CRDMs and reactor internals	Reactor internals	Core barrel	SS 304	W, CE, B&W	FAT/FIV	Cumulative fatigue damage
90	PWR CRDMs and reactor internals	Reactor internals	Core barrel	SS 304	W, CE, B&W	EMBR/IR	Loss of fracture toughness
91	PWR CRDMs and reactor internals	Reactor internals	Core barrel bolts	SS 316, A 286, X 750	W, CE, B&W	CORR/SCC	Crack initiation and growth
92	PWR CRDMs and reactor internals	Reactor internals	Core barrel bolts	SS 316, A-286, X-750	W, CE, B&W	RELAX	Stress relaxation
93	PWR CRDMs and reactor internals	Reactor internals	Core barrel bolts	SS 316, A-286, X-750	W, CE, B&W	FAT	Cumulative fatigue damage
94	PWR CRDMs and reactor internals	Reactor internals	Upper and lower core support structures	SS 304, CF-8 Alloy X-750 and A-286	W, CE, B&W	FAT/FIV	Cumulative fatigue damage
95	PWR CRDMs and reactor internals	Reactor internals	Upper and lower core support structures	SS 304, CF-8 Alloy X-750 and A-286	W, CE, B&W	CORR/SCC	Crack initiation and growth
96	PWR CRDMs and reactor internals	Reactor internals	Upper and lower core support structures	SS 304, CF-8 Alloy X-750 and A-286	W, CE, B&W	EMBR/TE	Loss of fracture toughness
97	BWR primary pressure boundary	Reactor pressure vessel	Beltline region	Low alloy steels (SA302B, SA533B-1, SA508-2), Weld deposited SS clad (308, 309)	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	EMBR/IR	Loss of fracture toughness
98	BWR primary pressure boundary	Reactor pressure vessel	Beltline region	Low alloy steels (SA302B, SA533B-1, SA508-2), Weld deposited SS clad (308, 309)	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	FAT/ENV	Cumulative fatigue damage
99	BWR primary pressure boundary	Reactor pressure vessel	Beltline region	Low alloy steels (SA302B, SA533B-1, SA508-2), Weld deposited SS clad (308, 309)	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	FAT/THERM	Cumulative fatigue damage
100	BWR primary pressure boundary	Reactor pressure vessel	Outlet/inlet nozzles	Low alloy steels A508-2, A105, A508-3	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	FAT/ENV	Cumulative fatigue damage
101	BWR primary pressure boundary	Reactor pressure vessel	Outlet/inlet nozzles	Low alloy steels A508-2, A105, A508-3	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	FAT/THERM	Cumulative fatigue damage
102	BWR primary pressure boundary	Reactor pressure vessel	Closure studs	Low alloy steels (A193-B7, SA540-B22 or B23)	Not stated	FAT	Cumulative fatigue damage
103	BWR primary pressure boundary	Reactor pressure vessel	Bimetallic/trimetallic weld nozzle to safeend	Safeend 304 SS Weld metal not identified	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	FAT	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Bolt failure. Loose parts.	Frequent	EPRI UT program for boltsVendor programs	ASME Sec XI IWB	Need to study alternate materials/heat treatments to get longer lifetimes. [4]	127-129. 138 V2	86
Loss of bolt preload.	Frequent	Not discussed in report	ASME Sec XI IWB	None	132, 138 V2	87
Bolt failure. Loose parts.	Frequent	EPRI UT program for boltsVendor programs	ASME Sec XI IWB	Develop high-cycle fatigue curves for high-strength materials [3]	123-125, 138 V2	88
Crack initiation and growth.	Frequent	Not discussed in report	ASME Sec XI IWB	None	125, 138 V2	89
Increased susceptibility to low ductility failure.	Frequent	Not discussed in report	ASME Sec XI IWB	None	131, 132, 138 V2	90
Bolt failure. Loose parts.	Frequent	EPRI UT program for boltsVendor programs	ASME Sec XI IWB	Need to study alternate materials/heat treatments to get longer lifetimes. [4]	127-129. 138 V2	91
Loss of bolt preload.	Frequent	Not discussed in report	ASME Sec XI IWB	None	132, 138 V2	92
Bolt failure. Loose parts.	Frequent	EPRI UT program for boltsVendor programs	ASME Sec XI IWB	Develop high cycle fatigue curves for high strength materials [3]	123 125, 138 V2	93
Crack initiation and growth.	Frequent	Not discussed in report	ASME Sec XI IWB	Develop high cycle fatigue curves for high strength materials [3]	123 125, 138 V2	94
Guide pin failure. Loose parts.	Frequent	EPRI UT program for boltsVendor programs	ASME Sec XI IWB	Need to study alternate materials/heat treatments to get longer lifetimes. [4]	127-129, 138 V2	95
Increased susceptibility to low ductility failure.	Frequent	EPRI, WOG, and USNRC research programs	ASME Sec XI IWB	Need research program on combined effect of radiation and temperature on embrittlement [3]	130, 131, 138 V2	96
Ductile high energy overload leading to a leak. Much less severe problem than in PWRs.	Frequent	USNRC Reg. Guide 1.99 Rev. 2	10 CFR App. G & ASME Sec XI IWB	None	105, 107 V1	97
Crack initiation & propagation could result in leakage.	Moderate	ASME Secs III & XI	10 CFR App. G & ASME Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [2]	105 107 V1	98
Crack initiation & propagation could result in leakage.	Moderate	ASME Secs III & XI	10 CFR App. G & ASME Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [2]	105-107 V1	99
Crack initiation & propagation could result in leakage.	Moderate	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	105-107 V1	100
Crack initiation & propagation could result in leakage.	Moderate	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Better monitoring of transients. Additional studies required to improve predictions [4]	105-107 V1	101
Crack initiation & propagation could result in ductile overload failure and leakage.	Moderate	ASME Secs III & XI	ASME Sec III & Sec XI IWB	Should be closely inspected at 40 year life [3]	104, 106, 107 V1	102
Crack initiation & propagation could result in leakage.	Moderate	Not discussed in report	ASME Sec III & Sec XI IWB	Should be closely inspected at 40 year life [4]	104, 105, 107 V1	103

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
104	BWR primary pressure boundary	Reactor pressure vessel	Bimetallic/trimetallic weld nozzle to safeend	Safeend 304 SS Weld metal not identified	Rotterdam Dockyard Co.	CORR/IGSCC	Crack initiation and growth
105	BWR primary pressure boundary	Reactor pressure vessel	Stub tube (attach ments for CRDs)	SS, Alloy 600	Chicago Bridge and Iron, Combustion Engineering, B&W, Babcock/Hitachi, Rotterdam Dockyard Co.	CORR/IGSCC	Crack initiation and growth
106	BWR primary pressure boundary	Recirculation piping system	Piping & safeends	SS 304, 316, 304L, 316L, 304NG, 316NG	General Electric	CORR/IGSCC	Crack initiation and growth
107	BWR primary pressure boundary	Recirculation piping system	Piping & safeends	SS 304, 316, 304L, 316L, 304NG, 316NG	General Electric	CORR/SCC	Crack initiation and growth
108	BWR primary pressure boundary	Recirculation piping system	Piping & safeends	SS 304, 316, 304L, 316L, 304NG, 316NG	General Electric	FAT/ENV	Cumulative fatigue damage
109	BWR primary pressure boundary	Recircula tion piping system	Piping & safeends	SS 304, 316, 304L, 316L, 304NG, 316NG	General Electric	FAT/ THERM	Cumulative fatigue damage
110	BWR primary pressure boundary	Recircula tion piping system	Welds	Not identified	General Electric	EMBR/ TE	Loss of fracture toughness
111	BWR primary pressure boundary	Recircula tion piping system	Fittings	Not identified	General Electric	EMBR/ TE	Loss of fracture toughness
112	BWR CRDMs and reactor internals	CRDMs	Pressure housing, stub tube	SS 304, Alloy 600	General Electric	CORR/ IGSCC	Crack initiation and growth
113	BWR CRDMs and reactor internals	CRDMs	Pressure housing, stub tube	SS 304, Alloy 600	General Electric	FAT/ THERM	Cumulative fatigue damage
114	BWR CRDMs and reactor internals	CRDMs	Latching mechanism	Alloy X 750	General Electric	CORR/ IGSCC	Crack initiation and growth
115	BWR CRDMs and reactor internals	CRDMs	Latching mechanism	Alloy X 750	General Electric	FAT/ THERM	Cumulative fatigue damage
116	BWR CRDMs and reactor internals	CRDMs	Latching mechanism	Alloy X 750	General Electric	WEAR	Loss of material
117	BWR CRDMs and reactor internals	CRDMs	Piston seal C spring	Alloy X 750	General Electric	CORR/ IGSCC	Crack initiation and growth
118	BWR CRDMs and reactor internals	CRDMs	Diaphragms in air operated solenoid valves	BUNA N rubber and nylon	General Electric	EMBR/ TE	Loss of flexibility
119	BWR CRDMs and reactor internals	CRDMs	Piston seals	Graphitar 14	General Electric	EMBR/ TE	Loss of flexibility
120	BWR CRDMs and reactor internals	CRDMs	Piston seals	Graphitar 14	General Electric	WEAR	Loss of material
121	BWR CRDMs and reactor internals	Reactor internals	Attachment welds to vessel	Alloy 182, 82	General Electric	CORR/ IGSCC	Crack initiation and growth
122	BWR CRDMs and reactor internals	Reactor internals	Attachment welds to vessel	Alloy 182, 82	General Electric	FAT/ THERM	Cumulative fatigue damage
123	BWR CRDMs and reactor internals	Reactor internals	Core shroud	SS 304, 304L	General Electric	CORR/ IGSCC	Crack initiation and growth
124	BWR CRDMs and reactor internals	Reactor internals	Core plate	SS 304L	General Electric	CORR/ IGSCC	Crack initiation and growth

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Crack initiation & propagation could result in leakage.	Moderate	Not discussed in report	ASME Sec XI IWB	Should be closely inspected at 40 year life [4]	107 V1	104
SS tubes on early reactors (pre 1968) sensitized and susceptible to crack initiation & propagation which could result in leakage. Alloy 600 used 1968-1974. Component eliminated in later reactors.	Frequent	Not discussed in report	ASME Sec XI IWB	None	104 V1	105
Crack initiation & propagation could result in leakage.	Frequent	Industry & USNRC programs	ASME Sec XI IWB	Long term field experience needed to assess effectiveness of countermeasures [4]	108, 110-112 V1; 275-295 V2	106
Crack initiation & propagation could result in leakage.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	280, 281, 283 V2	107
Crack initiation & propagation could result in leakage.	Moderate	Not discussed in report	ASME Sec III & Sec XI IWB	None	110 112 V1	108
Crack initiation & propagation could result in leakage.	Moderate	Not discussed in report	ASME Sec III & Sec XI IWB	None	108, 110 112 V1	109
Increased susceptibility to low ductility failure.	Infrequent	Not discussed in report	ASME Sec XI IWB	Need additional work to determine susceptibility [4]	108, 110, 112 V1 281 V2	110
Increased susceptibility to low ductility failure.	Infrequent	Not discussed in report	ASME Sec XI IWB	Need additional work to better evaluate embrittlement under BWR conditions and ferrite levels in cast compoments [4]	108, 110 112 V1 281 V2	111
Crack initiation & propagation could result in leakage.	Moderate	Vendor program	ASME Sec XI IWB & PS TS Req.	Hydrogen water chemistry effective mitigating action. [4]	254, 256, 257, 266, 269, 270 V2	112
Crack initiation & propagation could result in leakage.	Moderate	ASME XI	ASME Sec XI IWB & PS TS Req.	None	251, 252, 263, 264, 266, 270 V2	113
Drive may not lock properly. Separation of CRA and CRDM.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	254, 264, 270 V2	114
Drive may not lock properly. Separation of CRA and CRDM.	Infrequent	Not discussed in report	ASME Sec XI IWB & PS TS Req.	None	263, 264, 270 V2	115
Drive may not lock properly.	Moderate	Not discussed in report	ASME Sec XI IWB & PS TS Req.	Internals should be inspected periodically for excessive wear damage [2]	253, 265, 269, 270 V2	116
Could cause control rod to stick.	Moderate	USNRC IE IN 86-88	ASME Sec XI IWB & PS TS Req.	Internals should be inspected periodically for excessive wear damage [2]	254, 259, 270 V2	117
May become brittle over time and break up. Broken pieces may block vent ports in the scram pilot valves.	Frequent	USNRC IE IN 86-109	ASME Sec XI IWB & PS TS Req.	Internals should be inspected periodically for excessive wear damage [2]	255, 269, 270 V2	118
Could cause control rod to stick.	Moderate	USNRC IE IN 86-88	ASME Sec XI IWB & PS TS Req.	Internals should be inspected periodically for excessive wear damage [2]	252, 270 V2	119
Could cause control rod to stick.	Moderate	USNRC IE IN 86-88	ASME Sec XI IWB & PS TS Req.	Internals should be inspected periodically for excessive wear damage [2]	269, 270 V2	120
Crack could progress into vessel.	Frequent	ASME XI Table IWB 2500 1	ASME Sec XI IWB	Need to develop remote inspection tools for these locations [3]	260, 263, 269, 271 V2	121
Crack could progress into vessel.	Moderate	ASME XI Table IWB 2500 1	ASME Sec XI IWB	Need to develop remote inspection tools for these locations [2]	264, 269, 271 V2	122
Cracking could lead to loss of core geometry.	Frequent	ASME XI Table IWB 2500 1	ASME Sec XI IWB	None	253, 255, 270, 271 V2	123
Cracking could lead to loss of core geometry.	Frequent	USNRC IE IN 84 89ASME XI Table IWB 2500 1	ASME Sec XI IWB	None	253, 255, 270, 271 V2	124

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
125	BWR CRDMs and reactor internals	Reactor internals	Jet pumps	SS 304, 304L, 316L, Alloy 600, SS CF 8, CF 3	General Electric	CORR/ IGSCC	Crack initiation and growth
126	BWR CRDMs and reactor internals	Reactor internals	Jet pumps	SS 304, 304L, 316L, Alloy 600, SS CF 8, CF 3	General Electric	FAT/	Cumulative fatigue damage
127	BWR CRDMs and reactor internals	Reactor internals	Jet pumps	SS 304, 304L, 316L, Alloy 600, SS CF 8, CF 3	General Electric	FAT/ FIV	Cumulative fatigue damage
128	BWR CRDMs and reactor internals	Reactor internals	Jet pumps	SS 304, 304L, 316L, Alloy 600, SS CF 8, CF 3	General Electric	EMBR/ TE	Loss of fracture toughness
129	BWR CRDMs and reactor internals	Reactor internals	Jet pumps	SS 304, 304L, 316L, Alloy 600, SS CF 8, CF 3	General Electric	ERO/ CORR	Loss of material
130	BWR CRDMs and reactor	Reactor internals	Top guide	SS 304L	General Electric	CORR/ IGSCC	Crack initiation and growth
131	Internals	Reactor internals	Top guide	SS 304L	General Electric	CORR/ IASCC	Crack initiation and growth
132	Internals	Reactor internals	Core spray spargers and piping	SS 304	General Electric	CORR/IGSCC	Crack initiation and growth
133	BWR CRDMs and reactor internals	Reactor internals	Core spray spargers and piping	SS 304	General Electric	FAT/FIV	Cumulative fatigue damage
134	BWR CRDMs and reactor internals	Reactor internals	Feedwater spargers	304 SS, Alloy 600	General Electric	FAT/THERM	Crack initiation and growth
135	BWR CRDMs and reactor internals	Reactor internals	Feedwater spargers	304 SS, Alloy 600	General Electric	CORR/IGSCC	Crack initiation and growth
136	BWR CRDMs and reactor internals	Reactor internals	Fuel assembly supports	SS CF-8, 304, 304L	General Electric	CORR/IGSCC	Crack initiation and growth
137	BWR CRDMs and reactor internals	Reactor internals	Fuel assembly supports	SS CF-8, 304, 304L	General Electric	CORR/IASCC	Crack initiation and growth
138	BWR CRDMs and reactor internals	Reactor internals	Fuel assembly supports	SS CF-8, 304, 304L	General Electric	FAT/FIV	Crack initiation and growth
139	BWR CRDMs and reactor internals	Reactor internals	Fuel assembly supports	SS CF-8, 304, 304L	General Electric	EMBR/TE	Loss of fracture toughness
140	BWR CRDMs and reactor internals	Reactor internals	Baffle plate access hole covers	Alloy 600	General Electric	CORR/IGSCC	Crack initiation and growth
141	BWR CRDMs and reactor internals	Reactor internals	Steam separator assembly/dryer bolts	SS 304, CF-8	General Electric	CORR/IGSCC	Crack initiation and growth
142	BWR CRDMs and reactor internals	Reactor internals	Steam separator assembly/dryer bolts	SS 304, CF-8	General Electric	FAT/FIV	Cumulative fatigue damage
143	BWR CRDMs and reactor internals	Reactor internals	Steam separator assembly/dryer bolts	SS 304, CF-8	General Electric	EMBR/TE	Loss of fracture toughness
144	BWR CRDMs and reactor internals	Reactor internals	Steam separator dryer assembly beams	A-286	General Electric	CORR/IGSCC	Crack initiation and growth
145	BWR CRDMs and reactor internals	Reactor internals	Steam separator dryer assembly beams	A 286	General Electric	FAT/ FIV	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of adequate core flow.	Frequent	General Electric and EPRI programs	ASME Sec XI IWB	None	253, 257, 258, 271 V2	125
Loss of adequate core flow.	Frequent	General Electric and EPRI programs	ASME Sec XI IWB	Need fatigue crack initiation and crack growth data in HWC environments [4]	253, 264, 267, 271 V2	126
Loss of adequate core flow.	Infrequent	General Electric and EPRI programs	ASME Sec XI IWB	None	264, 271 V2	127
Concern is for cast SS components. Loss of toughness could enhance susceptibility to failure, if a crack develops due to IGSCC or fatigue. Loss of adequate core flow.	Infrequent	WOG, EPRI, and NRC work at ANL	ASME Sec XI IWB	Continue research on embrittlement of cast SS [4]	265, 271 V2	128
Could lead to wall thinning.	Rare	Not discussed in report	ASME Sec XI IWB	None	265, 271 V2	129
Cracking could lead to loss of core geometry.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	253, 258, 271 V2	130
Cracking could lead to loss of core geometry.	Frequent	General Electric program	ASME Sec XI IWB	Current studies ignored swelling, multiple beam failures; only rough estimates for materials propertiesBetter understanding needed to evaluate damage due to IASCC [4-ANL]	253, 255, 263, 270, 271 V2	131
Loss of effective ECCS.	Frequent	General Electric, EPRI and USNRC research	ASME Sec XI IWB	None	253, 257, 271 V2	132
Loss of effective ECCS.	Frequent	Not discussed in report	ASME Sec XI IWB	None	253, 271 V2	133
Improper feedwater flow.	Frequent	Not discussed in report	ASME Sec XI IWB	None	253, 255, 267, 271 V2	134
Improper feedwater flow.	Frequent	General Electric, EPRI and USNRC research	ASME Sec XI IWB	None	253, 271 V2	135
Loss of fuel geometry.	Frequent	General Electric, EPRI and USNRC research	ASME Sec XI IWB	None	243, 253, 271 V2	136
Loss of fuel geometry.	Frequent	General Electric program	ASME Sec XI IWB	Better understanding needed to evaluate damage due to IASCC [4-ANL]	243, 253, 255, 263, 267, 271 V2	137
Loss of fuel geometry.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	243, 253, 271 V2	138
Loss of fuel geometry.	Infrequent	USNRC research	ASME Sec XI IWB	None	243, 253, 265, 271 V2	139
Improper core flow.	Frequent	General Electric, EPRI and USNRC research	ASME Sec XI IWB	None	243, 271 V2	140
Damage to steam lines and turbines.	Frequent	General Electric, EPRI and USNRC research	ASME Sec XI IWB	None	248, 255, 253, 271 V2	141
Damage to steam lines and turbines.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	248, 253, 255, 271 V2	142
Damage to steam lines and turbines.	Infrequent	USNRC Research	ASME Sec XI IWB	None	248, 253, 255, 271 V2	143
Damage to steam lines and turbines.	Frequent	Not discussed in report	ASME Sec XI IWB	None	248, 253, 255 V2	144
Damage to steam lines and turbines.	Infrequent	Not discussed in report	ASME Sec XI IWB	None	248, 253, 255 V2	145

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
146	BWR reactor feedwater system and main steam line	Feedwater piping	Piping	SA 333 Gr 6. SA 106 Gr B	General Electric	ERO/ CORR	Loss of material
147	BWR reactor feedwater system and main steam line	Feedwater piping	Piping	SA 333 Gr 6. SA 106 Gr B	General Electric	FAT/ THERM	Cumulative fatigue damage
148	BWR reactor feedwater system and main steam line	Feedwater piping	Piping	SA 333 Gr 6. SA 106 Gr B	General Electric	FAT/ ENV	Cumulative fatigue damage
149	BWR reactor feedwater system and main steam line	Main steam piping	Piping	SA 106 Gr B,	General Electric	ERO/ CORR	Loss of material
150	BWR reactor feedwater system and main steam line	Main steam piping	Piping	SA 106 Gr B,	General Electric	FAT	Cumulative fatigue damage
151	BWR reactor feedwater system and main steam line	Main steam piping	Elbows	SA 182 Gr B (forged elbows), SA 234 Grs WPC,, WPB, or WPCW (welded elbows)	General Electric	ERO/ CORR	Loss of material
152	BWR reactor feedwater system and main steam line	Main steam piping	Elbows	SA 182 Gr B (forged elbows), SA 234 Grs WPC,, WPB, or WPCW (welded elbows)	General Electric	FAT	Cumulative fatigue damage
153	BWR Containments	Metal containments	Exterior surface of Mark I drywell base near sand pocket	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR	Loss of material
154	BWR Containments	Metal containments	Exterior surface of Mark I drywell base near sand pocket	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ CREV	Local loss of materia
155	BWR Containments	Metal containments	Exterior surface of Mark I drywell base near sand pocket	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ MIC	Loss of material
156	BWR Containments	Metal containments	Exterior surface of Mark I and II drywell	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR	Loss of material
157	BWR Containments	Metal containments	Exterior surface of Mark I and II drywell	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ CREV	Local loss of materia
158	BWR Containments	Metal containments	Exterior surface of Mark I and II drywell	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ PIT	Local loss of materia
159	BWR Containments	Metal containments	Cylindrical spherical shell transition region	SA 516 Gr 70 SA 212 Gr B	Not stated	FAT	Cumulative fatigue damage

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage or rupture.	Moderate	USNRC IE IN 87 01, ASME XI	ASME Sec XI IWB	Need on line monitoring. Need to monitor dissolved oxygen levels. Evaluate use of flame sprayed SS coatings. [4]	208-210, 212, 215, 216, 226, 227 V2	146
Crack initiation & propagation could result in leakage.	Frequent	ASME Section III, ANSI B31.1, ASME XI	ASME Sec III & Sec XI IWB	Need on line monitoring [2]	208-210, 219, 221-224, 226, 227 V2	147
Crack initiation & propagation could result in leakage.	Frequent	ASME Section III, ANSI B31.1, ASME XI	ASME Sec III & Sec XI IWB	Need on line monitoring. Need evironmental fatigue data. Need to monitor dissolved oxygen levels. [4]	208-210, 220, 221, 226, 227 V2	148
Leakage or rupture.	Infrequent	USNRC IE IN 87 01, ASME XI	ASME Sec XI IWB	Need on line monitoring [2]	208-210, 217-219, 226, 227 V2	149
Crack initiation & propagation could result in leakage.	Frequent	ASME Section III, ANSI B31.1, ASME XI	ASME Sec III & Sec XI IWB	Need on line monitoring [2]	208-210, 212, 226, 227 V2	150
Leakage or rupture.	Infrequent	USNRC IE IN 87 01, ASME XI	ASME Sec XI IWB	Need on line monitoring [2]	208-210, 217-219, 226, 227 V2	151
Crack initiation & propagation could result in leakage.	Frequent	ASME Section III, ANSI B31.1, ASME XI	ASME Sec III & Sec XI IWB	Need on line monitoring [2]	208-210, 212, 226, 227 V2	152
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC GL 87-05	ASME Sec XI IWE	Mitigation methods need to be developed. Use zinc rich or phenolic coatings instead of red lead or epoxy coatings [4]	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	153
Leakage of radioactive gases.	Moderate	10CFR50 Appendix J, USNRC GL 87-05	ASME Sec XI IWE	Mitigation methods need to be developed. Use zinc rich or phenolic coatings instead of red lead or epoxy coatings [4]	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	154
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC GL 87-05	ASME Sec XI IWE	Mitigation methods need to be developed. Use zinc rich or phenolic coatings instead of red lead or epoxy coatings [4]	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	155
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC GL 87-05	ASME Sec XI IWE	Mitigation methods need to be developed. Use zinc rich or phenolic coatings instead of red lead or epoxy coatings [4]	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	156
Leakage of radioactive gases.	Moderate	10CFR50 Appendix J, USNRC GL 87-05	ASME Sec XI IWE	Mitigation methods need to be developed. Use zinc rich or phenolic coatings instead of red lead or epoxy coatings [4]	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	157
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC GL 87-05	ASME Sec XI IWE & 10CFR50 App. J	Mitigation methods need to be developed. Use zinc rich or phenolic coatings instead of red lead or epoxy coatings [4]	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	158
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 193, 200, 201 V2	159

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
160	BWR Containments	Metal containments	Cylindrical spherical shell transition region	SA 516 Gr 70 SA 212 Gr B	Not stated	EMBR/ IR	Loss of fracture toughness
161	BWR Containments	Metal containments	Embedded shell	SA 516 Gr 70 SA 212 Gr B	Not stated	FAT/ THERM	Cumulative fatigue damage
162	BWR Containments	Metal containments	Embedded shell	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ PIT	Local loss of materia
163	BWR Containments	Metal containments	High energy piping penetrations	Not identified	Not stated	FAT	Cumulative fatigue damage
164	BWR Containments	Metal containments	SS bellows	Type 304 SS	Not stated	CORR/ SCC	Crack initiation and growth
165	BWR Containments	Metal containments	Suppression pool/chamber Mark I and II	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR	Loss of material
166	BWR Containments	Metal containments	Suppression pool/chamber Mark I and II	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ PIT	Local loss of materia
167	BWR Containments	Metal containments	Suppression pool/chamber Mark I and II	SA 516 Gr 70 SA 212 Gr B	Not stated	CORR/ MIC	Loss of material
168	BWR Containments	Metal containments	Dissimilar metal welds	Ferritic to SS	Not stated	CORR	Loss of material
169	BWR Containments	Metal containments	Dissimilar metal welds	Ferritic to SS	Not stated	FAT/ THERM	Cumulative fatigue damage
170	BWR Containments	Reinforced concrete containments	Reinforcing bars	Not identified	Not stated	CORR	Loss of material
171	BWR Containments	Reinforced concrete containments	Reinforcing bars	Not identified	Not stated	FAT	Cumulative fatigue damage
172	BWR Containments	Reinforced concrete containments	Mark I and II suppression pool steel liner	SA 516 Gr 60	Not stated	CORR	Loss of material
173	BWR Containments	Reinforced concrete containments	Mark I and II suppression pool steel liner	SA 516 Gr 60	Not stated	CORR/ MIC	Loss of material

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage of radioactive gases.	Infrequent	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 193, 194, 200, 201 V2	160
Loss of structural integrity.	Occasional	Not discussed in report	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 172-178, 193, 200, 201 V2	161
Loss of structural integrity.	Frequent	Not discussed in report	ASME Sec XI IWE & 10CFR50 App. J	Develop electromagnetic acoustic tranducers to detect corrosion [2]	169, 170, 172-178, 200, 201 V2	162
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	177, 180, 200, 201 V2	163
Leakage of radioactive gases.	Moderate	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	177, 190, 196, 200, 201 V2	164
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC IN 88-82	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	165
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC IN 88-82	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	166
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J, USNRC IN 88-82	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 172-178, 188, 190-192, 195, 196, 200, 201 V2	167
Leakage of radioactive gases.	Frequent	ASME XI, 10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 172-178, 200, 201 V2	168
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	169, 170, 172-178, 193, 200, 201 V2	169
Loss of structural integrity.	Frequent	USNRC Reg. Guide 1.136, Rev 2	ASME Sec XI IWL & 10CFR50 App. J	None	169, 170, 182 185, 189, 194, 196, 203 V2	170
Loss of structural integrity.	Occasional	USNRC Reg. Guide 1.136, Rev 2	ASME Sec XI IWL & 10CFR50 App. J	None	169, 170, 182 185, 189, 194, 196, 203 V2	171
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	169, 170, 182 185, 189, 194, 196, 203 V2	172
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	169, 170, 182 185, 189, 194, 196, 203 V2	173

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
174	BWR Containments	Reinforced concrete containments	Mark I and II suppression pool steel liner	SA 516 Gr 60	Not stated	FAT	Cumulative fatigue damage
175	BWR Containments	Reinforced concrete containments	Drywell steel liner	SA 516 Gr 60	Not stated	CORR	Loss of material
176	BWR Containments	Reinforced concrete containments	Drywell steel liner	SA 516 Gr 60	Not stated	FAT	Cumulative fatigue damage
177	BWR Containments	Reinforced concrete containments	Concrete	Not stated	Not stated	AGR-CHEM	Chemical or physical degradation
178	BWR Containments	Reinforced concrete containments	Concrete	Not stated	Not stated	AGREAC	Chemical or physical degradation
179	BWR Containments	Reinforced concrete containments	Concrete	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
180	BWR Containments	Mark II Prestressed concrete	Postensioning anchors	Not identified	Not stated	CORR	Loss of material
181	BWR Containments	Mark II Prestressed concrete	Postensioning anchors	Not identified	Not stated	CORR/ SCC	Crack initiation and growth
182	BWR Containments	Mark II Prestressed concrete	Tendons	Not identified	Not stated	CORR/ MIC	Loss of material
183	BWR Containments	Mark II Prestressed concrete	Suppression pool steel liner	Not identified	Not stated	CORR	Loss of material
184	BWR Containments	Mark II Prestressed concrete	Suppression pool steel liner	Not identified	Not stated	CORR/ MIC	Loss of material
185	BWR Containments	Mark II Prestressed concrete	Suppression pool steel liner	Not identified	Not stated	FAT	Cumulative fatigue damage
186	BWR Containments	Mark II Prestressed concrete	Drywell steel liner	Not identified	Not stated	CORR	Loss of material
187	BWR Containments	Mark II Prestressed concrete	Drywell steel liner	Not identified	Not stated	FAT	Cumulative fatigue damage
188	BWR Containments	Mark II Prestressed concrete	Reinforcing bars	Not identified	Not stated	CORR	Loss of material
189	BWR Containments	Mark II Prestressed concrete	Concrete	Not identified	Not stated	AGREAC	Chemical or physical degradation
190	BWR Containments	Mark II Prestressed concrete	Concrete	Not identified	Not stated	ELE-TEMP	Chemical or physical degradation
191	PWR Containments	Metal containments	Shell welds & base metal	Not identified	Not stated	CORR	Loss of material

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWL	None	169, 170, 182 185, 189, 193, 194, 196, 203 V2	174
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	169, 170, 182 185, 189, 194, 196, 203 V2	175
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWL	None	169, 170, 182 185, 189, 193, 194, 196, 203 V2	176
Degradation of shielding properties.	Moderate	USNRC Reg. Guide 1.136, Rev 2	ASME Sec XI IWL	None	169, 170, 182 185, 189, 194, 196, 203 V2	177
Degradation of shielding properties.	Occasional	USNRC Reg. Guide 1.136, Rev 2	ASME Sec XI IWL	None	169, 170, 182 185, 189, 194, 196, 203 V2	178
Degradation of shielding properties.	Moderate	USNRC Reg. Guide 1.136, Rev 2	ASME Sec XI IWL	None	169, 170, 182 185, 189, 194, 196, 203 V2	179
Loss of prestress.	Frequent	Not discussed in report	ASME Sec XI IWL	Improved methods of monitoring degradation needed. [4]	185 187, 195, 196, 204 V2	180
Loss of prestress.	Frequent	Not discussed in report	ASME Sec XI IWL	None	185 187, 195, 196, 204 V2	181
Loss of prestress.	Frequent	USNRC Reg. Guide 1.35 Rev 2, USNRC Reg. Guide 1.90 Rev 1,	ASME Sec XI IWL	Improved methods of monitoring decomposition of tendon grease needed. [4]	185 187, 195, 196, 204 V2	182
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	190 192, 204 V2	183
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	190 192, 204 V2	184
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWL	None	193, 204 V2	185
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	190 192, 204 V2	186
Leakage of radioactive gases.	Occasional	10CFR50 Appendix J	ASME Sec XI IWL	None	193, 204 V2	187
Loss of structural integrity.	Frequent	Not discussed in report	ASME Sec XI IWL	None	194, 204 V2	188
Degradation of shielding properties. Loss of prestress.	Occasional	Not discussed in report	ASME Sec XI IWL	None	194, 204 V2	189
Degradation of shielding properties.	Moderate	Not discussed in report	ASME Sec XI IWL	None	194, 204 V2	190
Loss of structural integrity. Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	32, 39, 52 V1	191

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
192	PWR Containments	Metal containments	Interface between shell and concrete slab at base	Not identified	Not stated	CORR	Loss of material
193	PWR Containments	Metal containments	Disconti nuities in shell	Not identified	Not stated	CORR	Loss of material
194	PWR Containments	Metal containments	Embedded portion of shell	Not identified	Not stated	CORR	Loss of material
195	PWR Containments	Metal containments	Base slab concrete	Not identified	Not stated	AGREAC	Chemical or physical degradation
196	PWR Containments	Metal containments	Base slab concrete	Not identified	Not stated	AGR-CHEM	Chemical or physical degradation
197	PWR Containments	Reinforced concrete containments	Reinforcing bars	Not identified	Not stated	CORR	Loss of material
198	PWR Containments	Reinforced concrete containments	Steel liner	Not identified	Not stated	CORR	Loss of material
199	PWR Containments	Reinforced concrete containments	Concrete	Not identified	Not stated	AGREAC	Chemical or physical degradation
200	PWR Containments	Reinforced concrete containments	Concrete	Not identified	Not stated	AGR-CHEM	Chemical or physical degradation
201	PWR Containments	Pre-stressed concrete containments	Postensioning anchors	Not identified	Not stated	CORR	Loss of material
202	PWR Containments	Pre-stressed concrete containments	Tendons	Not identified	Not stated	CORR/PIT	Local loss of materia
203	PWR Containments	Pre-stressed concrete containments	Tendons	Not identified	Not stated	CORR/MIC	Loss of material
204	PWR Containments	Pre-stressed concrete containments	Steel liner	Not identified	Not stated	CORR	Loss of material
205	PWR Containments	Pre-stressed concrete containments	Reinforcing bars	Not identified	Not stated	CORR	Loss of material
206	PWR Containments	Pre-stressed concrete containments	Concrete	Not identified	Not stated	AGREAC	Chemical or physical degradation
207	PWR Containments	Pre-stressed concrete containments	Concrete	Not identified	Not stated	AGR-CHEM	Chemical or physical degradation
208	BWR and PWR reactor pressure vesssel supports	PWR support systems	Neutron shield tank	A516 Gr 60, A516 Gr 70, A302 Gr B, SA533 Gr B1	Not stated	EMBR/IR	Loss of fracture toughness
209	BWR and PWR reactor pressure vesssel supports	PWR support systems	Column support	A572, A36	Not stated	EMBR/IR	Loss of fracture toughness
210	BWR and PWR reactor pressure vesssel supports	PWR support systems	Cantilever support	A572, A36	Not stated	EMBR/IR	Loss of fracture toughness
211	BWR and PWR reactor pressure vesssel supports	PWR support systems	Threaded parts in sliding foot assembly	Not identified	Not stated	CORR/SCC	Crack initiation and growth

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of structural integrity. Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	32, 39, 52 V1	192
Leakage of radioactive gases.	Frequent	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	32, 39, 52 V1	193
Leakage of radioactive material.	Frequent	10CFR50 Appendix J	ASME Sec XI IWE & 10CFR50 App. J	None	32, 39, 52 V1	194
Cracking and spalling.	Moderate	Not discussed in report	ASME Sec XI IWE	Additional information on long term degradation needed. [2]	32, 37, 52 V1	195
Cracking and spalling.	Frequent	Not discussed in report	ASME Sec XI IWE	Additional information on long term degradation needed. [2]	32, 37, 52 V1	196
Loss of structural integrity.	Frequent	Not discussed in report	ASME Sec XI IWL	None	32, 39, 43, 45, 51 V1	197
Leakage of radioactive material.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	32, 39, 51 V1	198
Cracking and spalling. Exposure of reinforcing steel to corrosion.	Moderate	Not discussed in report	ASME Sec XI IWL	Additional information on long term degradation needed. [2]	42 45, 51 V1	199
Cracking and spalling. Exposure of reinforcing steel to corrosion.	Frequent	Not discussed in report	ASME Sec XI IWL	Additional information on long-term degradation needed. [2]	42-45, 51 V1	200
Loss of prestress.	Frequent	Not discussed in report	ASME Sec XI IWL	Monitoring system needed to detect degradation. [2]	45, 46, 50 V1	201
Loss of prestress.	Frequent	Not discussed in report	ASME Sec XI IWL	Monitoring system needed to detect degradation. [2]	45, 46, 50 V1	202
Loss of prestress.	Frequent	Not discussed in report	ASME Sec XI IWL	Monitoring system needed to detect degradation. [2]	45, 46, 50 V1	203
Leakage of radioactive material.	Frequent	10CFR50 Appendix J	ASME Sec XI IWL & 10CFR50 App. J	None	32, 39, 50 V1	204
Loss of structural integrity.	Frequent	Not discussed in report	ASME Sec XI IWL	None	43, 45, 50 V1	205
Cracking and spalling. Exposure of reinforcing steel to corrosion.	Moderate	Not discussed in report	ASME Sec XI IWL	Additional information on long-term degradation needed. [2]	42-45, 50 V1	206
Cracking and spalling. Exposure of reinforcing steel to corrosion.	Frequent	Not discussed in report	ASME Sec XI IWL	Additional information on long-term degradation needed. [2]	42-45, 50 V1	207
Low ductility fracture.	Moderate	Not discussed in report	ASME Sec XI IWB	Need additional data on effects of irradiation at temperatures less than 232 deg. C. Need additional data on spectra and flux levels at supports [4]	79-90, 93 V1	208
Low ductility fracture.	Frequent	Not discussed in report	ASME Sec XI IWB	Need additional data on effects of irradiation at temperatures less than 232 deg. C. Need additional data on spectra and flux levels at supports [4]	79 90, 93 V1	209
Low ductility fracture.	Frequent	Not discussed in report	ASME Sec XI IWB	Need additional data on effects of irradiation at temperatures less than 232 deg. C. Need additional data on spectra and flux levels at supports [4]	79-90, 93 V1	210
Binding that may cause excessive stresses in primary coolant system.	Frequent	Not discussed in report	ASME Sec XI IWB	None	92, 93 V1	211

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
212	BWR and PWR reactor pressure vesssel supports	PWR support systems	Dry lubricant in sliding foot assembly	Not identified	Not stated	EMBR/IR	Degradation of properties
213	BWR and PWR reactor pressure vesssel supports	PWR support systems	Skirt support	A516 Gr 60, A516 Gr 70, A302 Gr B, SA533 Gr B1	Babcock & Wilcox	FAT	Cumulative fatigue damage
214	BWR and PWR reactor pressure vesssel supports	BWR support system	Skirt support	A516 Gr 60, A516 Gr 70, A302 Gr B, SA533 Gr B1	General Electric	FAT	Cumulative fatigue damage
215	Emergency diesel generators	Fuel system	Piping on engine	Not identified	Not stated	FAT	Cumulative fatigue damage
216	Emergency diesel generators	Fuel system	Fuel injection pumps	Not identified	Not stated	CONTAM	Buildup of deposits from corrosion and wear
217	Emergency diesel generators	Fuel system	Fuel injectors	Not identified	Not stated	CONTAM	Buildup of deposits from corrosion and wear
218	Emergency diesel generators	Fuel system	Fuel nozzles	Not identified	Not stated	CONTAM	Buildup of deposits from corrosion and wear
219	Emergency diesel generators	Fuel system	Fuel supply pumps	Not identified	Not stated	FAT	Cumulative fatigue damage
220	Emergency diesel generators	Fuel system	Filters & strainers	Not identified	Not stated	CONTAM	Buildup of deposits from corrosion and wear
221	Emergency diesel generators	Starting system	Starting air valve	Not identified	Not stated	CONTAM	Buildup of deposits from corrosion and wear
222	Emergency diesel generators	Starting system	Actuators, controls	Not identified	Not stated	CORR	Corrosion deposits cause plugging and binding
223	Emergency diesel generators	Cooling system	Pumps	Not identified	Not stated	WEAR	Failure of seals or packing; wear of impellers and wearing rings
224	Emergency diesel generators	Cooling system	Pumps	Not identified	Not stated	ERO/CAV	Due to poor suction conditions (blocked filters, etc.)
225	Emergency diesel generators	Cooling system	Piping	Not identified	Not stated	VIB	Cumulative fatigue damage
226	Emergency diesel generators	Cooling system	Piping	Not identified	Not stated	ENVIR	Deterioration of gaskets and flex joints

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Degradation of the lubricant could cause binding that may cause excessive stresses in primary coolant system.	Frequent	Not discussed in report	ASME Sec XI IWB	Investigate irradiation effects on lubricants [2]	92, 93 V1	212
Crack initiation and growth.	Frequent	Not discussed in report	ASME Sec XI IWB	None	92, 93 V1	213
Crack initiation and growth.	Frequent	Not discussed in report	ASME Sec XI IWB	None	92, 93 V1	214
Occurs during start or run modes. Failure can lead to leakage and fire. Poor manufacturing or maintnenance errors.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	340, 342, 343, 344, 346, 347, 360 365 V2	215
Buildup causes binding of plunger. Affects start and run modes.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	336, 344, 349, 350, 360 365 V2	216
Buildup causes binding of plunger. Affects start and run modes.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	336, 344, 349, 350, 360 365 V2	217
Plugging of nozzle holes. Affects start and run modes.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	336, 344, 349, 350, 360-365 V2	218
Pump shaft or coupling fails. Fuel supply is then lost or reduced. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	336, 344, 349, 350, 360-365 V2	219
Clogging. Fuel supply is then lost or reduced. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	336, 344, 349, 350, 360-365 V2	220
Dirt and corrosion products can plug or bind valve. Affects start mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	336, 344, 349, 350, 360-365 V2	221
Plugging and binding from corrosion products. Affects start mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	336, 344, 349, 350, 360-365 V2	222
Leakage at seals. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	337, 338, 342, 347, 348, 350, 360-365 V2	223
Loss of pressure and flow. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	337, 338, 342, 347, 348, 350, 360-365 V2	224
Leakage. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	337, 338, 342, 347, 348, 350, 360-365 V2	225
Leakage. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	337, 338, 342, 347, 348, 350, 360-365 V2	226

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
227	Emergency diesel generators	Cooling system	Heat exchangers	Not identified	Not stated	CORR	Loss of material
228	Emergency diesel generators	Cooling system	Heat exchangers	Not identified	Not stated	ERO/CAV	Loss of material
229	Emergency diesel generators	Cooling system	Radiator	Not identified	Not stated	CORR	Loss of material
230	Emergency diesel generators	Engine structure	Crankcase and cylinder block	Cast iron, welded steel	Not stated	FAT/THER	Cumulative fatigue damage
231	Emergency diesel generators	Engine structure	Crankcase and cylinder block	Cast iron, welded steel	Not stated	FAT	Cumulative fatigue damage
232	Emergency diesel generators	Engine structure	Liners and seals	Cast iron	Not stated	WEAR	Loss of material
233	Emergency diesel generators	Engine structure	Main bearings	Not identified	Not stated	FAT	Cumulative fatigue damage
234	Emergency diesel generators	Engine structure	Cylinder heads	Nodular iron or cast steel	Not stated	FAT/THER	Cumulative fatigue damage
235	Emergency diesel generators	Engine structure	Bolting	Not identified	Not stated	VIB	Cumulative fatigue damage
236	Emergency diesel generators	Intake and exhaust system	Turbo charger	Not identified	Not stated	VIB	Cumulative fatigue damage
237	Emergency Diesel Generators	Lubrication system	Pumps	Not identified	Not stated	FAT	Cumulative fatigue damage
238	Emergency Diesel Generators	Lubrication system	Heat exchangers	Not identified	Not stated	CORR	Loss of material
239	Emergency Diesel Generators	Lubrication system	Lube oil	Not identified	Not stated	ENVIR	Deterioration by heat
240	Emergency Diesel Generators	Lubrication system	Lube oil	Not identified	Not stated	CONTAM	Leakage and wear particle contaminate lubricant
241	Emergency Diesel Generators	Lubrication system	Piping	Not identified	Not stated	VIB	Cumulative fatigue damage

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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	337, 338, 342, 347, 348, 360-365 V2	227
Leakage. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	337, 338, 342, 347, 348, 360-365 V2	228
Leakge or plugging. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	337, 338, 342, 347, 348, 360 365 V2	229
Cracking of block or crankage produces leakage into lube oil. Shaft and bearing failure. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	335, 342, 347, 348, 350, 360-365 V2	230
Cracking of block or crankage produces leakage into lube oil. Shaft and bearing failure. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 342, 347, 348, 350, 360-365 V2	231
Piston seizure. Leakage to lube oil. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 342, 347, 348, 350, 360-365 V2	232
Bearing failure. Damage to crankshaft. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 342, 347, 348, 350, 360-365 V2	233
Cracking/fracture. Water leakage leads to additional damage. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 342, 347, 348, 350, 360-365 V2	234
Fracture leading to other consequences. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	342, 347, 348, 360-365 V2	235
Fracture or bearing seizure; high speed rotating part critically dependent on proper lubrication of bearings.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	335, 336, 342, 348, 349, 360-365 V2	236
Cracking, fracture of drive shaft. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	335, 336, 360-365 V2	237
Leakage. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 336, 360-365 V2	238
Loss of lubrication effectiveness. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9 ,RG 1.108	None	335, 336, 360-365 V2	239
Loss of lubrication effectiveness. Affects run mode.	Frequent	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 336, 360-365 V2	240
Leakage. Loss of lubrication effectiveness. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	335, 336, 360-365 V2	241

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
242	Emergency Diesel Generators	Drive train	Pistons	Cast iron or steel	Not stated	FAT	Cumulative fatigue damage
243	Emergency diesel generators	Drive train	Piston rings	Not identified	Not stated	WEAR	Loss of material, seizure
244	Emergency diesel generators	Drive train	Connecting rods	Forged steel	Not stated	FAT	Cumulative fatigue damage
245	Emergency diesel generators	Drive train	Crankshaft	Not identified	Not stated	FAT	Cumulative fatigue damage

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Service Water System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition
2	Service Water System	Check Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
3	Service Water System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition
4	Service Water System	Check Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
5	Service Water System	Check Valves	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
6	Service Water System	Check Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
7	Service Water System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition
8	Service Water System	Check Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
9	Service Water System	Check Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
10	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
11	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	CORR	Loss of Material

Document: NUREG/CR-4731 Vols. 1&2, Residual Life Assessment of Major Light Water Reactor Components Overview
Reviewed by: W. J. Shack, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Piston seizure. Affects start and run modes.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	Based on experience in other industries diesel generator sets with good maintenance have high reliability. Nuclear fast start test requirements degrade equipment and need for such tests should be analyzed and kept to a minimum [4]	333, 335, 346, 347, 360-365 V2	242
Piston seizure. Affects start and run modes.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	333, 335, 346, 347, 360-365 V2	243
Piston seizure. Affects run mode.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	333, 335, 346, 347, 360-365 V2	244
Failure of crankshaft. Crankcase explosion.	Moderate	NRC and EPRI programs on diesel reliability	PS TS Req., RG 1.9, RG 1.108	None	333, 335, 346, 347, 360-365 V2	245

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
External Leakage - The most common case is flange leakage.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F 8	1
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F 8	2
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-8	3
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-8	4
Internal Leakage - (Reverse Leakage) - Reverse leakage is a failure mode to describe internal leakage through a check valve.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-9	5
Internal Leakage - (Reverse Leakage) - Reverse leakage is a failure mode to describe internal leakage through a check valve.	Occasional	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-9	6
Internal Leakage - (Reverse Leakage) - Reverse leakage is a failure mode to describe internal leakage through a check valve.	Frequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-9	7
Internal Leakage - (Reverse Leakage) - Reverse leakage is a failure mode to describe internal leakage through a check valve.	Moderate	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-9	8
Internal Leakage - (Reverse Leakage) - Reverse leakage is a failure mode to describe internal leakage through a check valve.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-9	9
External Leakage - The most common case is a flange leakage.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-10	10
External Leakage - The most common case is a flange leakage.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-10	11

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
12	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
13	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
14	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
15	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
16	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
17	Service Water System	Hand Control Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
18	Service Water System	Motor Operated Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
19	Service Water System	Motor Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
20	Service Water System	Motor Operated Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
21	Service Water System	Motor Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
22	Service Water System	Motor Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
23	Service Water System	Motor-Operated Valves	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
24	Service Water System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
25	Service Water System	Motor-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
26	Service Water System	Motor-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
27	Service Water System	Motor-Operated Valves	Not stated	Not stated	Not stated	DRIFT	Signal Drift
28	Service Water System	Motor Operated Valve	Not stated	Not stated	Not stated	ERO	Wall Thinning

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-10	12
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-10	13
Fails to Close - Valve fails to close fully when demanded.	Moderate	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-10	14
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-10	15
Failure to Operate as Required - (a) A valve fails to meet specific requirements such as a stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-11	16
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-12	17
Fails to Close - Valve fails to close fully when demanded.	Occasional	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-13	18
Fails to Close - Valve fails to close fully when demanded.	Moderate	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-13	19
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-13	20
Fails to Close - Valve fails to close fully when demanded.	Frequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-13	21
Fails to Close - Valve fails to close fully when demanded.	Frequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-13	22
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-14	23
Fails to Open - Valve fails to open fully when demanded.	Occasional	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-14	24
Fails to Open - Valve fails to open fully when demanded.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-14	25
Fails to Open.	Rare	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-14	26
Fails to Open.	Rare	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-14	27
Failure to Operate as Required (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	28

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
29	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	WEAR	Attrition
30	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	CORR	Loss of Material
31	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	ADH	Loss of Movement
32	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	VIBR	Loosening
33	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	WEAR	Attrition
34	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	CORR	Loss of Material
35	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	WEAR	Attrition
36	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	ADH	Loss of Movement
37	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	ELE-TEMP	Physical Degradation
38	Service Water System	Motor-Operated Valve	Not stated	Not stated	Not stated	VIBR	Loosening
39	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
40	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
41	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
42	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
43	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	VIBR	Loosening
44	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	FAT	Fatigue Cumulative Damage
45	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to Operate as Required (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Occasional	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	29
Failure to Operate as Required (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	30
Failure to Operate as Required (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	31
Failure to Operate as Required (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	32
External leakage - The most common case is a flange leak.	Frequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	33
External leakage - The most common case is a flange leak.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-15	34
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Infrequent	Not stated	GL 89-10 & Suppl. ASME Sec XI IWV & PS TS Req	Not stated	F-16	35
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-16	36
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	GL 89-10 & Suppl. ASME Sec XI-IWV & PS TS Req	Not stated	F-16	37
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-16	38
External Leakage - The most common cases is a flange leak.	Frequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-17	39
Fails to Close - Valve fails to close fully when demanded.	Frequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-17	40
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-17	41
Fails to Close - Valve fails to close fully when demanded.	Moderate	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-17	42
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-17	43
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	44
Fails to Open - Valve fails to open fully when demanded.	Occasional	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	45

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
46	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
47	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	EMBR	Loss of Fracture Toughness
48	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
49	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
50	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	DRIFT	Set Point Drift
51	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	VIBR	Loosening
52	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
53	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
54	Service Water System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	VIBR	Loosening
55	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	EMBR	Loss of Fracture Toughness
56	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
57	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
58	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage
59	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	VIBR	Loosening

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Open - Valve fails to open fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	46
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	47
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Frequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	48
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	49
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	50
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Infrequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-18	51
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-19	52
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-19	53
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Infrequent	Not stated	ASME Sec XI IWV & PS TS Req. and/or PS S&T Re	Not stated	F-19	54
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	55
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	56
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Frequent	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	57
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Moderate	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	58
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Infrequent	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	59

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
60	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Inadequate Maintenance Causes Accelerated Aging
61	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Inadequate Operational Procedures Causes Accelerated Aging
62	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Construction Errors Cause Accelerated Aging
63	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Construction Inadequacy Causes Accelerated Aging
64	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	BIO	Buildup of Organisms
65	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	ERO	Wall Thinning
66	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
67	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	CORR	Loss of Material
68	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	ADH	Movement Loss
69	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage
70	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Improper Lubrication Causes Accelerated Aging
71	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Insulation Breakdown Causes Abnormal Resistance
72	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Open Circuit Causes Abnormal Resistance

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	60
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-19	61
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	62
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	63
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	64
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Infrequent	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	65
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Frequent	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	66
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Moderate	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	67
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	68
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Frequent	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	69
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Occasional	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	70
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Infrequent	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	71
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	72

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
73	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	VIBR	Loosening
74	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Inadequate Maintenance Causes Accelerated Aging
75	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
76	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
77	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage
78	Service Water System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Current Over/Under Causes Degradation of Equipment
79	Service Water System	Strainers	Not stated	Not stated	Not stated	WEAR	Attrition
80	Service Water System	Strainers	Not stated	Not stated	Not stated	CORR	Loss of Material
81	Service Water System	Strainers	Not stated	Not stated	Not stated	BIO	Buildup or Organisms
82	Service Water System	Strainers	Not stated	Not stated	Not stated	CLOG	Flow Blockage
83	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Design Inadequacy Causes Accelerated Aging
84	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	WEAR	Attrition
85	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
86	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
87	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	EMBR	Loss of Fracture Toughness

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Occasional	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	73
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-21	74
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-22	75
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-22	76
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-22	77
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP & PS TS Req. and/or PS S&T Re	Not stated	F-22	78
Loss of Function - Inability to perform its intended function.	Frequent	Not stated	PS TS Req & PS S&T Req.	Not stated	F-23	79
Loss of Function - Inability to perform its intended function.	Occasional	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-23	80
Plugged - Plugging of Strainers	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-23	81
Plugged - Plugging of Strainers	Moderate	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-23	82
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach rated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-33	83
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach rated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-33	84
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach rated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-33	85
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach rated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Rare	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-33	86
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	87

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
88	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
89	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	WEAR	Attrition
90	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	ADH	Loss of Movement
91	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
92	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Mechanical Overload Causes Degradation of Equipment
93	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	DRIFT	Set Point Drift
94	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
95	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Short Circuit Causes Abnormal Resistance
96	Service Water System	Diesel Generator	Not stated	Not stated	Not stated	VIBR	Loosening

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
2	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-4747, Vol. 1, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Rare	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	88
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Frequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	89
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Rare	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	90
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	91
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	92
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Moderate	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	93
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	94
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	95
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Rare	Not stated	PS TS Req., RG 1.9,& RG 1.108	Not stated	F-34	96

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
External Leakage - The most common case is a flange leak.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-18	1
External Leakage - The most common case is a flange leak.	Frequent	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-18	2

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	VIBR	Loosening
4	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	Not stated	Improper Maintenance Causes Accelerated Aging
5	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
6	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
7	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
8	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	VIBR	Loosening
9	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
10	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
11	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition
12	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
13	Auxiliary Feedwater System	Check Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
14	Auxiliary Feedwater System	AC Circuit Breakers	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
15	Auxiliary Feedwater System	AC Circuit Breakers	Not stated	Not stated	Not stated	WEAR	Attrition
16	Auxiliary Feedwater System	AC Circuit Breakers	Not stated	Not stated	Not stated	VIBR	Loosening
17	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	CLOG	Flow Blockage
18	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
19	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Loss of Function Due to Faulty Electrical Module

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
External Leakage - The most common case is a flange leak.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-18	3
External Leakage - The most common case is a flange leak.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-18	4
Fails to Open - Valve fails to open fully when demanded.	Infrequent	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-18	5
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-18	6
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Moderate	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	7
Failure to Operate as Required - (a) a valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	8
Internal Leakage (Reverse Leakage) - Reverse leakage is a failure mode used to describe internal leakage through a check valve.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	9
Internal Leakage (Reverse Leakage) - Reverse leakage is a failure mode used to describe internal leakage through a check valve.	Occasional	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	10
Internal Leakage (Reverse Leakage) - Reverse leakage is a failure mode used to describe internal leakage through a check valve.	Frequent	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	11
Internal Leakage (Reverse Leakage) - Reverse leakage is a failure mode used to describe internal leakage through a check valve.	Infrequent	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	12
Internal Leakage (Reverse Leakage) - Reverse leakage is a failure mode used to describe internal leakage through a check valve.	Occasional	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-19	13
Fails to Close.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Not stated	F-20	14
Failure to Operate - The circuit breaker does not function properly, either fails to open or fails to close on demand.	Occasional	Not stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Not stated	F-20	15
Failure to Operate - The circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	Not stated	F-20	16
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	17
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	18
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	19

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
20	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Set Point Drift Causes Loss of Function
21	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Electrical Failure Causes Loss of Function
22	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
23	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Electrical Contact Failure Causes Loss of Function
24	Auxiliary Feedwater System	Flow Control Recorders	Not stated	Not stated	Not stated	WEAR	Attrition
25	Auxiliary Feedwater System	Flow Control Recorders	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
26	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
27	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	Not stated	Set Point Drift Causes Loss of Performance
28	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
29	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
30	Auxiliary Feedwater System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
31	Auxiliary Feedwater System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
32	Auxiliary Feedwater System	Hand Control Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
33	Auxiliary Feedwater System	Hand Control Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
34	Auxiliary Feedwater System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
35	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
36	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	20
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	21
Failure to Operate.	Infrequent	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	22
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-21	23
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Infrequent	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-22	24
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Occasional	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-22	25
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-23	26
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Infrequent	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-23	27
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-23	28
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR50.49 otherwise PS TS Req.	Not stated	F-23	29
Failure to Operate.	Frequent	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-23	30
External Leakage - The most common case is a flange leak.	Occasional	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-24	31
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-24	32
Failure to Operate as Required.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-25	33
Internal Leakage.	Rare	Not stated	ASME Sec XI IWB or IWV, PS TS Req. & PS S&T R	Not stated	F-25	34
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-26	35
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Infrequent	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-26	36

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
37	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
38	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	WEAR	Attrition
39	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
40	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	Not stated	End of Life Electrical Failure
41	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
42	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
43	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
44	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	Not stated	Faulty Component Causes Loss of Performance
45	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
46	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
47	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	Attrition	Buildup of Deposits
48	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage
49	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	Not stated	Poor Maintenance Causes Acceler ated Aging
50	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
51	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
52	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-27	37
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-27	38
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-27	39
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-27	40
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-28	41
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Occasional	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-28	42
Failure to Operate.	Occasional	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-28	43
Failure to Operate.	Rare	Not stated	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	F-28	44
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Occasional	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-29	45
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-29	46
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-29	47
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-29	48
Fails to Start - Pumps did not start upon demand or which started and only operated for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-29	49
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-30	50
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Frequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-30	51
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-30	52

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
53	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	Not stated	Set Point Drift Loss of Function
54	Auxiliary Feedwater System	Motor Driven Pumps	Not stated	Not stated	Not stated	Not stated	Improper Lubrication Causes Accelerated Aging
55	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
56	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
57	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
58	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
59	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
60	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
61	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	Not stated	Improper Lubrication Causes Accelerated Aging
62	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
63	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
64	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
65	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
66	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
67	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
68	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-30	53
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-30	54
External Leakage - The most common cause is flange leak.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-30	55
Fails to Close - Valve fails to close fully when demanded.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-31	56
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-31	57
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-31	58
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-31	59
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-31	60
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-31	61
Fails to Open - Valve Fails to open fully when demanded.	Moderate	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-32	62
Failure to Operate as required - (a) valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-32	63
Failure to Operate as required - (a) valve fails to meet specific requirements such as stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-32	64
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-33	65
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-33	66
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-33	67
Erroneous/Erratic Signals.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-33	68

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
69	Auxiliary Fedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
70	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
71	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
72	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
73	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
74	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
75	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
76	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	Not stated	Human Error Causes Accelerated Aging
77	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
78	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
79	Auxiliary Fedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
80	Auxiliary Feedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
81	Auxiliary Feedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	Not stated	Water Intrusion Causes Accelerated Aging
82	Auxiliary Feedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
83	Auxiliary Feedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	Not stated	Improper Lubrication Causes Accelerated Aging
84	Auxiliary Feedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
85	Auxiliary Feedwater System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Erroneous/Erratic Signals.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-33	69
External Leakage.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	70
Fails to Close - Valve fails to close fully when demanded.	Moderate	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	71
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	72
Fails to Close - Valve fails to close fully when demanded.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	73
Fails to Close - Valve fails to close fully when demanded.	Moderate	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	74
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	75
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-35	76
Fails to Open - Valve fails to open fully when demanded.	Occasional	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	77
Fails to Open - Valve fails to open fully when demanded.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	78
Fails to Open - Valve fails to open fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	79
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	80
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	81
Failure to Operate as Required - (a) A valve fails to meet specific requirements such as a stroke time or (b) a valve loses the ability to control system parameters.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	82
Failure to Operate as Required - (a) A valve fails to meet specific requirements such as a stroke time or (b) a valve loses the ability to control system parameters.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	83
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	84
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-36	85

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
86	Auxiliary Feedwater System	Pressure Switches	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
87	Auxiliary Feedwater System	Pressure Switches	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
88	Auxiliary Feedwater System	Pressure Switches	Not stated	Not stated	Not stated	WEAR	Attrition
89	Auxiliary Feedwater System	Pressure Switches	Not stated	Not stated	Not stated	CORR	Loss of Material
90	Auxiliary Feedwater System	Pressure Switches	Not stated	Not stated	Not stated	Not stated	Electrical Arcing Causes Loss of Function
91	Auxiliary Feedwater System	Pressure Transmitter	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
92	Auxiliary Feedwater System	Pressure Transmitter	Not stated	Not stated	Not stated	WEAR	Attrition
93	Auxiliary Feedwater System	Pressure Transmitter	Not stated	Not stated	Not stated	Not stated	Electrical Open Circuit Causes Abnormal Resistance
94	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	WEAR	Attrition
95	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	Not stated	Set Point Drift Causes Loss of Function
96	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	Not stated	End of Life Electrical Failure Causes Accelerated Aging
97	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	WEAR	Attrition
98	Auxiliary Feedwater System	Relief Valves	Not stated	Not stated	Not stated	WEAR	Attrition
99	Auxiliary Feedwater System	Relief Valves	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
100	Auxiliary Feedwater System	Relief Valves	Not stated	Not stated	Not stated	Not stated	Set Point Drift Causes Loss of Function
101	Auxiliary Feedwater System	Snubbers	Not stated	Not stated	Not stated	WEAR	Attrition
102	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	WEAR	Attrition
103	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
104	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	WEAR	Attrition
105	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	CLOG	Flow Blockage

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-38	86
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Moderate	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-38	87
Failure to Operate.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-38	88
Failure to Operate.	Infrequent	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-38	89
Failure to Operate.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-38	90
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Occasional	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-39	91
Failure to Operate.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-39	92
Failure to Operate.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-39	93
Fails to Open - Failure of a normally closed relay to open upon demand.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-40	94
Fails to Open - Failure of a normally closed relay to open upon demand.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-40	95
Failure to Operate.	Rare	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-40	96
Failure to Operate.	Infrequent	Not stated	PS TS Req, & PS S&T Req.	Not stated	F-40	97
Fails to Open - Failure of the relay to operate due to lack of an input signal.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-40	98
Fails to Open - Failure of the relay to operate due to lack of an input signal.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-42	99
Premature Open - A typical example is the relief valve opening prior to its pressure setting.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-42	100
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Frequent	Not stated	ASME Sec XI ISTD	Not stated	F-45	101
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	102
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	103
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	104
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	105

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
106	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	CORR	Loss of Material
107	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	ADH	Loss of Movement
108	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	CLOG	Flow Blockage
109	Auxiliary Feedwater System	Turbine-Driven Pump	Not stated	Not stated	Not stated	VIBR	Loosening
110	Auxiliary Feedwater System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
111	Auxiliary Feedwater System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
112	Auxiliary Feedwater System	Motor-Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage
113	Auxiliary Feedwater System	Motor-Driven Pumps	Not stated	Not stated	Not stated	VIBR	Loosening
114	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
115	Auxiliary Feedwater System	Motor-Operated Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
116	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Design Error Causes Accelerated Aging
117	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	WEAR	Attrition
118	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
119	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	DRIFT	Set Point Drift Causes Loss of Performance

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	106
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	107
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	108
Fails to Start - Pumps did not start upon demand or which started and only opened for a brief period of time before tripping off-line.	Occasional	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-45	109
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Frequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-51	110
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Frequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-51	111
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-51	112
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-51	113
External Leakage - The most common case is a flange leak.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-53	114
External Leakage - The most common case is a flange leak.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-53	115
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach stated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-59	116
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach stated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-59	117
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach stated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-59	118
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach stated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Rare	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-59	119

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
120	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Loss of Performance due to Faulty Electrical Module
121	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Electrical Short Circuit Causes Abnormal Resistance
122	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	EMBR	Loss of Fracture Toughness
123	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
124	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	WEAR	Attrition
125	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	ADH	Loss of Movement
126	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
127	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Improper Lubrication Causes Acceleration of Aging
128	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	DRIFT	Set Point Drift Causes Loss of Performance
129	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Loss of Performance due to Faulty Electrical Module
130	Auxiliary Feedwater System	Diesel Generator	Not stated	Not stated	Not stated	VIBR	Loosening
131	High Pressure Safety Injection System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach stated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Rare	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-59	120
Fails to Start - Fails to start encompasses diesel generator failures that resulted from the diesel failing to start, failing to reach stated speed and voltage once a start sequence was initiated, and failing to achieve expected loading (kW).	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-59	121
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	122
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Rare	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	123
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Frequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	124
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Rare	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	125
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	126
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	127
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Occasional	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	128
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Infrequent	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	129
Fails to Run - Failure to run is any failure of an operating diesel generator to supply power to the emergency bus, given that the diesel generator had undergone a successful start. It also includes the spurious stopping of the diesel generator.	Rare	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	F-60	130
External Leakage - The most common case is a flange leak.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-63	131

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
132	High Pressure Safety Injection System	Check Valves	Not stated	Not stated	Not stated	CONTAM	Buildup of Deposits
133	High Pressure Safety Injection System	Check Valves	Not stated	Not stated	Not stated	WEAR	Attrition
134	High Pressure Safety Injection System	Check Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
135	High Pressure Safety Injection System	Check Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
136	High Pressure Safety Injection System	Flow Transmitters	Not stated	Not stated	Not stated	Not stated	Materials Defect Causes Accelerated Aging
137	High Pressure Safety Injection System	Flow Transmitters	Not stated	Not stated	Not stated	Not stated	Out of Calibration Causes Loss of Performance
138	High Pressure Safety Injection System	Flow Transmitters	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
139	High Pressure Safety Injection System	Flow Transmitters	Not stated	Not stated	Not stated	WEAR	Attrition
140	High Pressure Safety Injection System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
141	High Pressure Safety Injection System	Hand Control Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
142	High Pressure Safety Injection System	Hand Control Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
143	High Pressure Safety Injection System	Hand Control Valves	Not stated	Not stated	Not stated	Not stated	Improper Lubrication Causes Accelerated Aging
144	High Pressure Safety Injection System	Hand Control Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
145	High Pressure Safety Injection System	Hand Control Valves	Not stated	Not stated	Not stated	WEAR	Attrition
146	High Pressure Safety Injection System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
147	High Pressure Safety Injection System	Motor-Driven Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
148	High Pressure Safety Injection System	Motor-Driven Pumps	Not stated	Not stated	Not stated	CLOG	Flow Blockage

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Internal Leakage - (reverse leakage) - Reverse leakage is a failure mode used to describe internal leakage though a check valve.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-62	132
Internal Leakage - (reverse leakage) - Reverse leakage is a failure mode used to describe internal leakage though a check valve.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-62	133
Internal Leakage - (reverse leakage) - Reverse leakage is a failure mode used to describe internal leakage though a check valve.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-62	134
Internal Leakage - (reverse leakage) - Reverse leakage is a failure mode used to describe internal leakage though a check valve.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-62	135
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Rare	Not stated	PS S&T Req.	Not stated	F-67	136
Erroneous/Erratic Signals - Erroneous or erratic signals are produced by the instrument.	Occasional	Not stated	PS S&T Req.	Not stated	F-67	137
Failure to Operate.	Rare	Not stated	PS S&T Req.	Not stated	F-67	138
Failure to Operate.	Infrequent	Not stated	PS S&T Req.	Not stated	F-67	139
External Leakage - The most common case is a flange leak.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-68	140
External Leakage - The most common case is a flange leak.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-68	141
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-69	142
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-69	143
Failure to Operate as Required.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-69	144
Failure to Operate as Required.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-69	145
External Leakage - The leakage failure mode describes a fault in which the pump is operational, but is removed from service because of excessive leakage of the pumped medium. A common example of this mode is a packing leak.	Infrequent	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-74	146
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Occasional	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-75	147
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-75	148

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
149	High Pressure Safety Injection System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Poor Maintenance Causes Accelerated Aging
150	High Pressure Safety Injection System	Motor-Driven Pumps	Not stated	Not stated	Not stated	Not stated	Failure to Follow Procedures Causes Accelerated Aging
151	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
152	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
153	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
154	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
155	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	FAT	Cumulative Fracture Damage
156	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
157	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
158	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
159	High Pressure Safety Injection System	Motor-Operated Valves	Not stated	Not stated	Not stated	VIBR	Loosening
160	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
161	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CORR	Loss of Material
162	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	ADH	Loss of Movement
163	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	CLOG	Flow Blockage
164	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-75	149
Fails to Run - An operating pump was automatically or manually tripped off-line to prevent damage to the pump. It also includes pumps that fail to run to specifications.	Rare	Not stated	ASME Sec XI IWP, PS TS Req & PS S&T Req.	Not stated	F-75	150
External Leakage - The most common case if a flange leak.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-76	151
Fails to Close - Valve fails to close fully when demanded.	Occasional	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-76	152
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-76	153
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-76	154
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-77	155
Fails to Open - Valve fails to open fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-77	156
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-77	157
Fails to Operate as Required - (a) a valve fails to meet specific requirements such as a stroke time or (b) a valve loses the ability to control system parameters.	Occasional	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-77	158
Fails to Operate as Required - (a) a valve fails to meet specific requirements such as a stroke time or (b) a valve loses the ability to control system parameters.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, GL 89-10 & Suppl.	Not stated	F-77	159
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-78	160
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-78	161
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-78	162
Fails to Open/Fails to Close - This failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Occasional	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-78	163
External Leakage - The most common case is a flange leak.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-79	164

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
165	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	WEAR	Attrition
166	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	Not stated	Coil Burnout Failure
167	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	ERO	Wall Thinning
168	High Pressure Safety Injection System	Pneumatic-Operated Valves	Not stated	Not stated	Not stated	FAT	Cumulative Fatigue Damage
169	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	WEAR	Attrition
170	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	CORR	Loss of Material
171	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	CLOG	Flow Blockage
172	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	CLOG	Flow Blockage
173	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	Not stated	Set Point Drift Causes Loss of Performance
174	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	Not stated	Set Point Drift Causes Loss of Performance
175	High Pressure Safety Injection System	Relief Valve	Not stated	Not stated	Not stated	Not stated	Poor Maintenance Causes Accelerated Aging
176	High Pressure Safety Injection System	Snubbers	Not stated	Not stated	Not stated	WEAR	Attrition
177	High Pressure Safety Injection System	Snubbers	Not stated	Not stated	Not stated	ELE-TEMP	Material Degradation
178	High Pressure Safety Injection System	Snubbers	Not stated	Not stated	Not stated	Not stated	Poor Maintenance Causes Accelerated Aging

Document: NUREG/CR-4769, Risk Evaluations of Aging Phenomena in Linear Aging Reliability Model and Its Extensions
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various reactor safety systems, including trip and safety features actuation systems, Class 1E electrical power distribution systems, service water system, and coolant injection systems.	Various, including piping, pipe supports, bistables/switches, indicators, recorders, conductors, relays, valves, controllers, circuit breakers, motors, pumps, valve operators, and heat exchangers.	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-4747, Vol. 2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to Close - Valve fails to close fully when demanded.	Occasional	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-79	165
Fails to Open - Valve fails to open fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-80	166
Internal Leakage.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-80	167
Fails to Open/Fails to Close - this failure mode is used when the narrative lacks specific information on whether the valve failed to open or failed to close.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-81	168
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-83	169
Fails to Close - Valve fails to close fully when demanded.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-83	170
Fails to Close - Valve fails to close fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-83	171
Fails to Open - Valve fails to open fully when demanded.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-83	172
Fails to Open - Valve fails to open fully when demanded.	Frequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-83	173
Premature Open - A typical example is the relief valve opening prior to its pressure setting.	Infrequent	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-84	174
Premature Open - A typical example is the relief valve opening prior to its pressure setting.	Rare	Not stated	ASME Sec XI IWV, PS TS Req, & PS S&T Req.	Not stated	F-84	175
Loss of Function.	Infrequent	Not stated	ASME Sec XI ISTD	Not stated	F-85	176
Loss of Function.	Frequent	Not stated	ASME Sec XI ISTD	Not stated	F-85	177
Loss of Function.	Infrequent	Not stated	ASME Sec XI ISTD	Not stated	F-85	178

Document: NUREG/CR-4769, Risk Evaluations of Aging Phenomena in Linear Aging Reliability Model and Its Extensions
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Table A.1 Gall Report for NPAR Reports

Document: NUREG/CR-4769, Risk Evaluations of Aging Phenomena in Linear Aging Reliability Model and Its Extensions
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects

Document: NUREG/CR-4967, Nuclear Plant Aging Research on High Pressure Injection Systems
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR high pressure injection system	Piping	Thermal sleeves and nozzles	Not stated	Not stated	FAT/THERM	Cumulative fatigue damage
2	PWR high pressure injection system	Piping	Elbows	Not stated	Not stated	FAT/THERM	Cumulative fatigue damage
3	PWR high pressure injection system	Piping	Pipe	Stainless steel	Not stated	FAT	Cumulative fatigue damage
4	PWR high pressure injection system	Piping	Pipe	Stainless steel	Not stated	CORR/SCC	Crack initiation and growth
5	PWR high pressure injection system	Piping	Pipe welds and flanges	Not stated	Not stated	VIBR	Crack initiation and growth, loosening
6	PWR high pressure injection system	Piping	Pipe welds	Type 304 SS	Not stated	CORR/SCC	Crack initiation and growth
7	PWR high pressure injection system	Piping	Nozzles, safe ends, and threaded fasteners	Ferritic (carbon) steel	Not stated	CORR	Crack initiation and growth
8	PWR high pressure injection system	Valves	Stem, packing, and body	Not stated	Not stated	CLOG	Blockage of flow passages
9	PWR high pressure injection system	Valves	Packing, seat, and disk	Not stated	Not stated	WEAR	Attrition
10	PWR high pressure injection system	Valves	Packing, seat, and disk	Not stated	Not stated	CONTAM	Buildup of deposits
11	PWR high pressure injection system	Pumps	Impeller blades	Types 304 and 316 SS	Not stated	CORR/MIC	Loss of material; corrosion product buildup
12	PWR high pressure injection system	Instrumentation and controls	Switches and relays	Not stated	Not stated	WEAR	Attrition
13	PWR high pressure injection system	Instrumentation and controls	Contacts	Not stated	Not stated	CORR	Corrosion product buildup
14	PWR high pressure injection system	Instrumentation and controls	Insulation	Not stated	Not stated	FAT/THERM	Cumulative fatigue damage

Document: NUREG/CR-4977, Vol. 1, SHAG Test Series: Seismic Research on an Aged United States Gate Valve and on a Piping System in the Decommission
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Motor Operated Gate Valve	Torque Switch Helical Spring (SMA Type)	Not stated	Limitorque Corp.	RATCH	Change in dimension

Document: NUREG/CR-4769, Risk Evaluations of Aging Phenomena in Linear Aging Reliability Model and Its Extensions
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item

Document: NUREG/CR-4967, Nuclear Plant Aging Research on High Pressure Injection Systems
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High-pressure injection/makeup nozzles have developed through-wall cracks due to thermal fatigue. All cracks were associated with loose thermal sleeves.	Not stated	Not discussed in report	ASME Sec III & Sec XI IWB	Not stated	29, 30, 33, 36, 53	1
Elbows in the safety injection piping between the cold leg and the first check valve have developed through-wall cracks.	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	33	2
Cracks or through-wall leakage.	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	30, 36	3
Cracking was discovered in some safety system pipes containing borated water, but no losses due to this problem were reported.	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	30	4
Cracks have occurred due to vibration and dynamic loading (water hammer).	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	30	5
Cracks occur in the weld heat affected zone.	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	30, 53, H-3	6
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB	Not stated	53, H-3	7
MOVs and check valves have failed to operate due to boron crystallization on the valve stems and in the valve packing and body. Boric acid crystals have caused blockage, resulting in malfunction of an HPI pump in one instance.	Not stated	Not discussed in report	ASME Sec XI IWV	Not stated	30, 33, 53, H-3	8
Leakage, fail to operate, and blockage.	Not stated	Not discussed in report	ASME Sec XI IWV	Not stated	30, 36	9
Leakage, fail to operate, and blockage.	Not stated	Not discussed in report	ASME Sec XI IWV	Not stated	30, 36	10
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWP	Not stated	30, 33	11
Not stated.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	33	12
Not stated.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	33	13
Not stated.	Not stated	Not discussed in report	If Class 1E 10CFR 50.49 otherwise PS TS Req.	Not stated	33	14

Document: NUREG/CR-4977, Vol. 1, SHAG Test Series: Seismic Research on an Aged United States Gate Valve and on a Piping System in the Decommissioned
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Motor operator torque switch spring had a permanent deformation after 25 years of service (0.47 in. shorter than original length of 4.46 in.) due to yielding and ratcheting effects so that the motor operator was unable to properly close (More)	Moderate	Not discussed in report	ASME Sec XI IWV, Req, GL 89-10 & Suppl., & PS	Not stated	34-37, 41	1

Document: NUREG/CR-4977, Vol. 2, SHAG Test Series: Seismic Research on an Aged United States Gate Valve and on a Piping System in the Decommission
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Piping	Motor-Operated Gate Valve	Torque Switch Helical Spring of SMA Type Limitorque Motor Operator	Not Stated	Limitorque Corp.	RATCH	Change in Dimension

Document: NUREG/CR-4985, Indian Point 2 Reactor Coolant Pump Seal Evaluations
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Reactor coolant pump	First stage seal (hydrostatic filmridng face seal)	Aluminum-oxide face plates, O-ring polymers	Westinghouse	WEAR	Attrition
2	Cooling system	Reactor coolant pump	Second stage seal (rubbing face seal)	Carbon graphite-stator and chrome carbide coated-runner, O-ring polymers	Westinghouse	WEAR	Attrition
3	Cooling system	Reactor coolant pump	Third stage seal (rubbing face seal)	Carbon graphite stator and chrome carbide coated-runner, O-ring polymers	Westinghouse	WEAR	Attrition

Document: NUREG/CR-5052, Operating Experience and Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Component cooling water systems in PWRs	Valves (motor and air operated, manual, check and relief)	Operator	Not stated	Not stated	Not stated	Not stated
2	Component cooling water systems in PWRs	Valves (motor and air operated, manual, check and relief)	Seat	Not stated	Not stated	WEAR	Attrition
3	Component cooling water systems in PWRs	Valves (motor and air operated, manual, check and relief)	Seat	Not stated	Not stated	VIBR	Crack initiation and growth
4	Component cooling water systems in PWRs	Valves (motor and air operated, manual, check and relief)	Seat	Not stated	Not stated	CONTAM	Buildup of deposits
5	Component cooling water systems in PWRs	Pumps (centrifugal)	Seals	Not stated	Not stated	WEAR	Attrition
6	Component cooling water systems in PWRs	Pumps (centrifugal)	Seals	Not stated	Not stated	VIBR	Crack initiation and growth

Document: NUREG/CR-4977, Vol. 2, SHAG Test Series: Seismic Research on an Aged United States Gate Valve and on a Piping System in the Decommissioned
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The permanent deformation of the torque spring is caused by two effects: 1. The new spring had significant yielding 2. Full time compression may cause accelerated aging. (More)	Moderate	Not stated	ASME Sec XI IWV, Req, GL 89-10 & Suppl., & PS	Simple torque wrench handwheel may detect the permanent deformation of the torque spring. [4 MOV Program]	A.25-A.27, A.32	1

Document: NUREG/CR-4985, Indian Point 2 Reactor Coolant Pump Seal Evaluations
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Wear due to relative motion between rotating seal surfaces, which can be hastened or aggravated by crud in water, causes leakage. If wear becomes excessive, it can cause loss of significant quantities of primary coolant and difficulties on pump startup.	Frequent	Not discussed in report	10CFR50 App. B & PS S&T Req.	Not stated	S-1, 1-1, 1-6, 2-2, 2-4, 4-2,3, 4-23	1
Wear due to relative motion between rotating seal surfaces, which can be hastened or aggravated by crud in water, causes leakage. Newer seal designs and improved seal materials have reduced some of the problems.	Frequent	Not discussed in report	10CFR50 App. B & PS S&T Req.	Not stated	S-1, 1-1, 1-6, 2-2, 2-4, 4-4, 4-23	2
Wear due to relative motion between rotating seal surfaces, which can be hastened or aggravated by crud in water, causes leakage. Newer seal designs and improved seal materials have reduced some of the problems.	Frequent	Not discussed in report	10CFR50 App. B & PS S&T Req.	Not stated	S-1, 1-1, 1-6, 2-2, 2-4, 4-5, 4-23	3

Document: NUREG/CR-5052, Operating Experience and Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of valve operator causes failure of valve to open or close.	Moderate	Not discussed in report	ASME Sec XI IWB or IWC & IWV, Req, GL 89-10 &	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-5	1
Wear of seat causes valve leakage.	Frequent	Not discussed in report	ASME Sec XI IWB or IWC & IWV, Req, & PS S&T R	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-5	2
Cracking of seat causes valve leakage.	Moderate	Not discussed in report	ASME Sec XI IWB or IWC & IWV, Req, & PS S&T R	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-5	3
Foreign contaminants in cooling water and failure to seat and leakage.	Occasional	Not discussed in report	ASME Sec XI IWB or IWC & IWV, Req, & PS S&T R	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-5	4
Wear of seals causes coolant leakage.	Frequent	Not discussed in report	10CFR50 App. B & PS S&T Req.	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-7	5
Cracking of seals causes leakage.	Occasional	Not discussed in report	10CFR50 App. B & PS S&T Req.	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-7	6

Document: NUREG/CR-5052, Operating Experience and Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	Component cooling water systems in PWRs	Pumps (centrifugal)	Bearings	Not stated	Not stated	WEAR	Attrition
8	Component cooling water systems in PWRs	Pumps (centrifugal)	Bearings	Not stated	Not stated	VIBR	Crack initiation and growth
9	Component cooling water systems in PWRs	Heat exchangers (Shell-U-tube)	Tube	Not stated	Not stated	CORR	Loss of material
10	Component cooling water systems in PWRs	Heat exchangers (Shell-U-tube)	Tube	Not stated	Not stated	ERO	Loss of material
11	Component cooling water systems in PWRs	Heat exchangers (Shell-U-tube)	Shell	Not stated	Not stated	CORR	Loss of material
12	Component cooling water systems in PWRs	Heat exchangers (Shell-U-tube)	Shell	Not stated	Not stated	ERO	Loss of material
13	Component cooling water systems in PWRs	Heat exchangers (Shell-U-tube)	Tubesheet	Not stated	Not stated	CORR	Loss of material
14	Component cooling water systems in PWRs	Heat exchangers (Shell-U-tube)	Tubesheet	Not stated	Not stated	ERO	Loss of material
15	Component cooling water systems in PWRs	Piping components	Not delineated	Not stated	Not stated	CORR	Loss of material
16	Component cooling water systems in PWRs	Piping components	Not delineated	Not stated	Not stated	ERO	Loss of material

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Diesel generator	Instruments and controls	Governor	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening

Document: NUREG/CR-5052, Operating Experience and Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Bearing wear can cause excessive rotor vibration and vane damage, resulting in complete failure of pump.	Moderate	Not discussed in report	ASME Sec XI IWB or IWC & IWP, PS TS Req & PS	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-7	7
Hydraulic induced dynamic forces can cause bearing vibration and cracking, resulting in seizure of shaft.	Occasional	Not discussed in report	ASME Sec XI IWB or IWC & IWP, PS TS Req & PS	Not stated	1-2, 1-3, 1-4, 1-5, 2-1, 4-15, 4-18, 4-20, 4-34, 8-3, 8-7	8
Corrosion causes holes in tubes and contamination of coolants and reduced heat transfer.	Frequent	Not discussed in report	PS TS Req. & PS S&T Req.	Heat exchanger aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 2-1, 4-18, 4-20, 4-34, 8-6, 8-3	9
Corrosion causes holes in tubes and contamination of coolants and reduced heat transfer.	Occasional	Not discussed in report	PS TS Req. & PS S&T Req.	Heat exchanger aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 2-1, 4-18, 4-20, 4-34, 8-6, 8-3	10
Loss of material causes holes in shell and leakage to ambient.	Occasional	Not discussed in report	PS TS Req. & PS S&T Req.	Heat exchanger aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 2-1, 4-18, 4-20, 4-34, 8-6, 8-3	11
Loss of material causes holes in shell and leakage to ambient.	Occasional	Not discussed in report	PS TS Req. & PS S&T Req.	Heat exchanger aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 2-1, 4-18, 4-20, 4-34, 8-6, 8-3	12
Loss of material in tubesheet causes cross contamination between coolant.	Occasional	Not discussed in report	PS TS Req. & PS S&T Req.	Heat exchanger aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 2-1, 4-18, 4-20, 4-34, 8-6, 8-3	13
Loss of material in tubesheet causes cross contamination between coolant.	Occasional	Not discussed in report	PS TS Req. & PS S&T Req.	Heat exchanger aging can increase dramatically in the out years [4]		14
Poor water quality causes corrosion and leakage holes or cracks in piping. In addition, external corrosion is caused by auxiliary building environment.	Moderate	Not discussed in report	ASME Sec Sec XI IWB or IWC	Piping aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 3-1, 4-18, 8-3	15
High flow velocity can cause material removal and leakage holes.	Occasional	Not discussed in report		Piping aging can increase dramatically in the out years [4]	1-2, 1-3, 1-4, 1-5, 3-1, 4-18, 8-3	16

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Frequent	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4	1

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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2	Diesel generator	Instruments and controls	Control air systems	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
3	Diesel generator	Instruments and controls	Wiring and terminations	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
4	Diesel generator	Instruments and controls	Sensors	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
5	Diesel generator	Fuel system	Engine piping	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
6	Diesel generator	Fuel system	Injector pumps	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
7	Diesel generator	Fuel system	Injectors and nozzles	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
8	Diesel generator	Starting system	Starting air valve	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	CONTAM	Loss of desired surface properties

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Occasional	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4	2
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Infrequent	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4	3
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Infrequent	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4	4
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Infrequent	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	5
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Occasional	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	6
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Infrequent	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	7
Environmental dust and corrosion product buildup from environmental moisture cause fouling of the subcomponents.	Moderate	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	8

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9	Diesel generator	Starting system	Controls	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	CONTAM	Loss of desired surface properties
10	Diesel generator	Starting system	Starting motor	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	CONTAM	Loss of desired surface properties
11	Diesel generator	Cooling system	Piping	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
12	Diesel generator	Cooling system	Pumps	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
13	Diesel generator	Cooling system	Heat exchangers	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
14	Diesel generator	Engine structure	Crankcase	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	VIBR	Loosening
15	Diesel generator	Engine structure	Cylinder lines	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	FAT	Cumulative fatigue damage

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Environmental dust and corrosion product buildup from environmental moisture cause fouling of the subcomponents.	Occasional	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	9
Environmental dust and corrosion product buildup from environmental moisture cause fouling of the subcomponents.	Occasional	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	10
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Moderate	Not discussed in report	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	11
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Occasional	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	12
Internal components become sufficiently loosened that it no longer functions and the component fails.	Occasional	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	13
Subcomponent becomes sufficiently loosened that it no longer functions and the component fails.	Moderate	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	14
Repeated thermal loadings lead to fatigue crack initiation and growth and eventual mechanical failure	Occasional	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	15

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
16	Diesel generator	Engine structure	Main bearings	Not stated	ALCO, Allis Chalmers, Caterpillar, Cooper, Bessemer, Electromotive Division, Fairbanks Morse, Nordberg, Transamerica Delaval, and Worthington	CONTAM	Loss of lubricant properties

Document: NUREG/CR-5159, Prediction of Check Valve Performance and Degradation in Nuclear Power Plant Systems
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor	Check valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5248, Prioritization of TIRGALEX-Recommended Components for Further Aging Research
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	All major systems	All major structures/components	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5268, Aging Study of Boiling Water Reactor Residual Heat Removal System
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR residual heat removal system	Motor operated valves	Not stated	Not stated	Not stated	WEAR	Attrition
2	BWR residual heat removal system	Motor operated valves	Not stated	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
3	BWR residual heat removal system	Instrumentation	Not stated	Not stated	Not stated	Calibration drift	Change in set points
4	BWR residual heat removal system	Supports for piping	Not stated	Not stated	Not stated	Not stated	Not stated
5	BWR residual heat removal system	Breakers	Not stated	Not stated	Not stated	Not stated	Not stated
6	BWR residual heat removal system	Heat exchangers	Not stated	Not stated	Not stated	CORR	Loss of material

Document: NUREG/CR-5057, Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Oil contamination leads to loss of lubrication in the bearing assemblies, resulting in loss of function.	Occasional	PNL NPAR Diesel Generator Study	PS TS Req., RG 1.9, RG 1.108	Reduce fast starts imposed by present regulation; implement new testing and trending procedures as recommended in the report; improve maintenance practices. [4]	2.4, 2.5	16

Document: NUREG/CR-5159, Prediction of Check Valve Performance and Degradation in Nuclear Power Plant Systems
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5248, Prioritization of TIRGALEX-Recommended Components for Further Aging Research
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5268, Aging Study of Boiling Water Reactor Residual Heat Removal System
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Wear of packing and drive can cause leakage and failure to operate due to binding.	Frequent	Reliability improvement studies are ongoing	ASME Sec XI IWB & IWV, Req, GL 89-10 & Suppl.	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	1
High temperatures in motor windings can cause insulation deterioration and motor failure. Highest failure component in RHR systems.	Frequent	Reliability improvement studies are ongoing	ASME Sec XI IWB & IWV, Req, GL 89-10 & Suppl.	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	2
Change in set points with time can cause system components to shut down or fail to shut down when critical thresholds are exceeded. Second highest failure component in RHR system.	Moderate	Reliability improvement studies are ongoing	If Class 1E 10CFR 50.49 otherwise PS S&T Req	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	3
Not stated.	Occasional	Reliability improvement studies are ongoing	ASME Sec XI	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	4
Not stated.	Occasional	Reliability improvement studies are ongoing	If Class 1E 10CFR 50.49 otherwise PS S&T Req	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	5
Tube wall thinning can cause leakage across tubes, reduced heat transfer, and possible radioactive contamination.	Infrequent	Reliability improvement studies are ongoing	PS S&T Req.	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	6

Document: NUREG/CR-5268, Aging Study of Boiling Water Reactor Residual Heat Removal System
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	BWR residual heat removal system	Heat exchangers	Not stated	Not stated	Not stated	CLOG	Blockage of flow passages
8	BWR residual heat removal system	Pumps/motors	Not stated	Not stated	Not stated	WEAR	Attrition
9	BWR residual heat removal system	Pumps/ motors	Not stated	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
10	BWR residual heat removal system	Pumps/ motors	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
11	BWR residual heat removal system	Pipes	Not stated	Not stated	Not stated	CORR/IGSCC	Loss of material
12	BWR residual heat removal system	Pipes	Not stated	Not stated	Not stated	FAT/ THERM	Cumulative fatigue damage

Document: NUREG/CR-5314, Vol. 3, Life Assessment Procedures for Major LWR Components, Cast Stainless Steel Components
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR cooling water system	Coolant pump	Types C, E, and F pump bodies	CF-8, CF-8A, or CF-8M cast SS	Borg-Warner, Westinghouse	EMBR/TE	Loss of fracture toughness
2	PWR cooling water system	Piping	Pipes	CF-8A or CF-8M cast SS	Westinghouse	EMBR/TE	Loss of fracture toughness
3	PWR cooling water system	Piping	Fittings	CF-8A cast SS	Westinghouse	EMBR/TE	Loss of fracture toughness
4	PWR cooling water system	Piping	Surge line	Cast duplex SS	Westinghouse	EMBR/TE	Loss of fracture toughness
5	PWR cooling water system	Piping	Surge line	CF-8M cast SS	Combustion Engineering	EMBR/TE	Loss of fracture toughness

Document: NUREG/CR-5268, Aging Study of Boiling Water Reactor Residual Heat Removal System
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Foreign contaminants can cause tube blockage and reduced heat transfer.	Infrequent	Reliability improvement studies are ongoing	PS S&T Req.	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	7
Wear causes increased internal leakage flows and loss of capacity to pump at design values as well as external leakage.	Infrequent	Reliability improvement studies are ongoing	ASME Sec XI IWP	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	8
Inadequate cooling of seals results in pump inoperability and winding failure in motors.	Infrequent	Reliability improvement studies are ongoing	ASME Sec XI IWP	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	9
Operation of pumps at very low flows causes hydraulic flow instabilities and vibration of impeller and rotor and breakage of these subcomponents.	Infrequent	Reliability improvement studies are ongoing	ASME Sec XI IWP	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	10
Wall thinning can cause leakage through pipe walls and cracking in welds.	Occasional	Reliability improvement studies are ongoing	ASME Sec XI IWB & PS S&T Req	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	11
Large time dependent temperature gradients in piping can cause cracking and leakage.	Occasional	Reliability improvement studies are ongoing	ASME Sec XI IWB & PS S&T Req	Perform study of the relationship between frequent performance testing of RHR components and aging detection and mitigation [4]	5-1 to 5-35, 10-1	12

Document: NUREG/CR-5314, Vol. 3, Life Assessment Procedures for Major LWR Components, Cast Stainless Steel Components
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWP & IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	1-3, 11, 26-44	1
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	3, 11, 26-44	2
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	3, 11, 26-44	3
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	4
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modelng of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	5

Document: NUREG/CR-5314, Vol. 3, Life Assessment Procedures for Major LWR Components, Cast Stainless Steel Components
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
6	PWR cooling water system	Pressurizer	Spray head	Cast SS	Westinghouse	EMBR/TE	Loss of fracture toughness
7	PWR cooling water system	Check valves	Valve body	Cast SS	Not stated	EMBR/TE	Loss of fracture toughness
8	PWR cooling water system	Recirculation piping	Fittings and valves	Cast SS	Not stated	EMBR/TE	Loss of fracture toughness
9	Control rod system	Control rod drive	Drive mechanism housing	CF-8 cast SS (Westinghouse); not stated (CE and GE)	Westinghouse, Combustion Engineering, and General Electric	EMBR/TE	Loss of fracture toughness
10	Reactor core	Core internals	Control rod assembly shrouds	CF-8 cast SS	Combustion Engineering	EMBR/TE	Loss of fracture toughness
11	Reactor core	Core internals	Lower support structures and instruments	Cast SS	Westinghouse	EMBR/TE	Loss of fracture toughness
12	Reactor core	Core internals	Orificed fuel supports	CF-8 cast SS	General Electric	EMBR/TE	Loss of fracture toughness
13	Reactor core	Core internals	Unspecified jet pump assembly	CF-8 and CF-3 cast SS	General Electric	EMBR/TE	Loss of fracture toughness

Document: NUREG/CR-5378, Aging Data Analysis and Risk Assessment-Development and Demonstration Study
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Auxiliary feedwater system.	Various, including steam-driven pumps, motor- and air-operated valves, check valves, stop valves, piping, and instruments.	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5314, Vol. 3, Life Assessment Procedures for Major LWR Components, Cast Stainless Steel Components
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB & Assoc NRC GC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. [4]	4, 11, 26-44	6
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modelng of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	7
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB or IWC	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	8
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB & PS TS Req.	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	9
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	10
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	11
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	12
Component becomes less flaw tolerant (critical flaw size decreases), resulting in diminished structural integrity.	Not stated	ANL aging studies, NRC and EPRI UT studies	ASME Sec XI IWB	Estimate the extent of thermal embrittlement by a combination of (a) analytical modeling of in-service degradation, (b) metallurgical evaluation, and (c) NDE. Consider weldrepair procedures as an option for license extension. (More) [4]	4, 11, 26-44	13

Document: NUREG/CR-5378, Aging Data Analysis and Risk Assessment-Development and Demonstration Study
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5379, Vol. 1, Nuclear Plant Service Water System Aging Degradation Assessment, Phase I
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Open and closed service water systems	Piping	Not stated	Carbon steel	Not stated	CORR/PIT	Local loss of materia
2	Open and closed service water systems	Piping	Not stated	Carbon steel	Not stated	CORR	Loss of material and corrosion product buildup
3	Open and closed service water systems	Check valve	Check valve swing arm	Carbon steel	Not stated	CORR/UA	Loss of material
4	Open and closed service water systems	Gage valve	Gage valve disk	Carbon steel	Not stated	CORR/UA	Loss of material
5	Open and closed service water systems	Heat exchanger	Tubing	90Cu-10Ni	Not stated	CORR/PIT	Local loss of materia
6	Open and closed service water systems	Heat exchanger	Tubing	90Cu-10Ni	Not stated	CORR/PIT	Local loss of materia
7	Open and closed service water systems	Heat exchanger	Tubing	90Cu-10Ni	Not stated	CORR/ leaching	Loss of material

Document: NUREG/CR-5379, Vol. 2, Nuclear Plant Service Water System Aging Degradation Assessment, Phase II
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Open service water systems	Valves	Valve stems	Type 410 stainless steel	Not stated	CORR	Loss of material
2	Open service water systems	Heat exchanger	Tubing	90/10 copper-nickel	Not stated	CORR/leaching	Loss of material
3	Open service water systems	Piping, coolers, and valves	Piping, cooler U-joints, and valve internals	Carbon steel	Not stated	CORR	Loss of material
4	Open service water systems	Motor-operated valves	Valve disk	Not stated	Not stated	CORR	Loss of material
5	Open service water systems	Heat exchangers	Tubing and instrument lines	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
6	Open service water systems	Pumps	Impellers and screens	Brass	Not stated	ERO	Wall thinning
7	Open service water systems	Heat exchangers	Tubing	Not stated	Not stated	BIO	Buildup of deposits
8	Open service water systems	Various	Not stated	Not stated	Not stated	BIO	Buildup of deposits

Document: NUREG/CR-5379, Vol. 1, Nuclear Plant Service Water System Aging Degradation Assessment, Phase I
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Tuberculation or concentration cell corrosion from deposits on the I.D. piping surface results in localized pitting corrosion and penetration of the piping wall.	Frequent	Not discussed in report	ASME Sec XI & PS S&T Req.	Some benefit obtained from replacing carbon steel piping with stainless steel. [2]	B.2, B.7, B.8	1
Rust deposits from general corrosion and biological and/or inorganic deposition results in pipe plugging.	Moderate	Not discussed in report	ASME Sec XI & PS S&T Req.	Some benefit obtained from replacing carbon steel piping with stainless steel. [2]	B.2, B.6, B.7	2
Rust produced by general corrosion is removed by chaffing as the swing arm rotates, producing failure by an unspecified process.	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	Not stated	B.2	3
General corrosion results in loss of net section and eventual separation of disk from valve stem.	Occasional	Not discussed in report	ASME Sec XI & PS S&T Req.	Not stated	B.2	4
Pitting corrosion, commonly associated with concentration cells set up at I.D. surface deposits, leads to localized pitting and penetration of the tube wall	Occasional	Not discussed in report	PS S&T Req.	Not stated	B.2	5
Tuberculation deposits from localized corrosion can break off, and the resulting fragments can result in tube plugging.	Occasional	Not discussed in report	PS S&T Req.	Not stated	B.2	6
Preferential dissolution of Ni (denickellification) from the tubing alloy can lead to loss of tube integrity and leakage.	Occasional	Not discussed in report	PS S&T Req.	Not stated	B.2	7

Document: NUREG/CR-5379, Vol. 2, Nuclear Plant Service Water System Aging Degradation Assessment, Phase II
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Stainless steel components operating in stagnant loops of open service water systems are subject to corrosive attack due to depletion of the dissolved oxygen in the water needed to maintain a protective oxide surface layer.	Frequent	Not discussed in report	ASME Sec IX IWV or PS S&T Req.	Maintain a minimum water flow to prevent oxygen depletion. [4]	3.3	1
Copper-nickel tubing in open service water systems is subject to nickel leaching, particularly under stagnant conditions where oxygen depletion occurs.	Not stated	Not discussed in report	PS S&T Req.	Maintain a minimum water flow to prevent oxygen depletion. [4]	3.3	2
Corrosion of carbon steel components is accelerated by the flowing water conditions used to counter the problems caused by oxygen depletion.	Frequent	Not discussed in report	ASME Sec XI or PS S&T Req.	Not stated	3.3	3
The majority of electrical failures experiences with the motors on motor-operated valves were found to be corrosion related	Frequent	Not discussed in report	ASME Sec XI & GL 89-10 & Suppl. or PS S&T Re	Not stated	3.3	4
Corrosion products, primarily from carbon steel, can cause flow blockage in small tubed heat exchangers and instrument lines.	Occasional	Not discussed in report	PS S&T Req.	Not stated	3.3	5
Erosion of brass pump impellers has required replacement of these components every two years; similar erosion has been observed in pump impellers and coarse screens in fire water systems	Occasional	Not discussed in report	ASME Sec XI IWP or PS S&T Req.	Not stated	3.3	6
Biofouling from microorganism growth can cause decreased efficiency, component corrosion, and reduced system flow.	Not stated	Not discussed in report	PS S&T Req.	Not stated	3.4	7
Biofouling from large organisms can cause corrosion, local erosion and pitting, and plugging and fouling.	Not stated	Not discussed in report	PS S&T Req.	Not stated	3.4	8

Document: NUREG/CR-5379, Vol. 2, Nuclear Plant Service Water System Aging Degradation Assessment, Phase II
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9	Recirculating service water systems	Piping	Not stated	Carbon steel	Not stated	CORR	Loss of material
10	Open service water systems	Ring headers	Ring header supports	Carbon steel	Not stated	CORR/PIT	Local loss of materia
11	Open service water systems	Discharge butterfly valves		Not stated	Not stated	ERO/CAV	Loss of material
12	Open service water systems	Valve actuators		Not stated	Not stated	FAT/ vibration	Cumulative fatigue damage
13	Open service water systems	Multiple		Not stated	Not stated	Water hammer	Excessive pressure loading
14	Closed service water systems	Air intake structure		Concrete with carbon steel rebar and aluminum embedment	Not stated	CORR/SA	Crack initiation and growth
15	Closed service water systems	Air intake structure		Concrete	Not stated	CORR; AGGR-CHEM	Loss of integrity
16	Closed service water systems	Pump	Pump shaft sleeves	Not stated	Not stated	CORR	Loss of material
17	Closed service water systems	Piping components (non-safety-related)		Carbon steel	Not stated	CORR	Loss of material
18	Closed service water systems	Packing followers and other valve parts		Ductile iron and other materials	Not stated	CORR/ SCC	Crack initiation and growth
19	Closed service water systems	Butterfly valves	Misc. sub-components	Monel and carbon steel	Not stated	CORR	Loss of material and corrosion product buildup
20	Closed service water systems	Check valves		Unspecified elastomer and other materials	Not stated	WEAR	Attrition
21	Closed service water systems	Valves		Not stated	Not stated	ADH	Component failure
22	Closed service water systems	Heat exchanger	Tubing	Copper-nickel	Not stated	CORR/UA	Loss of material
23	Closed service water systems	Heat exchanger	Tubing	Copper-nickel	Not stated	BIO	Buildup of deposits

Document: NUREG/CR-5379, Vol. 2, Nuclear Plant Service Water System Aging Degradation Assessment, Phase II
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Small bore carbon steel piping had been subject to significant corrosion problems, but the problem has been largely eliminated proper water treatment.	Formerly frequent; now rare	Not discussed in report	ASME Sec XI or PS S&T Req.	Change make-up water sources and introduce corrosion control. [4]	3.4	9
Ring header supports for pond spray rings have suffered some pitting attacks, resulting in areas of slight metal removal.	Occasional	Not discussed in report	PS S&T Req.	Not stated	3.4	10
Some cavitation erosion has been observed on discharge butterfly valves, but the use of hardened steel components is expected to mitigate this problem.	Once occasional; now rare	Not discussed in report	ASME Sec XI IWV	Replace affected components with steel. [2]	3.5	11
Vibration, usually from motor operation, has caused air leaks in air-operated valve actuators.	Occasional	Not discussed in report	ASME Sec XI IWV	Not stated	3.5	12
Water hammer results in excessive pressure loading of unspecified recirculation system components.	Once occasional; eliminated	Not disucssed in report	ASME Sec XI or PS S&T req.	Add a keep-full or jockey pump and motor-operated valve sequencing. [1]	3.5	13
Concrete pedestal cracking at the intake structure can occur because of rebar corrosion and aluminum embedment failure.	Not stated	Not discussed in report	PS S&T Req.	Not stated	3.5	14
Intake structure degradation can occur through attack from marine and groundwater chemicals on concrete binders and cements.	Occasional	Not discussed in report	PS S&T Req.	Not stated	3.5	15
Corrosion of pump shaft sleeves has been observed under shaft sleeves, necessitating replacement of the shaft.	Rare	Not discussed in report	ASME Sec XI IWP or PS S&T Req.	Not stated	3.5	16
Drains and intake wash screens in non-safety-related piping has suffered uniform corrosion and biofouling.	Occasional; rare with SS re	Not discussed in report	PS S&T Req.	Replace with lined or stainless steel pipe. [2]	3.6	17
Non-wetted valve parts have failed under stress-induced corrosion. In addition, a series of corrosion failures of ductile iron packing followers, caused by dampness, leakage, and other possibly factors, has occurred.	Occasional	Not discussed in report	ASME Sec XI IWV or PS S&T Req.	Not stated	3.6	18
Corrosion in butterfly valves between the carbon steel packing follower and the monel shaft has caused binding of the shaft.	Occasional	Not discussed in report	ASME Sec XI IWV or PS S&T Req.	Not stated	3.6	19
Check valves were suffering premature wear in valve seat area and check disk. New elastomer seals and protectant paint on check disk has reduced rate of degradation; existing valves are to be replaced with aluminum bronze.	Occasional; new valve elim.	Not discussed in report	ASME Sec XI IWV or PS S&T Req.	New elastomer seals and protective painting reduced problem until Al-bronze replacements can be installed. [1]	3.6	20
Valve body to valve liner adhesion can cause loss of liner integrity, leading to rapid corrosion and failure.	Occasional	Not discussed in report	ASME Sec XI IWV or PS S&T Req.	Not stated	3.6	21
Copper-nickel heat exchanger tubes previously used were subject to salt-water corrosion and are being replaced with titanium alloy tubes.	Occasional; eliminated with	Not discussed in report	PS S&T Req.	Replace with Ti alloy tubes [4]	3.6	22
Accumulation of vegetation, micoorganisms, and larger organisms can result in plugging of heat exchanger.	Common	Not discussed in report	PS S&T Req.	Removed by heat treatment, chlorine injection, and backflushing. [4]	3.6	23

Document: NUREG/CR-5386, Basis for Snubber Aging Research: Nuclear Plant Aging Research Program
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Snubber	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5404, Vol. 1, Auxiliary Feedwater System Aging Study
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Auxiliary feedwater system	All major components	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5404, Vol. 2, Auxiliary Feedwater System Aging Study: Phase I Follow-On Study
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Auxiliary feedwater	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5406, Vol. 1, BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption T
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR water cleanup system	Motor operated flexible wedge gate isolation valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5406, Vol. 2, BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption T
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR water cleanup system	Motor operated flexible wedge gate isolation valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Table A.1 Gall Report for NPAR Reports

Document: NUREG/CR-5386, Basis for Snubber Aging Research: Nuclear Plant Aging Research Program
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5404, Vol. 1, Auxiliary Feedwater System Aging Study
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5404, Vol. 2, Auxiliary Feedwater System Aging Study: Phase I Follow-On Study
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5406, Vol. 1, BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption T
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5406, Vol. 2, BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption T
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5406, Vol. 3, BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruptior
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR water cleanup system	Motor operated flexible wedge gate isolation valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5419, Aging Assessment of Instrument Air Systems in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Instrument air/service air systems	Compressor and receiver	Compressors	Not stated	Not stated	WEAR	Attrition
2	Instrument air/service air systems	Compressor and receiver	Compressors	Not stated	Not stated	VIBR	Loosening; crack initiation and growth
3	Instrument air/service air systems	Compressor and receiver	Aftercoolers/moisture separators	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
4	Instrument air/service air systems	Compressor and receiver	Aftercoolers/moisture separators	Not stated	Not stated	ENVIR	Deterioration
5	Instrument air/service air systems	Compressor and receiver	Aftercoolers/moisture separators	Not stated	Not stated	CLOG	Blockage of flow passages
6	Instrument air/service air systems	Compressor and receiver	Air receivers	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
7	Instrument air/service air systems	Compressor and receiver	Air receivers	Not stated	Not stated	CONTAM	Loss of desired surface properties
8	Instrument air/service air systems	Filter/dryer train	Air dryers	Not stated	Not stated	CLOG	Blockage of flow passages
9	Instrument air/service air systems	Filter/dryer train	Air dryers	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
10	Instrument air/service air systems	Filter/dryer train	Air dryers	Not stated	Not stated	ENVIR	Deterioration
11	Instrument air/service air systems	Filter/dryer train	Air dryers	Not stated	Not stated	CONTAM	Loss of desired surface properties
12	Instrument air/service air systems	Filter/dryer train	Pre-filters	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
13	Instrument air/service air systems	Filter/dryer train	Pre-filters	Not stated	Not stated	MOIST	Increased pressure drop; reduced strength
14	Instrument air/service air systems	Filter/dryer train	After-filters	Not stated	Not stated	PART	Increased pressure drop
15	Instrument air/service air systems	Filter/dryer train	After-filters	Not stated	Not stated	WEAR	Attrition
16	Instrument air/service air systems	Air distribution system	Valves	Not stated	Not stated	WEAR	Attrition
17	Instrument air/service air systems	Air distribution system	Valves	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
18	Instrument air/service air systems	Air distribution system	Valves	Not stated	Not stated	CONTAM	Loss of desired surface properties

Document: NUREG/CR-5406, Vol. 3, BWR Reactor Water Cleanup System Flexible Wedge Gate Isolation Valve Qualification and High Energy Flow Interruption T
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5419, Aging Assessment of Instrument Air Systems in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to load/unload properly and air/lubricating oil leaks would cause the immediate loss of a compressor.	Frequent	Not discussed in report	PS S&T Req.	Not stated	4-12, 13, 17	1
Excess vibration would cause the compressor to automatically trip or lead to required shutdown.	Moderate	Not discussed in report	PS S&T Req.	Not stated	4-12, 13, 18	2
Air/water leaks and loss of function.	Frequent	Not discussed in report	PS S&T Req.	Not stated	4-13, 18	3
Air/water leaks and loss of function.	Moderate	Not discussed in report	PS S&T Req.	Not stated	4-13, 18	4
Air/water leaks and loss of function.	Occasional	Not discussed in report	PS S&T Req.	Not stated	4-13, 18	5
Leaking air, drain valve stuck or clogged, and excessive water buildup.	Frequent	Not discussed in report	PS S&T Req.	Not stated	4-13, 18, 19	6
Leaking air, drain valve stuck or clogged, and excessive water buildup.	Infrequent	Not discussed in report	PS S&T Req.	Not stated	4-13, 18, 19	7
Degraded function of the dryers, air leaks, and desiccant/moisture carry-over to contaminate the instrument air system.	Occasional	Not discussed in report	PS S&T Req.	Not stated	4-13, 15, 19	8
Degraded function of the dryers, air leaks, and desiccant/moisture carry-over to contaminate the instrument air system.	Infrequent	Not discussed in report	PS S&T Req.	Not stated	4-13, 15, 19	9
Degraded function of the dryers, air leaks, and desiccant/moisture carry-over to contaminate the instrument air system.	Infrequent	Not discussed in report	PS S&T Req.	Not stated	4-13, 15, 19	10
Degraded function of the dryers, air leaks, and desiccant/moisture carry-over to contaminate the instrument air system.	Infrequent	Not discussed in report	PS S&T Req.	Not stated	4-13, 15, 19	11
Diminished or loss of air flow and leaking.	Frequent	Not discussed in report	PS S&T Req.	Not stated	4-15, 19	12
Diminished or loss of air flow and leaking.	Infrequent	Not discussed in report	PS S&T Req.	Not stated	4-15, 19	13
Diminished or loss of air flow and leaking.	Moderate	Not discussed in report	PS S&T Req.	Not stated	4-16, 20	14
Diminished or loss of air flow and leaking.	Rare	Not discussed in report	PS S&T Req.	Not stated	4-16, 20	15
Failure to open/close, seat leaking, and leakage from packing, gaskets, or valve body cracks.	Occasional	Not discussed in report	PS S&T Req.	Not stated	4-16, 17, 20	16
Failure to open/close, seat leaking, and leakage from packing, gaskets, or valve body cracks.	Occasional	Not discussed in report	PS S&T Req.	Not stated	4-16, 17, 20	17
Failure to open/close, seat leaking, and leakage from packing, gaskets, or valve body cracks.	Rare	Not discussed in report	PS S&T Req.	Not stated	4-16, 17, 20	18

Document: NUREG/CR-5419, Aging Assessment of Instrument Air Systems in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19	Instrument air/service air systems	Air distribution system	Piping	Not stated	Not stated	ERO/CORR	Wall thinning
20	Instrument air/service air systems	Air distribution system	Instrumentation	Not stated	Not stated	CONTAM	Loss of desired surface properties

Document: NUREG/CR-5479, Current Applications of Vibration Monitoring and Neutron Noise Analysis
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5490, Regulatory Instrument Review: Management of Aging of LWR Major Safety-Related Components
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR-pressure vessel	Beltline region	Not stated	533B-1, SA-508-2, SA-302 B	Not stated	EMBR/IR	Loss of fracture toughness
2	PWR-pressure vessel	Beltline region	Not stated	533B-1, SA-508-2, SA-302 B	Not stated	ENVIR, FAT	Chemical or physical degradation, cumulative fatigue damage
3	PWR-pressure vessel	Outlet/inlet nozzles	Weldments	Linde 80, 91, 124, and 1092	Not stated	ENVIR, FAT	Chemical or physical degradation, cumulative fatigue damage
4	PWR-pressure vessel	Instrumentation nozzles, CRDM housing nozzles	Weldments	Linde 80, 91, 124, and 1092	Not stated	ENVIR, FAT	Chemical or physical degradation, cumulative fatigue damage
5	PWR-pressure vessel	Closure studs	Not stated	SA-540 Gr. B24 Class 3	Not stated	ENVIR, FAT	Chemical or physical degradation, cumulative fatigue damage
6	BWR-pressure vessel	Feedwater nozzles and safe ends	Welds	SA-508-2, SA-193 Gr. B7	Not stated	FAT	Cumulative fatigue damage
7	BWR-pressure vessel	Recirculation system	Inlet/outlet nozzles and dissimilar metal welds	SA-508-2, SA-193 Gr. B7	Not stated	CORR/ IGSCC	Crack initiation and growth
8	BWR-pressure vessel	Recirculation system	Other welds	SA-193 Gr. B7	Not stated	CORR/IGSCC	Crack initiation and growth
9	BWR pressure vessel	Beltline region	Not stated	Various low carbon steel	Not stated	EMBR/IR	Loss of fracture toughness
10	BWR pressure vessel	Closure studs	Not stated	SA-540 Gr. B22 or B23	Not stated	FAT, WEAR/ FRET	Cumulative fatigue damage, Attrition
11	BWR pressure vessel	External attachment welds	Not stated	SA-193 Gr. B7	Not stated	FAT	Cumulative fatigue damage
12	PWR steam generator	Tubes	Recirculating inside surface	Inconel 600 or 690	Westinghouse, Combustion Engineering, Babcock & Wilcox	CORR/PWSSC	Crack initiation and growth

Document: NUREG/CR-5419, Aging Assessment of Instrument Air Systems in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Cracked piping, leaking joints and plugged lines cause a diminished or complete loss of compressed air.	Moderate	Not discussed in report	PS S&T Req.	Not stated	4-17, 20	19
Incorrect signal.	Infrequent	Not discussed in report	PS S&T Req.	Not stated	4-17, 21	20

Document: NUREG/CR-5479, Current Applications of Vibration Monitoring and Neutron Noise Analysis
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5490, Regulatory Instrument Review: Management of Aging of LWR Major Safety-Related Components
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Irradiation causes a drop in upper-shelf energy and a shift in nil-ductility transition temperature.	Not stated	10 CFR 50 App. H, Reg. Guide 1.99, Rev. 2	10CFR50 App. G & RG 1.99	Reduce neutron flux, develop techniques for in-situ testing [4]	II-1	1
Not stated.	Not stated	10 CFR 50, App. G, 10 CFR 50.55a, IWB-2500, IWB-3000, IWB-5000	10CFR50 App. G & RG 1.99	Use state-of-the-art ultrasonic inspection techniques to monitor defect size and location [4]	II-1	2
Not stated.	Not stated	10 CFR 50, IWB-2500	ASME Sec III & Sec XI IWB	Use on-line fatigue monitoring, evaluate irradiation embrittlement damage [4]	II-1	3
Not stated.	Not stated	10 CFR 50, IWB-2500	ASME Sec III & Sec XI IWB	Not stated	II-1	4
Preload cycles during head replacement and boric acid corrosion can cause damage.	Not stated	10 CFR 50, IWB-2500	ASME Sec III & Sec XI IWB	Not stated	II-1	5
High-cycle thermal fatigue caused by feedwater leakage led to the development of cracks in nozzles.	Not stated	10 CFR 50, IWB-2500	ASME Sec III & Sec XI IWB	Use on-line fatigue monitoring, modify design, revise operating procedures [4]	II-2	6
IGSCC initiated in HAZ may propagate into base metal.	Not stated	10 CFR 50, IWB-2500	ASME Sec XI IWB	Control hydrogen water chemistry to reduce IGSCC damage [4]	II-2	7
IGSCC initiated in HAZ may propagate into base metal by corrosion and/or environmental fatigue.	Not stated	10 CFR 50, IWB-2500	ASME Sec XI IWB	Control hydrogen water chemistry to reduce IGSCC damage [4]	II-2	8
Irradiation caused a drop in upper shelf energy and a shift in nil-ductility-transition temperature. Welds were more susceptible to embrittlement than base metal.	Not stated	10 CFR 50 App. H and G, Reg. guide 1.99, Rev.2; 10 CFR 50.55a IWB-2500, 3000, 5000	10CFR50 App. G & RG 1.99	Adopt in-service annealing, implement neutron flux reduction program, develop acoustic emission monitoring to detect crack growth [4]	II-2	9
Fatigue and fretting are major aging concerns for studs.	Not stated	10 CFR 50.55a IWB-2500	10CFR50 App. G, RG 1.99 & ASME Sec XI IWB	Not stated	II-2	10
Low-cycle thermal and mechanical fatigue can cause damage in welds.	Not stated	10 CFR 50.55a IWB-2500	ASME Sec III & Sec XI IWB	Not stated	II-2	11
U-bends, roll transition, and dented tube regions are susceptible to PWSCC. Tubes with low mill-annealing temperature are more susceptible.	Not stated	10 CFR 50.55a IWB-2500	ASME Sec XI IWB & PS TS req.	Control water chemistry, install filters [4]	III-1	12

Document: NUREG/CR-5490, Regulatory Instrument Review: Management of Aging of LWR Major Safety-Related Components
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13	PWR steam generator	Tubes	Recirculating outside surface	Inconel 600 or 690	Westinghouse, Combustion Engineering, Babcock & Wilcox	CORR/ IGSCC	Crack initiation and growth
14	PWR steam generator	Tubes	Once-through outside surface	Inconel 600 or 690	Babcock & Wilcox	ERO, FAT	Wall thinning, loss of material; cumulative fatigue damage
15	PWR steam generator	Multiple	Various	Various inconel and ferritic SS	Westing-house, Combustion Engineering, Babcock & Wilcox	CORR/PIT, FAT, WEAR/ FRET	Local loss of material, cumulative fatigue damage, wall thinning, loss of material
16	PWR reactor coolant system	Piping	Nozzles and thermal sleeves	SA 105 Gr. 2, 304N SS, Inconel SB-166 and 168	Westinghouse, Combustion Engineering, Babcock & Wilcox	FAT/THERM	Cumulative fatigue damage
17	PWR reactor coolant system	Piping	Terminal ends dissimilar metal welds	Not stated	Not stated	FAT/THERM	Cumulative fatigue damage
18	PWR reactor coolant system	Piping	Surge and spray lines	316 SS, CF8M	Combustion Engineering	FAT/ THERM	Cumulative fatigue damage
19	PWR reactor coolant system	Piping	Hot and cold legs, cross-over leg, fittings, surge line	Various cast SS or Austenitic SS	Westinghouse, Combustion Engineering, Babcock & Wilcox	EMBR/TE	Loss of fracture toughness
20	Pressure vessel	Pressurizer, surge and spray lines	Nozzles and thermal sleeves	SA-105 Gr. 2, 304N SS, Inconel SB-168	Westinghouse, Combustion Engineering	FAT/THERM, ERO	Cumulative fatigue damage; wall thinning, loss of material
21	Pressure vessel	Pressurizer, surge and spray lines	Terminal end dissimilar metal welds	Not stated	Not stated	FAT/THERM	Cumulative fatigue damage
22	Pressure vessel	Cast SS piping	Surge line, spray line, valves, fittings	CF8A, CF8M, SA 516 Gr. 70, 308L and 309L SS	Westinghouse, Combustion Engineering, Babcock & Wilcox	FAT/THERM, EMBR/TE, ERO, CORR/BA	Cumulative fatigue damage; loss of fracture toughness; wall thinning, loss of material
23	Pressure vessel	Vessel wall	Not stated	A-533, GL B, Class 1	Not stated	FAT/THERM	Cumulative fatigue damage
24	Emergency diesel generator	Various	Multiple	Various alloy steels, cast iron, aluminum, Stellite seats, gaskets, hoses	ALCO, Allis Chalmers, Caterpillar, and others	Various	Various

Document: NUREG/CR-5491, Shippingport Station Aging Evaluation
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5490, Regulatory Instrument Review: Management of Aging of LWR Major Safety-Related Components
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Hot-leg tubes in tube-to-tubesheet crevice region are susceptible to IGSCC.	Not stated	10 CFR 50.55a IWB-2500	ASME Sec XI IWB & PS TS req.	Introduce compressive residual stresses [4]	III-1	13
Not stated.	Not stated	Not stated	ASME Sec XI IWB & PS TS req.	Control chemistry to prevent concentration of impurities leading to fatigue cracks [4]	III-1	14
Does not provide detailed information on age-related degradation processes.	Not stated	Not stated	ASME Sec XI IWB & PS TS req.	Not stated	III-1	15
Low and high-cycle thermal and mechanical fatigue can cause damage on various nozzles and thermal sleeve components.	Not stated	10 CFR 50.55a, IWB-2500	ASME Sec III & Sec XI IWB	Maintain full flow in spray line, prevent thermal shock conditions, examine welds more frequently [4]	IV-1	16
Low- and high-cycle thermal and mechanical fatigue can cause cumulative fatigue damage in dissimilar metal welds.	Not stated	10 CFR 50.55a, IWB-2500	ASME Sec III & Sec XI IWB	Use acoustic emission method to detect crack growth in welded regions [2]	IV-1	17
Low- and high-cycle thermal and mechanical fatigue can cause cumulative fatigue damage in surge and spray lines.	Not stated	10 CFR 50.55a, IWB-2500	ASME Sec III & Sec XI IWB	Use acoustic emission method to detect crack growth in welded regions [2]	IV-1	18
Large fluctuations in coolant temperature can cause thermal embrittlement in cast SS piping.	Not stated	10 CFR 50.55a, IWB-3000 and 5000	ASME Sec XI IWB	Develop ultrasonic techniques to detect flaws in cast SS piping [4]	IV-1	19
Not discussed.	Not stated	10 CFR 50.55a, IWB-2500	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Maintain full flow in spray lines, prevent thermal shock conditions [4]	V-1	20
Not discussed.	Not stated	10 CFR 50.55a, IWB-2500	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Develop and use improved NDE methods to monitor the degree of embrittlement [2]	V-1	21
Not discussed.	Not stated	10 CFR 50.55a, IWB-2500	ASME Sec III, Sec XI IWB & Assoc. NRC GC	Develop and use improved NDE methods to monitor the degree of embrittlement and to detect flaws; monitor valve leakage [2]	V-1	22
Not discussed.	Not stated	10 CFR 50.55a, IWB-2500	10CFR50 App. G, ASME Sec III	Not stated	V-1	23
Does not provide specific detailed information on age-related degradation processes.	Not stated	Not stated	PS TS Req., RG 1.9, RG 1.108	Not stated	VI-1	24

Document: NUREG/CR-5491, Shippingport Station Aging Evaluation
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5507, Results from the Nuclear Plant Aging Research Program: Their Use in Inspection Activities
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Not stated	Inverters	Filter Capacitors	Not stated	Not stated	Electrical Transient	Not stated
2	Not stated	Inverters	Thyristors	Not stated	Not stated	Over heating	Not stated
3	Not stated	Inverters	Fuses	Not stated	Not stated	FAT	Not stated
4	Not stated	Motors (for pump and valve operation)	Stator Insulating, Bearing Assemblies, Rotor	Not stated	Not stated	FAT/THERM	Cumulative Fatigue Damage
5	Not stated	Motors (for pump and valve operation)	Stator Insulating, Bearing Assemblies, Rotor	Not stated	Not stated	ENVIR	Chemical, Physical Degradation
6	Not stated	Motors (for pump and valve operation)	Stator Insulating, Bearing Assemblies, Rotor	Not stated	Not stated	VIBR	Loosening
7	Not stated	Battery Chargers	Capacitors, Transformers, Inductors, Diodes and Thyristors	Not stated	Not stated	FAT/THERM	Overheating
8	Not stated	Battery Chargers	Capacitors, Trans formers, Inductors, Diodes and Thyristors	Not stated	Not stated	Not stated	Loss of Connection
9	Not stated	Motor Control Centers	Circuit Breaker, Contactor, Transformer, Relays and Thermal Overload Devices	Not stated	Not stated	CONTAM	Contact surface degradation, set point drift
10	Component Cooling Water Systems (PWRs)	Valves	Valve Operator and Valve Seat	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-5507, Results from the Nuclear Plant Aging Research Program: Their Use in Inspection Activities
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure of filter capacitors directly related to ambient temperatures, applied voltage and ripple current; failure of thyristors due to over heating of thyristor/heat sink connection caused by improper torque and thermal fatigue. (More)	Moderate	Not stated	PS S&T Req.	Use of an automatic transfer switch; installation of higher voltage and temperature rated components; forced air cooling and adding additional temperature monitoring capabilities [2]	A 2, A 3, A 4	1
Failure of filter capacitors directly related to ambient temperatures, applied voltage and ripple current; failure of thyristors due to over heating of thyristor/heat sink connection caused by improper torque and thermal fatigue. (More)	Moderate	Not stated	PS S&T Req.	Use of an automatic transfer switch; installation of higher voltage and temperature rated components; forced air cooling and adding additional temperature monitoring capabilities [2]	A 2, A 3, A 4	2
Failure of filter capacitors directly related to ambient temperatures, applied voltage and ripple current; failure of thyristors due to over heating of thyristor/heat sink connection caused by improper torque and thermal fatigue. (More)	Moderate	Not stated	PS S&T Req.	Use of an automatic transfer switch; installation of higher voltage and temperature rated components; forced air cooling and adding additional temperature monitoring capabilities [2]	A 2, A 3, A 4	3
The stator insulating system and bearing assemblies are most frequently failed by aging effects for smaller motors (<200 lbs.). Large motor failures are primarily due to voltage surges and mechanical stress from centrifugal and magnetic forces. (More)	Moderate	Not stated	ASME Sec XI IWB or IWC, GL 89-10 & Suppl. & P	Perform periodic insulation resistance test, partical discharge test and power factor test. Perform AC/DC leakage test, voltage impulse test and chemical analysis of lube oil. (More) [2]	A-7, A-11	4
The stator insulating system and bearing assemblies are most frequently failed by aging effects for smaller motors (<200 lbs.). Large motor failures are primarily due to voltage surges and mechanical stress from centrifugal and magnetic forces. (More)	Moderate	Not stated	ASME Sec XI IWB or IWC, GL 89-10 & Suppl. & P	Perform periodic insulation resistance test, partical discharge test and power factor test. Perform AC/DC leakage test, voltage impulse test and chemical analysis of lube oil. (More) [2]	A-7, A-11	5
The stator insulating system and bearing assemblies are most frequently failed by aging effects for smaller motors (<200 lbs.). Large motor failures are primarily due to voltage surges and mechanical stress from centrifugal and magnetic forces. (More)	Moderate	Not stated	ASME Sec XI IWB or IWC, GL 89-10 & Suppl. & P	Perform periodic insulation resistance test, partical discharge test and power factor test. Perform AC/DC leakage test, voltage impulse test and chemical analysis of lube oil. (More) [2]	A-7, A-11	6
Aging impact on battery chrager is minimal. High voltage, current, humidity, and temperature decrease the life of the battery charger. Failure of the battery charger could result in depletion of its associated battery and a potential loss of dc power.	Moderate	Not stated	PS S&T Req.	Periodic checking of connection between SCR and heat sink; monitoring insulation resistance and winding temperature; periodic manual operation and calibration of the circuit breakers and protective relays; periodically replace the filter capacitors. [2]	A-14, A-18	7
Aging impact on battery chrager is minimal. High voltage, current, humidity, and temperature decrease the life of the battery charger. Failure of the battery charger could result in depletion of its associated battery and a potential loss of dc power.	Moderate	Not stated	PS S&T Req.	Periodic checking of connection between SCR and heat sink; monitoring insulation resistance and winding temperature; periodic manual operation and calibration of the circuit breakers and protective relays; periodically replace the filter capacitors. [2]	A-14, A-18	8
Significant component failure of the motor control center. The failure mode includes failure to close, failure to open, failure to operate, open circuit, short circuit, tripped. Age related degradation of subcomponents has impacted safety system.	Frequent	Not stated	PS S&T Req.	Perform periodic maintenance including: checking for moisture, oil and foreign material in cabinet; example for pitting, corrosion, and overheating for bus bar; check for arcing or overheating for fuses; inspect contacts for starter; (More) [2]	A-19, A-22	9
Aging is a significant factor in failure of the CCW system (over 70%). The failures are dominated by the wear induced leakage in the valve operator and valve seat (37% of total failures).	Frequent	Not stated	ASME Sec XI IWB, GL 89-10 & Suppl., & PS TS	Perform periodic visual inspection, leakage tests, stem torque check, torque/limit switch setting and current/voltage monitoring. [4]	A-24, A-25	10

Document: NUREG/CR-5507, Results from the Nuclear Plant Aging Research Program: Their Use in Inspection Activities
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	Component Cooling Water Systems (PWRs)	Valves	Valve Operator and Valve Seat	Not stated	Not stated	CONTAM	Buildup deposits
12	Component Cooling Water Systems (PWRs)	Valves	Valve Operator and Valve Seat	Not stated	Not stated	ERO/CORR	Wall thinning, loss of material
13	Component Cooling Water Systems (PWRs)	Valves	Valve Operator and Valve Seat	Not stated	Not stated	Setpoint Drift	Loss of performance
14	Component Cooling Water Systems (PWRs)	Pumps	Seals, Bearings	Not stated	Not stated	WEAR	Attrition
15	Component Cooling Water Systems (PWRs)	Heat Exchangers	Tubes, Tube Sheet	Not stated	Not stated	WEAR/DENT	Denting
16	Component Cooling Water Systems (PWRs)	Heat Exchangers	Tubes, Tube Sheet	Not stated	Not stated	ERO/CORR	Wall thinning, loss of material
17	Component Cooling Water Systems (PWRs)	Heat Exchangers	Tubes, Tube Sheet	Not stated	Not stated	CLOG	Blockage of flow passages
18	Residual Heat Removal Systems (BWRs)	Valves, Pumps, Heat Exchangers	Not stated	Not stated	Not stated	WEAR	Attrition
19	Residual Heat Removal Systems (BWRs)	Valves, Pumps, Heat Exchangers	Not stated	Not stated	Not stated	CORR	Loss of Material
20	Residual Heat Removal Systems (BWRs)	Valves, Pumps, Heat Exchangers	Not stated	Not stated	Not stated	Setpoint Drift (EDS)	Loss of function
21	Residual Heat Removal Systems (BWRs)	Valves, Pumps, Heat Exchangers	Not stated	Not stated	Not stated	EMBR	Loss of fracture toughness

Document: NUREG/CR-5507, Results from the Nuclear Plant Aging Research Program: Their Use in Inspection Activities
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Aging is a significant factor in failure of the CCW system (over 70%). The failures are dominated by the wear induced leakage in the valve operator and valve seat (37% of total failures).	Moderate	Not stated	ASME Sec XI IWB, GL 89-10 & Suppl., & PS TS	Perform periodic visual inspection, leakage tests, stem torque check, torque/limit switch setting and current/voltage monitoring. [4]	A-24, A-25	11
Aging is a significant factor in failure of the CCW system (over 70%). The failures are dominated by the wear induced leakage in the valve operator and valve seat (37% of total failures).	Moderate	Not stated	ASME Sec XI IWB, GL 89-10 & Suppl., & PS TS	Perform periodic visual inspection, leakage tests, stem torque check, torque/limit switch setting and current/voltage monitoring. [4]	A-24, A-25	12
Aging is a significant factor in failure of the CCW system (over 70%). The failures are dominated by the wear induced leakage in the valve operator and valve seat (37% of total failures).	Moderate	Not stated	ASME Sec XI IWB, GL 89-10 & Suppl., & PS TS	Perform periodic visual inspection, leakage tests, stem torque check, torque/limit switch setting and current/voltage monitoring. [4]	A-24, A-25	13
Pump failure is dominated by wear induced leakage in the seal in the bearing.	Frequent	Not stated	ASME Sec XI IWP & PS TS Req.	Perform periodic visual inspection for leakage; vibration recordings; temperature, quality and level checking for lube oil, bearing temperature check. [4]	A-26, A-27	14
The stressors are high pressure, high flow and service water exposure.	Frequent	Not stated	ASME Sec XI, PS S&T Req., & PS TS Req.	Perform periodic visual inspections, temperature monitoring, acoustic/eddy current test, and bolt torque check. [2]	A-25	15
The stressors are high pressure, high flow and service water exposure.	Moderate	Not stated	ASME Sec XI, PS S&T Req., & PS TS Req.	Perform periodic visual inspections, temperature monitoring, acoustic/eddy current test, and bolt torque check. [2]	A-25	16
The stressors are high pressure, high flow and service water exposure.	Moderate	Not stated	ASME Sec XI, PS S&T Req., & PS TS Req.	Perform periodic visual inspections, temperature monitoring, acoustic/eddy current test, and bolt torque check. [2]	A-25	17
More than 50% of the failure in RHR systems are attributed to aging. Wear is the aging mechanism in the shutdown or testing mode. Corrosion, set point drift and embrittlement are aging mechanisms in the standby mode. (More)	Frequent	Not stated	ASME Sec XI IWB, IWP, IWV, & PS TS Req.	For valves: Perform periodic valve stroke tests for valve stroke time and valve seat leakage. Periodically check valve correct position. Monitoring valve degradation by relief valve set point verification (5 years), (More) [2]	A-29, A-34	18
More than 50% of the failure in RHR systems are attributed to aging. Wear is the aging mechanism in the shutdown or testing mode. Corrosion, set point drift and embrittlement are aging mechanisms in the standby mode. (More)	Occasional	Not stated	ASME Sec XI IWB, IWP, IWV, & PS TS Req.	For valves: Perform periodic valve stroke tests for valve stroke time and valve seat leakage. Periodically check valve correct position. Monitoring valve degradation by relief valve set point verification (5 years), (More) [2]	A-29, A-34	19
More than 50% of the failure in RHR systems are attributed to aging. Wear is the aging mechanism in the shutdown or testing mode. Corrosion, set point drift and embrittlement are aging mechanisms in the standby mode. (More)	Frequent	Not stated	ASME Sec XI IWB, IWP, IWV, & PS TS Req.	For valves: Perform periodic valve stroke tests for valve stroke time and valve seat leakage. Periodically check valve correct position. Monitoring valve degradation by relief valve set point verification (5 years), (More) [2]	A-29, A-34	20
More than 50% of the failure in RHR systems are attributed to aging. Wear is the aging mechanism in the shutdown or testing mode. Corrosion, set point drift and embrittlement are aging mechanisms in the standby mode. (More)	Occasional	Not stated	ASME Sec XI IWB, IWP, IWV, & PS TS Req.	For valves: Perform periodic valve stroke tests for valve stroke time and valve seat leakage. Periodically check valve correct position. Monitoring valve degradation by relief valve set point verification (5 years), (More) [2]	A-29, A-34	21

Document: NUREG/CR-5510, Evaluations of Core Melt Frequency Effects Due to Component Aging and Maintenance
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5515, Light Water Reactor Pressure Isolation Valve Performance Testing
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Light water reactor pressure isolation	Check and gate valves	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5519, Aging of Control and Service Air Compressors and Dryers Used in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Control and service air system	Air compressors	Running gear bearings	Full-floating: Al; spherical roller: steel or steel-backed Cu-Pb; double roller: steel or babbitt-lined steel	Ingersoll-Rand, Joy, Worthington	WEAR	Attrition
2	Control and service air system	Air compressors	Seals/packing including piston rod packing	Elastomer/TFE or carbon rings	Ingersoll-Rand, Joy, Worthington	WEAR	Attrition
3	Control and service air system	Air compressors	Crosshead	Al, tin-faced cast iron, babbitted cast iron	Ingersoll-Rand, Joy, Worthington	WEAR	Attrition
4	Control and service air system	Air compressors	Belts	Not stated	Not stated	WEAR	Attrition
5	Control and service air system	Air compressors	Piston rod	Hardened steel, chrome-plated hardened steel	Ingersoll-Rand, Joy, Worthington	CORR	Loss of material; corrosion product buildup
6	Control and service air system	Air compressors	Piston rider/compression rings	TFE (teflon)	Ingersoll-Rand, Joy, Worthington	WEAR	Attrition

Document: NUREG/CR-5510, Evaluations of Core Melt Frequency Effects Due to Component Aging and Maintenance
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5515, Light Water Reactor Pressure Isolation Valve Performance Testing
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5519, Aging of Control and Service Air Compressors and Dryers Used in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,20	1
Seals and packing undergo gradual deterioration due to aging and wear, resulting in leaks and reduced compressor output. However, sudden failure of the compressor does not normally occur.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,20,21, 29	2
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,21	3
Belt failures (either breaking or being thrown off).	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	21,26	4
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,23	5
Wear of piston rings would result in reduced compressor outputs.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,21,22	6

Document: NUREG/CR-5519, Aging of Control and Service Air Compressors and Dryers Used in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	Control and service air system	Air compressors	Cylinder bore	Cast iron, cast semi-steel	Ingersoll-Rand, Joy, Worthington	CORR	Loss of material; corrosion product buildup
8	Control and service air system	Air compressors	Intake/exhaust valves	Stainless steel, nodular iron	Ingersoll-Rand, Joy, Worthington	FAT	Cumulative fatigue damage
9	Control and service air system	Air compressors	Intake/exhaust valves	Stainless steel, nodular iron	Ingersoll-Rand, Joy, Worthington	ERO	Wall thinning; loss of material
10	Control and service air system	Air compressors	Cooling water passages	Not stated	Not stated	CLOG	Blockage of flow passages
11	Control and service air system	Air dryers	Valves	Stainless steel	Not stated	WEAR	Attrition
12	Control and service air system	Air dryers	Desiccant	Silica gel or activated alumina	Not stated	ERO	Loss of material
13	Control and service air system	Air dryers	Filter elements	Not stated	Not stated	CLOG	Blockage of flow passages

Document: NUREG/CR-5555, Aging Assessment of the Westinghouse PWR Control Rod Drive System
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor Protection	Control Rod Drive System	Absorber Rods	Ag-In-Cd in 304SS Tubes	Not stated	WEAR	Attrition
2	Reactor Protection	Control Rod Drive System	Absorber Rods	Ag-In-Cd in 304SS Tubes	Not stated	FAT	Cumulative fatigue damage
3	Reactor Protection	Control Rod Drive System	Absorber Rods	Ag-In-Cd in 304SS Tubes	Not stated	CORR/ IGSCC	Crack initiation and growth

Document: NUREG/CR-5519, Aging of Control and Service Air Compressors and Dryers Used in Nuclear Power Plants
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,22;23	7
Leaking, broken, or loose valves would result in reduced compressor outputs.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,22,43	8
Leaking, broken, or loose valves would result in reduced compressor outputs.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	13,22,43	9
Sediment and dissolved minerals in well water result in scale buildup and blockage in the cooling water passages.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	27	10
Valves stuck, leaking, or inoperative.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	24,31	11
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	17,30,31	12
Failure of the afterfilter resulted in desiccant carryover into the instrument air system.	Not stated	Not discussed in report	PS S&T Req.	Loss of the air supply due to compressor or dryer failure is rare. An effective surveillance and monitoring program, can provide reliable service from the compressors and dryers should no longer consider in NPAR prog. [2]	30,31	13

Document: NUREG/CR-5555, Aging Assessment of the Westinghouse PWR Control Rod Drive System
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Rupture of control rod cladding.	Frequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	1
Rupture of control rod cladding.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	2
Rupture of control rod cladding.	Infrequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	3

Document: NUREG/CR-5555, Aging Assessment of the Westinghouse PWR Control Rod Drive System
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4	Reactor Protection	Control Rod Drive System	Split Pin	Inconel X-750	Not stated	CORR/SCC	Crack initiation and growth
5	Reactor Protection	Control Rod Drive System	Spider Assembly	304SS	Not stated	WEAR	Attrition
6	Reactor Protection	Control Rod Drive System	Spider Assembly	304SS	Not stated	FAT	Cumulative fatigue damage
7	Reactor Protection	Control Rod Drive System	Spider Assembly	304SS	Not stated	CORR/SCC	Crack initiation and growth
8	Reactor Protection	Control Rod Drive System	Control Rod Guide Tube	Inconel X-750	Not stated	WEAR	Attrition
9	Reactor Protection	Control Rod Drive System	Guide Thimble	Inconel X-750	Not stated	WEAR	Attrition
10	Reactor Protection	Control Rod Drive System	Pressure Housing	304SS	Not stated	EMBR/TE	Loss of fracture toughness
11	Reactor Protection	Control Rod Drive System	Pressure Housing	304SS	Not stated	CORR	Loss of material
12	Reactor Protection	Control Rod Drive System	Pressure Housing	304SS	Not stated	FAT	Cumulative fatigue damage
13	Reactor Protection	Control Rod Drive System	Latch Assembly	Stellite 6, Haynes 25, and 304SS	Not stated	WEAR	Attrition
14	Reactor Protection	Control Rod Drive System	Latch Assembly	Stellite 6, Haynes 25, and 304SS	Not stated	FAT	Cumulative fatigue damage
15	Reactor Protection	Control Rod Drive System	Drive Rod	410SS	Not stated	WEAR	Attrition
16	Reactor Protection	Control Rod Drive System	Drive Rod	410SS	Not stated	FAT	Cumulative fatigue damage
17	Reactor Protection	Control Rod Drive System	Coil Stack Assembly	Electrical insulation	Not stated	CORR	Loss of material

Document: NUREG/CR-5555, Aging Assessment of the Westinghouse PWR Control Rod Drive System
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loose parts in reactor coolant system and stuck control rod.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	4
Dropped and/or stuck control rod.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	5
Dropped and/or stuck control rod.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	6
Dropped and/or stuck control rod.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	7
Stuck control rod.	Frequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	8
Stuck control rod and fuel assembly mechanical degration.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	9
Rod control system leakage and rupture of the primary pressure boundary.	Infrequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	10
Rod control system leakage and rupture of the primary pressure boundary.	Infrequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	11
Rod control system leakage and rupture of the primary pressure boundary.	Infrequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	12
Dropped and/or stuck control rod.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	13
Dropped and/or stuck control rod.	Infrequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	14
Dropped and/or stuck control rod.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	15
Dropped and/or stuck control rod.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	16
Dropped and/or stuck control rod.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	17

Document: NUREG/CR-5555, Aging Assessment of the Westinghouse PWR Control Rod Drive System
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
18	Reactor Protection	Control Rod Drive System	Coil Stack Assembly	Electrical insulation	Not stated	EMBR/TE	Breakdown
19	Reactor Protection	Control Rod Drive System	Coil Stack Assembly	Electrical Connector	Not stated	CORR	Loss of Material
20	Reactor Protection	Control Rod Drive System	Coil Stack Assembly	Electrical Connector	Not stated	WEAR	Attrition
21	Reactor Protection	Control Rod Drive System	Coil Stack Assembly	Electrical Connector	Not stated	FAT	Cumulative fatigue damage
22	Reactor Protection	Control Rod Drive System	Rod Control System & Logic Cabinets	Semi-conductor devices, electronic components, and connectors	Not stated	CORR	Loss of Material
23	Reactor Protection	Control Rod Drive System	Rod Control System & Logic Cabinets	Semi-conductor devices, electronic components, and connectors	Not stated	FAT	Cumulative fatigue damage
24	Reactor Protection	Control Rod Drive System	Rod Control System & Logic Cabinets	Semi-conductor devices, electronic components, and connectors	Not stated	WEAR	Attrition
25	Reactor Protection	Control Rod Drive System	Rod Position Indication Systems	Electrical wiring, insulation, connectors, semi-conductor devices, and electro-mechanical components	Not stated	CORR	Loss of Material
26	Reactor Protection	Control Rod Drive System	Rod Position Indication Systems	Electrical wiring, insulation, connectors, semi-conductor devices, and electro-mechanical components	Not stated	WEAR	Attrition
27	Reactor Protection	Control Rod Drive System	Rod Position Indication Systems	Electrical wiring, insulation, connectors, semi-conductor devices, and electro-mechanical components	Not stated	FAT	Cumulative fatigue damage

Document: NUREG/CR-5558, Generic Issue 87: Flexible Wedge Gate Valve Test Program, Phase II Results and Analysis
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR water cleanup system and the high-pressure coolant injection (HPCI) steam line	Motor-operated flexible wedge gate valve	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Table A.1 Gall Report for NPAR Reports

Document: NUREG/CR-5555, Aging Assessment of the Westinghouse PWR Control Rod Drive System
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Rupture of control rod cladding.	Frequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	18
Dropped and/or stuck control rod.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	19
Dropped and/or stuck control rod.	Frequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	20
Dropped and/or stuck control rod.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	21
Single/multiple rod drop, inability to move rods on demand, erroneous rod movement, incorrect or spurious rod control system failure alarms, and incorrect rod position indication.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	22
Single/multiple rod drop, inability to move rods on demand, erroneous rod movement, incorrect or spurious rod control system failure alarms, and incorrect rod position indication.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	23
Single/multiple rod drop, inability to move rods on demand, erroneous rod movement, incorrect or spurious rod control system failure alarms, and incorrect rod position indication.	Frequent	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	24
Incorrect/inaccurate rod position information and possibly a false dropped rod indication.	Occasional	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	25
Incorrect/inaccurate rod position information and possibly a false dropped rod indication.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	26
Incorrect/inaccurate rod position information and possibly a false dropped rod indication.	Moderate	ASME Sect. III Div. 1	PS S&T Req. & PS TS Req.	System redesign and selection of alternate materials, improve ventilation to electronics, and improve monitoring and maintenance [2]	3-12, 3-13	27

Document: NUREG/CR-5558, Generic Issue 87: Flexible Wedge Gate Valve Test Program, Phase II Results and Analysis
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5583, Prediction of Check Valve Performance and Degradation in Nuclear Power Plant Systems - Wear and Impact Tests
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR core discharge system	Swing check valves	Hinge pin	The hinge pin and the bushing are made of cobalt-based alloys (Haynes Stellite #25 and Stoody #6 respectively)	Not stated	WEAR	Attrition
2	Auxiliary feedwater turbine steam supply system	Tilting disc check valves	Hinge pin	410 stainless steel hinge pin and Stellite-6 bushing	Not stated	WEAR	Attrition
3	PWR feedwater system	Swing check valves	Disc stud	A217	MCC Pacific Valve Company	FAT	Cumulative fatigue damage

Document: NUREG/CR-5587, Approaches for Age-Dependent Probabilistic Safety Assessments with Emphasis on Prioritization and Sensitivity Studies
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Accumulators, auxiliary feedwater, high/low pressure injection, safety injection system, low pressure recirculation, primary pressure relief, onsite emergency power, main steam system	Actuator, check valve, diesel generator, motor driven pump, motor operated valve, safety relief valve, turbine driven pump	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5612, Degradation Modeling with Applications to Aging and Maintenance Effectiveness Evaluations
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5643, Insights Gained From Aging Research
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Auxiliary feedwater pumps	Pump parts	Not stated	Not stated	WEAR	Attrition
2	Various	Auxiliary feedwater pumps	Turbine steam supply valve stems	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
3	Various	Auxiliary feedwater pumps	Diesel fuel oil line	Not stated	Not stated	FAT	Cumulative fatigue damage
4	Various	Auxiliary feedwater pumps	Bearings	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-5583, Prediction of Check Valve Performance and Degradation in Nuclear Power Plant Systems - Wear and Impact Tests
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Excessive wear of the hinge pin bushings had caused some of the bushings to completely wear through, and the debris of the worn-through bushings for some valves were found downstream, resulting in massive change-out of components.	Frequent	Not discussed in report	ASME Sec XI IWB & IWV	Not stated	41, 42	1
The 410 SS hinge pins had almost completely worn through due to the disc oscillation caused by the low rate of steam flow, resulting in material modifications to Stellite-6 vs. Stellite-6.	Frequent	Not discussed in report	ASME Sec XI IWB, IWV & PS TS Req.	Not stated	44, 45	2
The disc stud/nut connection had fractured due to repeated impact against the open stop, which had allowed the disc to separate from the hinge and subsequently, a water hammer event occurred in the horizontal feedwater line caused by failed check valves.	Frequent	Not discussed in report	ASME Sec XI IWB & IWV	Not stated	45, 46, C.1	3

Document: NUREG/CR-5587, Approaches for Age-Dependent Probabilistic Safety Assessments with Emphasis on Prioritization and Sensitivity Studies
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5612, Degradation Modeling with Applications to Aging and Maintenance Effectiveness Evaluations
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5643, Insights Gained From Aging Research
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1	1
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1	2
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1	3
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	4

Document: NUREG/CR-5643, Insights Gained From Aging Research
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5	Various	Auxiliary feedwater pumps	Bearings	Not stated	Not stated	CORR	Loss of material
6	Various	Auxiliary feedwater pumps	Impellers	Not stated	Not stated	WEAR	Attrition
7	Various	Auxiliary feedwater pumps	Thrust balancer	Not stated	Not stated	WEAR	Attrition
8	Various	Auxiliary feedwater pumps	Thrust balancer	Not stated	Not stated	WEAR/GALL	Attrition
9	Various	Check valves	Body assembly, hinge pins, discs and seats	Not stated	Not stated	WEAR	Attrition
10	Various	Check valves	Body assembly, hinge pins, discs and seats	Not stated	Not stated	ERO	Wall thinning; loss of material
11	Various	Check valves	Body assembly, hinge pins, discs and seats	Not stated	Not stated	CORR	Loss of material
12	Various	Check valves	Hinge arms	Not stated	Not stated	WEAR	Attrition
13	Various	Motor-operated valves	Gear, shaft, stem nut, drive sleeve, seal, clutch mechanism, motor operator switch gear/cam, yoke bushing, valve stem, and stem packing	Not stated	Not stated	WEAR	Attrition
14	Various	Motor-operated valves	Bearings, valve obturator, obturator guide, and valve seat	Not stated	Not stated	WEAR	Attrition
15	Various	Motor-operated valves	Bearings, valve obturator, obturator guide, and valve seat	Not stated	Not stated	CORR	Loss of material
16	Various	PORVs and block valves	Valve disks and seats	Not stated	Not stated	WEAR	Attrition
17	Various	PORVs and block valves	Valve disks and seats	Not stated	Not stated	WEAR/GALL	Attrition
18	Various	Snubbers	"Blank"	Not stated	Not stated	WEAR/FRET	Attrition
19	Various	Snubbers	"Blank"	Not stated	Not stated	CORR	Loss of material
20	Various	Solenoid-operated valves	Insulating material	Polymer	Not stated	EMBR/IR	Loss of fracture toughness

Table A.1 Gall Report for NPAR Reports

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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	5
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	6
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	7
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWP, & PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	8
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1	9
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1	10
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1	11
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	12
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV, & GL 89-10 & Suppl.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	13
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV, & GL 89-10 & Suppl.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	14
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV, & GL 89-10 & Suppl.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	15
PORVs stuck-open or with leakage.	Not stated	Not discussed in report	ASME Sec XI IWB & IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	16
PORVs stuck-open or with leakage.	Not stated	Not discussed in report	ASME Sec XI IWB & IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	17
Loosening of fasteners and an increase in clearances between mating parts.	Not stated	Not discussed in report	ASME Sec XI ISTD	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	18
Not stated.	Not stated	Not discussed in report	ASME Sec XI ISTD	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	19
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	20

Document: NUREG/CR-5643, Insights Gained From Aging Research
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
21	Various	Solenoid-operated valves	Insulating material	Polymer	Not stated	ELE-TEMP	Chemical and physical degradation
22	Various	Solenoid-operated valves	O-rings, diaphragms, gaskets, seals, core seats	Not stated	Not stated	AGRCHEM	Chemical degradation
23	Various	Solenoid-operated valves	O-rings, diaphragms, gaskets, seals, core seats	Not stated	Not stated	EMBR/IR	Loss of fracture toughness
24	Various	Solenoid-operated valves	O-rings, diaphragms, gaskets, seals, core seats	Not stated	Not stated	ELE-TEMP	Chemical and physical degradation
25	Various	Solenoid-operated valves	Metallic parts	Not stated	Not stated	WEAR	Attrition
26	Various	Solenoid-operated valves	Metallic parts	Not stated	Not stated	FAT	Cumulative fatigue damage
27	Various	Solenoid-operated valves	Valve orifice	Not stated	Not stated	FAT	Cumulative fatigue damage
28	Component cooling water system (PWR)	Valves	Valve seats and operators	Not stated	Not stated	WEAR	Attrition
29	Component cooling water system (PWR)	Pumps	Seals and bearings	Not stated	Not stated	WEAR	Attrition
30	CRD system (Westinghouse)	RCAA	Cladding, RCAA to CRDM coupling	Not stated	Westinghouse	WEAR	Attrition
31	CRD system (Westinghouse)	RCAA	Spider assembly vane weld	Not stated	Westinghouse	FAT	Cumulative fatigue damage
32	CRD system (Westinghouse)	RCAA	Reactor internal components	Not stated	Westinghouse	CORR/SCC	Crack initiation and growth
33	CRD system	CRDM	Operating coil	Not stated	Not stated	ELE-TEMP	Chemical and physical degradation
34	CRD system	CRDM	Cast housings	Not stated	Not stated	EMBR	Loss of fracture toughness
35	CRD system	CRDM	Latch assembly	Not stated	Not stated	CONTAM	Buildup of deposits
36	CRD system	Power and logic cabinets	Temperature sensitive components and heat sinks	Not stated	Not stated	CONTAM	Buildup of deposits
37	CRD system	Power and logic cabinets	Temperature sensitive components and heat sinks	Not stated	Not stated	ELE-TEMP	Chemical and physical degradation

Table A.1 Gall Report for NPAR Reports

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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	21
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	22
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	23
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	24
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	25
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	26
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, IWV	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	27
Leakage.	Not stated	Not discussed in report	ASME Sec XI IWV, PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	28
Leakage.	Not stated	Not discussed in report	ASME Sec XI IWP, PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1	29
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	30
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB, PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	31
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	32
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [3]	2	33
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	34
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	2	35
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	36
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	37

Document: NUREG/CR-5643, Insights Gained From Aging Research
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
38	CRD system	RPI	Detector coil	Not stated	Not stated	ELE-TEMP	Chemical and physical degradation
39	CRD system	Cable and connectors	Connectors	Not stated	Not stated	CORR	Corrosion product buildup
40	CRD system	Cable and connectors	In-containment cables	Not stated	Not stated	ELE-TEMP	Chemical and physical degradation
41	CRD system	Cable and connectors	Connector mating pins	Not stated	Not stated	WEAR	Attrition
42	BWR high pressure injection systems (HPCI and HPCS)	Valves and valve operators	Not stated	Not stated	Not stated	WEAR	Attrition
43	BWR high pressure injection systems (HPCI and HPCS)	Turbines	Not stated	Not stated	Not stated	WEAR	Attrition
44	BWR high pressure injection systems (HPCI and HPCS)	Turbines	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
45	BWR high pressure injection systems (HPCI and HPCS)	Turbines	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
46	BWR high pressure injection systems (HPCI and HPCS)	Instrumentation and controls	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
47	BWR high pressure injection systems (HPCI and HPCS)	Instrumentation and controls	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
48	BWR high pressure injection systems (HPCI and HPCS)	Pumps	Not stated	Not stated	Not stated	WEAR	Attrition
49	BWR high pressure injection systems (HPCI and HPCS)	Pipe	Not stated	Not stated	Not stated	CORR	Loss of material
50	BWR high pressure injection systems (HPCI and HPCS)	Pipe	Not stated	Not stated	Not stated	ENVIR	Degradation
51	BWR high pressure injection systems (HPCI and HPCS)	Pipe	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
52	BWR high pressure injection systems (HPCI and HPCS)	Pipe	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
53	BWR high pressure injection systems (HPCI and HPCS)	Pipe supports	Not stated	Not stated	Not stated	ENVIR	Degradation
54	High pressure injection system (PWR)	HPIS components	Not stated	Not stated	Not stated	CORR	Loss of material;corrosion product buildup

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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	38
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	39
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	40
Not stated.	Not stated	Not discussed in report	PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	2	41
Degraded operation.	Frequent	Not discussed in report	ASME Sec. XI IWB, IWV, GL 89-10 & Suppl.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	42
Degraded operation.	Infrequent	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	43
Degraded operation.	Rare	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	44
Degraded operation.	Rare	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	45
Loss of function.	Occasional	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	46
Loss of function.	Infrequent	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	47
Low injection flow.	Frequent	Not discussed in report	ASME Sec XI IWB & IWP	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	48
Leakage.	Frequent	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	49
Leakage.	Infrequent	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	50
Leakage.	Infrequent	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	51
Leakage.	Infrequent	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	52
Failure to operate.	Infrequent	Not discussed in report	ASME Sec XI	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	53
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	54

Document: NUREG/CR-5643, Insights Gained From Aging Research
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
55	High pressure injection system (PWR)	Thermal sleeves and nozzles	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
56	High pressure injection system (PWR)	Elbows	Not stated	Not stated	Not stated	FAT/THERM	Cumulative fatigue damage
57	Instrument air system	Compressors	Not stated	Not stated	Not stated	WEAR	Attrition
58	Instrument air system	Compressors	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
59	Instrument air system	Air dryers	Not stated	Not stated	Not stated	CLOG	Blockage of flow passages
60	Instrument air system	Air dryers	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
61	Instrument air system	Air dryers	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
62	Instrument air system	Filters	Not stated	Not stated	Not stated	CLOG	Blockage of flow passages
63	Instrument air system	Filters	Not stated	Not stated	Not stated	WEAR	Attrition
64	Instrument air system	Valves	Not stated	Not stated	Not stated	WEAR	Attrition
65	Instrument air system	Valves	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
66	Instrument air system	Piping	Not stated	Not stated	Not stated	ERO/CORR	Wall thinning;loss of material
67	Service water system (open)	Piping	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
68	Service water system (open)	Piping	Not stated	Not stated	Not stated	BIO	Buildup of deposits
69	Service water system (closed)	Heat exchangers	Not stated	Not stated	Not stated	BIO	Buildup of deposits
70	Service water system (closed)	Heat exchangers	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup
71	Service water system (closed)	Valves	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup

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Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	55
Not stated.	Not stated	Not discussed in report	ASME Sec XI IWB	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	56
Degraded operation, failure to load/unload, leaks (air and oil).	Moderate	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	57
Degraded operation, failure to load/unload, leaks (air and oil).	Infrequent	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	58
Delivery of compressed air with a higher dew point than specified, desiccant and moisture carry-over.	Occasional	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	59
Delivery of compressed air with a higher dew point than specified, desiccant and moisture carry-over.	Infrequent	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	60
Delivery of compressed air with a higher dew point than specified, desiccant and moisture carry-over.	Infrequent	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	61
Reduced air flow.	Frequent	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	62
Reduced air flow.	Rare	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	63
Fail to open/close valves.	Occasional	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	64
Fail to open/close valves	Occasional	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	65
Plugged piping, leaks	Not stated	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [2]	1, 2	66
Not stated	Not stated	Not discussed in report	PS S&T Req., PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	67
Not stated	Not stated	Not discussed in report	PS S&T Req., PS TS Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	68
Not stated	Not stated	Not discussed in report	ASME Sec XI or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	69
Not stated	Not stated	Not discussed in report	ASME Sec XI or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	70
Not stated	Not stated	Not discussed in report	ASME Sec XI or PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	71

Document: NUREG/CR-5643, Insights Gained From Aging Research
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
72	Recirculating SWS	Valves and sensors	Not stated	Not stated	Not stated	CORR	Loss of material and corrosion product buildup

Document: NUREG/CR-5646, Piping System Response During High Level Simulated Seismic Tests at the Heissdampfreaktor Facility (SHAM Test Facility)
Reviewed by: David C. Ma, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Piping System	Motor Operated Gate Valve, Snubbers, Rigid Struts, Piping	Not stated	Not stated	Mov-Limitorque; snubbers-Pacific Scientific; Rigid struts & piping-ITTGrinnell	Not stated	Not stated

Document: NUREG/CR-5693, Vol. 2, Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Component cooling water systems in pressurized water reactors	Heat exchanger	Tubes	Admiralty metals, brass, bronze or copper-nickel	Not stated	CORR	Loss of material
2	Component cooling water systems in pressurized water reactors	Heat exchanger	Tubes	Admiralty metals, brass, bronze or copper-nickel	Not stated	ERO	Loss of material
3	Component cooling water systems in pressurized water reactors	Heat exchanger	Tubes	Admiralty metals, brass, bronze or copper-nickel	Not stated	WEAR	Loss of material
4	Component cooling water systems in pressurized water reactors	Heat exchanger	Tubes	Admiralty metals, brass, bronze or copper-nickel	Not stated	CLOG	Flow blockage
5	Component cooling water systems in pressurized water reactors	Heat exchanger	Tubesheets	Admiralty metals, brass, bronze or copper-nickel	Not stated	CORR	Loss of material
6	Component cooling water systems in pressurized water reactors	Heat exchanger	Tubesheets	Admiralty metals, brass, bronze or copper-nickel	Not stated	ERO	Loss of material
7	Component cooling water systems in pressurized water reactors	Heat exchanger	Channel/bonnet heads	Carbon steels	Not stated	CORR	Loss of material
8	Component cooling water systems in pressurized water reactors	Heat exchanger	Channel/bonnet heads	Carbon steels	Not stated	ERO	Loss of material
9	Component cooling water systems in pressurized water reactors	Valves	Seats	Bronze, SS316, SS410, stellite, elastomers	Not stated	CORR	Loss of material
10	Component cooling water systems in pressurized water reactors	Valves	Seats	Bronze, SS316, SS410, stellite, elastomers	Not stated	ERO	Loss of material
11	Component cooling water systems in pressurized water reactors	Valves	Seats	Bronze, SS316, SS410, stellite, elastomers	Not stated	CONTAM	Loss of desired surface properties
12	Component cooling water systems in pressurized water reactors	Valves	Plugs	Bronze, SS316, SS410, stellite	Not stated	CORR	Loss of material

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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	PS S&T Req.	Recommendations for research, inspection, maintenance, operations, and design/test are listed on p. 2-6. [4]	1, 2	72

Document: NUREG/CR-5646, Piping System Response During High Level Simulated Seismic Tests at the Heissdampfreaktor Facility (SHAM Test Facility)
Reviewed by: David C. Ma, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
This report discusses the effects of increasing levels of seismic excitation on a full scale, in situ piping system containing a naturally aged motor operated valve. (More)	Not stated	Not stated	ASME Sec XI IWB, IWV, ISTD, GL 89-10 & Suppl.	Not stated	10	1

Document: NUREG/CR-5693, Vol. 2, Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Causes tube leakage and possible radiation release.	Moderate	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventative measures [4]	3-5, 3-6	1
Causes tube leakage and possible radiation release.	Moderate	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	2
Causes tube leakage and possible radiation release.	Moderate	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	3
Cause reduced flow and heat transfer.	Frequent	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	4
Loss of material can cause wall thinning and with time leakage or corrosion products fouling tubes.	Occasional	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	5
Loss of material can cause wall thinning and leakage.	Occasional	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	6
Corrosion products an cause tube fouling and reduced heat transfer or wall thinning leading to leakage.	Occasional	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	7
Loss of material causes wall thinning and possible leakage.	Occasional	Not discussed in report	ASME Sec XI, PS TS Req.	More study of preventive measures [3]	3-5, 3-6, 7-7	8
Causes valve leakage due to change in seat geometry.	Moderate	Not discussed in report	ASME Sec XI IWV & PS TS Req.	More study of preventive measures [3]	1-7, 3-12, 7-6	9
Causes valve leakage due to change in seat geometry.	Moderate	Not discussed in report	ASME Sec XI IWV & PS TS Req.	More study of preventive measures [3]	1-7, 3-12, 7-6	10
Foreign contaminants accumulate on seat causing valve to stick or failure to seat producing leakage.	Moderate	Not discussed in report	ASME Sec XI IWV & PS TS Req.	More study of preventive measures [3]	1-9, 3-12, 7-6	11
Causes failure of valve to seat and leakage.	Occasional	Not discussed in report	ASME Sec XI IWV & PS TS Req.	More study of preventive measures [3]	1-7, 3-10, 7-6	12

Document: NUREG/CR-5693, Vol. 2, Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13	Component cooling water systems in pressurized water reactors	Valves	Plugs	Bronze, SS316, SS410, stellite	Not stated	ERO	Loss of material
14	Component cooling water systems in pressurized water reactors	Valves	Packing	Asbestos, PTFE, aramid, graphite	Not stated	WEAR	Loss of material
15	Component cooling water systems in pressurized water reactors	Valves	Body	Carbon steel or stainless steel	Not stated	CORR	Loss of material
16	Component cooling water systems in pressurized water reactors	Pneumatic valve operator actuators	Diaphragms	Neoprene or other natural and synthetic rubbers reinforced with fibers	Not stated	EMBR	Loss of fracture toughness
17	Component cooling water systems in pressurized water reactors	Pneumatic valve operator actuators	Diaphragms	Neoprene or other natural and synthetic rubbers reinforced with fibers	Not stated	FAT	Cumulative fatigue damage
18	Component cooling water systems in pressurized water reactors	Pneumatic valve operator actuators	O-rings	Neoprene or other natural or synthetic rubbers reinforced with fibers	Not stated	EMBR	Loss of fracture toughness
19	Component cooling water systems in pressurized water reactors	Pneumatic valve operator actuators	O-rings	Neoprene or other natural or synthetic rubbers reinforced with fibers	Not stated	WEAR	Causes structural deterioration
20	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Mechanical seals	Stainless steel, tungsten carbide, lead bronze, carbon and many others including rubber in secondary seals	Not stated	WEAR	Causes loss of seal material
21	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Mechanical seals	Stainless steel, tungsten carbide, lead bronze, carbon and many others including rubber in secondary seals	Not stated	ELE-TEMP	Causes seal distortion or cracking
22	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Bearings	Tin bronze, steel, lead-bronze, or aluminum alloy	Not stated	WEAR	Causes loss of bearing material
23	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Bearings	Tin bronze, steel, lead-bronze, or aluminum alloy	Not stated	FAT	Cumulative fatigue damage
24	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Bearings	Tin bronze, steel, lead-bronze, or aluminum alloy	Not stated	ELE-TEMP	Causes distortion
25	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Packings	Asbestos, PTFE, aramid/PTFE, graphite	Not stated	WEAR	Causes loss of material
26	Component cooling water systems in pressurized water reactors	Centrifugal pumps	Gaskets	Non-asbestos in newer pumps	Not stated	Not stated	Causes leakage

Document: NUREG/CR-5699, ORNL-6666/V1, Vol. 1, Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	BWR Control Rod Drive System	Control Rod Drive Mechanism	Flange and plugs	Gauge F304 Stainless	GE	Not stated	Not stated

Document: NUREG/CR-5693, Vol. 2, Aging Assessment of Component Cooling Water Systems in Pressurized Water Reactors
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Causes failure of valve to seat and leakage.	Occasional	Not discussed in report	ASME Sec XI IWV & PS TS Req.	More study of preventive measures [3]	1-7, 3-10, 7-6	13
Relative motion between stem and packing causes loss of material and leaking which can result in a radiation release.	Moderate	Not discussed in report	ASME Sec XI IWV & PS TS Req.	More study of preventative measures [2]	1-7, 1-8, 1-9, 3-9, 3-10, 7-6	14
Corrosion can cause wall thinning through loss of material in body resulting in leakage.	Not stated	Not discussed in report	ASME Sec XI IWB or IWC, IWV & PS TS Req.	Need for improved monitoring to detect aging and preventive measures [2]	3-11, 8-4, 7-6	15
Contamination of air supply with dirt or moisture and elevated temperatures cause diaphragm to deteriorate and actuator to malfunction.	Frequent	Not discussed in report	ASME Sec XI IWV & PS TS Req.	Improved surveillance and better choice of materials to reduce aging [2]	1-7, 1-10, 3-15, 3-17	16
Repeated cycling of actuator causes fatigue of diaphragm and failure resulting in loss of actuator control of valves.	Frequent	Not discussed in report	ASME Sec XI IWV & PS TS Req.	Improved surveillance and better choice of materials to reduce aging [2]	1-7, 1-10, 3-15, 3-17	17
Contamination of air supply or elevated temperatures cause loss of O-ring integrity and air leakage resulting in erratic actuator control or loss of control.	Moderate	Not discussed in report	ASME Sec XI IWV & PS TS Req.	Improved surveillance and better choice of materials to reduce aging [2]	1-7, 1-10, 3-15, 3-17	18
Wear of O-ring causes air leakage and actuator sluggishness to respond or lack of response.	Moderate	Not discussed in report	ASME Sec XI IWV & PS TS Req.	Improved surveillance and better choice of materials to reduce aging [2]	1-7, 1-10, 3-15, 3-17	19
Wear of seals causes leakage of water and excessive shaft play.	Frequent	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Improved surveillance and better choice of materials [4]	1-6, 1-9, 3-23, 3-24, 3-25, 3-26	20
Seal distortion or cracking causes water leakage.	Frequent	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Improved surveillance and better choice of materials [4]		21
Excessive bearing wear resulting from shaft alignment problems, loss of lubricant or dirt can cause pump seizure.	Moderate	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Improved surveillance and better materials [4]	1-6, 1-9, 3-23, 3-27, 3-24	22
Cyclic stressing or operating for long periods outside optimum design flow limits can cause bearing breakage.	Moderate	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Improved surveillance [2]	1-6, 1-9, 3-23, 3-27, 3-24	23
Loss of bearing coolant or lubricant can cause thermal distortion of bearing and possible seizure.	Occasional	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Not stated		24
Wear of packing by rotating shaft can lead to pump leakage and possible release of radioactive water.	Moderate	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Use improved packing materials and monitor for leaks [2]	1-6, 1-9, 3-23	25
Faulty gasket can lead to leakage of water which may be radioactive.	Infrequent	Not discussed in report	ASME Sec XI IWP & PS TS Req.	Not stated	1-6, 1-9, 3-23	26

Document: NUREG/CR-5699, ORNL-6666/V1, Vol. 1, Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
None stated.	Rare	None stated	PS TS Req. & PS S&T Req.	None given	5	1

Document: NUREG/CR-5699, ORNL-6666/V1, Vol. 1, Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2	BWR Control Rod Drive System	Control Rod Drive Mechanism	Cylinder, tube, and flange assembly	Wrought 304 stainless in earlier designs; Cast 304L collet retainer tube; stainless steel in replacements and newer designs	GE	CORR/IGSCC	Crack initiation and growth
3	BWR Control Rod Drive System	Control Rod Drive Mechanism	Piston tube	Type 304 stainless in earlier designs; ASME SA-249 or SA-479 Grade XM-19 stainless in late designs	GE	Not stated	Not stated
4	BWR Control Rod Drive System	Control Rod Drive Mechanism	Index tube	Type 304 stainless in earlier designs; ASME SA-249 or SA-479 Grade XM-19 stainless in late designs	GE	Not stated	Not stated
5	BWR Control Rod Drive System	Control Rod Drive Mechanism	Collet piston	Type 304 stainless	GE	Not stated	Not stated
6	BWR Control Rod Drive System	Control Rod Drive Mechanism	Collet fingers, coupling spud, collet spring	Inconel alloy X-750	GE	Not stated	Not stated
7	BWR Control Rod Drive System	Control Rod Drive Mechanism	Drive and stop piston seals and bushings	Graphitar	GE	WEAR; EMBR/TE	Attrition; Loss of fracture toughness
8	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	Piston seal C-springs	Inconel alloy X-750	GE	Not stated	Not stated
9	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	Piston rings	Haynes 25	GE	Not stated	Not stated
10	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	Ball check valve	Haynes stellite or tungsten carbide base alloy	GE	Not stated	Not stated
11	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	Elastomeric O-ring seals	Ethylene propylene	Not stated	Not stated	Not stated
12	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	Drive piston head	17-4PH (precipitation hardened) stainless steel	GE	Not stated	Not stated
13	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	O-rings	Teflon-coated, type 304 stainless steel	Not stated	Not stated	Not stated
14	BWR Control Rod Drive Mechanism	Control Rod Drive Mechanism	Inner Filter	Not stated	GE	Not stated	Not stated
15	BWR Control Rod Drive Mechanism	Hydraulic Control Unit (HCU)	Accumulator nitrogen charging valve packing	Not stated	GE	WEAR	Attrition
16	BWR Control Rod Drive Mechanism	Hydraulic Control Unit (HCU)	Accumulator nitrogen charging valve stem	Not stated	GE	WEAR	Attrition
17	BWR Control Rod Drive Mechanism	Hydraulic Control Unit (HCU)	Scram discharge rise isolation valve stem and disks	Not stated	Dresser and Vogt	CORR/IGSCC	Crack initiation and growth
18	BWR Control Rod Drive Mechanism	Hydraulic Control Unit (HCU)	Scram water accumulator tank	Carbon Steel w/ chromium inner plating	GE	CORR	Loss of inner plating material
19	BWR Control Rod Drive System	Hydraulic Control Unit (HCU)	Scram water accumulator tank inlet and outlet valve seats	Teflon	GE	ERO	Loss of material
20	BWR Control Rod Drive System	Hydraulic Control Unit (HCU)	Scram water accumulator tank inlet and outlet valve diaphragms	Buna-N rubber reinforced with nylon	GE	WEAR	Attrition

Document: NUREG/CR-5699, ORNL-6666/V1, Vol. 1, Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
IGSCC leads to cracks in the collet housing region of flow holes, near the internal section change, and in the vicinity of the attachment weld. Circumferential separation of the tube is possible but not likely.	Rare	None stated	PS TS Req. & PS S&T Req.	Weekly surveillance testing. Successful response of a CRD to a normal withdrawal signal at normal drive operating pressures is a conclusive test of collet retainer tube integrity at all reactor operating conditions. [4]	55	2
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	3
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	4
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	5
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	6
Seal degradation leads to increase in pressure required to move the drive.	Moderate	None stated	PS TS Req. & PS S&T Req.	GE has improved graphitar seals available as of 1992 [1]	28	7
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	8
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	9
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	10
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	11
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	12
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	5	13
Not stated.	Not stated	None stated	PS TS Req. & PS S&T Req.	None stated	31	14
Wear of the valve packing can cause leakage of the nitrogen accumulator and loss of driving pressure for CRD.	Infrequent	None stated	PS TS Req. & PS S&T Req.	Use GE supplied packing tool when installing. [4]	27	15
Wear of the valve stem can cause leakage of the nitrogen accumulator and loss of driving pressure for CRD.	Rare	None stated	PS TS Req. & PS S&T Req.	Correct practice of operating valve with foot instead of hand [4]	27	16
IGSCC can cause separation of the disk from the stem and loss of valve function. This can cause failure for the CRD to scram.	Rare	None stated	PS TS Req. & PS S&T Req.	None stated	27	17
Corrosion of the chromium plating by high-chloride, low-PH water conditions can lead to water seepage and corrosion of the tank. Loss of function of this subcomponent can lead to control rod insertion.	Infrequent	None stated	PS TS Req.	None stated	27	18
Erosion by flakes of plating from a corroded accumulator can collect and erode the seat. This will cause leakage and control rod insertion.	Rare	None stated	PS TS Req.	None stated	27	19
Increased wear caused by improper installation and will cause eventual leakage. This will cause control rod insertion.	Infrequent	None stated	PS TS Req.	None stated	27	20

Document: NUREG/CR-5699, ORNL-6666/V1, Vol. 1, Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
21	BWR Control Rod Drive System	Hydraulic Control Unit (HCU)	Scram pilot valve seats	Buna-N rubber	GE	ELE-TEMP; WEAR	Physical degradation; Attrition
22	BWR Control Rod Drive System	Hydraulic Control Unit (HCU)	Scram pilot valve solenoid coils	Not stated	GE	ELE-TEMP	Physical degradation; Thermal distortion
23	BWR Control Rod Drive System	Balance of control rod drive system	Pump bearings	Not stated	Not stated	VIBR	Loosening
24	BWR Control Rod Drive System	Balance of control rod drive system	Electrical Components	Not stated	Not stated	WEAR	Attrition
25	BWR Control Rod Drive System	Balance of control rod drive system	Pump gaskets and seals	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-5706, Potential Safety-Related Pump Loss: An Assessment of Industry Data
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Safety	Pump	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5720, Motor-Operated Valve Research Update
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Motor-operated valves	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5754, Boiling Water Reactor Internals Aging Degradation Study, Phase 1
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor internals	Jet pump assembly	Pump holddown beams	Inconel X-750	Not stated	CORR/IGSCC	Crack initiation and growth
2	Reactor internals	Core spray system	Spray sparger	Type 304 SS	Not stated	CORR/IGSCC	Crack initiation and growth
3	Reactor internals	Shroud support	Access hole cover	Inconel 600	Not stated	CORR/IGSCC	Crack initiation and growth
4	Reactor internals	Feedwater sparger	Not stated	Types 304 and 316NG SS	Not stated	VIBR; FAT/THERM	Crack initiation and growth; Cumulative fatigue damage
5	Reactor internals	Jet pump assembly	Jet pump	Inconel X-750	Not stated	VIBR	Crack initiation and growth
6	Pressure vessel	Control rod drive (CRD) housing	Stub tube	Type 304 SS	Not stated	CORR/IGSCC	Crack initiation and growth

Table A.1 Gall Report for NPAR Reports

Document: NUREG/CR-5699, ORNL-6666/V1, Vol. 1, Aging and Service Wear of Control Rod Drive Mechanisms for BWR Nuclear Plants
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Prolonged exposure to service temperature causes degradation and increases in CRD scram times.	Infrequent	None stated	PS TS Req.	None stated	28	21
Prolonged exposure to service temperature causes degradation and increases in CRD scram times.	Infrequent	None stated	PS TS Req.	Periodic monitoring of surface temperatures with industrial pyrometers. [2]	28	22
Not stated.	Occasional	None stated	PS TS Req.	None stated	31	23
Loss of device setpoint and calibration.	Occasional	None stated	PS TS Req.	None stated	36	24
Loss of seal capability and pump head.	Infrequent	None stated	PS TS Req.	None stated	31	25

Document: NUREG/CR-5706, Potential Safety-Related Pump Loss: An Assessment of Industry Data
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5720, Motor-Operated Valve Research Update
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5754, Boiling Water Reactor Internals Aging Degradation Study, Phase 1
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
A combination of low heat treatment temperature (which led to the sensitization of the beam material) and high preloads on the beam bolt led to IGSCC of jet pump holddown beams.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI-IWB	Solution heat-treat at higher temperature, reduce preloads in the beam bolts [4]	30	1
Cold working and sensitization during fabrication of the spargers and stresses incurred during installation were the major factors leading to the IGSCC of core spray spargers.	Not stated	ASME B&PV Code, Section II & XI	ASME Sec XI-IWB	Not stated	30	2
Welding induced residual stresses and crevice conditions on the welded area led to the formation of through-the-wall cracks in the welds through IGSCC.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI-IWB	Not stated	30	3
Flow induced vibration and rapid thermal cycling led to the development of fatigue cracks in the vicinity of the feedwater nozzle corner and sparger.	Not stated	ASME B&PV Code, Section III	ASME Sec XI-IWB	Use new sparger with a thigh slip-fit joint. [4]	31	4
Flow induced vibration led to the development of fatigue cracks in the pump support system.	Not stated	ASME B&PV Code, Section III	ASME Sec XI-IWB	Redesign and use a stronger holddown beam [4]	32	5
Welding induced residual stresses led to the development of through-the-wall cracks in the HAZ of the J-welds that join the CRD housing to the top of the stub tube.	Not stated	ASME B&PV Code, Section III & XI	PS TS Req.	Not stated	31	6

Document: NUREG/CR-5754, Boiling Water Reactor Internals Aging Degradation Study, Phase 1
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	Pressure vessel	In-core neutron flux monitor	Guide tube	Type 304 SS	Not stated	CORR/IASCC	Crack initiation and growth
8	Pressure vessel	In-core neutron flux monitor	Local power range monitor dry tube	Type 304 SS	Not stated	VIBR	Loosening, crack initiation and growth
9	Reactor internals	Multiple	Various	Typically Type 304 SS	Not stated	CORR/SCC	Crack initiation and growth
10	Reactor internals	Multiple	Various	Typically Type 304 SS	Not stated	FAT	Cumulative fatigue damage
11	Reactor internals	Multiple	Various	Typically Type 304 SS	Not stated	CORR/SCC; FAT; EMBR; ERO; CREEP	Crack initiation and growth, cumulative fatigue damage, loss of fracture toughness, (More)

Document: NUREG/CR-5779, Aging of Non Power Cycle Heat Exchangers Used in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Non-Power-Cycle heat exchangers	Emergency diesel generator heat exchanger (mainly shell-and tube type)	Shell	Not stated	Not stated	ERO/CORR	Wall thinning
2	Non-Power-Cycle heat exchangers	Emergency diesel generator heat exchanger (mainly shell-and tube type)	Tubes	Not stated	Not stated	ERO/ CORR	Wall thinning
3	Non-Power-Cycle heat exchangers	Emergency diesel generator heat exchanger (mainly shell-and tube type)	Tubes	Not stated	Not stated	CONTAM	Buildup of deposits
4	Non-Power-Cycle heat exchangers	Emergency diesel generator heat exchanger (mainly shell-and tube type)	Tubes	Not stated	Not stated	FAT	Cumulative fatigue damage
5	Non-Power-Cycle heat exchangers	Emergency diesel generator heat exchanger (mainly shell-and tube type)	Tubesheet	Not stated	Not stated	CORR	Loss of material
6	Non-Power-Cycle heat exchangers	Emergency diesel generator heat exchanger (mainly shell-and tube type)	Heads/nozzles	Not stated	Not stated	ERO/CORR	Wall thinning
7	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Shell	Carbon steel	Not stated	ERO/CORR	Wall thinning
8	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Shell	Carbon steel	Not stated	CONTAM	Buildup of deposits

Document: NUREG/CR-5754, Boiling Water Reactor Internals Aging Degradation Study, Phase 1
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Combination of a high level of neutron irradiation and the presence of high tensile stresses due to crud and oxides that accumulated in crevices between the guide plug and the thin tube segment are considered as the major causes of the IASCC of tubes.	Not stated	ASME B&PV Code, Section III & XI	PS TS Req.	Not stated	31	7
Flow induced vibration generated by the low-pressure coolant flow resulted in fatigue failures in dry tubes.	Not stated	ASME B&PV Code, Section III	PS TS Req.	Install a flow deflector [4]	32-33	8
This report lists several other BWR internal components (e.g., shroud head bolts, access hole cover, core spray line internal piping, steam dryer support ring, jet pump assembly riser pipe, control plates, IRM/SRM dry tubes, neutron source holder) (More)	Not stated	ASME B&PV Code, Section III	ASME Sec III & XI IWB	Install a flow deflector [4]	32	9
This report lists several other BWR internal components (e.g., steam dryer, steam dryer sensing line, jet pump restrainer gate, in-core neutron flux monitor dry tube, feedwater sparger) with reported fatigue failures.			ASME Sec III & XI IWB		33	10
This report lists several BWR internal components by name as being susceptible to SCC, creep, fatigue, embrittlement, and erosion. however, it does not provide an in-depth discussion of these aging processes for any of the components listed.			ASME Sec III & XI IWB		27	11

Document: NUREG/CR-5779, Aging of Non Power Cycle Heat Exchangers Used in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage in shell wall could jeopardize cooling of emergency diesel generators.	Occasional	Not stated	PS S&T Req.	Not stated	18, 21	1
Leakage across tubes can produce contamination of shell and tube side fluids.	Occasional	Not stated	PS S&T Req.	Not stated	19, 23	2
Buildup of foreign contaminants in tubes such as scale, silt, debris, and biological organisms can cause partial or complete blockage of flow and reduced heat transfer.	Occasional	Not stated	PS S&T Req.	Not stated	18, 21	3
Fluctuating loads caused by flow induced vibration or thermal cycling can crack tubes and produce contamination of shell and tube side fluids.	Infrequent	Not stated	PS S&T Req.	Not stated	19, 23	4
Corrosion of the tube-to-tubesheet welds can cause leakage between the primary and secondary fluids.	Infrequent	Not stated	PS S&T Req.	Not stated	19, 23	5
Wall thinning caused by erosion/corrosion can lead to external leakage.	Occasional	Not stated	PS S&T Req.	Not stated	18, 23	6
Leakage in shell wall could jeopardize post-accident containment cooling through degrading of spray headers water supply.	Not stated	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	4, 6, 18	7
Buildup of foreign contaminants in shell such as scale, silt, debris, and biological organisms can cause partial or complete blockage of flow	Occasional	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18	8

Document: NUREG/CR-5779, Aging of Non Power Cycle Heat Exchangers Used in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Tubes	Austenitic stainless steel	Not stated	ERO/CORR	Wall thinning
10	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Tubes	Austenitic stainless steel	Not stated	CONTAM	Buildup of deposits
11	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Tubes	Austenitic stainless steel	Not stated	FAT	Cumulative fatigue damage
12	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Tubesheet	Not stated	Not stated	CORR	Loss of material
13	Non-Power-Cycle heat exchangers	Containment cooling heat exchanger (mainly shell- and tube type)	Heads/nozzles	Not stated	Not stated	ERO/CORR	Wall thinning
14	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Shell	Carbon steel	Not stated	ERO/CORR	Wall thinning
15	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Gasket	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
16	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Tubes	Austenitic stainless steel	Not stated	ERO/CORR	Wall thinning
17	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Tubes	Austenitic stainless steel	Not stated	CONTAM	Buildup of deposits
18	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Tubes	Austenitic stainless steel	Not stated	FAT	Cumulative fatigue damage
19	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Tubesheet	Carbon steel	Not stated	CORR	Loss of material
20	Non-Power-Cycle heat exchangers	Residual heat removal heat exchanger (mainly shell- and tube type)	Heads/nozzles	Not stated	Not stated	ERO/CORR	Wall thinning
21	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Shell	Carbon steel	Not stated	ERO/CORR	Wall thinning
22	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Gasket	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
23	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Tubes	Admiralty, 90-10 Cu-Ni, aluminum-brass, or titanium	Not stated	ERO/CORR	Wall thinning
24	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Tubes	Admiralty, 90-10 Cu-Ni, aluminum-brass, or titanium	Not stated	CONTAM	Buildup of deposits

Table A.1 Gall Report for NPAR Reports

Document: NUREG/CR-5779, Aging of Non Power Cycle Heat Exchangers Used in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage across tubes can cause reduced flow for emergency cooling	Moderate	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 23	9
Buildup of foreign contaminants in tubes such as scale, silt, debris, and biological organisms can cause partial or complete blockage of flow and reduced heat transfer	Occasional	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 21	10
Fluctuating loads caused by flow induced vibration or thermal cycling can crack tubes and produce contamination of shell and tube side fluids	Occasional	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18	11
Corrosion of the tube-to-tubesheet welds can cause leakage between the primary and secondary fluids	Infrequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	19	12
Erosion/corrosion caused wall thinning can cause leakage external to the heat exchanger	Infrequent	Not stated	PS S&T Req., PS TS Req.	Not stated	18, 19	13
Leakage in shell wall could reduce shutdown coolant effectiveness	Infrequent	Not stated	PS S&T Req., PS TS Req.	Not stated	4, 18	14
Gasket failure from elevated temperature causes leakage	Moderate	Not stated	PS S&T Req., PS TS Req.	Not stated	18, 22	15
Leakage across tubes can cause reduced flow for emergency cooling	Moderate	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	19, 21, 23	16
Buildup of foreign contaminants in tubes such as scale, silt, debris, and biological organisms can cause partial or complete blockage of flow and reduced heat transfer	Occasional	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 21	17
Fluctuating loads caused by flow induced vibration or thermal cycling can crack tubes and produce contamination of shell and tube side fluids	Infrequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 19	18
Corrosion of the tube-to-tubesheet welds can cause leakage between the primary and secondary fluids	Infrequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	19	19
Erosion/corrosion caused wall thinning can cause leakage external to the heat exchanger	Infrequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 19	20
Leakage in shell wall could cause contamination	Infrequent	Not stated	PS S&T Req., PS TS Req.	Not stated	4, 18	21
Gasket failure from elevated temperature causes leakage and possible contamination	Frequent	Not stated	PS S&T Req., PS TS Req.	Not stated	18, 22	22
Leakage across tubes can cause reduced flow for emergency cooling and possible contamination	Frequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	19, 21, 23	23
Buildup of foreign contaminants in tubes such as scale, silt, debris, and biological organisms can cause partial or complete blockage of flow and reduced heat transfer	Frequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 21	24

Document: NUREG/CR-5779, Aging of Non Power Cycle Heat Exchangers Used in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
25	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Tubes	Admiralty, 90-10 Cu-Ni, aluminum-brass, or titanium	Not stated	FAT	Cumulative fatigue damage
26	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Tubesheet	Carbon steel	Not stated	CORR	Loss of material
27	Non-Power-Cycle heat exchangers	Component cooling water heat exchanger (mainly shell-and tube type)	Heads/nozzles	Not stated	Not stated	ERO/CORR	Wall thinning

Document: NUREG/CR-5783, BNL-NUREG-52299, Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Combustion Engineering (CE) Control Rod Drive System	Control Element Assemblies	Control Elements	Clad-Inconel 625	CE	WEAR; CORR/ SCC	Attrition; Crack initiation and growth
2	Combustion Engineering (CE) Control Rod Drive System	Control Element Assemblies	Fuel Assembly Guide Tubes	Zircaloy-4	CE	WEAR	Attrition
3	Combustion Engineering (CE) Control Rod Drive System	Control Element Assemblies	Upper Guide Structure-Spider	Stainless Steel	CE	WEAR; EMBR/IR; FAT	Attrition; Loss of fracture toughness; Cumulative fatigue damage
4	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Motor Housing Assembly	403 Stainless Steel Ni-Cr-Fe alloy	CE	EMBR; CORR; FAT	Loss of fracture toughness; Loss of material; Cumulative fatigue damage
5	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Motor Assembly-Latches, Links and Pins	High Cobalt Alloy	CE	WEAR; FAT; CONTAM	Attrition; Cumulative fatigue damage; Buildup of deposits
6	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Upper Pressure Housing Assembly	Type 316 Stainless	CE	EMBR; CORR; FAT	Loss of fracture toughness; Loss of material; Loss of fracture toughness
7	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Extension Shaft	Type 304 Stainless, Chromium plated	CE	WEAR; FAT; CORR/SCC	Attrition; Loss of fracture toughness; Crack initiation and growth
8	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Vent Valves	Type 440 Stainless Steel, Type 316 Stainless Steel Seat	CE	CORR; FAT; WEAR; EMBR/TE	Corrosion product buildup; Cumulative fatigue damage; Attrition; Loss of fracture toughness
9	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Coil Stack Assembly - Coils	Copper wire insulated with high temperature enamel vacuum impregnated with high temperature varnish	CE	CORR; WEAR	Loss of material; Attrition
10	Combustion Engineering (CE) Control Rod Drive System	CEDM Control Systems	Control Element Drive Control System and Control Power Programmer	Not stated	CE	These components are referred to INEL for review.	
11	Combustion Engineering (CE) Control Rod Drive System	CEDM Control Systems	Rack and Pinion Control System	Not stated	CE	These components are referred to INEL for review.	
12	Combustion Engineering (CE) Control Rod Drive System	CEA Rod Position Indication	Reed Switch Position Transmitter Assembly	Not stated	CE	These components are referred to INEL for review.	

Document: NUREG/CR-5779, Aging of Non Power Cycle Heat Exchangers Used in Nuclear Power Plants
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fluctuating loads caused by flow induced vibration or thermal cycling can crack tubes and produce contamination of shell and tube side fluids	Occasional	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 19	25
Corrosion of the tube-to-tubesheet welds can cause leakage between the primary and secondary fluids and contamination	Infrequent	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	19	26
Erosion/corrosion caused wall thinning can cause leakage external to the heat exchanger and contamination	Moderate	Not stated	ASME Sec XI, PS S&T Req., PS TS Req.	Not stated	18, 19	27

Document: NUREG/CR-5783, BNL-NUREG-52299, Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Clad cracking and wash out of the poison.	Occasional	None stated	PS S&T Req., PS TS Req.	Rod exposure tracking; Increased visual inspection [2]	5-13	1
Cracking of the tube wall.	Frequent	None stated	PS S&T Req., PS TS Req.	Add guide tube sleeving; Increase inspection [2]	5-13	2
Cracking of the guide causing rod drops.	Rare	None stated	PS S&T Req., PS TS Req.	None given	5-13	3
Housing cracking leads to primary coolant leakage (SBLOCA) and jamming of the drive mechanism.	Frequent	None stated	PS S&T Req., PS TS Req.	Improve leakage monitoring [2]	5-13	4
Failure of these sub-components will lead to dropping or locking of the control element.	Rare	None stated	PS S&T Req., PS TS Req.	Increase inservice inspection [2]	5-13	5
Housing cracking leads to primary coolant leakage (SBLOCA) and jamming of the drive mechanism.	Frequent	None stated	PS S&T Req., PS TS Req.	Improve leakage monitoring [2]	5-13	6
Shaft cracking will lead to locking of the mechanical operation.	Occasional	None stated	PS S&T Req., PS TS Req.	Increase inservice inspection [2]	5-13	7
Loss of valve function and primary coolant leakage.	Rare	None stated	PS S&T Req., PS TS Req.	Increase inservice inspection [2]	5-13	8
Loss of coil function will lead to dropped, slipped or immovable control elements.	Rare	None stated	PS S&T Req., PS TS Req.	Increase inservice inspection [2]	5-13	9
			PS S&T Req., PS TS Req.			10
			PS S&T Req., PS TS Req.			11
			PS S&T Req., PS TS Req.			12

Document: NUREG/CR-5783, BNL-NUREG-52299, Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13	Combustion Engineering (CE) Control Rod Drive System	CEA Rod Position Indication	Pulse Count Position Indication System	Not stated	CE	These components are referred to INEL for review.	
14	Combustion Engineering (CE) Control Rod Drive System	CEDM Cooling System	Fans	Not stated	CE	Not stated	Not stated
15	Combustion Engineering (CE) Control Rod Drive System	CEDM Cooling System	Cooling Shroud	Sheet metal	CE	CORR/BA	Loss of material
16	Combustion Engineering (CE) Control Rod Drive System	CEDM Cooling System	Instrumentation	Not stated	CE	Not stated	Not stated
17	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Assemblies	Control Rod Cladding	Type 304 Stainless	B&W	CORR/SCC; WEAR	Crack initiation and growth; Attrition
18	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Assemblies	Fuel Assembly Guide Tubes	Zircaloy-4	B&W	WEAR	Attrition
19	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Assemblies	Upper Internal Brazement Assemblies-Spider	Grade CF3M Stainless	B&W	CORR/SCC; WEAR; EMBR/IR; FAT	Crack initiation and growth; Attrition; Loss of fracture toughness; Cumulative fatigue damage
20	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Motor Tube	Low alloy steel clad with Inconel or Type 403 stainless	B&W	EMBR/TE; CORR; FAT	Loss of fracture toughness; Loss of material; Cumulative fatigue damage
21	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Stator Coils	Copper Wire, Dow Corning 997 Varnish, Kapton, Nomex, Silicone Rubber	B&W	Referred to INEL for review.	
22	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Vent Valve O-rings	Stainless Steel	B&W	CORR; WEAR; FAT; EMBR/TE	Corrosion product buildup; Attrition; Cumulative fatigue damage; Loss of fracture toughness
23	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Rotor Assembly-roller nuts, segment arms, springs	Stellite Ni-Cr-Fe Alloy, Type 403 Stainless Steel	B&W	WEAR; FAT; CONTAM	Attrition; Cumulative fatigue damage; Buildup of deposits
24	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Leadscrew	17-4 PH Stainless Steel	B&W	WEAR; FAT; CORR/SCC	Attrition; Cumulative fatigue damage; Crack initiation and growth;
25	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Power Supplies	Not stated	B&W	Referred to INEL for review.	
26	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Programmers	Not stated	B&W	Referred to INEL for review.	
27	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Trip Breakers	Not stated	B&W	Referred to INEL for review.	
28	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Programmer Drive Motors	Not stated	B&W	Referred to INEL for review.	
29	Babcock & Wilcox (B&W) Control Rod Drive System	CRA Rod Position Indication	Absolute Position Indication System	Not stated	B&W	Referred to INEL for review.	
30	Babcock & Wilcox (B&W) Control Rod Drive System	CRA Rod Position Indication	Relative Rod Position Indication	Not stated	B&W	Referred to INEL for review.	

Document: NUREG/CR-5783, BNL-NUREG-52299, Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
			PS S&T Req., PS TS Req.			13
Loss of rod drive mechanism cooling capacity leading to inoperable CRDM or rod drops.	Not stated	None stated	PS S&T Req., PS TS Req.	Improve leakage monitoring [2]	5-13	14
Loss of rod drive mechanism cooling capacity leading to inoperable CRDM or rod drops.	Not stated	None stated	PS S&T Req., PS TS Req.	Improve leakage monitoring [2]	5-13	15
Loss of rod drive mechanism cooling capacity leading to inoperable CRDM or rod drops.	Not stated	None stated	PS S&T Req., PS TS Req.	Improve leakage monitoring [2]	5-13	16
Clad cracking and wash out of the poison.	Occasional	None stated	PS S&T Req., PS TS Req.	Rod exposure tracking; Increased visual inspection [2]	5-14	17
Cracking of the tube wall.	Rare	None stated	PS S&T Req., PS TS Req.	Component design modification [2]	5-14	18
Cracking of the guide causing rod drops.	Rare	None stated	PS S&T Req., PS TS Req.	None given	5-14	19
Housing cracks causing primary coolant leakage (SBLOCA) and jamming of the drive mechanism.	Rare	None stated	PS S&T Req., PS TS Req.	Improved leakage monitoring; Improved visual inspection [2]	5-14	20
			PS S&T Req., PS TS Req.			21
Loss of valve function and primary coolant leakage.	Occasional	None stated	PS S&T Req., PS TS Req.	Improved leakage monitoring; Improved visual inspection [2]	5-14	22
Failure of these sub-components will lead to dropping or locking of the control rod assembly.	Rare	None stated	PS S&T Req., PS TS Req.	None stated	5-14	23
Cracking of the leadscrew will cause a dropped or immovable control rod.	Rare	None stated	PS S&T Req., PS TS Req.	Periodic wear measurements [2]	5-14	24
			PS S&T Req., PS TS Req.			25
			PS S&T Req., PS TS Req.			26
			PS S&T Req., PS TS Req.			27
			PS S&T Req., PS TS Req.			28
			PS S&T Req., PS TS Req.			29
			PS S&T Req., PS TS Req.			30

Document: NUREG/CR-5783, BNL-NUREG-52299, Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
31	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Cooling System	Centrifugal Pumps	Not stated	B&W	CORR/BA	Loss of material
32	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Cooling System	Heat Exchangers	Not stated	B&W	CORR/BA	Loss of material
33	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Cooling System	Surge Tank	Not stated	B&W	CORR/BA	Loss of material

Document: NUREG/CR-5807, Improvements in Motor Operated Gate Valve Designs and Prediction Models for Nuclear Power Plant Systems
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Various	Motor operated gate valves	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5848, Recordkeeping Needs to Mitigate the Impact of Aging Degradation
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Multiple	Multiple	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: NUREG/CR-5870, Results of LWR Snubber Aging Research
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	PWR and BWR cooling and emergency cooling systems	Mechanical snubbers	Lead screw, thrust bearing, capstan spring, pins, and attachment lugs	Not stated	Not stated	VIBR (high-amplitude)	Loosening, wear
2	PWR and BWR cooling and emergency cooling systems	Mechanical snubbers	Fasteners, clevis pins, and attachments	Not stated	Not stated	VIBR (low-amplitude)	Loosening, wear
3	PWR and BWR cooling and emergency cooling systems	Mechanical snubbers	Lubricants	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
4	PWR and BWR cooling and emergency cooling systems	Mechanical snubbers	Capstan and capstan spring	Not stated	Not stated	CORR	Loss of material; corrosion product buildup

Document: NUREG/CR-5783, BNL-NUREG-52299, Aging Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of cooling leading to inoperable CRDM.	Rare	None stated	PS S&T Req., PS TS Req.	None stated		31
Loss of cooling leading to inoperable CRDM.	Rare	None stated	PS S&T Req., PS TS Req.	None stated		32
Loss of cooling leading to inoperable CRDM.	Rare	None stated	PS S&T Req., PS TS Req.	None stated		33

Document: NUREG/CR-5807, Improvements in Motor Operated Gate Valve Designs and Prediction Models for Nuclear Power Plant Systems
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5848, Recordkeeping Needs to Mitigate the Impact of Aging Degradation
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: NUREG/CR-5870, Results of LWR Snubber Aging Research
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High-amplitude vibration can result in localized fretting and wear of mating parts. It can also result in an increase in drag force, an increase in mechanical clearances, jamming, and/or an increase in the acceleration threshold.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	17,19	1
Low-amplitude vibration can lead to loosening of fasteners and, in combination with the weight of the snubber, can cause wear of clevis pins and attachments, resulting in elongated attachment holes, and can cause internal wear.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	17,19	2
Solidification of lubricants increases friction and results in an increase in drag force.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	17,19	3
Internal corrosion can lead to increasing drag force, jamming, and/or a decrease in the snubber's acceleration threshold as a result of a buildup of rust.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	17,19	4

Document: NUREG/CR-5870, Results of LWR Snubber Aging Research
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5	PWR and BWR cooling and emergency cooling systems	Hydraulic snubbers	Seals	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
6	PWR and BWR cooling and emergency cooling systems	Hydraulic snubbers	Plastic hydraulic reservoirs	Not stated	Not stated	ELE-TEMP	Chemical or physical degradation
7	PWR and BWR cooling and emergency cooling systems	Hydraulic snubbers	Control valve	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
8	PWR and BWR cooling and emergency cooling systems	Hydraulic snubbers	Control valve	Not stated	Not stated	VIBR	Loosening, wear
9	PWR and BWR cooling and emergency cooling systems	Hydraulic snubbers	Threaded fasteners, clevis pins, attachment holes	Not stated	Not stated	VIBR	Loosening, wear
10	PWR and BWR cooling and emergency cooling systems	Hydraulic snubbers	Hydraulic fluid	Not stated	Not stated	VIBR	Gelation

Document: NUREG/CR-5944, A Characterization of Check Valve Degradation and Failure Experience in the Nuclear Power Industry
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor flow control	Check valves	Hinge pin/bushings	Not stated	Not stated	CORR; WEAR	Loss of material, attrition
2	Reactor flow control	Check valves	Disk stud	Not stated	Not stated	FAT; VIBR	Cumulative fatigue damage
3	Reactor flow control	Check valves	Hinge arm	Not stated	Not stated	FAT; VIBR	Cumulative fatigue damage
4	Reactor flow control	Check valves	Seat	Not stated	Not stated	CORR; ERO	Loss of material
5	Reactor flow control	Check valves	Valve body	Not stated	Not stated	WEAR	Attrition

Document: NUREG/CR-5870, Results of LWR Snubber Aging Research
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Seal leaks would result in loss of fluid from the snubber.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	3,11	5
Elevated temperature can lead to deformation of plastic hydraulic reservoirs.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	3,11	6
Internal corrosion resulting in the generation of corrosion products can cause a malfunction of the snubber control valve.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	3,11	7
Wear due to high-amplitude vibration can result in particle generation, potentially affecting control valve performance.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	3,12	8
High- or low-amplitude vibration can result in loosening of threaded fasteners and/or wear or deformation of clevis pins and attachment holes.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	3,12,J.6	9
Extreme high-amplitude vibration can result in gelated, blackened hydraulic fluid.	Not stated	Not discussed in report	ASME Sec XI ISTD	Monitor service-life to include determination of snubber failure or degradation causes, operating environment, managing snubbers in severe environments, augmented surveillance, trending degradation parameters & testing. [2]	3,12,J.2	10

Document: NUREG/CR-5944, A Characterization of Check Valve Degradation and Failure Experience in the Nuclear Power Industry
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Corrosion and wear of hinge pins and bushings can cause valve to open or close sluggishly or not move, resulting in leakage or reduced flow.	Rare	ASME Working Group on Check Valves (OM 22)	ASME Sec XI IWV	Not stated	10, 21	1
Fatigue due to flow impact and vibration can cause misalignment of valve disk and seat, resulting in leakage.	Occasional	ASME Working Group on Check Valves (OM 22)	ASME Sec XI IWV	Not stated	7, 17	2
Fatigue due to flow impact and vibration can cause misalignment of valve disk and seat, resulting in leakage.	Occasional	ASME Working Group on Check Valves (OM 22)	ASME Sec XI IWV	Not stated	7, 17	3
Erosion and/or corrosion causes valve to seat improperly, resulting in minor or major fluid leakage. The impact depends on where valve is located in plant, and can lead to important safety related events. This degradation is prevalent in large values.	Moderate	ASME Working Group on Check Valves (OM 22)	ASME Sec XI IWV	Not stated	7, 21, 32	4
Degradation of a body penetration, such as packing or a valve stem, due to wear interferes with proper valve functioning and causes possible leakage.	Moderate	ASME Working Group on Check Valves (OM 22)	ASME Sec XI IWB, IWV	Not stated	10	5

Document: NUREG/CR-6001, Aging Assessment of BWR Standby Liquid Control Systems
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Standby liquid control in BWR	Relief valves	Not delineated	Not stated	Not stated	WEAR	Attrition
2	Standby liquid control in BWR	Relief valves	Not delineated	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
3	Standby liquid control in BWR	Relief valves	Not delineated	Not stated	Not stated	CONTAM	Buildup of deposits
4	Standby liquid control in BWR	Accumulators	Not delineated	Not stated	Not stated	Not stated	Nitrogen blanket pressure reduction
5	Standby liquid control in BWR	Pumps	Not delineated	Not stated	Not stated	Not stated	Aging degradation of packing, seals and internal valves
6	Standby liquid control in BWR	Instrumentation	Not delineated	Not stated	Not stated	Not stated	Impaired ability to monitor system

Document: NUREG/CR-6029, Vol. 1, Aging Assessment of Nuclear Air-Treatment System HEPA Filters and Adsorbers, Phase I
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Air-treatment system	HEPA filters	Filtering media	Glass fiber filter "paper," possibly with organic additions	Not stated	PART	Increased pressure drop
2	Air-treatment system	HEPA filters	Filtering media	Glass fiber filter "paper," possibly with organic additions	Not stated	MOIST	Increased pressure drop and reduced strength
3	Air-treatment system	HEPA filters	Filtering media	Glass fiber filter "paper," possibly with organic additions	Not stated	ENVIR	Physical degradation
4	Air-treatment system	HEPA filters	Frames and separators	Aluminum and other metals	Not stated	CORR	Loss of material
5	Air-treatment system	HEPA filters	Sealants, gaskets, and water repellents	Unidentified organic materials	Not stated	ELE-TEMP; ENVIR	Chemical and physical degradation
6	Air-treatment system	Air treatment system adsorbers	Adsorber medium	Activated charcoal (carbon)	Not stated	WEATH	Loss of capacity
7	Air-treatment system	Air treatment system adsorbers	Adsorber medium	Activated charcoal (carbon)	Not stated	ENVIR	Chemical and physical degradation

Document: NUREG/CR-6001, Aging Assessment of BWR Standby Liquid Control Systems
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Wear can cause valve setpoint to drift. Higher value results in a loss of system overpressure protection; a decrease could reduce the rate of boron injection effecting reactivity control.	Moderate	Not discussed in report	ASME Sec XI IWV	Not stated	6, 13, 14, 23	1
Improper concentrations of boric acid causes corrosion of valve internals and reduced valve function.	Occasional	Not discussed in report	ASME Sec XI IWV	Not stated	6, 13, 14, 23	2
Buildup of sodium pentaborate precipitates on valve internals causes changes in valve opening characteristics and injection of borate.	Occasional	Not discussed in report	ASME Sec XI IWV	Not stated	13, 14	3
Loss of nitrogen pressure is caused by valve wear and failure of gas bladder. However the accumulators would stay intact and still would pass flow in times of critical need.	Not stated	Not discussed in report	ASME Sec XI IWV	Not stated	13, 14	4
Degradation could prevent pumps from operating within technical specifications and change borate injection characteristics.	Occasional	Not discussed in report	ASME Sec XI IWP	Not stated	13, 14, 23	5
Instrumentation required to monitor the system, such as component status lights, tank level sensors, temperature, pressure and flow gauges, are subject to aging but are not stated to be necessary for system operation during critical need.	Occasional	Not discussed in report	10CFR50.49	Not stated	13, 14	6

Document: NUREG/CR-6029, Vol. 1, Aging Assessment of Nuclear Air-Treatment System HEPA Filters and Adsorbers, Phase I
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Dust pickup increase the pressure drop across the filter. Dust pickup can also reduce the effectiveness of organic materials added for strengthening and water repellency.	Frequent	ASME N509-1989; ASME N510-1989;NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Monitor pressure drop across filter and change filter as required. [2]	4.1, 5.1, 6.1	1
Moisture incorporation into the filter medium causes increased pressure drop and reduced filter strength, and structural failure of the filter can occur even under design flow rates.	Frequent	ASME N509-1989; ASME N510-1989;NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.1, 7.4	2
Prolonged exposure to air containing normal concentrations of oxygen and oxides of nitrogen can cause embrittlement of the filter media material, resulting in possible leakage and loss of filtration.	Occasional	ASME N509-1989; ASME N510-1989;NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.1	3
Corrosive attack of metallic components in HEPA filters exposed to aggressive environments can cause structural failure and consequent leakage and loss of filtration.	Occasional	ASME N509-1989; ASME N510-1989;NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.1, 5.2	4
Heat and radiation are reported to cause aging and deterioration of face gaskets, adhesives, sealants, and water repellents. resulting in filter leakage and loss of effective filtration.	Occasional	ASME N509-1989; ASME N510-1989;NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.1, 5.2	5
Airborne moisture, contaminants, and pollutants are readily absorbed by carbon bed adsorbers, thereby depleting adsorbent capacity and reducing efficiency.	Frequent	ASME N510-1989; NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.2, 5.2	6
Oxidation of the carbon adsorbent medium has been found to deplete adsorbent capacity and reduce efficiency.	Occasional	ASME N510-1989; NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.2	7

Document: NUREG/CR-6029, Vol. 1, Aging Assessment of Nuclear Air-Treatment System HEPA Filters and Adsorbers, Phase I
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
8	Air-treatment system	Air treatment system adsorbers	Unidentified stainless steel components	Stainless steel	Not stated	CORR; CORR/PIT	Loss of material

Document: NUREG/CR-6043, Aging Assessment of Essential HVAC Chillers Used in Nuclear Power Plants
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Heating, ventilating and air conditioning (HVAC)	Centrifugal chiller	Compressor seals	Non-ferrous metals or carbon and elastomers	Not stated	WEAR	Attrition
2	Heating, ventilating, and air conditioning (HVAC)	Centrifugal chiller	Compressor motor bearings	Not stated	Not stated	WEAR	Attrition
3	Heating, ventilating, and air conditioning (HVAC)	Centrifugal chiller	Compressor motor	Not stated	Not stated	ELE-TEMP	Chemical and physical degradation
4	Heating, ventilating, and air conditioning (HVAC)	Centrifugal chiller	Condenser and evaporator/cooler heat exchangers	Carbon steel plate; Cu or Cu-10% Ni tubing	Carrier, Trane, and York	CORR; CORR/PIT; CORR/MIC	Loss of material and corrosion product buildup
5	Heating, ventilating, and air conditioning (HVAC)	Centrifugal chiller	Condenser and evaporator/cooler heat exchangers	Carbon steel plate; Cu or Cu-10% Ni tubing	Carrier, Trane, and York	VIBR	Loosening
6	Heating, ventilating, and air conditioning (HVAC)	Centrifugal chiller	Refrigerant lines	Cu or Cu-10% Ni tubing	Not stated	FAT; VIBR	Cumulative fatigue damage; loosening
7	Heating, ventilating, and air conditioning (HVAC)	Condenser cooling water system	Piping and tubing	Not stated	Carrier, Trane, and York	CORR	Loss of material and corrosion product buildup
8	Heating, ventilating, and air conditioning (HVAC)	Condenser cooling water system	Piping and tubing	Not stated	Carrier, Trane, and York	FAT	Cumulative fatigue damage
9	Heating, ventilating, and air conditioning (HVAC)	Lubrication system	Tubing and other components	Not stated	Carrier, Trane, and York	FAT	Cumulative fatigue damage
10	Heating, ventilating, and air conditioning (HVAC)	Lubrication system	Lubricant	Hydrocarbon	Not stated	CORR; WEAR	Loss of material; attrition
11	Heating, ventilating, and air conditioning (HVAC)	Control system	Misc. small components	Not stated	Carrier, Trane, and York	FAT	Cumulative fatigue damage
12	Heating, ventilating, and air conditioning (HVAC)	Control system	Float valve bearings and pivots	Not stated	Carrier, Trane, and York	CORR; CORR/IGSCC	Loss of material; crack initiation and growth

Document: NUREG/CR-6029, Vol. 1, Aging Assessment of Nuclear Air-Treatment System HEPA Filters and Adsorbers, Phase I
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Relatively rapid galvanic corrosion and severe pitting can occur in stainless steel adsorber components in contact with wet carbon, resulting in loss of integrity and effectiveness by the adsorber assembly.	Occasional	ASME N510-1989; NRC RG 1.52 and RG 1.140	PS S&T Req., RG 1.140, RG 1.52	Not stated	4.3	8

Document: NUREG/CR-6043, Aging Assessment of Essential HVAC Chillers Used in Nuclear Power Plants
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Components are subject to time-dependent wear and ultimate failure, resulting in loss of refrigerant through leakage.	Occasional	Not discussed in report	PS S&T Req.	Periodically (3 to 10 years) overhaul and inspect all wearing parts, with interval based on shortest material life. [4]	31, 33, C.3	1
Components are subject to time-dependent wear, resulting in loss of bearing function and motor failure.	Occasional	Not discussed in report	PS S&T Req.	Periodically (3 to 10 years) overhaul and inspect all wearing parts, with interval based on shortest material life. [4]	26, 31, 32, C.3	2
Motor insulation and internal electrical components are subject to thermal breakdown, resulting in motor failure.	Occasional	Not discussed in report	PS S&T Req., RG 1.32, RG. 1.140	Heat scan with infrared temperature-sensing instruments. [4]	31, 33, D.2, D.3	3
Corrosion failures associated with moisture ingress into the refrigerant in refrigerant systems can lead to leakage and loss of refrigerant. Others include heat exchanger tube fouling and plugging, crevice corrosion at tube sheets, and bio-fouling.	Frequent	Not discussed in report	PS S&T Req.	Control water quality supplied to the condenser and evaporator; periodically examine tubes and clean of necessary. [4]	26, 27, 28, 30, 31, 32, 33, 39, C.2, D.5, E.2, E.4	4
Loosening of bolts by vibration has been observed to cause component failure.	Occasional	Not discussed in report	PS S&T Req.	Periodically perform vibration analysis. [4]	31, D.3	5
Leakage of refrigerant lines apparently caused by vibrational fatigue or loosening can lead to loss of refrigerant and system failure .	Occasional	Not discussed in report	PS S&T Req.	Periodically perform vibration analysis . [4]	31, 33, C.2, C.3, C.4, D.7, E.2	6
System components are subject to corrosion, fouling, and plugging if good water chemistry is not maintained, resulting in system failure.	Frequent	Not discussed in report	PS S&T Req.	Control water quality supplied to the condenser and evaporator; periodically examine tubes and clean of necessary. [4]	31, 33, C.2, C.3, C.4, D.7, E.2	7
Vibrational fatigue failure of cooling system piping has been reported, resulting in cooling water leakage and possible system failure.	Occasional	Not discussed in report	PS S&T Req.	Periodically perform vibration analysis. [4]	29, 31, D.2	8
Lubrication system leaks apparently caused by vibrational fatigue have been reported, and such leaks can lead to loss of lubricant and compressor and pump bearing failure.	Occasional	Not discussed in report	PS S&T Req.	Periodically perform vibration analysis; routinely analyze lubrication oil to ensure correct chemistry. [4]	31, 31, C.2, D.2, D.4, E.2, E.3	9
Leakage from corrosion can cause contamination of lubrication system by acids, leading to accelerated wear and ultimate failure of compressor and pump bearings.	Moderate	Not discussed in report	PS S&T Req.	Routinely analyze lubrication oil to ensure correct chemistry. [4]	30, 32, E.2, E.5	10
Small control system components such as timers, cam switches, relays, terminal and wire connectors, and lamp bulbs are subject to mechanical fatigue-related failures due to vibration.	Frequent	Not discussed in report	PS S&T Req.	Periodically perform vibration analysis; annually service and test components to ensure reliability. [4]	29, 30, 31, 33, D.6, E.2, E.3, E.6	11
Corrosive attack of bearings and pivots in float valves due to water ingress into the refrigerant can lead to failure. IGSCC of a valve ball float in Waterford Unit 3 has also been observed.	Rare	Not discussed in report	PS S&T Req.	Routinely analyze refrigerant to ensure correct chemistry. [4]	31, 33, C.2, C.3, C.4, D.3	12

Document: NUREG/CR-6048, Pressurized-Water Reactor Internals Aging Degradation Study, Phase 1
Reviewed by: Ali Erdemir, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor internals	Lower core support structure	Thermal shield	Type 304 SS	Westinghouse.	VIBR	Crack initiation and growth
2	Reactor internals	Lower core support structure	Thermal shield radial limiter pin	Type 304 SS	Westinghouse.	VIBR	Crack initiation and growth
3	Reactor internals	Lower core support structure	Thermal shield flexure support system	Type 304 SS	Westinghouse	VIBR	Crack initiation and growth
4	Reactor internals	Lower core support structure	Thermal shield	Type 304 SS	Combustion Engineering	VIBR; WEAR	Crack initiation and growth; attrition
5	Reactor internals	Lower core support structure	Hold-down ring	Type 304 SS	Combustion Engineering	VIBR; WEAR	Crack initiation and growth; attrition
6	Reactor internals	Lower core support structure	Fuel rods	Type 304 SS	Westinghouse	VIBR	Crack initiation and growth
7	Reactor internals	Lower core support structure	Thermal shield support bolts	Alloy A-286	Babcock & Wilcox	CORR/IGSCC	Crack initiation and growth
8	Reactor internals	Lower core support structure	Barrel-to-core support shield bolts	Alloy A-286	Babcock & Wilcox	CORR/IGSCC	Crack initiation and growth
9	Reactor internals	Core barrel	Baffle bolts	Inconel X-750	Westinghouse	CORR/IGSCC	Crack initiation and growth
10	Reactor internals	Upper core support structure	Control rod guide tube support pins	Inconel X-750	Westinghouse	CORR/IGSCC	Crack initiation and growth
11	Reactor internals	In-core instrumentation support structure	Flux thimbles and guide tube	Types 304 and 316 SS	Westinghouse	VIBR, WEAR	Crack initiation and growth, attrition
12	Reactor internals	In-core instrumentation support structure	Surveillance specimen holder tube	Type 304 SS	Babcock & Wilcox	VIBR, WEAR	Crack initiation and growth, attrition

Document: ORNL/NRC/LTR-91/25, Throttled Valve Cavitation and Erosion
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Component cooling water	Valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material

Document: NUREG/CR-6048, Pressurized-Water Reactor Internals Aging Degradation Study, Phase 1
Reviewed by: Ali Erdemir, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Vibration of thermal shield in a shell mode caused some of the shell segments to come into contact with the core barrel. The repeated impact loadings caused failures in the core barrel support bolts and also damaged the thermal shield.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI IWB & Assoc. NRC GC	Not stated	38	1
Flow-induced vibration caused radial limiter pins to come into contact with the sides of the keyway in the core barrel, eventually leading to cracking of the fillet welds between pins and thermal shield.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI IWB & Assoc. NRC GC	Not stated	38	2
The top mounted flexure support system failed due to high-cycle fatigue caused by small-amplitude flow-induced vibration of the thermal shield.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI IWB & Assoc. NRC GC	Not stated	38	3
Pump-generated pressure pulsations caused excessive wear damage and loss of some support and positioning pins. Lugs welded to the core barrel were also damaged. In one unit the damaged lugs caused a through-the-wall crack in the core barrel.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI IWB & Assoc. NRC GC	Not stated	38	4
Flow-induced vibration caused excessive mechanical wear in the hold-down ring of a CE unit due to the insufficient levels of hold-down spring force.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI IWB & Assoc. NRC GC	Use 403 SS, increase hold-down spring force. [4]	38	5
Baffle plate water-jetting due to pressure differential set fuel rods into whirling motions and excessive vibrations, which eventually led to cladding degradation and failures.	Not stated	ASME B&PV Code, Section XI	ASME Sec XI IWB & Assoc. NRC GC	Change design, modify downward bypass flow to an upward bypass flow scheme [4]	38-39	6
High tensile stresses due to preloads and poor design in the shank region of bolts led to the development of IGSCC at the bolt-head-to-bolt shank transition area. As a result, some bolts were lost and others became loose.	Not stated	Not discussed in report	ASME Sec XI IWB & Assoc. NRC GC	Change design, reduce tensile stress level, change material to X-750 [1]	40	7
Overtorquing on bolts and hot-head manufacturing process were the most probable cause of IGSCC in a number of bolts that join core barrel to core support shield.	Not stated	Not discussed in report	ASME Sec XI IWB & Assoc. NRC GC	Reduce torque to bolts, change fabrication practice, use bolts made by machining [1]	41	8
Routine inspections detected signs of cracks in core baffle bolts, and the failures were attributed to IGSCC possibly due to sensitization of the Inconel X-750 bolts.	Not stated	Not discussed in report	ASME Sec XI IWB & Assoc. NRC GC	Use austenitic stainless steel bolts [4]	42	9
Crevice conditions, improper heat treatment, and overtorquing of nuts during installation of the support pins may have contributed to IGSCC.	Not stated	NRC Information Notice 82-29	ASME Sec XI IWB & Assoc. NRC GC	Solution heat treat at a higher temper-ature, increase pin size, reduce preloads during installation. [4]	41	10
Fretting and mechanical wear resulted in thinning and eventual leakage of the thimble and guide tubes. Flow-induced vibration was identified as the leading contributor to fretting and wear.	Not stated	NRC Information Notice 87-44	ASME Sec XI IWB & Assoc. NRC GC	Move thinned segments away from the vibrating region. Use thicker-walled tubes [4]	43	11
Flow induced vibration due to pump-generated pressure pulsations caused excessive wear on tubes.	Not stated	Not discussed in report	ASME Sec XI IWB & Assoc. NRC GC	Change stiffness of tubes [4]	43	12

Document: ORNL/NRC/LTR-91/25, Throttled Valve Cavitation and Erosion
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Occasional	Not discussed in report	ASME Sec XI IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 18	1

Document: ORNL/NRC/LTR-91/25, Throttled Valve Cavitation and Erosion
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2	Condensate/feedwater	Valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material
3	Chemical volume and control	Valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material
4	Service water	Valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material
5	Main steam	Valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material
6	Residual heat removal	Globe valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material
7	Residual heat removal	Butterfly valve	Internals: body/seat/plug	316 SS, stellite over SS, cast iron, carbon steel	Not stated	ERO/CAV	Loss of material

Document: PNL-5722, Operating Experience and Aging Assessment of ECCS Pump Room Coolers
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	All systems in general and RHR system in particular	ECCS pump room coolers	Fan V-Belts/Sheaves	Cord (cotton, rayon, synthetic, steel) fiber, rubber/steel	Not stated	VIBR	Loosening; crack initiation and growth
2	All systems in general and RHR system in particular	ECCS pump room coolers	Fan V-Belts/Sheaves	Cord (cotton, rayon, synthetic, steel) fiber, rubber/steel	Not stated	WEAR	Attrition
3	All systems in general and RHR system in particular	ECCS pump room coolers	Motor- and fan-bearings	Steel, brass, bronze, grease, lube oil	Not stated	WEAR	Attrition
4	All systems in general and RHR system in particular	ECCS pump room coolers	Motor- and fan-bearings	Steel, brass, bronze, grease, lube oil	Not stated	CORR	Loss of material;corrosion product buildup

Document: ORNL/NRC/LTR-91/25, Throttled Valve Cavitation and Erosion
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Moderate	Not discussed in report	ASME Sec XI IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 18	2
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Occasional	Not discussed in report	ASME Sec XI IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 18	3
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Moderate	Not discussed in report	ASME Sec XI IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 18	4
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Occasional	Not discussed in report	ASME Sec XI IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 18	5
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Occasional	Not discussed in report	ASME Sec XI IWB, IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 12, 13, 18	6
Valves used under throttled service can experience cavitation, which can remove material. For butterfly type valves, wall thinning can occur in adjacent downstream pipe. Cavitation can cause vibration damage.	Moderate	Not discussed in report	ASME Sec XI IWB, IWV, GL 89-10 & Suppl.	More carefully select valve type, trim and materials appropriate for operating conditions [4]	3, 4, 8, 10, 12, 13, 18	7

Document: PNL-5722, Operating Experience and Aging Assessment of ECCS Pump Room Coolers
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Frequent	Not discussed in report	PS S&T Req.	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use strip heaters to control humidity. [4]	2.4, 5.3	1
Not stated.	Not stated	Not discussed in report	PS S&T	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	5.4	2
Not stated.	Frequent	Not discussed in report	PS S&T Req., RG 1.32	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	2.4,5.4	3
Not stated.	Not stated	Not discussed in report	PS S&T Req., RG 1.32	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	6.5	4

Document: PNL-5722, Operating Experience and Aging Assessment of ECCS Pump Room Coolers
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5	All systems in general and RHR system in particular	ECCS pump room coolers	Couplings/fans	Not stated/Galvanized, carbon and stainless steel, aluminum	Not stated	VIBR	Loosening; crack initiation and growth
6	All systems in general and RHR system in particular	ECCS pump room coolers	Cooling coils	Copper, copper-nickel, aluminum	Not stated	VIBR	Loosening; crack initiation and growth
7	All systems in general and RHR system in particular	ECCS pump room coolers	Cooling coils	Copper, copper-nickel, aluminum	Not stated	CORR	Loss of material;corrosion product buildup
8	All systems in general and RHR system in particular	ECCS pump room coolers	Fan motors	Copper, steel, silicon steel, aluminum, insulating materials, cast iron, brass, mica, plastics, graphite, cable, seals and gaskets	Not stated	VIBR	Loosening; crack initiation and growth
9	All systems in general and RHR system in particular	ECCS pump room coolers	Fan motors	Copper, steel, silicon steel, aluminum, insulating materials, cast iron, brass, mica, plastics, graphite, cable, seals and gaskets	Not stated	ELE-TEMP	Degradation
10	All systems in general and RHR system in particular	ECCS pump room coolers	Fan motor mounting bolts, lead connection, conduit boxes, housing enclosures	Not stated	Not stated	CORR	Loss of material;corrosion product buildup

Document: PNL-6287, Study Group Review of Nuclear Service Diesel Generator Testing and Aging Mitigation
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Diesel Generator	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: PNL-7516, Emergency Diesel Generator Technical Specifications Study Results
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Diesel Generator	Various	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: PNL-5722, Operating Experience and Aging Assessment of ECCS Pump Room Coolers
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	2.4, 6.1-6.3	5
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	2.4, 6.3	6
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	6.6	7
Not stated.	Not stated	Not discussed in report	PS S&T Req., RG 1.32	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	2.4, 6.1	8
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	6.4	9
Not stated.	Not stated	Not discussed in report	PS S&T Req.	Follow mfg. recommendations for installation, surveillance, and maintenance, add vibration isolation mounts, use acoustic and temp. monitoring techniques, regularly check vibration amplitudes and frequencies, use [4]	6.5	10

Document: PNL-6287, Study Group Review of Nuclear Service Diesel Generator Testing and Aging Mitigation
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: PNL-7516, Emergency Diesel Generator Technical Specifications Study Results
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: PNL-7823, Maintenance Practices to Manage Aging: A Review of Several Technologies
Reviewed by: Ken E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor	All major components	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: PNL-SA-18407, Understanding and Managing Corrosion in Nuclear Power Plants
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Containment	Metal containment	Drywell base	Not stated	Not stated	CORR	Loss of material
2	Containment	Metal containment	Drywell base	Not stated	Not stated	CORR/CREV	Loss of material
3	Containment	Metal containment	Drywell base	Not stated	Not stated	CORR/MIC	Loss of material
4	Containment	Metal containment	Embedded shell	Not stated	Not stated	CORR/CREV	Loss of material
5	Containment	Metal containment	Embedded shell	Not stated	Not stated	CORR/PIT	Loss of material
6	Containment	Metal containment	Embedded shell	Not stated	Not stated	CORR	Loss of material
7	Containment	Metal containment	Bellows	Stainless steel	Not stated	CORR/IGSCC	Crack initiation and growth
8	Containment	Metal containment	Bellows	Stainless steel	Not stated	CORR/TGSCC	Crack initiation and growth
9	Containment	Metal containment	Suppression pool	Not stated	Not stated	CORR	Loss of material
10	Containment	Metal containment	Suppression pool	Not stated	Not stated	CORR/MIC	Loss of material
11	Containment	Metal containment	Suppression pool	Not stated	Not stated	CORR/PIT	Loss of material
12	Containment	Metal containment	Dissimilar metal welds	Not stated	Not stated	CORR	Loss of material
13	Containment	Reinforced concrete containment	Reinforcing bars	Not stated	Not stated	CORR	Loss of material
14	Containment	Reinforced concrete containment	Suppression pool liner	Steel	Not stated	CORR	Loss of material

Document: PNL-7823, Maintenance Practices to Manage Aging: A Review of Several Technologies
Reviewed by: Ken E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: PNL-SA-18407, Understanding and Managing Corrosion in Nuclear Power Plants
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage of radioactive gases.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	1
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	2
Leakage of radioactive gases.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	3
Loss of structural integrity.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	4
Loss of structural integrity.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	5
Loss of structural integrity.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	6
Leakage of radioactive gases.	Frequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	7
Leakage of radioactive gases.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	8
Leakage of radioactive gases.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	9
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	10
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	17	11
Leakage of radioactive gases.	Frequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWE & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	12
Loss of structural integrity.	Infrequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	13
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	14

Document: PNL-SA-18407, Understanding and Managing Corrosion in Nuclear Power Plants
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15	Containment	Reinforced concrete containment	Suppression pool liner	Steel	Not stated	CORR/MIC	Loss of material
16	Containment	Prestressed concrete containment	Posttensioning system anchor	Not stated	Not stated	CORR	Loss of material
17	Containment	Prestressed concrete containment	Posttensioning wire or strand	Not stated	Not stated	CORR/PIT	Loss of material
18	Containment	Prestressed concrete containment	Posttensioning wire or strand	Not stated	Not stated	CORR/MIC	Loss of material
19	Containment	Prestressed concrete containment	Suppression pool liner	Steel	Not stated	CORR	Loss of material
20	Containment	Prestressed concrete containment	Suppression pool liner	Steel	Not stated	CORR/MIC	Loss of material
21	Containment	Prestressed concrete containment	Drywall liner	Steel	Not stated	CORR	Loss of material
22	Containment	Prestressed concrete containment	Reinforcing bar	Not stated	Not stated	CORR	Loss of material
23	Containment	Prestressed and reinforced concrete	Liner over wall dome and base slab	Steel	Not stated	CORR	Loss of material
24	BWR cooling system	Reactor pressure vessel	Nozzles	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
25	BWR cooling system	Recirculation piping	Weld heat-affected zones	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
26	BWR cooling system	Feedwater and main steam lines	Near fittings and discontinuities	Not stated	Not stated	CORR	Loss of material
27	BWR cooling system	Feedwater and main steam lines	Near fittings and discontinuities	Not stated	Not stated	ERO/CORR	Loss of material
28	BWR cooling system	Control rod drive mechanisms	Pressure housing & stub tube	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
29	BWR cooling system	Reactor internals	Attachment welds	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
30	BWR cooling system	Reactor internals	Jet pumps	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
31	PWR cooling system	Reactor pressure vessel	Vessel flange and studs	Not stated	Not stated	FAT	Cumulative fatigue damage
32	PWR cooling system	Recirculation steam generator tubes	Hot-leg tubes and U-bends	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
33	PWR cooling system	Recirculation steam generator tubes	Cold-leg side in sludge pile	Not stated	Not stated	CORR/PIT	Loss of material
34	PWR cooling system	Recirculation steam generator tubes	Tubing O.D. above tube sheet	Not stated	Not stated	CORR/UA	Loss of material
35	PWR cooling system	Once-through steam generators	Steam generator tubes	Not stated	Babcock & Wilcox	ERO/CORR	Loss of material

Document: PNL-SA-18407, Understanding and Managing Corrosion in Nuclear Power Plants
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	15
Reduction of load-carrying capacity.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	16
Reduction of load-carrying capacity.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	17
Reduction of load-carrying capacity.	Infrequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	18	18
Leakage of radioactive gases.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	19	19
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	19	20
Leakage of radioactive gases.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	19	21
Loss of structural integrity.	Infrequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	19	22
Leakage of radioactive gases and interaction of liner and concrete.	Infrequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWL & 10CFR50 App. J	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	19-20	23
Ductile overload leading to leakage.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	21	24
Cracking and leakage.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	21	25
Cracking, large deformations, rupture, and leakage.	Frequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	21	26
Cracking, large deformations, rupture, and leakage.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	21	27
Cracking leading to leakage.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	21	28
Crack growth progressing into reactor vessel.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	21	29
Loss of adequate core flow.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	22	30
Eventual ductile overload failure.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec III & XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	23	31
Possible eventual cracking.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB & PS TS Req.	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	23	32
Possible eventual perforation, resulting in leakage.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB & PS TS Req.	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	23	33
Tube thinning, possibly leading to penetration and leakage.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB & PS TS Req.	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	23	34
Tube thinning, possibly leading to penetration and leakage.	Frequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB & PS TS Req.	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	35

Document: PNL-SA-18407, Understanding and Managing Corrosion in Nuclear Power Plants
Reviewed by: John W. Holland, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
36	PWR cooling system	Pressurizer sleeve	Heater sheaths	Not stated	Not stated	CORR/SCC	Crack initiation and growth
37	PWR cooling system	Pressurizer sleeve	Heater sheaths	Not stated	Not stated	WEAR	Attrition
38	PWR cooling system	Pressurizer sleeve	Manway bolts	Not stated	Not stated	CORR/SCC	Crack initiation and growth
39	PWR cooling system	Reactor internals	Thermal shield, bolts, core barrel, and core support structure	Not stated	Not stated	FAT	Cumulative fatigue damage
40	PWR cooling system	Reactor internals	Thermal shield, bolts, core barrel, and core support structure	Not stated	Not stated	CORR/IGSCC	Crack initiation and growth
41	PWR cooling system	Reactor internals	Thermal shield, bolts, core barrel, and core support structure	Not stated	Not stated	EMBR/IR	Loss of fracture toughness
42	PWR cooling system	Reactor internals	Thermal shield, bolts, core barrel, and core support structure	Not stated	Not stated	EMBR/TE	Loss of fracture toughness
43	PWR cooling system	Feedwater piping and nozzle	Piping and nozzle inside containment	Not stated	Not stated	ERO/CORR	Loss of material
44	PWR cooling system	Feedwater piping and nozzle	Piping and nozzle inside containment	Not stated	Not stated	FAT	Cumulative fatigue damage

Document: PNL-SA-20219, ASME Subsection ISTD Recommendations based upon NPAR Snubber Aging Research Results
Reviewed by: Steve U. Choi, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Piping	Snubber	This report does not provide specific detailed information on age-related degradation processes for specific nuclear components or systems.				

Document: TR-3270, 9-90, An Operational Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Combustion Engineering (CE) Control Rod Drive System	Control Element Assemblies	Control Elements	Clad-Inconel 625	CE	WEAR; CORR/SCC	Attrition; Crack initiation and growth
2	Combustion Engineering (CE) Control Rod Drive System	Control Element Assemblies	Fuel Assembly Guide Tubes	Zircaloy-4	CE	WEAR	Attrition
3	Combustion Engineering (CE) Control Rod Drive System	Control Element Assemblies	Upper Guide Structure-Spider	Stainless Steel	CE	WEAR; EMBR/IR; FAT	Attrition; Loss of fracture toughness; Cumulative fatigue damage
4	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Motor Housing Assembly	403 Stainless Steel Ni-Cr-Fe alloy	CE	EMBR; CORR; FAT	Loss of fracture toughness; Loss of material; Cumulative fatigue damage
5	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Motor Assembly-Latches, Links and Pins	High Cobalt Alloy	CE	WEAR; FAT; CONTAM	Attrition; Cumulative fatigue damage; Buildup of deposits

Document: PNL-SA-18407, Understanding and Managing Corrosion in Nuclear Power Plants
Reviewed by: John W. Holland, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Cracking leading to leakage.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	36
Metal loss leading to leakage.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	37
Bolt breakage leading to leakage.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	38
Broken bolts, cracks, and loose parts.	Frequent	ASME B&PV Code Sect. III and XI	ASME Sec III & XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	39
Broken bolts, cracks, and loose parts.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	40
Broken bolts, cracks, and loose parts.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	41
Broken bolts, cracks, and loose parts.	Infrequent	ASME B&PV Code Sect. III and XI	ASME Sec XI IWB	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	42
Rupture caused by water pressure.	Moderate	ASME B&PV Code Sect. III and XI	ASME Sec XI & PS S&T Req.	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	43
Leakage through fatigue cracks.	Occasional	ASME B&PV Code Sect. III and XI	ASME Sec XI & PS S&T Req.	Effective application of mainteance, refurbishent, and replacement on a timely basis. [4]	24	44

Document: PNL-SA-20219, ASME Subsection ISTD Recommendations based upon NPAR Snubber Aging Research Results
Reviewed by: Steve U. Choi, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						1

Document: TR-3270, 9-90, An Operational Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Clad cracking and wash out of the poison.	Occasional	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		1
Cracking of the tube wall.	Frequent	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		2
Cracking of the guide causing rod drops.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		3
Housing cracking leads to primary coolant leakage (SBLOCA) and jamming of the drive mechanism.	Frequent	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		4
Failure of these sub-components will lead to dropping or locking of the control element.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		5

Document: TR-3270, 9-90, An Operational Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
6	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Upper Pressure Housing Assembly	Type 316 Stainless	CE	EMBR; CORR; FAT	Loss of fracture toughness; Loss of material; Loss of fracture toughness
7	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Extension Shaft	Type 304 Stainless, Chromium plated	CE	WEAR; FAT; CORR/SCC	Attrition; Loss of fracture toughness; Crack initiation and growth
8	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Vent Valves	Type 440 Stainless Steel, Type 316 Stainless Steel Seat	CE	CORR; FAT; WEAR; EMBR/TE	Corrosion product buildup; Cumulative fatigue damage; Attrition; Loss of fracture toughness
9	Combustion Engineering (CE) Control Rod Drive System	Control Element Drive Mechanisms (CEDM)	Coil Stack Assembly - Coils	Copper wire insulated with high temperature enamel vacuum impregnated with high temperature varnish	CE	CORR; WEAR	Loss of material; Attrition
10	Combustion Engineering (CE) Control Rod Drive System	CEDM Control Systems	Control Element Drive Control System and Control Power Programmer	Not stated	CE	These components are referred to INEL for review.	
11	Combustion Engineering (CE) Control Rod Drive System	CEDM Control Systems	Rack and Pinion Control System	Not stated	CE	These components are referred to INEL for review.	
12	Combustion Engineering (CE) Control Rod Drive System	CEA Rod Position Indication	Reed Switch Position Transmitter Assembly	Not stated	CE	These components are referred to INEL for review.	
13	Combustion Engineering (CE) Control Rod Drive System	CEA Rod Position Indication	Pulse Count Position Indication System	Not stated	CE	These components are referred to INEL for review.	
14	Combustion Engineering (CE) Control Rod Drive System	CEDM Cooling System	Fans	Not stated	CE	Not stated	Not stated
15	Combustion Engineering (CE) Control Rod Drive System	CEDM Cooling System	Cooling Shroud	Sheet metal	CE	CORR/BA	Loss of material
16	Combustion Engineering (CE) Control Rod Drive System	CEDM Cooling System	Instrumentation	Not stated	CE	Not stated	Not stated
17	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Assemblies	Control Rod Cladding	Type 304 Stainless	B&W	CORR/SCC; WEAR	Crack initiation and growth; Attrition
18	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Assemblies	Fuel Assembly Guide Tubes	Zircaloy-4	B&W	WEAR	Attrition
19	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Assemblies	Upper Internal Brazement Assemblies-Spider	Grade CF3M Stainless	B&W	CORR/SCC; WEAR; EMBR/IR; FAT	Crack initiation and growth; Attrition; Loss of fracture toughness; Cumulative fatigue damage
20	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Motor Tube	Low alloy steel clad with Inconel or Type 403 stainless	B&W	EMBR/TE; CORR; FAT	Loss of fracture toughness; Loss of material; Cumulative fatigue damage

Document: TR-3270, 9-90, An Operational Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
Reviewed by: Jeffrey L. Binder, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Housing cracking leads to primary coolant leakage (SBLOCA) and jamming of the drive mechanism.	Frequent	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		6
Shaft cracking will lead to locking of the mechanical operation.	Occasional	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		7
Loss of valve function and primary coolant leakage.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		8
Loss of coil function will lead to dropped, slipped or immovable control elements.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		9
Referred to INEL for review.	Rare					10
				None given		11
	Rare					12
						13
Loss of rod drive mechanism cooling capacity leading to inoperable CRDM or rod drops.	Not stated	None stated	ASME Sec XI and PS Tech Spec. Req.	None given		14
Loss of rod drive mechanism cooling capacity leading to inoperable CRDM or rod drops.	Not stated	None stated	ASME Sec XI and PS Tech Spec. Req.	None given		15
Loss of rod drive mechanism cooling capacity leading to inoperable CRDM or rod drops.	Not stated	None stated	If Class 1E 10CFR 50.49 otherwise PS S&T Req.	None given		16
Clad cracking and wash out of the poison.	Occasional	None stated	ASME Sec XI IWB and PS Tech Spec. Req.	None given		17
Cracking of the tube wall.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		18
Cracking of the guide causing rod drops.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		19
Housing cracks causing primary coolant leakage (SBLOCA) and jamming of the drive mechanism.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		20

Document: TR-3270, 9-90, An Operational Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
21	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Stator Coils	Copper Wire, Dow Corning 997 Varnish, Kapton, Nomex, Silicone Rubber	B&W	Referred to INEL for review.	
22	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Vent Valve O-rings	Stainless Steel	B&W	CORR; WEAR; FAT; EMBR/TE	Corrosion product buildup; Attrition; Cumulative fatigue damage; Loss of fracture toughness
23	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Rotor Assembly-roller nuts, segment arms, springs	Stellite Ni-Cr-Fe Alloy, Type 403 Stainless Steel	B&W	WEAR; FAT; CONTAM	Attrition; Cumulative fatigue damage; Buildup of deposits
24	Babcock & Wilcox (B&W) Control Rod Drive System	Control Rod Drive Mechanisms (CRDM)	Leadscrew	17-4 PH Stainless Steel	B&W	WEAR; FAT; CORR/SCC	Attrition; Cumulative fatigue damage; Crack initiation and growth;
25	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Power Supplies	Not stated	B&W	Referred to INEL for review.	
26	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Programmers	Not stated	B&W	Referred to INEL for review.	
27	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Trip Breakers	Not stated	B&W	Referred to INEL for review.	
28	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Power and Control Systems	Programmer Drive Motors	Not stated	B&W	Referred to INEL for review.	
29	Babcock & Wilcox (B&W) Control Rod Drive System	CRA Rod Position Indication	Absolute Position Indication System	Not stated	B&W	Referred to INEL for review.	
30	Babcock & Wilcox (B&W) Control Rod Drive System	CRA Rod Position Indication	Relative Rod Position Indication	Not stated	B&W	Referred to INEL for review.	
31	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Cooling System	Centrifugal Pumps	Not stated	B&W	CORR/BA	Loss of material
32	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Cooling System	Heat Exchangers	Not stated	B&W	CORR/BA	Loss of material
33	Babcock & Wilcox (B&W) Control Rod Drive System	CRDM Cooling System	Surge Tank	Not stated	B&W	CORR/BA	Loss of material

Document: TR-3270, 9-90, An Operational Assessment of the Combustion Engineering and Babcock & Wilcox Control Rod Drives
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
						21
Loss of valve function and primary coolant leakage.	Occasional	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		22
Failure of these sub-components will lead to dropping or locking of the control rod assembly.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		23
Cracking of the leadscrew will cause a dropped or immovable control rod.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		24
						25
						26
						27
						28
						29
						30
Loss of cooling leading to inoperable CRDM.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		31
Loss of cooling leading to inoperable CRDM.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		32
Loss of cooling leading to inoperable CRDM.	Rare	None stated	ASME Sec XI IWB & PS Tech Spec. Req.	None given		33

Table A.1 Gall Report for NRC Generic Letters

Document: GL Letters, NRC Generic Letters, 1989-1994
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling System	Feedwater piping	Not stated	Carbon steel	Not stated	ERO/CORR	Wall thinning
2	Cooling System	Feedwater piping	Nozzles	Not stated	General Electric Co.	FAT/THERM	Cumulative fatigue damage
3	Cooling System	Steam generator and coolant pump	Supports	Not stated	Not stated	EMBR/IR	Loss of fracture toughness
4	Cooling System	BWR primary system piping	Not stated	Type 304 stainless steel	General Electric Co.	CORR/IGSCC	Crack initiation and growth
5	Cooling System	Piping, heat exchangers, and other components	Not stated	Various	Not stated	BIO	Buildup of deposits
6	Containment system	Reactor pressure vessel	Not stated	Not stated	Not stated	EMBR/IR	Loss of fracture toughness

Document: GL Letters, NRC Generic Letters, 1989-1994
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Erosion/corrosion caused by high-velocity flow of water through piping has caused several incidents of piping failure or wall thinning below ASME Code allowables.	Moderate	NUREG-1344		Implement long-term erosion-corrosion monitoring programs. [4]	89-08	1
Fluctuations in water temperature within BWR vessel in nozzle region produces high-cycle fatigue and resulting crack initiation and growth in nozzles.	Frequent	NUREG-0619		Not stated	89-21, p. 5	2
Fracture toughness of support materials may be inadequate, creating the potential for fracture or lamellar tearing in service.	Not stated	NUREG-0577		Maintain minimum temperature above fracture transition temperature; replace supports if necessary [4]	89-21, pp. 6	3
The gradual buildup of macroscopic biological fouling organisms (e.g., blue mussels, American oysters, Zebra mussels, and Asiatic clams) inhibits coolant flow, ultimately resulting in flow rates below technical specifications.	Frequent	NUREG/CR-5210; NUREG/CR-5234		Implement surveillance and control program outlined in Generic Letter 89-13[4]	89-13; 89-13, Suppl. 1	4
Combination of residual or service stresses, sensitization from welding, and oxygenated cooling water can cause IGSCC of piping, resulting in leakage.	Formerly frequent	NUREG-0313		Follow recommendations in NUREG-0313. [4]	89-21, p. 11	5
Neutron irradiation over extended time periods can cause embrittlement of the reactor pressure vessel material, particularly near the beltline, resulting in loss of impact resistance and possible failure in a severe pressurized overcool event.	Not stated	NUREG-0744;ASTM E-185;Reg. Guide 1.99, Rev. 2		Follow NUREG-0744 methods for evaluating Charpy upper shelf impact strength. [4]	89-21, pp. 5-6, 16; 92-01, Rev. 1	6

Document: IN&B 1989, 1989 NRC Information Notices and Bulletins
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Valves	Carbon steel valve bodies	Carbon steel	Not stated	ERO/CAV	Loss of material
2	Cooling system	Coolant pump	Pump shaft	A-286	Byron Jackson	FAT	Cumulative fatigue damage
3	Cooling system	Coolant pump	Ring surrounding bearing housing	Not stated	Byron Jackson	Not stated	Not stated
4	Cooling system	Steam generator	Tubing mechanical plugs	Inconel 600	Westinghouse	CORR/PWSCC	Crack initiation and growth
5	Cooling system	Steam generator	Tubing mechanical plugs	Inconel 600	Babcock & Wilcox	CORR/PWSCC	Crack initiation and growth
6	Cooling system	Steamlines	Atmospheric dump valves	Not stated	Control Components, Inc.	CONTAM	Loss of desired surface properties
7	(Various water systems)	Pumps	Impeller, bushings, and other internal components	Brass bushings; other materials not stated.	Not stated	ERO/CAV; VIBR	Loss of material; physical damage
8	Electrical control system		Electrical cable insulation	Neoprene chloroprene and other organic polymers	Not stated	ELE-TEMP	Chemical and physical degradation
9	Turbine	High-press. steam extraction line	14-in. piping	Carbon steel	Not stated	ERO/CORR	Wall thinning
10	Containment system	Containment structure	Steel shell	(Carbon?) steel	Not stated	CORR/BA	Loss of material

Document: IN&B 1990, 1990 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Service water system	Check valve	Swing arm	17-4 PH stain-less steel, H1100 heat treatment	Borg-Warner	CORR/SCC	Crack initiation and growth
2	Service water system	Motor-operated butterfly valve	Valve seat	Not stated	BIF/General Signal Corp.	ENVIR	Physical degradation
3	Service water system	Piping and heat exchangers	Valve seat	Not stated	Not stated	CONTAM	Buildup of deposits

Document: IN&B 1989, 1989 NRC Information Notices and Bulletins
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Significant localized wall thinning of 16- and 24-in. valve bodies apparently caused by cavitation can lead to rupture.	Not stated	Not discussed in report		Not stated	89-01	1
Abrupt decoupling of pump shaft and impeller probably caused by shaft fracture or failure of cap screws and drive pins, resulting in pump failure. Root cause is undetermined, but possibly fatigue.	Not stated	Not discussed in report		Use improved vibration monitoring system to detect growing cracks in shaft [2]	89-15	2
Failure of attachment weld was repaired by fillet welds that failed four years later, resulting in pump failure and loose parts in the recirculation loop.	Not stated	Not discussed in report		Repair with full-penetration welds and realignment of ring. [2]	89-20	3
Intergranular cracking, apparently associated with improper heat treatment and/or susceptible heats of material, can cause mechanical tube plugs to loosen, leak, and sometimes be forcibly ejected, causing additional tube damage.	Not stated	Not discussed in report		Replace plugs from suspect heats of material; discontinue use of Westinghouse plugs. [4]	89-33; Bull. 89-01, 89-01, Suppl. 1 & 2.	4
Intergranular cracking, apparently associated with intragranular carbides and relatively little intergranular precipitation improper heat treatment and susceptible heats of material, could lead to possible plug failure.	Not stated	NRC Bull. 89-01		Conduct eddy current inspections of installed plugs. [4]	89-65	5
Foreign particles from steamlines lodge in valve clearance areas and on sealing surfaces, resulting in leakage past valve plug piston ring and consequent valve malfunctioning.	Not stated	Not discussed in report		Design modifications have been implemented by the manufacturer [1]	89-38	6
Repeated operation of the pumps at 60% or less of their design flow resulted in slow deterioration of internal components, causing eventual loss of pump function.	Not stated	Not discussed in report		Avoid sustained operation of pumps at low flow rates [4]	89-08	7
Prolonged exposure of electrical cable insulation to temperatures above their environmental qualification (EQ) design temperature, e.g., in reactor containment, can lead to insulation breakdown and failure.	Not stated	NRC Temporary Instruction 2515/98		Provide better containment cooling to maintain temperatures below the EQ temperature [4]	89-30	8
Abrupt change in I.D. at nozzle-to-pipe connection apparently causes flow turbulence, leading to accelerated erosion-corrosion of adjacent piping.	Not stated	NRC Bull. 87-01		Not stated	89-53	9
Boric acid leaking from instrument line compression fittings condenses on the outer surface of the containment steel shell, resulting in general and pitting corrosion.	Not stated	10CFR50, Appendix J		Containment in-service inspection for wall thinning by corrosion [4]	89-79; 89-79, Suppl. 1	10

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Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Preexisting casting defects, including porosity, hot cracks, and weld repairs, plus improper heat treatment, resulted in propagating cracks in the high chloride service water that caused fracture and loss of function.	Not stated	Aerospace Materials Spec. 5398A and Mil. Spec. MIL-H-6875		Replace with parts from another vendor; inspect parts for flaws before installation. [4]	90-03	1
Valve seat material hardens with time under service conditions, causing increase in coefficient of friction and possible failure of valve to open.	Not stated	GL 89-10		Set open torque switch to maximum value; test and inspect valves. [4]	90-21	2
Accumulation of silt and corrosion products in piping reduced emergency water flows to levels below design basis conditions.	Not stated	10CFR50, Append. A and B		Cleaning of contamination and adjustments in flow distribution [4]	90-39	3

Document: IN&B 1990, 1990 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4	Service water system	Containment air coolers	Tubes	Not stated	Not stated	CONTAM	Buildup of deposits
5	Service water system	Service water lines	Check valves	Not stated	Not stated	CONTAM	Buildup of deposits
6	Service water system	Piping		Not stated	Not stated	CORR; CORR/MIC	Loss of material; corrosion product buildup
7	Cooling system	Steam generator	Upper shell-to-transition cone girth welds	Not stated	Westinghouse and Combustion Engineering	CORR; FAT/THERM	Loss of material; cumulative fatigue damage
8	Cooling system	Steam generator	Tubes	Not stated	Westinghouse and Combustion Engineering	CORR/SCC	Crack initiation and growth
9	Cooling system	Pressurizer	Pressurizer heater thermal sleeves	Inconel 600	Not stated	CORR/PWSCC	Crack initiation and growth
10	Cooling system	Coolant pumps	Bolts fastening turning vanes	A453, Gr. 660 (Alloy A-286)	Not stated, but similar to Westinghouse design	CORR/IGSCC	Crack initiation and growth
11	Pressure vessel	Pressure vessel upper head	Weld cladding and base-metal heat-affected zone	Not stated	Not stated	CORR/SCC	Crack initiation and growth

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Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Moisture separator drain	6-inch, schedule 40 piping	Carbon steel	Not stated	ERO/CORR	Wall thinning
2	Cooling system	Feedwater regulating valve bypass line	6-inch piping	Carbon steel	Not stated	ERO/CORR	Wall thinning
3	Cooling system	Low-pressure drain system	Piping	Carbon steel	Not stated	ERO/CORR	Wall thinning
4	Cooling system	Flow-measuring-orifice	Orifice flange	Carbon steel	Not stated	ERO/CORR	Wall thinning
5	Cooling system	Moisture separator reheater	8-inch elbow	Carbon steel	Not stated	ERO/CORR	Wall thinning
6	Cooling system	Steam generators	Feedwater distribution feedring piping	Carbon steel	Combustion Engineering	FAT/THERM;ERO/CORR	Cumulative fatigue damage; wall thinning

Document: IN&B 1990, 1990 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Buildup of silt and corrosion products in containment air cooler tubes reduced service water flow rates to unacceptable levels.	Not stated	10CFR50, Append. A and B		Remove deposits [4]	90-39	4
Buildup of silt in emergency water service line check valve could have prevented system from functioning.	Not stated	10CFR50, Append. A and B		Remove deposits [4]	90-39	5
Acidic well water and MIC have resulted in a corrosion pitting rate of 24 mils per year in the affected components.	Not stated	10CFR50, Append. A and B		Chemically clean system and/or replace pipe [4]	90-39	6
Corrosion fatigue from thermal cycling, dissolved oxygen in feedwater, and Cu alloys in feedwater system result in crack initiation at surface corrosion pits and subsequent crack growth into girth welds.	Not stated	Not discussed in report		Perform more frequent inspections of affected region. [4]	90-04	7
Secondary side-initiated cracking of steam generator tubes, typically in the expansion transition near the tubesheet or at the support plate, has resulted in leaking cracks in several PWRs.	Not stated	Not discussed in report		Plug leaking tubes; develop improved NDE techniques to detect cracks [4]	90-49	8
Residual stresses from reaming or roll joining plus a susceptible Inconel 600 microstructure and the PWR coolant environment lead to PWSCC and leakage.	Not stated	Not discussed in report		Implement augmented inspection program. [4]	90-10	9
Alloy A-286 is subject to IGSCC at peak stresses >100 ksi, depending upon Cr content, fabrication practice, and environment. The present failures occurred in foreign reactors and threatened coolant pump function.	Not stated	B&W Owner's Group Report BAW-1842		Discontinue the use of Alloy A-286 as a reactor structural material. [4]	90-68	10
Grinding residual stresses, low delta-ferrite content, and high dissolved-oxygen in the coolant induce interdendritic SCC of weld cladding, and resulting cracks propagate into underlying base metal, possibly threatening structural integrity.	Not stated	General Electric Co. RICSIL No. 050		PT of back-clad region for surface cracks and enhanced UT for subsurface cracks. [4]	90-29	11

Document: IN&B 1991, 1991 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High-velocity turbulent flow of water through piping caused wall thinning by erosion/corrosion and resulted in pipe rupture and actuation of fire-protection deluge system.	Not stated	Not discussed in report		System found to be susceptible by EPRI CHEC code and should have been inspected [4]	91-18	1
High-velocity turbulent flow of water through piping caused wall thinning by erosion/corrosion and resulted in steam leak and repair outage.	Not stated	Not discussed in report		Failed piping replaced [4]	91-18	2
High-velocity turbulent flow of water through piping caused wall thinning by erosion/corrosion and resulted in piping rupture.	Not stated	Not discussed in report		Failed piping temporarily replaced with A106, Gr. B; permanent replacement to be A335-P22. [4]	91-18	3
High-velocity turbulent flow of water through piping caused wall thinning by erosion/corrosion and resulted in flange rupture.	Not stated	Not discussed in report		Failed flanges temporarily replaced with same material; more-resistant material being considered for permanent replacement. [4]	91-18	4
High-velocity turbulent flow of water through piping caused wall thinning by erosion/corrosion and resulted in elbow rupture and actuation of fire-protection deluge system.	Not stated	Not discussed in report		System found to be susceptible by CHECMATE code and should have been inspected [4]	91-18, Suppl. 1	5
Cracking and wall thinning resulted in component failure and introduction of loose parts into secondary side of steam generator.	Not stated	Not discussed in report		Component redesigned for increased strength and erosion resistance. [4]	91-19	6

Document: IN&B 1991, 1991 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	Cooling system	Steam generators	Tubing	Not stated	Mitsubishi (based on Westinghouse design)	FAT	Cumulative fatigue damage
8	Cooling system	Steam generators	Tubing	Not stated	Combustion Engineering	Not stated	Not stated
9	Cooling system	Steam generators	Tubing	Not stated	Babcock & Wilcox	FAT	Cumulative fatigue damage
10	Cooling system	1-inch accumulator fill line	Nozzle-to-pipe weld	Not stated	Not stated	FAT; VIBR	Cumulative fatigue damage; crack initiation and growth
11	Cooling system	Condensate storage tanks	Diaphragm	Not stated	Goodyear Co.; Lorel Corp.	ENVIR	Chemical or physical degradation

Document: IN&B 1992, 1992 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Steam generators	4-inch, schedule 80 feedwater piping	A106B carbon steel	Westinghouse	ERO/CORR	Wall thinning
2	Cooling system	Primary coolant loop	Reducing tee riser	Not stated	Not stated	ERO/CORR	Wall thinning
3	Cooling system	Pressurizer power-operated relief valves	Valve stems	SA 564, Type 630, H900-H1150 (17-4 PH) stainless steel	Rockwell International (now Edward Valve Co.)	EMBR/TE	Loss of fracture toughness
4	Emergency condenser system	Manual gate valves	Valve bodies	CF8M cast stainless steel	Not stated	FAT	Cumulative fatigue damage
5	Reactor internal support structure	Core shroud support plate	Welded access hole	Inconel 600 with Inconel 82 or 182 weld filler metal	General Electric	CORR/IGSCC	Crack initiation and growth

Document: IN&B 1993, 1993 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Emergency Core Cooling system	Residual heat removal pump	Thrust bearing	Not stated	Ingersoll-Rand	WEAR	Attrition
2	Emergency Core Cooling system	Residual heat removal pump	Discharge check valve lock wire	Not stated	Copes-Vulcan	FAT	Cumulative fatigue damage
3	Emergency Core Cooling system	Residual heat removal pump	Discharge check valve disk and hanger assembly	Stainless steel locking device; other parts not stated	Pacific Valve Engineering	VIBR	Loosening

Document: IN&B 1991, 1991 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High-cycle fatigue failure of steam generator tube at uppermost support plate resulted in excessive primary-to-secondary leak rate.	Not stated	Not discussed in report		Incorrect insertion of antivibration corrected [4]	91-43	7
Cracking of steam generator tube at U-bend at a location where flow conditions permit contaminants to be deposited on the tube surface resulted in excessive primary-to-secondary leak rate.	Not stated	NRC Bull. 88-02, Fig. 1		Not stated	91-43	8
Tube cracking at lower face of upper tubesheet resulted in excessive primary-to-secondary leak rate.	Not stated	NRC Bull. 88-02, Fig. 1		Not stated	91-43	9
Two ruptures of the nozzle-to-pipe weld in the accumulator fill line during filling were caused by flow-induced vibration and resulted in spillage of coolant.	Not stated	Not discussed in report		Revise operation procedures [4]	91-50	10
Long-term deterioration of diaphragms in contact with their service environment results in the development of holes and tears, with consequent leaks and possible clogging of equipment.	Not stated	Not discussed in report		Replace diaphragms after 9 years or more frequently if indicated by inspections. [4]	91-82	11

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Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High-velocity flow of water through piping caused wall thinning by erosion/corrosion and necessitated the replacement of 90 feet of piping for which the wall thickness was at or near the minimum allowable.	Not stated	Not discussed in report		Redesign piping to reduce flow velocity. [4]	92-07	1
High-velocity flow of water through reducing tee riser caused wall thinning by erosion/corrosion and necessitated component replacement because wall thickness was near the minimum allowable.	Not stated	NRC Bull. 87-01; NRC GL 89-08		Not stated	92-35	2
Valve stems are subject to secondary aging after several thousand hours at 600 F, resulting in increased susceptibility to fracture when subjected to excessive torque from power actuator.	Not stated	Not discussed in report		Not stated	92-60	3
Fatigue (possibly thermal) resulted in leaking cracks in at least one gate valve and partially through-wall cracks in several other valves.	Not stated	Not discussed in report		Not stated	92-50	4
Apparent IGSCC of welds joining access hole covers to shroud support plates resulted in circumferential cracking in weld region, with some cracks possibly propagating into the adjacent base metal.	Not stated	GE SIL No. 462, Súppl. 3		Perform periodic visual and UT examinations of region; repair procedures being developed [4]	92-57	5

Document: IN&B 1993, 1993 NRC Information Notices
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Thrust load during normal operation exceeded design value, resulting in abnormally high wear of bearing and failure after approx. eight fuel cycles.	Not stated	Not discussed in report		Redesign pump to reduce bearing load; replace periodically. [4]	93-08	1
Inadequate disk nut torquing allowed nut to rotate back and forth. Resulting cyclic loading caused high-cycle fatigue failure of lock wire, loss of disk nut and washer, and check valve failure.	Not stated	Not discussed in report		Replace lock wire with 1/8-in. cotter pin [4]	93-16	2
Inadequate capscrew torquing, missing capscrews, and improper reuse of locking device results in capscrew loosening, loss of disk and hanger assembly, and check valve failure.	Not stated	Not discussed in report		Revise maintenance procedure to ensure correct installation. [4]	93-16	3

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Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4	Emergency Core Cooling system	Residual heat removal pump	Coolant pump strainers and containment sump screens	Not stated	Not stated	CLOG	Blockage of flow passages
5	Emergency Core Cooling system	High-pressure coolant injection pump	Steam exhaust rupture disk	Stainless steel	Black Sivalls & Bryson, Inc.	Not stated	Not stated
6	Cooling system	Steam generators	Feedwater piping	Not stated	Westinghouse and Combustion Engineering	FAT/THERM	Cumulative fatigue damage
7	Cooling system	Piping	Feedwater piping and other components	Carbon steel	Not stated	ERO/CORR	Wall thinning
8	Cooling system	Turbine-driven feedwater pumps	Turbine stop valve	Not stated	Not stated	CONTAM	Loss of lubricant properties
9	Cooling system	Motor-operated gate and globe valves	Valve yoke	Case carbon steel	Walworth	FAT	Cumulative fatigue damage
10	Cooling system	Jet pump	Hold-down beam	Not stated	General Electric Co.	CORR/IGSCC; FAT	Crack initiation and growth; cumulative fatigue damage
11	Spent fuel storage system	Spent fuel storage racks	Boraflex neutron absorbing material	Polymer base with silica filler and neutron absorber (boron?)	Brand Industrial Services, Inc.	ENVIR	Physical degradation
12	Reactor internals	Core shroud	Beltline region welds	Stainless steel	General Electric Co.	CORR/IGSCC	Crack initiation and growth
13	Reactor internals	Fuel rods	Fuel rod cladding	Zircaloy	Westinghouse, Siemens, General Electric Co.	WEAR/FRET	Attrition

Document: IN&B 1994, 1994 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Electrical generating system	Turbines	Turbine blades	Not stated	General Electric Co.	FAT	Cumulative fatigue damage
2	Electrical generating system	Turbine low auto stop oil pressure switch	Plunger rod, bushing, and case	stainless steel and aluminum	Not stated	CORR	Corrosion product buildup
3	Cooling system	Steam generator	Kinetically weld-repaired tubes	Inconel 600	Babcock & Wilcox	CORR/PWSCC	Crack initiation and growth

Document: IN&B 1993, 1993 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Foreign debris can block emergency core cooling screens and sumps, resulting in possible reduced emergency core cooling in and accident situation.	Not stated	Not discussed in report		Remove debris [4]	93-34 and 93-34, Suppl. 1	4
Rupture disk failed unexpectedly after 20 years of service, resulting in personal injuries. Cause of failure is unclear, but vendor speculated that an unspecified aging process may have caused the strength to degrade.	Not stated	Not discussed in report		Replace 20-year-old rupture disks with new ones. [4]	93-67	5
Thermal stratification in feedwater lines, particularly during cold, low-flow conditions, leads to rapid thermal fatigue loading, resulting in cracking and leakage.	Frequent	NUREG/CR-0691		Reduce severity of thermal cycles. [4]	93-20	6
Erosion/corrosion has been observed to cause excessive wall thinning and possible piping failure in numerous plants. Inspection and repair procedures are often inadequate.	Frequent	ASME Section XI, IWA 4100 and 4300		Develop improved inspection and repair procedures in accordance with ASME Section XI. [4]	93-21	7
Gradual buildup of contaminants in the control oil for the stop valve on the turbine-driven feed water pump caused the valve to stick open when the main turbine tripped, resulting in overfill of the pressure vessel.	Not stated	Not discussed in report		Flush oil system [4]	93-48	8
Preexisting defects, component design, and insufficient bolt torque can lead to the initiation and growth of fatigue cracks that could cause eventual component failure.	Not stated	Not discussed in report		Weld repair cracks; torque bolts sufficiently when reinstalling yokes. [4]	93-97	9
IGSCC that initiated at a machined radius propagated over ~80% of the cross-sectional area. The resulting loss of preload apparently led to fatigue crack growth and eventual component failure.	Not stated	Not discussed in report		Replace beams of similar design if in service for more than 8 years. [4]	93-101	10
Surveillance coupons of Boraflex tested after five years had degraded substantially. Similar degradation of the Boraflex used in the high-density spent fuel storage racks would result in loss of subcriticality margin in the pool.	Not stated	EPRI TR-101986		Not stated	93-70	11
IGSCC in the HAZ of core shroud circumferential welds near the beltline resulted in axial cracking that may compromise the structural integrity of the shroud.	Not stated	GE RICSIL 054, Rev. 1		Add stiffening braces to the top portion of the shroud. [4]	93-79	12
Debris-induced fretting and grid-to-rod flow-induced vibrational fretting can lead to cladding perforation and fuel rod failure.	Not stated	Not discussed in report		Install vibration damping; redesign core to reduce vibration. [4]	93-82	13

Document: IN&B 1994, 1994 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Torsional excitation of the turbine-generator shaft from an electrical system disturbance causes vibration, resulting in separation of turbine blades by high-cycle fatigue.	Not stated	Not discussed in report		Not stated	94-01	1
Apparent galvanic corrosion between the SS plunger rod and the remaining Al parts caused corrosion product buildup and switch malfunction, resulting in an erroneous signal to the control computer and turbine overspeed.	Not stated	Not discussed in report		Not stated	94-11	2
Tubes repaired with kinetically welded sleeves may be susceptible to PWSCC adjacent to the sleeve because of residual stresses introduced, despite the post-weld heat treatment. Result is tube leakage.	Not stated	Not discussed in report		Not stated; problem still under investigation [4]	94-05	3

Document: IN&B 1994, 1994 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4	Cooling system	Main steam isolation valve	Guide ribs	Not stated	Atwood & Morrill Co., Inc.	WEAR	Attrition
5	Cooling system	Standby service water pump	Bolts and lockwashers in shaft coupling assemblies	Carbon steel	Not stated	CORR	Loss of material
6	Cooling system	Pipe snubbers	Internal lubricant	Hydrocarbon grease	Pacific Scientific	ELE-TEMP	Chemical and physical degradation
7	Emergency core cooling system	Air dampers and solenoid valves	Elastomer seals	Buna-N	Not stated	ELE-TEMP	Chemical and physical degradation
8	Emergency core cooling system	Shutdown cooling suction isolation valves	Sealing surfaces of valve disk and slide seat ring	Stellite	Anchor-Darling	RESID; FAT/THERM	Crack initiation; cumulative fatigue damage
9	Emergency core cooling system	High-pressure coolant injection motor-operated valve	Torque switch drive pinion gear roll pin	AISI 1070 carbon steel	Limitorque	EMBR; ENVIR	Loss of fracture toughness; chemical and physical degradation
10	Emergency core cooling system	High head safety injection pump	Pump casing	Carbon steel clad with stainless steel	Dresser Industries, Pacific Pump Division	Not stated; CORR/BA	Crack initiation and growth; loss of material
11	Reactor internals	Core shroud	Core plate support ring weldment	Stainless steel	General Electric Company	CORR/IGSCC	Crack initiation and growth

Document: IN&B 1994, 1994 NRC Information Notices
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Improper clearances between valve poppet and body can cause excessive wear of guide ribs, resulting in failure of valve to close properly.	Not stated	NRC Inspect. Rept. 50-458/93-18		Install anti-rotation modification from manufacturer [4]	94-08	4
Extensive general corrosion of the bolts and lockwashers in the pump shaft coupling assemblies caused shifting of internal parts and damage to impellers and bowls, resulting in degraded vibration performance.	Not stated	Not discusses in report		Rebuild pumps; modify testing procedure to detect internal changes before severe damage occurs. [4]	94-45	5
Prolonged exposure to temperatures of 38 to 93 deg. C caused the internal lubricant grease to bake and dry out, resulting in insufficient drag resistance during testing.	Common	Not discussed in report		Replace failed snubbers; develop criteria for service life program. [4]	94-48	6
Prolonged exposure to elevated temperatures causes the Buna-N elastomer seal material to break down, resulting in leakage of the nitrogen supply for the automatic depressurization valves and possible failure of these valves in a LOCA situation.	Not stated	Not discussed in report		Replace affected components with qualified replacements. [4]	94-06	7
High residual stresses from inadequate stress relief or thermal fatigue led to the initiation and growth of cracks in the sealing surfaces of the valves, resulting in excessive valve leakage.	Not stated	Not discussed in report		Not stated	94-30	8
Brittleness of roll pin material, possibly combined with hardening of grease in drive mechanism in one case, caused shear fracture of pin under load, resulting in failure of valve.	Not stated	Not discussed in report		Replace with larger diameter pin fabricated of Type 416 stainless steel for better ductility and impact resistance. [4]	94-49	9
Cracking of the stainless steel cladding from an unidentified cause leads to exposure of the underlying carbon steel, which corrodes relatively rapidly in contact with boric acid in the coolant.	Not stated	Pacific Pump Bulletin 037-0-0104-0		Perform field inspections described in Pacific Pump Bulletin 037-0-0104-0. [4]	94-63	10
IGSCC in and near the HAZ of the outside circumference of the core plate support ring weldment resulted in a 360 circum-ferential crack with a max. depth of ~2.13 cm in two different reactors.	Not stated	GE RICSIL 054, Rev. 1		Safety implications under investigation by NRC. [4]	94-42	11

Document: LER's, Licensee Event Reports (LERs)
Reviewed by: Ma and K. E. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Control Rod Drive	Scram Solenoid Pilot Valves	Pressure and Exhaust Diaphragms	Rubber	Automatic Switch Company	ELE-TEMP	Hardening, cracking
2	Control rod drive	Scram solenoid pilot valves	Diaphragm	Buna-N	General Electric	EMBR	Loss of fracture toughness
3	Containment	Personal Airlock	Door Shaft Seal Flange Bolts	Not stated	Not stated	WEAR	Attrition
4	Containment	Main Steam Isolation Valves	Seat Surfaces, Actuator Spring	Not stated	Not stated	WEAR, RATCH	Attrition, change in dimension
5	Containment	Vent Valve	Seal	Nitrile Elastomer	Atwood and Morrill Co.	WEATH	Loss of capacity
6	Containment	H2/O2 gas analyzer	Analyzer pump diaphragm	Not stated	Teledyne	Not stated	Not stated
7	Penetration Pressurization System	Inboard Containment Purge Exhaust Valves	Boot Seal	Not stated	Not stated	ENVIR	Chemical or physical degradation
8	Condenser System	Low Pressure Turbines	Exhaust Boot Seal	Fabric Reinforced Rubber	Uniroyal	FAT	Cumulative Fatigue Damage
9	Feedwater	Check Valve	Seal	Rubber (Parker E692)	Not stated	ELE-TEMP/ERO	Physical degradation, loss of material
10	Hot Leg Loop	Isolation Valve	Valve Stem	17 4PH Stainless Steel (ASTM A 56M Type 630)	Not stated	CORR/SCC	Crack initiation and growth
11	Auxiliary Feedwater	Pump Pneumatic Speed Control Loop	Different Pressure Transmitter	Not stated	Not stated	EDS (setpoint drift)	Loss of function
12	Emergency diesel generator	Fuel oil injector pump	Injector screw	Not stated	Nordberg	Not stated	Not stated
13	Spent fuel pool exhaust ventilation	Charcoal absorber	Seal on bypass damper blade edge	Rubber	Johnson Controls	Not stated	Not stated
14	Spent fuel pool exhaust ventilation	Charcoal absorber	Damper blades	Not stated	Johnson Controls	Not stated	Not stated
15	Fail-safe accumulator	2 way solenoid valve	Seal O-ring	Not stated	Versa Product Co.	FAT	Cumulative fatigue damage
16	Power system	Steam generator	Tube	Not stated	Combustion Engineering System-80	CORR/IGSCC	Crack initiation and growth

Document: LER's, Licensee Event Reports (LERs)
Reviewed by: Ma and K. E. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Control rod failed to scram due to degradation of pilot valve elastomers (hardening, cracking and permanent set) caused by high temperature produced by the energized solenoid coils.	Frequent	Not discussed in report	PS TS Req.	Use of new diaphragm material [2]	94-005-01	1
Control air leakage through degraded solenoid diaphragms rendered valve inoperable and failure to scram a control rod resulted.	Not applicable	Not discussed in report	PS TS Req.	Not stated	94-005-00	2
Excessive force to support shaft bearing and increased use of the airlock caused the shaft seal flange to loosen and move away from its seating, resulting in test pressure drop below criteria of containment airlock leakage test.	Moderate	Not discussed in report	10CFR50 App. J & PS TS Req.	Including inspection of the shaft seal gasket bolts in plant maintenance and inspection [4]	92-026-00	3
During local leak rate testing, the leak rate limit was exceeded due to degraded valve seal seat surfaces (misalignment of the poppet seat caused by wear of the guide ribs.)	Frequent	Not discussed in report	PS TS Req.	Replace springs on regular basis [4]	92-013-01	4
Leakage of rubber seal attributed to weather checking on exposed surface and storage causing unacceptable leakage in an Appendix J Type B leakrate test.	Not stated	Not discussed in report	PS TS Req.	The failed seal was replaced and the leak rate met acceptance cri teria. To prevent recurrence, both shelf life and durometer testing requirements shall be considered in the procurement documents [4]	89-005-00	5
Incorrect readings of oxygen concentration because of air leak into analyzer.	Not applicable	Not discussed in report	PS TS Req.	Not stated	92-009-00	6
Environmental aging of seal material caused leakage of PPS exceeding allowable rate. Seating area was cleaned and the leakage stopped.	Not stated	Not discussed in report	ASME Sec XI & PS TS Req.	Not stated	93-001-00	7
Loss of condenser vacuum due to fatigue failure of the north low pressure turbine exhaust boot seal (a fabric reinforced rubber expansion joint), causing an automatic turbine trip and reactor trip.	Moderate	Not discussed in report	PS TS Req.	Replace entire boot seal rather than performing local repair [2]	92-010-00	8
Leakage of rubber seal due to thermal aging and erosive wear, causing excessive leak rate of the check valves.	Frequent	Not discussed in report	ASME Sec XI IWV & PS TS Req.	Replace the soft seal material (Parker E692) with a new material more resistive to thermal aging and erosive wear than the original [4]	86-017-01	9
Crack due to tensile stress on the stem and entrapped water propagated through the valve stem diameter, resulting in the valve gate being in a partially closed position.	Infrequent	Not discussed in report	ASME Sec XI IWV & PS TS Req.	To minimize the in service stresses, the valves will be soft back seated during plant heatup and hard back seated only when operating temperature is reached [4]	86-008-01	10
Inoperability of the pump pneumatic speed control loop due to leaking bellows, setpoint drift, limited pump speed and discharge pressure below that needed to inject water into the steam generators under some accident conditions.	Not stated	Not discussed in report	PS TS Req.	Record turbine steam bowl pressures, including the speed control loop. In the preventive maintenance/calibration program at initial plant startup, perform periodic full flow test [4]	89-016-02	11
Emergency diesel generator not operable to allow fixing of injector pump.	Not applicable	Not discussed in report	PS TS Req.	Not stated	92-009-00	12
Over time the rubber seals lose pliability and allow leakage in the ventilation system.	Not applicable	Not discussed in report	PS TS Req.	Not stated	92-008-00	13
Bent damper blades prevented sealing and caused leakage in the ventilation system.	Not applicable	Not discussed in report	PS TS Req.	Not stated	92-008-00	14
Deterioration of O-ring caused control air leakage and failure of solenoid to meet specs.	Not applicable	Not discussed in report	PS TS Req.	Not stated	93-005-00	15
Rupture of tube causes leakage leading to low pressurizer level and pressure causing reactor trip and radiation in secondary system.	Not applicable	Steam Generator Task Force formed	ASME Sec XI IWB & PS TS Req.	Not stated	93-001-02	16

Document: LER's, Licensee Event Reports (LERs)
Reviewed by: Ma and K. Kasza, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
17	Main steam line	Isolation valve (globe valve)	Seat	Not stated	Atwood and Morrill Company Inc.	CORR/PIT	Local loss of materia
18	Main steam line	Isolation valve (globe valve)	Seat	Not stated	Atwood and Morrill Company Inc.	CREEP	Change in dimension
19	Essential cooling water	Traveling screen filter	Flexible coupling	Elastomeric	Rexnord	ENVIR	Chemical or physical degradation
20	Not stated	High Pressure Turbine Stop Valve	Auto Stop Oil Line	Not stated	Not stated	RESID/FAT	Crack initiation, cumulative fatigue damage
21	Penetration Pressurization System	Inboard Containment Purge Exhaust Valves	Seal Seat	Not stated	Not stated	ENVIR	Chemical or Physical Degradation
22	Emergency Power System	Diesel Generator	Fuel Oil	Not stated	Not stated	OX	Buildup of Deposit
23	Emergency Power System	Diesel Generator	Fuel Oil	Not stated	Not stated	OX	Buildup of Deposit
24	Containment Spray System	Heading Piping	Spray Nozzle	Piping: Carbon Steel	Not stated	CLOG	Blockage of flow passages
25	Fire Protection	3-hour Fire-rated Barriers	Penetration Fire Seal	Silicone Foam	Not stated	Improper installation/lack of inspection rqmt.	Loss of Function
26	Steam Generator Blowdown Outlet	Air-operated Isolation Valve	Valve Actuator Rubber Diaphragm	Rubber	Not stated	ENVIR	Physical Degradation
27	Not stated	Main Condenser	Expansion Joint	Rubber	Not stated	ENVIR	Physical Degradation
28	Not stated	Turbine	Low Pressure Exhaust Boot Seal	Rubber	Uniroyal	FAT	Cumulative Fatigue Damage
29	Emergency Cooling System and Containment Spray System	Motor-operated Valves	Not stated	Not stated	Not stated	Improper Switch Setting	Loss of Function
30	Primary Containment Isolation System	Isolation Valves, Reactor Vessel Stabilizer Hatch	O-rings, Seat Rings, Gaskets	Ethylene-propylene, Rubber	Various	ENVIR/WEAR	Physical Degradation, Attrition
31	Containment Penetration	Electric Penetration Assemblies	Seals	Polyurethane	Bunker Ramo	Hydrolysis	Physical Degradation, Attrition

Table A.1 Gall Report for Licensee Event Reports

Document: LER's, Licensee Event Reports (LERs)
Reviewed by: Ma and K. Kasza, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Technical specifications for leakage limits on valves is exceeded.	Moderate	Not discussed in report	ASME Sec XI & PS TS Req.	Not stated	93-003-01; 003-02	17
Technical specification for leakage limits on valves is exceeded.	Infrequent	Not discussed in report	ASME Sec XI & PS S&T Req.	Not stated	93-003-01	18
Aging of elastomeric couplings resulted in their cracking and failure of traveling screen filter to operate.	Not applicable	Not discussed in report	PS S&T Req.	Not stated	93-010-00	19
Turbine stop valve closure due to auto stop oil line weld leak resulted in a manual reactor trip and a manual safety injection. The weld failure was due to inadequate field installation (overlapping welds) and fatigue.	Rare	Not stated	PS S&T Req.	Perform visual inspection of the accessible welds, measure vibration of the auto stop oil line during plant startup [4]	89-011-00	20
Environmental aging of seal material caused leakage of PPS exceeding allowable rate. Seating area was cleaned and the leakage stopped.	Not stated	Not stated	PS S&T Req.	Not stated	93-013-01	21
Oxidation of fuel oil due to a high concentration of insolubles clogging the sample filter, causing inoperability of diesel generator.	Infrequent	Not stated	RG 1.9, RG 1.108 & PS TS Req.	Periodic replace ment of the fuel oil and use of a higher grade diesel fuel oil which has a longer shelf life [4]	89-001-00	22
Oxidation of fuel oil due to a high concentration of insolubles clogging the sample filter, causing inoperability of diesel generator.	Infrequent	Not stated	RG 1.9, RG 1.108 & PS TS Req.	Periodic replacement of the fuel oil and use of a higher grade diesel fuel oil which has a longer shelf life. Add a biocide, a dispersant and a stabilizer to extend the shelf life. [4]	89-001-01	23
Nozzle blockage due to accumulation of the deteriorated coating of the CSS piping inner surface could block the CSS flow.	Frequent	Not stated	PS S&T Req. & PS TS Req.	Replacement of the CSS nozzles with clog resistant nozzles [4]	90-021-00	24
Gaps, tears, or splits due to improper installation and lack of inspection requirements were found in the seals. Propagation of a fire across boundary would affect the plant safe shutdown.	Frequent	Not stated	PS S&T Req.	Use a different type of foam and different installation techniques [4]	90-002-00	25
Failure of rubber diaphragm resulting in air leakage and failure of the valve closure.	Not stated	Not stated	ASME Sec XI IWV & PS S&T Req.	Not stated	92-001-00	26
The air leakage through the torn expansion joint rubber belt caused low vacuum in the main condenser and subsequent manual reactor and main turbine trip.	Infrequent	Not stated	PS S&T Req. & PS TS Req.	Periodic replacement of the expansion joints [2]	92-003-00	27
Failure of the north low pressure turbine boot seal due to fatigue caused condenser low vacuum and subsequent automatic reactor and turbine trip.	Not stated	Not stated	PS S&T Req.	Not stated	92-007-00	28
Isolation valves were not capable of full closure under design basis conditions due to improper drive gear sets and torque switch settings.	Frequent	GL89-10	ASME	Reconfigure and test the MOVs to satisfy the GL89 10 criteria [4]	92-006-00	29
Brittle and broken O-ring seals of the reactor vessel stabilizer hatch indicated that the ethylene propylene (EP) material is generally unable to resist harsh environments. O-rings made of silicone rubber were in good condition.	Frequent	Not stated	10CFR50 App. J	Periodic replacement of the O-rings [4]	88-014-00	30
Degradation of seal material, polyurethane, due to hydrolysis would allow moisture intrusion into the electrical penetration assembly during a LOCA event, potentially resulting in discontinuity of off-site power.	Frequent	Not stated	PS S&T Req	Use a more durable material, ethylene propylene rubber; install a silicone rubber O-ring as a backup seal; upgrade the nitrogen supply system to safety-grade system [4]	91-011-02	31

Table A.1 Gall Report for NRC Bulletins

Document: BL 89-01, 1989 NRC Information Notices and Bulletins
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Cooling system	Steam generator	Tubing mechanical plugs	Inconel 600	Westinghouse	CORR/PWSCC	Crack initiation and growth

Document: BL 89-02, 1989 NRC Information Notices and Bulletins
Reviewed by: Dwight R. Diercks, ANL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Residual heat-removal system	Swing check valve	Retaining block stud (bolt)	Type 410 stainless steel (A193, Gr B6, Type 410 SS)	Anchor Darling	CORR/SCC	Crack initiation and growth

Document: BL 89-01, 1989 NRC Information Notices and Bulletins
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Intergranular cracking, apparently associated with improper heat treatment and/or susceptible heats of material, can cause mechanical tube plugs to loosen, leak, and sometimes be forcibly ejected, causing additional tube damage.	Not stated	Not discussed in report		Replace plugs from suspect heats of material; discontinue use of Westinghouse plugs. [4]	89-33; Bull. 89-01, 89-01, Suppl. 1 & 2.	1

Document: BL 89-02, 1989 NRC Information Notices and Bulletins
Reviewed by: Dwight R. Diercks, ANL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Susceptibility to SCC was apparently enhanced by improper heat treatment (hardness too high), coupled with presence of borated water. Resulting cracking led to bolt fracture.	Not stated	ASME SA193-B6		Inspect bolts for cracks; replace defective bolts with bolts having Rc hardness <=26. [4]	BL 89-02	1

A.2 Electrical Components and Systems

Document: BNL A-3270-11-85, Seismic Endurance Tests of Naturally Aged Small Electric Motors
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electric Motors	Terminal Boxes	Not stated	Not stated	CORR	Improper sealing of the cover gaskets
2		Electric Motors	Stator Winding	Not stated	Not stated	Not stated	Break down of varnish and insulation
3		Electric Motors	All Other Components	Not stated	Not stated	Not stated	Not stated

Document: BNL A-3270-3-86, Testing Program For The Monitoring of Degradation in a Continuous Duty 460 volt Class "B", 10 hp Electric Motor
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electric Motor	Dielectrics (Insulation)	Organic insulation materials	Not stated	ELETEMP MOIST-EL RAD, VIBR, CURSTR, VOLSTR, CONTAM	Insultion degradation causes leakage through the insulation
2		Electric Motor	Bearings	Not stated	Not stated	Not stated	Ball or roller surface defects cause vibration
3		Electric Motor	Cage (Rotor)	Not stated	Not stated	Not stated	Damaged or defective cage
4		Electric Motor	Stator	Steel, Copper, Organic insulation	Not stated	THERM-CY, FAT	Stress caused by differences in thermal expansion rates

Document: CHAPTER 24 CABLES, Aging and Life Extension of Major Light Water Reactor Components
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1			Non-Shielded Single & Multi-Conductor Jacketed	Polymers, Rubber, Sicicon, Copper, Kapton	Not stated	ELETEMP, MOIST-EL, OXIDAT, & RAD	Jacket embrittlement & cracking, propagating thru insulation
2			Shielded Pair Multi-Conductor Jacketed	Polymers, Rubber, Silicon & Copper	Not stated	ELETEMP, MOIST-EL, OXIDAT, & RAD	Jacket & cracking-moisture diffuses through jacket and cond.
3			Connections - Non-Sealed	Not stated	Not stated	ELETEMP & MOIST-EL	Moisture diffuses into cables and connection internals
4			Connections - Compression Sealed	Polymers	Not stated	ELETEMP, RAD, & VIBR	Seals not hermetic
5			Cables, Halogination of Filled Polymers	Polymers	Not stated	ELETEMP, RAD, & MOIST-EL	Electrolytes that increase leakage or losses
6			Mineral Insulated Cable	Not stated	Not stated	THERMO-CY & VIBR	Open hermetic seals
7			Terminal Strips	Not stated	Not stated	CONTAM	Increase leakage or losses

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Battery Chargers and Inverters	Circuit Breakers	Contacts, Coil, Linkages, & Case	Not stated	Not stated	WEAR & LOSLUB	Bearing wear & solidification of lubrication
2	Battery Chargers and Inverters	Circuit Breakers	Contacts, Coil, Linkages, & Case	Not stated	Not stated	FAT, OXIDAT	Metal fatigue, embrittlement & cracking of insulation
3	Battery Chargers and Inverters	Circuit Breakers	Contacts, Coil, Linkages, & Case	Not stated	Not stated	OXIDAT & WEAR	Oxidation and pitting of contact surfaces

Document: BNL A-3270-11-85, Seismic Endurance Tests of Naturally Aged Small Electric Motors
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage of moisture into the box could lead to termination corrosion and overheating which could cause degraded performance or failure to operate	Not stated	Not discussed in report	No specific program	Not stated	3, 4	1
Excessive leakage current and decreased performance or failure to operate	Not stated	Not discussed in report	No specific program	Not stated	4	2
Not stated	Not stated	Not discussed in report	No specific program	Not stated	A-6	3

Document: BNL A-3270-3-86, Testing Program For The Monitoring of Degradation in a Continuous Duty 460 volt Class "B", 10 hp Electric Motor
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage through the insulation causes imbalances between phases, phases with below normal current, and overheating in phases with above normal current. Results in decreased output.	Not stated	Not discussed in report	IEEE 334-1974 Section 14	Not stated	1, 3, 12	1
Increased friction and reduced output	Not stated	Not discussed in report	IEEE 334-1974 Section 14	Not stated	3, 15	2
Decreased speed or torque	Not stated	Not discussed in report	IEEE 334-1974 Section 14	Not stated	15	3
Additional aging stress to the windings	Not stated	Not discussed in report	IEEE 334-1974 Section 14	Not stated	3	4

Document: CHAPTER 24 CABLES, Aging and Life Extension of Major Light Water Reactor Components
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Circuit ground or short	Frequent	Limited	No specific program	Utilities (1) monitor temp/rad determine hot spots, (2) perform periodic inspections, & (3) don't disturb cables [4]	845,848,854,863, & 865	1
Circuit opens, grounds, total loss of function	Frequent	Limited	No specific program	Utilities adopt improved failure analysis & recording [4]	845,848,854,863, 865	2
Circuit opens, grounds, total loss of function	Not stated	Not discussed in report	No specific program	Not stated	845,848,863, 865	3
During DBE moisture enters through connection, contacts corride, circuit grounds or shorts	Not stated	Not discussed in report	No specific program	Not stated	845,848,850,863, & 865	4
Disable function during dbe	Not stated	Not discussed in report	No specific program	Not stated	845,848,863, & 865	5
DBE-excessive leakage disables cable	Not stated	Not discussed in report	No specific program	Not stated	845,848,851, & 865	6
DBE-excessive leakage disables cable	Not stated	Not discussed in report	No specific program	Not stated	833,845,848, & 865	7

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to operate	Occasional	Not discussed in report	Vendor specific program, Tech. Spec. surveil.	Not stated	4-18	1
Fails to open - trip coil force becomes less than spring force.	Occasional	Not discussed in report	Vendor specific program, Tech. Spec. surveil.	Not stated	4-18	2
Fails to open - loss of continuity across contacts.	Rare	Not discussed in report	Vendor specific program, Tech. Spec. surveil.	Not stated	4-18	3

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4	Battery Chargers and Inverters	Fuse		Not stated	Not stated	FAT	Metal fatigue
5	Battery Chargers and Inverters	Fuse		Not stated	Not stated	ELE-TEMP	Melting of link
6	Battery Chargers and Inverters	Relay	Contacts	Not stated	Not stated	OXIDAT & WEAR	Oxidation & pitting of contact surfaces
7	Battery Chargers and Inverters	Relay	Coil	Not stated	Not stated	CORR	Electromechanical action causing corrosion of fine wires.
8	Battery Chargers and Inverters	Electrolytic Capacitors		Not stated	Not stated	ELETEMP	Over heating by internal stresses causes loss of electrolyte
9	Battery Chargers and Inverters	Electrolytic Capacitors		Not stated	Not stated	VIB	Failure of leads
10	Battery Chargers and Inverters	Oil Filled Capacitors		Not stated	Not stated	ELETEMP	Over heating forms gasses and dielectric breakdown
11	Battery Chargers and Inverters	Oil Filled Capacitors		Not stated	Not stated	VIB	Failure of leads
12	Battery Chargers and Inverters	Transformer	Wire	Not stated	Not stated	THERM-CY & ELETEMP	Cracking of insulation
13	Battery Chargers and Inverters	Transformer	Wire	Not stated	Not stated	LOTEMP	Cracking of moisture seals
14	Battery Chargers and Inverters	Transformer	Wire	Not stated	Not stated	VOLSTR	Insulaton material deterioration
15	Battery Chargers and Inverters	Transformer	Wire	Not stated	Not stated	VIB & ELETEMP	Fracture of connecting wires and changes in shunting.
16	Battery Chargers and Inverters	Silicon Controlled Rectifier		Not stated	Not stated	VOLSTR & CURSTR	Transients resulting in over voltage & current & overheating
17	Battery Chargers and Inverters	Resistor		Not stated	Not stated	VIB	Lead fails
18	Battery Chargers and Inverters	Resistor		Not stated	Not stated	ELETEMP	Decrease in resistance values as temperature increases
19	Battery Chargers and Inverters	Printed Circuit Boards		Not stated	Not stated	THERM-CY	Cracking of input lines
20	Battery Chargers and Inverters	Printed Circuit Boards		Not stated	Not stated	CORR	Loss of material
21	Battery Chargers and Inverters	Printed Circuit Boards		Not stated	Not stated	VIB	Loose or open connection
22	Battery Chargers and Inverters	Surge Suppressor		Not stated	Not stated	VOLSTR OR CURSTR	Semiconductor barrier breakdown due to overheating.
23	Battery Chargers and Inverters	Connectors		Not stated	Not stated	FAT & VIB	Fatigue of wires at terminals
24	Battery Chargers and Inverters	Meters		Not stated	Not stated	CONTAM	Dirt on movement and increase in bearing friction
25	Battery Chargers and Inverters	Meters	Coil Insulation	Not stated	Not stated	ELETEMP	Coil insulation degrades causing shorting
26	Battery Chargers and Inverters	Meters	Contacts	Not stated	Not stated	WEAR & CORR	Contacts pitting or corrosion
27		Cable	Insulation	Not stated	Not stated	ELETEMP, RAD, & MOIST-EL	Loss of dielectric properties & changes in structure

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Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails open due to equipment load cycling	Occasional	Not discussed in report	Vendor specific program, Tech. Spec. surveil.	Not stated	4-18	4
Fails open due to heat generated by surrounding components.	Rare	Not discussed in report	Vendor specific program, Tech. Spec. surveil.	Not stated	4-18	5
Contacts open - loss of continuity across contacts	Rare	Not discussed in report	Tech. Spec. surveillance	Not stated	4-18	6
Open circuit of coil - loss of continuity through coil wires.	Rare	Not discussed in report	Vendor specific program	Not stated	4-18	7
Loss of capacitance and degraded system operation.	Occasional	Not discussed in report	Vendor specific program	Not stated	4-18	8
Open circuit	Rare	Not discussed in report	Vendor specific program	Not stated	4-18	9
Loss of capacitance	Occasional	Not discussed in report	Vendor specific program	Not stated	4-18	10
Open circuit	Rare	Not discussed in report	Vendor specific program	Not stated	4-18	11
Short circuit - turn to turn or to ground	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	12
Short circuit - turn to turn or to ground	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	13
Short circuit - turn to turn or to ground	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	14
Change in inductance	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	15
Short or open circuit	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	16
Open circuit	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	17
Change in resistance value and degraded circuit operation.	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	18
Change in output	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	19
Open circuit at terminals or within printed circuit board.	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	20
Change in output	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	21
Short circuit	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	22
Open or short circuit	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	23
No response (stuck)	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	24
No response from meter	Rare	Not discussed in report	Vendor specific program	Not stated	4-19	25
Fails to open or close	Occasional	Not discussed in report	Vendor specific program	Not stated	4-19	26
Cracks when flexed & loss of flexibility, loss of imperviousness, failure frequently coupled with presence of moisture or water.	Rare	Not discussed in report	No specific program	Not stated	3-33	27

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
28		Cable	Insulation	Not stated	Not stated	ELETEMP, RAD, & MOIST-EL	Loss of dielectric properties & changes in structure
29		Cable	Insulation	Not stated	Not stated	ELETEMP, RAD, & MOIST-EL	Loss of dielectric properties & changes in structure
30	(Pressure Transmitters)	Force Balance Type	Force Bar & Linkage	Not stated	Not stated	WEAR & VIB	Wear of pivot points
31	(Pressure Transmitters)	Force Balance Type	Force Motor (Feedback Coil)	Not stated	Not stated	VOLSTR ELETEMP	Insulation failure & coil burnout
32	(Pressure Transmitters)	Force Balance Type	Amplifier	Not stated	Not stated	THER-CY & VOLSTR	Shorting or opening of electronic components
33	(Pressure Transmitters)	Force Balance Type	Housing Seals	Not stated	Not stated	ELETEMP, RAD, OR EMBR	Compresive set or cracking
34	(Pressure Transmitters)	Force Balance Type	Diaphragm	Not stated	Not stated	CORR	Perforation of diaphragm from corrosion
35	(Pressure Transmitters)	Force Balance Type	Diaphragm Seal	Not stated	Not stated	Not stated	Seal deterioration from decomposition
36	(Pressure Transmitters)	Capicitance Type Transmitters	Sensing Cell	Not stated	Not stated	Not stated	Perforation in cell allowing leakage of fluid
37	(Pressure Transmitters)	Capicitance Type Transmitters	Terminal Cover Plate Seal	Not stated	Not stated	EMBR, ELETEMP, & RAD	Embrittlement and seal cracking
38	(Pressure Transmitters)	Capicitance Type Transmitters	Electronics	Not stated	Not stated	OXIDAT & CONTAM	Circuit continuity lost and bridging of circuits
39	(Pressure Transmitters)	Capicitance Type Transmitters	Electronics	Not stated	Not stated	VOLSTR & ELETEMP	Shorting or opening of component
40	(Pressure Transmitters)	Capicitance Type Transmitters	Sensing Cell	Not stated	Not stated	ELETEMP OR RAD	Chemical changes in fill-oil
41	(Pressure Transmitters)	Capicitance Type Transmitters	Electronics	Not stated	Not stated	RAD, ELETEMP, OR VOLSTR	Change in component parameters

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Cracks when flexed & loss of flexibility, loss of imperviousness, failure frequently coupled with presence of moisture or water.	Rare	Not discussed in report	No specific program	Not stated	3-34	28
Cracks when flexed & loss of flexibility, loss of imperviousness, failure frequently coupled with presence of moisture or water. Adverse changes in insulation resistance may cause attenuation of signals.	Rare	Not discussed in report	No specific program	Not stated	3-34	29
Failure to operate - decrased accuracy or complete failure. Zero shift may result from bent components causing transmitter failure to operate as required.	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-43	30
Failure to operate - loss of output	Rare	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-43	31
Failure to operate - may fail high, low, lose accuracy, or fail with steady output.	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-43	32
Failure to operate - inability of seal to provide moisture and pressure barrier results in failure of electronics due to shorting and corrosion from ingress of environmental contaminants.	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-43	33
Failure to operate as required - zero shift or leakage through diaphram causing variable instrument drift as pressures across diapharam equalize	Occasional	Not discussed in report	RG 1.118,IEEE 338-1987,ISA 67.06,10 CFR 50.49	Not stated	4-43	34
Failure to operate as required - leakage through diaphram causing variable instrument drift as pressures across diapharam equalize	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-43	35
Failure to operate or loss of accuracy or drift	Rare	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Bul 90-01	Not stated	4-44	36
Failure to operate - inability to provide moisture and pressure boundary resulting in loss of electronics due to ingress of environmental contaminants	Rare	Not discussed in report	RG 1.118,IEEE 338-1987,ISA 67.06,10 CFR 50.49	Not stated	4-44	37
Failure to operate or loss of signal or sporadic operation	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-44	38
Failure to operate - loss of output, may fail high or low.	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-44	39
Failure to operate as required such as zero shift, reduced accuracy, or changes in response time.	Rare	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, IN 95-20	Not stated	4-45	40
Failure to operate as required - loss of accuracy, drift, or zero shift.	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-45	41

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
42	(Pressure Transmitters)	Strain Gage Type	Strain Gage	Not stated	Not stated	Not stated	Loss of continuity in bridge circuit related to aging
43	(Pressure Transmitters)	Strain Gage Type	Seals	Not stated	Not stated	CONTAM, EMBR, ELETEMP, OR RAD	Embrittlenent or cracking
44	(Pressure Transmitters)	Strain Gage Type	Potentiometer	Not stated	Not stated	CORR & ELETEMP	Corrodes open due to thermal stress
45	(Pressure Transmitters)	Strain Gage Type	Electric Module	Not stated	Not stated	Not stated	Component deterioration or change in parameters
46	(Pressure Transmitters)	Strain Gage Type	Bourdon Tube	Not stated	Not stated	CORR	Perforation of tube allowing leaks to transmitter housing

Document: NISTIR 4485, Annotated Bibliography - Diagnostic Methods and Measurement Approached to Detect Incipient Defects Due to Aging of Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Cable	Not stated	Not stated	Not stated	Not stated	Not stated

Document: NISTIR 4487, Detection of Incipient Defects in Cables by Partial Discharge Signal Analysis
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Cable	Insulation	Not stated	Not stated	MOIST-EL, OXIDAT, ELETEMP, & RAD	Defects develop from these mechanisms

Document: NISTIR 4787, The Use of Time-Domain Dielectric Spectroscopy to Evaluate the Lifetime of Nuclear Power Station Cables
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electrical Cable	Jacket	Vinyl	Not stated	Not stated	Not stated
2		Electrical Cable	Insulation	PE, XLPE, XLPO	Not stated	ELETEMP & RAD	Chemical reactions, crosslinking, ionization
3		Electrical Cable	Insulation	PE, XLPE, XLPO	Not stated	ELETEMP COMBINED WITH RAD	Chemical reactions, crosslinking, ionization

Document: NUREG-1377 R3, NRC Research Program on Plant Aging: Listing and Summaries of Reports Issued Through July 1992
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Listing and Summaries of 123 NPAR Reports					NOT SPECIFICALLY ADDRESSED IN THE REPORT	

Document: Letter Report/INEL, Summaries of Research Reports Submitted in Connection With the Nuclear Aging RESEARCH (NPAR) PROGRAM
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to operate - loss of output.	Rare	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-45	42
Failure to operate - inability to provide moisture and pressure barrier leading to failure of electronics due to contamination.	Occasional	Not discussed in report	RG 1.118,IEEE 338-1987,ISA 67.06,10 CFR 50.49	Not stated	4-45	43
Failure to operate - fails over range, wire-wound potentiometer corrosion of resistive elements leads to failure	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-45	44
Failure to operate or loss of full output	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-45	45
Failure to operate as required - drift, contamination of transmitter internals, and failure to respond	Rare .	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Not stated	4-45	46

Document: NISTIR 4485, Annotated Bibliography - Diagnostic Methods and Measurement Approached to Detect Incipient Defects Due to Aging of Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
This is a collection of 156 reveiwed abstracts of reports and papers related to cable aging and defect assessment covering the 1970-1986 period. An additional list of 850 citations was compiled from references given in the reveiwed papers.	Not stated	Not discussed in report	No specific program	Not stated	NA	1

Document: NISTIR 4487, Detection of Incipient Defects in Cables by Partial Discharge Signal Analysis
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The defects will degrade insulating properties of cable insulation.	Occasional	Not discussed in report	No specific program	Six recommendations each for partial discharge research and hardware development. Three for software. [4]	1 and 120	1

Document: NISTIR 4787, The Use of Time-Domain Dielectric Spectroscopy to Evaluate the Lifetime of Nuclear Power Station Cables
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	No specific program	Not stated	15	1
Embrittlement, softening, loss of elongation and reduced dielectric strength could cause failure to accurately transmit voltage or current.	Not stated	Not discussed in report	No specific program	Not stated	1, 2, 4, 7, 8, 15, 17, 22-38	2
Embrittlement, softening, loss of elongation and reduced dielectric strength could cause failure to accurately transmit voltage or current.	Not stated	Not discussed in report	No specific program	Not stated	1, 2, 4, 7, 8, 15, 17, 22-38	3

Document: NUREG-1377 R3, NRC Research Program on Plant Aging: Listing and Summaries of Reports Issued Through July 1992
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The purpose of the report is to present a listing and summaries of 123 NPAR reports. Specific aging effects and recommendations are addressed by the individual reports.		Not discussed in the report	No specific program	Not stated		1

Document: NUREG/CP-0100, Proceedings of the International Nuclear Aging Symposium, Session 3
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
17		Resistance Temperature Devices		Not stated	Not stated	THERM-CY	Conductive compounds become insulative
18		Electrical Wiring	Insulation	Kapton (Aeromatic polymide)	Not stated	MOIST-EL & ELE-TEMP	Insulation cracking and loss of mechanical properties
19		Pressure Transducers	Force Balance Type Sensors	Not stated	Foxboro	CONTAM & FRZ-THAW	Blockage of sensing lines
20		Pressure Transducers	Not stated	Not stated	Rosemount	CONTAM & FRZ-THAW	Blockage of sensing lines
21		Micro Processor & ICs	IC DIE	Silicon, Silicon oxide, & interfaces	Not stated	CONTAM, VOTSTR, CURSTR	Contamination causes shorts, V & I stresses cause burnout
22		Micro Processor & ICs	IC DIE	Metalization	Not stated	CORR	Corrosion from adjacent materials
23		Micro Processor & ICs	IC Package	Metalic leads & container and glass seals	Not stated	FAT, CORR, VIB, & CONTAM	Corr from adjacent materials, vib causes fat, contam shorts
24	Diesel Generator	Not stated	Not stated	Not stated	Not stated	WEAR & LOSLUB	Wear from lack of lubrication during fast starts
25		Cable	Insulation	EPR, CSPE, & XLPE	Four vendors listed	RAD, ELETEMP, & MOIST-EL	Insulation degradation from all three mechanisms

Document: NUREG/CP-0105, Seventeenth Water Reactor Safety Information Meeting (Electrical Parts)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
14	Auxiliary Feedwater System		Not stated	Not stated	Not stated	Not stated	
15	Auxiliary Feedwater System	Cable		Various cable materials	Seven vendors Identified	RAD AND ELETEMP	Not stated
16	Auxiliary Feedwater System	Steam Generator	Tubes	Not stated	Westinghouse	FAT, EROS, CORR	Primary water stress corrosion cracking (PWSCC)
17	Auxiliary Feedwater System	Circuit Breakers		Not stated	Not stated	Not stated	Not stated
18	Auxiliary Feedwater System	Turbine Driven Pump		Not stated	Not stated	Not stated	Not stated
19	Auxiliary Feedwater System	Compressors		Not stated	Not stated	WEAR, CONTAM, & VIB	Set point drift, degraded parts, & loose connections
20	Auxiliary Feedwater System	Dryers		Not stated	Not stated	CORR & CONTAM	Blockage, deteriation of components
21	Auxiliary Feedwater System	Valve		Not stated	Not stated	WEAR, CONTAM, AND CORR	Set point drift, fracture/cracking, component deterioration

Document: NUREG/CP-0100, Proceedings of the International Nuclear Aging Symposium, Session 3
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Never-seez usd in thermal wells lose conductivity with age and effects response time of RTD.	Not stated	Reg Guides 1.118 and 1.105	Reg Guides 1.118 and 1.105	Not stated	363-366	17
Cracking can result in contamination intrusion and improper output.	Occasional	Not discussed in report	No specific program	Not stated	130-131	18
Partial or full blockage of sensing lines effects the transducer response time.	Not stated	IEEE-Std 338, Reg Guide 1.118, & ISA Std 67.06	IEEE 338, Reg Guide 1.118, ISA 67.06	Not stated	137-139	19
Partial or full blockage of sensing lines effects the transducer response time.	Not stated	IEEE-Std 338, Reg Guide 1.118, & ISA Std 67.06	IEEE 338, Reg Guide 1.118, ISA 67.06	Not stated	138-139	20
Contamination enters by cracks or from MFG process and if moved by handling can short gate elements, voltage and current spikes may overstress leads or connections weakened by manufacturing process or chemical reactions of materials used in IC.	Not stated	IEEE-323-1983	No specific program	As new vendors & technologies emerge, their aging sensitivity should be addressed. [2]	146-152	21
Metalization may fail because of corrosion from adjacent materials	Not stated	IEEE-323-1983	No specific program	As new vendors & technologies emerge, their aging sensitivity should be addressed. [2]	146-152	22
Vibration may crack glass seals allowing contamination to enter case, corr from moisture entering cracked seals or adjacent materials, contamination left from mfg process or entering through seal cracks may cause component shorting.	Not stated	IEEE-323-1983	No specific program	As new vendors & technologies emerge, their aging sensitivity should be addressed. [2]	146-152	23
Decreases reliable life of diesels	Not stated	Not discussed in report	IEEE 387-1984 Section 7.5, IEEE 749-1983	Not stated	153-157	24
The report is not an aging evaluation, but only describes long term tests to determine the amount of insulation degratation from radiation, elevated temperature, pwr atmospheres, and inerted BWR atmospheres.	Not stated	IEEE Std-74 & IEEE STD-383-1974	No specific program	Not stated	158-166	25

Document: NUREG/CP-0105, Seventeenth Water Reactor Safety Information Meeting (Electrical Parts)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
This report develops an aging risk assesment methodology using the aPWR AFW system to demonstrate method	Not stated	Not discussed in report	No specific program	Not stated	377-398	14
This report covered loca testing of aged cables. Aging information provided in other Sandia reports on cable aging	Not stated	Not discussed in report	No specific program	Not stated	399-410	15
PWSCC damages steam tubes at three locations; roll transition regions, U-bends, and tube dents. Leaks at these locations can lead to shuting down the reactor.	Rare	Not discussed in report	No specific program	Not stated	411-431	16
This report covers NPAR phase 2 tasks related to resolving technical safety issues	Not stated	NPAR	No specific program	Not stated	433-437	17
This report only provides an overview and identifies the turbine driven pump as historically having the most failures with the turbine i&c/governor control system having half of these failures. Does not have specific aging data.	Not stated	Not discussed in report	No specific program	Comprehensive testing of components and i&c. [2]	439-451	18
Degraded operation or failure	Occasional	Not discussed in report	No specific program	Not stated	453-471	19
Failure or degraded operation	Occasional	Not discussed in report	No specific program	Not stated	453-471	20
Failure to operate, failure to open or close, or degraded operation	Occasional	Not discussed in report	No specific program	Not stated	453-471	21

Document: NUREG/CP-0105, Seventeenth Water Reactor Safety Information Meeting (Electrical Parts)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
22	Auxiliary Feedwater System	Diesel Generator		Not stated	Not stated	Not stated	Not stated
23	Auxiliary Feedwater System	Circuit Breakers	Not stated	Not stated	Not stated	Not stated	Not stated
24	Auxiliary Feedwater System	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
25	Auxiliary Feedwater System	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated

Document: NUREG/CR-3956, In Situ Testing of the Shippingport Atomic Power Station Electrical Circuits
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Pressurizer Heater Feeder Circuit	Cable	Conductor	NO. 6 AWG, single copper conductor	Okonite	CORR	Increased loop resistance
2	Pressurizer Heater Feeder Circuit	Cable	Insulation	1/16 IN. thick oil base	Okonite	Not stated	Low insulation resistance
3	Pressurizer Heater Feeder Circuit	Cable	Jacket	1/32-IN. black neoprene	Okonite	Not stated	Not stated
4	Pressurizer Heater Main Feeder Circuit	Cable	Conductor	NO. 10 AWG Copper	Not stated	CORR	Not stated
5	Pressurizer Heater Main Feeder Circuit	Cable	Insulation	Silicon rubber with glass braid	Not stated	OXIDAT	Degraded insulation resistance
6	Pressurizer Heater Main Feeder Circuit	Cable	Jacket	Silicon rubber	Not stated	Not stated	Not stated
7	Instrumentation and Control	Heater, MOV, and RTD Circuits	Stop Joint, Splices, and Terminals	Not stated	Not stated	MOIST-EL AND CORR	Loss of material, and corrosion product buildup
8	Rod Control Position Indicator Cables	Cable	33 Conductor, NO. 16 AWG, Stranded Wire	Copper	Okonite	Not stated	Not stated
9	Rod Control Position Indicator Cables	Cable	Insulation	Oil base insulation	Okonite	Not stated	Not stated
10	Rod Control Position Indicator Cables	Cable	Jacket	Neoprene	Okonite	Not stated	Not stated
11	Resistance Temperature Detector Circuits	Cable	Insulation	NO. 18 AWG, tinned copper stranded. spiral wrapped and shielded with a chrome vinyl jacket	Not stated	Not stated	Not stated
12	Resistance Temperature Detector Circuits	RTDs	Sensing Element	Platinum	Leeds and Northrup	Not stated	Not stated
13	Resistance Temperature Detector Circuits	Terminals and Stop Joints	Not stated	Not stated	Not stated	CORR AND MOIST-EL	Increase in resistance, open circuit, and film on terminals
14	Nuclear Instrumentation	RG-149U Cables	Insulation	NO. 18 AWG copper center conductor and polyethylene insulation	Not stated	Not stated	Not stated
15	Motor Operated Valves	Limit Switches	Contacts	Not stated	Not stated	CORR	Material buildup on contacts
16	Motor Operated Valves	Cable	Not stated	Not stated	Not stated	Not stated	Not stated
17	Motor Operated Valves	Motor	Not stated	Not stated	Not stated	Not stated	Not stated

Document: NUREG/CP-0105, Seventeenth Water Reactor Safety Information Meeting (Electrical Parts)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to start	Occasional	Not discussed in report	IEEE 387-1984 Section 7.5, IEEE 749-1983	Not stated	473-495	22
Failure to transfer	Occasional	Not discussed in report	IEEE 741-1986 Section 7	Not stated	473-495	23
This report only covers the use of NPAR results in inspection activities. Aging summaries are covered in other npar reports	Not stated	Not discussed in report	N/A	Not stated	497-407	24
This report covers a methodology for managing aging in nuclear power plants	Not stated	Not discussed in report	N/A	Not stated	509-529	25

Document: NUREG/CR-3956, In Situ Testing of the Shippingport Atomic Power Station Electrical Circuits
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The effect was a small decrease in available wattage to heaters	Rare	Plant specific maintenance	No specific program	Keep moisture out [2]	5, 6, & 7	1
Degraded heater oeration, one circuit failed because of low insulation resistance	Rare	Plant specific maintenance	No specific program	Keep moisture out of cables [2]	5, 6, 7, & 21	2
Not stated	Rare	Not discussed in report	No specific program	Not stated	6	3
Marginal operation	Rare	Not discussed in report	No specific program	Not stated	6	4
Marginal operation of heaters	Rare	Not discussed in report	No specific program	Not stated	6	5
Not stated	Rare	Not discussed in report	No specific program	Not stated	6	6
Nonenvironmentaly sealed splices and terminals presents vulnerable areas for oxidation, corrosion, dust, and moisture contamination to set in.	Occasional	Not discussed in report	No specific program	Periodic plant maintenance to clean terminals and check seals and to use ECCAD to check circuits before failure [2]	7 and 21	7
None	Rare	Not discussed in report	No specific program	Not stated	7, 8, and 21	8
None	Rare	Not discussed in report	No specific program	Not stated	7, 8, and 21	9
None	Rare	Not discussed in report	No specific program	Not stated	7, 8, and 21	10
None	Rare	Not discussed in report	No specific program	Not stated	7, 8, and 21	11
One circuit shorted to ground at the instrument end	Rare	Not discussed in report	ANSI/IEEE 338-1987	Not stated	8, 9, and 21	12
Circuits had higher than expected loop resistance, four circuits had a series resistance occuring at the stop joints, resistance problem also observed at termination points in the control room, one circuit was shorted to ground at the instrument end	Occasional	Not discussed in report	No specific program	Not stated	9, 10, and 21	13
None	Rare	Not discussed in report	ANSI N42.4-1971	Not stated	12. 13, and 21	14
Insulation resistance exceeded the standard recommended minimum, although not serious enough to alter the intended limit switch function	Rare	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Not stated	12, 20, and 21	15
None	Rare	Not discussed in report	No specific program	Not stated	12, 20, and 21	16
None except two movs located outside, exposed to weather were inoperable.	Rare	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Not stated	12, 20, and 21	17

Document: NUREG/CR-3956, In Situ Testing of the Shippingport Atomic Power Station Electrical Circuits
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
18	Motor Operated Valves	Not stated	Not stated	Not stated	Not stated	WEATH	Not stated

Document: NUREG/CR-4156, Operating Experience and Aging-Seismic Assessment of Electric Motors
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		3 Phase Induction & Synchronous Motors	Stator - Conductors and Structural Components	Copper	Not stated	VIB, THERM, AND SHRINK	Loosening of laminations and locking devices
2		3 Phase Induction & Synchronous Motors	Stator - Insulation	Mica, glass, resins, enamels, mylars, figer, varnish, and nonhygroscopic materials	Not stated	THERM, OXIDAT, MOIST-EL, AND RAD	Degraded dielectric properties & tensile strength, brittle
3		3 Phase Induction & Synchronous Motors	Rotor - Contuctors and Structural Components	Copper	Not stated	VIB & THERM	Rotor embalance, loose parts, and overheating
4		3 Phase Induction & Synchronous Motors	Rotor - Insulating Materials	Mica, glass, resins, enamels, mylars, fiber, varnish, and nonhygroscopic marteials	Not stated	CURSTR, THERM, RAD, AND MOIST-EL	Insulation damage, winding short, overheating of rotor coils
5		3 Phase Induction & Synchronous Motors	Rotor - Commutator and Brushes	Mica, copper, carbon, and steel in spring mechanism	Not stated	WEAR, FAT, DIRT, CONTAM, AND OXIDAT	Brush wearout, relaxed spring, oil deposits, & loose contact
6		3 Phase Induction & Synchronous Motors	Bearings	Steel, brass, and bronze	Not stated	VIB, THERM, WEAR, CONTAMIN, AND LOSLUBE	Material attrition, cracking of bearings, scoring of surface
7		3 Phase Induction & Synchronous Motors	Bolts, Flanges, and Housing	Steel, cast iron, brass, and copper	Not stated	VIB, CORR, FAT, THERM, AND MECHSTR	Sheared bolts, cracked flanges or housing, overheated frame
8		3 Phase Induction & Synchronous Motors	Seals and Gaskets	Polymers	Not stated	THERM, VIB, AND RAD	Cracking, shrinking, leaking of oil or water, embrittlement
9		3 Phase Induction & Synchronous Motors	MOV's Break Coils	Copper	Not stated	THERM, CORR, CURSTR	Corrosion product buildup, current overload, & misoperation
10		3 Phase Induction & Synchronous Motors	Conduit Box, Leads, and Connections	Copper	Not stated	VIB AND CORR, CONTAM, MOIST-EL	Leak, poor electrical contact, loose leads, improper seals
11		3 Phase Induction & Synchronous Motors	Motor	See sub-components	Not stated	WEAR, THERM, VIB, CURSTR, RAD, FAT, AND MOIST-EL	Misaligned parts, burned out motor, & disengaged motor

Document: NUREG/CR-4234 V2, Aging and Service Wear of Electric Motor-Operated Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plar
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Motor Operated Valve	Gearbox - Gears	Not stated	EIM, Limitorque, Rotork	WEAR	Not stated

Document: NUREG/CR-3956, In Situ Testing of the Shippingport Atomic Power Station Electrical Circuits
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inoperable	Rare	Not discussed in report	N/A	Not stated	12, 20, and 21	18

Document: NUREG/CR-4156, Operating Experience and Aging-Seismic Assessment of Electric Motors
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	S-2, 2-15, and 4-23	1
Degraded operation or failure to function	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	S-2, 2-15, & 4-23	2
Frame distortion, shift in rotor center of gravity, insuficient cooling, winding short short or overheating of rotor coils leading to burnt motor and failure to function.	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	S-2, 2-20, 4-23	3
Excess current due to aging from many starts, cage winding failure due to jogging, over heating of rotor coils leading to burnt motor, winding shorts, insulation shrinkage results in decreased output or failure to function.	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	2-15, S-2, 4-24	4
Loose brush connection, dirt & foreign particles, wear out of carbon brushes, relaxed spring load in the brush holder mechanisms, dirt/ moisture on commutator and oxidation effects results in decreased output or failure to function.	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	2-22, S-2, 4-25	5
Seized bearings, and overheating, excessive vibration could cause fracture and bearing scoring, corrosion due to exposure to air.	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	2-15, 4-22, 4-23, 4-25, 4-26, and 4-27	6
Failure to function or degraded operation	OCCCASIONAL	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	2-15, 4-24, 4-25, 4-25, 4-27, and 4-28	7
Decreased output or failure to function.	Occasional	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	5-15 & 4-28	8
Burning of motor windings, jamming of break coil, overload the motor drawing large currents into the windings results in failure to operate.	Rare	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	5-15 & 4-28	9
Degraded insulation, shorts, or open circuits result in decreased output or failure to function.	Occasional	Not discussed in report	No specific program	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	4-28	10
Burned or dead motor, disengaged motor, & overcurrent results in decreased output or failure to function.	Rare	Not discussed in report	IEEE 334-1974 Section 14	Preventive maintenance programms, operational readiness acceptance criteria, in-situ testing and monitoring programs [2]	4-29	11

Document: NUREG/CR-4234 V2, Aging and Service Wear of Electric Motor-Operated Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	1

Document: NUREG/CR-4234 V2, Aging and Service Wear of Electric Motor-Operated Valves Used in Engineered Safety-Feature Systems of Nuclear Power Pla
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2		Motor Operated Valve	Gearbox -Fasteners	Not stated	EIM, Limitorque, Rotork	Not stated	Fastener loosening
3		Motor Operated Valve	Gearbox - Stem Nut	Not stated	EIM, Limitorque, Rotork	WEAR	Not stated
4		Motor Operated Valve	Gearbox - Drive Sleeve	Not stated	EIM, Limitorque, Rotork	WEAR	Not stated
5		Motor Operated Valve	Gearbox - Bearings	Not stated	EIM, Limitorque, Rotork	WEAR	Not stated
6		Motor Operated Valve	Gearbox - Lubericant	Not stated	EIM, Limitorque, Rotork	Not stated	Hardening
7		Motor Operated Valve	Gearbox - Shaft	Not stated	EIM, Limitorque, Rotork	WEAR, MECHSTR	Tapering of the shaft
8		Motor Operated Valve	Gearbox - Clutch	Not stated	EIM, Limitorque, Rotork	WEAR	Not stated
9		Motor Operated Valve	Gearbox - Spring Pack and Torque Switch	Not stated	EIM, Limitorque, Rotork	Not stated	Response change
10		Motor Operated Valve	Gearbox - Stem Lock Nut	Not stated	EIM, Limitorque, Rotork	Not stated	Loosening
11		Motor Operated Valve	Gearbox - Seal	Not stated	EIM, Limitorque, Rotork	WEAR	Deterioration
12		Motor Operated Valve	Motor	Not stated	EIM, Limitorque, Rotork	CORR, WEAR	Not stated
13		Motor Operated Valve	Motor	Not stated	EIM, Limitorque, Rotork	ELETEMP	Break down of insulation
14		Motor Operated Valve	Switches - Contacts	Not stated	EIM, Limitorque, Rotork	CORR, CORR/PIT	Not stated
15		Motor Operated Valve	Switches - Insulation	Not stated	EIM, Limitorque, Rotork	ELETEMP	Insulation breakdown
16		Motor Operated Valve	Switches - Grease	Not stated	EIM, Limitorque, Rotork	Not stated	Hamening
17		Motor Operated Valve	Switches - Gear and Cam	Not stated	EIM, Limitorque, Rotork	WEAR	Not stated
18		Motor Operated Valve	Switches - Fastener	Not stated	EIM, Limitorque, Rotork	Not stated	Loosening

Document: NUREG/CR-4234 V2, Aging and Service Wear of Electric Motor-Operated Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plants
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	2
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	3
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	4
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	5
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	6
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	7
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	8
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	9
Failure to open or close, failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	10
Leakage of lubricant out from gearbox or leakage of contaminants into the gear box resulting in failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	11
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	12
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	13
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	14
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	15
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	16
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	17
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	18

Document: NUREG/CR-4234 V2, Aging and Service Wear of Electric Motor-Operated Valves Used in Engineered Safety-Feature Systems of Nuclear Power Pla
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19		Motor Operated Valve	Valves - Operator	Not stated	Anchor Darling, Velan, ET	WEAR, CORR	Not stated
20		Motor Operated Valve	Valves - Yoke Bushing	Not stated	Anchor Darling, Velan, ET	WEAR	Not stated
21		Motor Operated Valve	Valves - Valve Stem	Not stated	Anchor Darling, Velan, ET	WEAR, MECHSTR	Tapering of the shaft
22		Motor Operated Valve	Valves - Fasteners	Not stated	Anchor Darling, Velan, ET	Not stated	Loosening
23		Motor Operated Valve	Valves - Valve Seat	Not stated	Anchor Darling, Velan, ET	WEAR, CORR	Not stated
24		Motor Operated Valve	Valves - Bonnet Seal	Not stated	Anchor Darling, Velan, ET	Not stated	Deterioration
25		Motor Operated Valve	Valves - Stem Packing	Not stated	Anchor Darling, Velan, ET	Not stated	Deterioration

Document: NUREG/CR-4257, Inspection, Surveillance, and Monitoring of Electrical Equipment Inside Containment of Nuclear Power Plants - With Applications to
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Cable	600 V, 4 kV, and 13 kV Power Cable Insulation	Cross-linked polyethylene (XLPE)	Not stated	THERM, RAD, CHEM, AND MOIST-EL	Chemical changes, dielectric degradation, & cracks
2		Cable	600 V, 4 kV, and 13 kV Power Cable Insulation	Ethylene propylene	Not stated	THERM, RAD, CHEM, AND MOIST-EL	Chemical changes, dielectric degradation, & cracks
3		Cable	600 V, 4 kV, and 13 kV Power Cable Insulation	Polyvinyl chloride (PVC)	Not stated	THERM, RAD, CHEM, AND MOIST-EL	Radiation deterioration, dielectric degradation, & cracks
4		Cable	Cable Sheathing and Jacket	Chlorosulfonated polyethylene (CSP) and Kapton	Not stated	THERM, RAD, & CHEM.	Radiation deterioration, dielectric degradation, & cracks
5		Cable	Control Cable	Cross-linked polyethylene (XLPE)	Not stated	THERM, RAD, & CHEM.	Radiation deterioration, dielectric degradation, & cracks
6		Cable	Coaxial Cable	Cross-linked polyethylene (XLPE)	Not stated	THERM, RAD, & CHEM.	Radiation deterioration, dielectric degradation, & cracks
7		Cable	Mineral Insulation Metal Jacket Cable	Not stated	Not stated	RAD & VIB	Wear

Document: NUREG/CR-4234 V2, Aging and Service Wear of Electric Motor-Operated Valves Used in Engineered Safety-Feature Systems of Nuclear Power Plant:
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	19
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	20
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	21
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	22
Failure to open or close or failure to operate as required	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	23
Leakage	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	24
Leakage	Not stated	Not discussed in report	Vendor specific, GL 89-10, NUREG-1352	Accurate and consistent mov testing should be performed. Good records should be maintained [4]	5 - 12, 15, 72, 167	25

Document: NUREG/CR-4257, Inspection, Surveillance, and Monitoring of Electrical Equipment Inside Containment of Nuclear Power Plants - With Applications to I
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Chemical changes in polymer resulting from aging, loss of dielectric generally occurs after deterioration of mechanical properties, treeing may cause rapid breakdown of dielectric capabilities. loss of flexibility, can't withstand voltage stress	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, determine root cause of failures, remove samples after 5 to 10 years for tests [4]	26,38, 40, & 53	1
Loss of dielectric generally occurs after deterioration of mechanical properties, treeing may cause rapid breakdown of dielectric capabilities. loss of flexibility, can't with stand voltage stress	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, determine root cause of failures, remove samples after 5 to 10 years for tests [4]	26,38, 40, & 53	2
Subject to deterioration from radiation, loss of dielectric generally occurs after deterioration of mechanical properties.	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, determine root cause of failures, remove samples after 5 to 10 years for tests [4]	26,38, 40, & 53	3
Major failure modes for sheathing are loss of flexibility and imperviousness. teflon glue fails at low radiaton doses resulting in inability to protect conductor insulation.	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, kapton not recommended for applications subject to radiation doses > 0.01 mrad [4]	26,38, 40, & 53	4
Loss of dielectric generally occurs after deterioration of mechanical properties, loss of flexibility, loss of imperviousness, aging similar to power cable. Results in failure to properly transmit voltage or current.	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, determine root cause of failures, remove samples after 5 to 10 years for tests [4]	26, 39, 40, & 53	5
Loss of dielectric generally occurs after deterioration of mechanical properties, loss of flexibility, loss of imperviousness, aging similar to power cable. Results in failure to properly transmit voltage or current.	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, determine root cause of failures, remove samples after 5 to 10 years for tests [4]	26, 39, 40, & 53	6
Conductor wear through insulation due to bending or vibration. Results in ffailure to ransmit voltage or current.	Rare	Not discussed in report	No specific program	Testing to be based on safety importance, determine root cause of failures. [4]	26, 30,	7

Document: NUREG/CR-4257 V2, Inspection, Surveillance, and Monitoring of Electrical Equipment in Nuclear Power Plants - Pressure Transmitters
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Force Balance Type Transmitter	Force Balance Bar & Linkage	316 stainless steel	The Foxboro Company	VIB AND WEAR	Wear, failure to operate, bending component, zero shift
2		Force Balance Type Transmitter	Feedback Coil	Copper	The Foxboro Company	THERM,	Burnout
3		Force Balance Type Transmitter	Amplifier	Carbon resistors, transistors, OP amps, capacitors & diodes	The Foxboro Company	THERM, RAD, VOLSTR	Degradation of insulation, insulation breakdown, & cracks
4		Force Balance Type Transmitter	Housing Seals	Viton	The Foxboro Company	THERM, RAD, & CONTAM	Embrittlement, cracking, and inability to seal
5		Force Balance Type Transmitter	Diaphragm Capsule	316 stainless steel	The Foxboro Company	CORR	Leakage or perforation
6		Force Balance Type Transmitter	Diaphragm Seal	316 stainless steel	The Foxboro Company	THERM OR RAD	Inability to maintain pressure barrier, variable instrument
7		Capacitance Type Transmitter	Sensing Cell	316 stainless steel	Rosemount	THERM AND RAD	Leakage, rupture, oil breakdown, or perforation
8		Capacitance Type Transmitter	Terminal Cover Seal	Ethylene propylene	Rosemount	THERM AND RAD	Embrittlement and cracking
9		Capacitance Type Transmitter	Electronics Cover Seal	Ethylene propylene	Rosemount	THERM AND RAD	Embrittlement and cracking
10		Capacitance Type Transmitter	Electronics Parts - Misc Small Components	Not stated	Rosemount	OXIDAT, THERM, AND VOLSTR	Degradation of insulation, arcing, shorts and open circuits
11		Strain Gage Type	Strain Gage	Resistive material	ITT Barton Instruments	VIB	Loss of continuity or open resistor
12		Strain Gage Type	Housing Seal	Ethylene propylene	ITT Barton Instruments	THERM AND RAD	Embrittlement or cracking
13		Strain Gage Type	Potentiometer	Phenolic body, nylon rotor, and slider	ITT Barton Instruments	CORR AND THERM	Corrosion material buildup lubricant loss
14		Strain Gage Type	Electric Module	Carbon resistor, transistors, operational amplifier, capacitors, and diodes	ITT Barton Instruments	VIB, THERM, OR RAD	Component deterioration or change in component parameters.
15		Strain Gage Type	Bourdon Tube	Haynes alloy NO 25	ITT Barton Instruments	CORR	Contamination build up and material loss.

Document: NUREG/CR-4257 V2, Inspection, Surveillance, and Monitoring of Electrical Equipment in Nuclear Power Plants - Pressure Transmitters
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Wear of pivot points, decreased accuracy, complete failure, zero shift, bending of components in level system,	Rare	Not discussed in report	IEEE 338-1987	Not stated	9, 18 & 21	1
Loss of output	Rare	Not discussed in report	IEEE 338-1987	Not stated	9, 18 & 21	2
Shorting or opening of electronic components, loss of accuracy, drift, zero shift, loss of signal, may fail high or low, lose accuracy, or fail with steady output.	Occasional	Not discussed in report	IEEE 338-1987	Not stated	9, 18 & 21	3
Inability of seal to provide moisture and pressure barrier, ingress of environmental contaminants, and loss of pressure barrier results in transmitter drift or failure to respond.	Occasional	Not discussed in report	10 CFR 50.49	Not stated	9, 18 & 21	4
Perforation of diaphragm from corrosion or flaw, variable instrument drift as pressures across diaphragm equalize, and leakage through diaphragm, permanent deformation of diaphragm, and zero shift.	Rare	Not discussed in report	IEEE 338-1987	Not stated	9, 18 & 21	5
Variable instrument drift as pressures across diaphragm equalize, and inablitity to maintain pressure barrier.	Rare	Not discussed in report	IEEE 338-1987	Not stated	9, 18 & 21	6
Leakage of cell fluid through diaphragm, loss of accuracy and drift, rupture allows equalization of forces on diaphragm, drastic change in sensing cell characteristics, oil breakdown due to thermal or radiation stress.	Rare	Not discussed in report	Enhanced Surveillance - GL 90-01 Suppl. 1	Not stated	9, 11, 19 & 21	7
Inability of seal to provide moisture and pressure boundary, cracking due to thermal or radiation stresses, and loss of electronics due to ingress of environmental contaminants. Results in transmitter drift or failure to respond.	Occasional	Not discussed in report	10 CFR 50.49	Not stated	9, 11, 19 & 21	8
Inability of seal to provide moisture and pressure boundary, cracking due to thermal or radiation stresses, and loss of electronics due to ingress of environmental contaminants. Results in transmitter drift or failure to respond.	Occasional	Not discussed in report	10 CFR 50.49	Not stated	9, 11, 19 & 21	9
Loss of signal, sporadic operation, shorting or opening of components, oxidation of contacts, bridging of circuits.	Occasional	Not discussed in report	IEEE 338-1987	Not stated	9, 11, 19 & 21	10
Loss of continuity in bridge circuit, loss of output, loss of response to input pressure, and failure of instrument.	Occasional	Not discussed in report	IEEE 338-1987	Not stated	6, 7, 20 & 22	11
Inability to provide moisture and pressure barrier, failure of electronics due to contamination. Results in instrument drift or failure to respond.	Occasional	Not discussed in report	10 CFR 50.49	Not stated	6, 7, 20 & 22	12
Corrosion of resistive elements in potentiometer, wirewound potentiometer corrodes open due to thermal stress and corrosive lubricant, fails over range, and loss of span adjustment.	Occasional	Not discussed in report	IEEE 338-1987	Not stated	6, 7, 20 & 22	13
Loss of full output, calibration shift, component parameters change.	Occasional	Not discussed in report	IEEE 338-1987	Not stated	6, 7, 20 & 22	14
Permanent deformation of tube, zero shift, leaks in bourdon tube to transmitter housing, perforatioon due to corrosion, drift of transmitter, failure of transmitter to respond.	Occasional	Not discussed in report	IEEE 338-1987	Not stated	6, 7, 20 & 22	15

Document: NUREG/CR-4457, Aging of Class 1E Batteries in Safety Systems of Nuclear Power Plants
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Batteries - General			GNB/Gould, Exide, C&D		
2		Batteries	Grids	Lead-calcium alloy	GNB/Gould, Exide, C&D	ELETEMP	Plate growth, loss of contact with active material
3		Batteries	Active Material	Lead, lead dioxide	GNB/Gould, Exide, C&D	GAS, CONTAM	Dislodging or shedding of active material from the grid
4		Batteries	Separators	Rubber/glass mat, polyethelene sheets	GNB/Gould, Exide, C&D	ELETEMP	Decreased electrical insulation
5		Batteries	Electrolyte	Sulfuric acid and water	GNB/Gould, Exide, C&D	CONTAM	Chemical reactions, hydolysis
6		Batteries	Vents	Fused Alumina	GNB/Gould, Exide, C&D	MECHSTR	Vent breaks allowing contamination to enter
7		Batteries	Top Conductors	Lead-calcium alloy	GNB/Gould, Exide, C&D	ELETEMP, CORR, EMBR	Low electrolyte level causes corrosion and embrittlement
8		Batteries	Terminals	Lead-calcium alloy, lead-calcium with copper insert	GNB/Gould, Exide, C&D	CORR/OX, CORR	Poor electrical contact with external busses
9		Batteries	Container and Cover	Polycarbonate, styrene acrylonitrile, acrylo butadiene styrene	GNB/Gould, Exide, C&D	MECHSTR, CORR/OX	Oxidation of the lead causes plate growth

Document: NUREG/CR-4564, Operating Experience and Aging-Seismic Assessment of Battery Chargers and Inverters
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Chargers and Inverters	General				
2		Chargers and Inverters	Circuit Breakers	Not stated	PCP, Elgar	CONTAM, WEAR, EMBR, FAT, CORR/PIT, LOSLUB	Increased friction, binding, loss of continuity
3		Chargers and Inverters	Fuse	Not stated	PCP, Elgar	FAT, ELETEMP	Metal fatigue and melting of the fuse material
4		Chargers and Inverters	Relay	Not stated	PCP, Elgar	CORR/PIT, CORR	Loss of continuity across contacts and thru coil
5		Chargers and Inverters	Electrolytic Capacitors	Not stated	PCP, Elgar	ELETEMP, VIBR	Loss of electrolyte, failure of leads
6		Chargers and Inverters	Oil Filled Capacitors	Not stated	PCP, Elgar	ELETEMP, VIBR	Dielectric breakdown, failure of leads
7		Chargers and Inverters	Magnetics (Transformer, Inductor)	Copper, polyamide polymer, mylar tape, ferite steel	PCP, Elgar	ELETEMP, THERM-CY, VIBR, LOTEMP, VOLSTR	Cracking/degr. of insulation and seals, wire fracture
8		Chargers and Inverters	Silicon Controlled Rectifier	Not stated	PCP, Elgar	ELETEMP, VOLSTR, CURSTR	Over heating due to transients

Document: NUREG/CR-4457, Aging of Class 1E Batteries in Safety Systems of Nuclear Power Plants
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
		Not discussed in report	N/A	A Phase 2 study of seismic vulnerability and advanced surveillance methods for identyting seismic vulnerability [1]	31	1
Increased temp. from overcharging, ac ripple, and the environment accelerates oxidation. Poor electrical contact and breaking of the container with subsequent loss of electrolyte results in reduced capacity or failure	Frequent	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	2
Gassing caused by overcharging or contamination introduced into the electrolyte deteriorates the active material resulting in reduced capacity	Occasional	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	3
Decreased electrical insulation resulting in internal shorts and failure of the battery	Not stated	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	4
Chemical reactions and hydrolysis causes loss of electrolyte and loss of sulfuric acid resulting in reduced battery capacity	Not stated	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	5
Contaminates in the electrolyte result in reduced capacity	Not stated	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	6
Embrittled top conductors are susceptible to breaking and causes loss of capacity	Occasional	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	7
Poor electrical contact results in loss of capacity and may result in total battery failure	Not stated	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	8
Plate growth and handling stresses results in cracked containers which allow electrolyte to escape resulting in reduced capacity or total failure	Frequent	IEEE 450, RG 1.129	IEEE 450, RG 1.129	Not stated	8, 12, 13, 14, 24-26, 32, 33	9

Document: NUREG/CR-4564, Operating Experience and Aging-Seismic Assessment of Battery Chargers and Inverters
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
		Not discussed in report	N/A	A comprehensive PM and testing program supported by personnel training should be implemented. Procedures are needed [2]	6-7	1
Failure to operate, fails open	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	ANSI/IEEE 741-1986 Section 7.3	Not stated	4-25, 4-27, 5-4 thru 5-9	2
Fuse fails open. Failure to operate	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	ANSI/IEEE 741-1986 Section 7.3	Pursue fuse failures due to thermal fatigue [2]	4-25, 4-27, 5-4 thru 5-9, 6-7	3
Contacts open, open ciruit of the coil, and relay fails to operate	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-27, 5-4 thru 5-9	4
Loss of capacitance and open circuit resulting in improper output or failure to operate	Frequent	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-27, 5-4 thru 5-9	5
Loss of capacitance and open circuit resulting in improper output or failure to operate	Frequent	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-27, 5-4 thru 5-9	6
Short circuits (turn to turn or to ground)or change in inductuance resulting in improper output.	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	2-19, 4-25, 4-28, 5-4 thru 5-9	7
Short or open circuit resulting in improper or no output	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	8

Document: NUREG/CR-4564, Operating Experience and Aging-Seismic Assessment of Battery Chargers and Inverters
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9		Chargers and Inverters	Resistors	Not stated	PCP, Elgar	ELETEMP, VIBR	Lead fails, decrease in resistance
10		Chargers and Inverters	Printed Circuit Boards	Not stated	PCP, Elgar	THERM-CY, CORR, VIBR	Cracking of circuit lines, open/loose at terminals
11		Chargers and Inverters	Surge Suppressors	Not stated	PCP, Elgar	ELETEMP, VOLSTR, CURSTR	Semiconductor barrier breakdown
12		Chargers and Inverters	Connectors	Not stated	PCP, Elgar	FAT	Wire breaks
13		Chargers and Inverters	Meters	Not stated	PCP, Elgar	CONTAM, ELETEMP	Increase in bearing friction, coil degrades
14		Chargers and Inverters	Switches	Not stated	PCP, Elgar	CORR, CORR/PIT	Loss of continuity across contacts
15		Chargers and Inverters	Potentiometer	Not stated	PCP, Elgar	ELETEMP	Loss of continuity across wiper arm and coil

Document: NUREG/CR-4715, An Aging Assessment of Relays and Circuit Breakers and System Interactions
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Protective, Auxiliary, and Control Relays	Relay	Steel, aluminum, lexan, and phenolic	GE & Westinghouse	THERM	Shape changes for lexan, no effect for steel, al., or phnol.
2		Protective, Auxiliary, and Control Relays	Coil Wire, Spools, & Coatings	polyamide-imide insulated wire, copper magnet wire, and nylon bobbins	Not stated	THERM & VOLSTR	Thermally caused failures, open circuits, and shorts
3		Protective, Auxiliary, and Control Relays	Coil Spools	Nylon, Zytel & lexan	Not stated	THERM	Thermally caused failures
4		Protective, Auxiliary, and Control Relays	Coil Coating	Polyester tape, fiber glass tape, & varnish	Not stated	THERM	Thermally caused failures
5		Protective, Auxiliary, and Control Relays	Contact Carriers	Phenolic, Zytel, delrin, & nylon	Not stated	THERM	Nylon may change in shape
6		Protective, Auxiliary, and Control Relays	Contacts	Silver alloy	Not stated	WEAR, CHEM	Oxidation when exosed to air & material attrition
7		Protective, Auxiliary, and Control Relays	Lead Wires	Copper	Not stated	VIB	Loose terminals
8		Protective, Auxiliary, and Control Relays	Coil Lead Wire Insulation	Teflon, silicon rubber, and Tefzel	Not stated	THERM & RAD	Slow aging effects, degradation in insulation

Document: NUREG/CR-4564, Operating Experience and Aging-Seismic Assessment of Battery Chargers and Inverters
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Open circuits, change in resistance values resulting in improper or no output	Rare	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	9
Change in output of the charger/inverter	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	10
Short ciruit within the surge arrestor and failure to operate	Rare	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	11
Fatigue caused by installation stress causes wires to break resulting in open or short circuits and failure to operate	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	12
No or improper response from the meter	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	13
Switch failes open or closed	Occasional	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	14
Thermal degradation results in open or short circuit and improper output	Frequent	IEEE-650, NEMA PE 5, IEC 146-2, IEEE-944	Vendor specific, NEMA PE 5, IEC 142-2	Not stated	4-25, 4-28, 5-4 thru 5-9	15

Document: NUREG/CR-4715, An Aging Assessment of Relays and Circuit Breakers and System Interactions
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Binding of control relays, have been noted for continuously energized compact relays with plastic cases resulting in improper operation or failure to operate	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	1
The higher temperatures associated with continuously energized coils have caused failures of relay coils and bobbins resulting in improper operation or failure to operate.	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	2
The higher temperatures associated with continuously energized coils have caused failures of relay bobbins resulting in relay having improper operation or failure to operate.	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	3
The higher temperatures associated with continuously energized coils have caused failures of relay coils (assumed it includes coatings) resulting in improper operation or failure of relay.	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	4
Change in shape due to thermal aging can cause binding or improper contact mating resulting in improper operation or failure of relay.	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	5
Wear due to use and testing resulting in failure to make proper contact.	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	6
Loose terminations can cause ohmic heating and burnout	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	7
Improper operation or failure to operate.	Rare	Not discussed in report	Protection: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	8

Document: NUREG/CR-4715, An Aging Assessment of Relays and Circuit Breakers and System Interactions
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9		Protective, Auxiliary, and Control Relays	Slip Motor Rotor	Aluminum disc & stainless steel shaft	Not stated	CONTAM	Metalic iron based particles can prevent operation
10		Time Delay Relays	Case	Steel, Lexan, and phenolic	Not stated	THERM	Shape changes for lexan & phenolic
11		Time Delay Relays	timing Motor	Magent wire with formal varnish	Not stated	THERM	Same as other insulation varnish
12		Time Delay Relays	Relay	Silver	Not stated	WEAR	Wear with use
13		Time Delay Relays	Relay	Delrin, Zytel, phenolic, & nylon.	Not stated	THERM	Oxidation of contacts
14		Time Delay Relays	Cams	Delrin & metal	Not stated	THERM & WEAR	Delrin may change shape, metal may wear
15		Time Delay Relays	Timing Circuits	Resistance and capacitance networks with solid state components	Not stated	Not stated	Not stated
16		Time Delay Relays	Timing Diaphragm (Applies to Pneumatic Relay Only)	Silicon rubber	Not stated	THERM	Material may take a set if not exercised periodically.
17		Solid State Relays	Solid state Components - SCRs & TRIAC	Not stated	Not stated	THERM, RAD, VOLSTR, CURSTR, & VIB.	Insulation degradation from therm & rad, fatique from vib.
18		Molded Case Circuit Breakers	Contacts, Trip Device, Spring, and Case	Not stated	GE, Westinghouse, & Gould	THERM, ELECT, MECH, & ENV.	Material vaporized, annealing bimetal, wear, friction & fat
19		Metal-Clad Circuit Breakers	Housing, Doors, Frame & Mechanisms	Steel, electroplated steel, & cast bronze	GE, Westinghouse, & Gould	CURSTR, VIB, FAT, & CORR.	Loose parts, component failure, stiffening of joints.
20		Metal-Clad Circuit Breakers	Mechanisms Lubricants	Molybenium disulfide & petroleum-based grease	Not stated	LOSLUB AND THERM	Dryout and hardening of lubricants
21		Metal-Clad Circuit Breakers	Contacts	Silver Alloy on copper base	GE, Westinghouse, & Gould	CURSTR, WEAR, THERM, AND CONTAM	Loss of material, wear, and contamination
22		Metal-Clad Circuit Breakers	Insulating Materials for Power Path	Polyester, glass fiber-filled epoxy resin, & phenolic	GE, Westinghouse, & Gould	THERM, EMBR, AND VOLSTR	Contamination, loss of dielectric properties, & leakage path
23	Safety Injection	Relays	See relay Subcomponent Descriptions	See relay material descriptions	GE & Agastat	VOLSTR, THERM, VIB, AND WEAR	Thermal stress, coil burnout, set point drift, & con. wear
24	Safety Injection	Circuit Breakers	Molded Case and Metal-Clad Circuit Breakers	See CB detail descriptions	GE, Westinghouse, & Gould	ELECT, THERM, VIB, WEAR, & ENV	Loss of material, corr, & arcing evaporation of contacts

Document: NUREG/CR-4715, An Aging Assessment of Relays and Circuit Breakers and System Interactions
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Metalic iron based particles can lodge between the disc and magnet preventing operation.	Rare	Not discussed in report	IEE 741-1986 Section 7, IEEE 338-1987	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 29, 35, and 160	9
Some rare instances of case shape changes resulting in binding of contacts resulting in failure to operate.	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Perform root cause failure evaluation, develop test method for thermally induced failure cause, see report for more rec. [2]	28, 30, 35, & 36.	10
Insulaton failure may cause shorts and failure to provide timing delay function.	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	30, 35, & 36.	11
Contacts wear with cycling and making and breaking load resulting in failure to make proper contact.	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	30, & 35	12
Failure to make proper contact.	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	30, & 35	13
Cams may wear and high temperature may deform delrin cams resulting in degraded operation or relay failure.	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	30, & 35	14
Not stated	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	30	15
The first operation of relay after a long period will have an improper time delay.	Rare	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	30 & 36	16
Breakdown of insulation, ohmic heating lead to insulation and component failure, vib. may loosen sockets/pins causing opens, shorts resulting relay failure.	Occasional	Not discussed in report	Safety related: IEEE 741, IEEE 338	Not stated	26, 27, 28, & 30.	17
Damage contacts & arc chute materials, annealed bimetal strips causes nuisance trips, vaporized material deposits on insulation, loose connections, leakage paths, component failure, hardening of lubricants, stiffening of joints, & loss of operability.	Occasional	Not discussed in report	Safety related: IEEE 741. Others: No specific	Replace after two nuisance trips, develop diagnostic techniques for early detection of component failures. [2]	78, 83, 91, 97,99, 113, and 163	18
Freezing of joints, increased friction, & loss of operability	Rare	Not discussed in report	Safety related: IEEE 741. Others: No specific	Inspection and cleaning after each interruption of a major fault. [2]	85, 98, 99, 100, & 163	19
Evaporation of petrolium based grease may leave a nonlubricating soap base & high temperatures may cause harding of lubricants resulting in loss of operability.	Occasional	Not discussed in report	Vendor specific programs	Inspection and cleaning after each interruption of a major fault. [2]	85, 98, 99, 100, & 163	20
Failure to operate as required.	Occasional	Not discussed in report	Vendor specific programs	Inspection and cleaning after each interruption of a major fault. [2]	85, 98, 99, 100, 101, & 163.	21
Failure to provide insulation results in circuit failure.	Occasional	Not discussed in report	Vendor specific programs	Inspection and cleaning after each interruption of a major fault. [2]	85, 98, 99, 100, 101, & 163.	22
Coil failures, binding, and electrical component failures increase with age. Protection relays may also fail due to drift	Occasional	Not discussed in report	IEE 741-1986 Section 7, IEEE 338-1987	Desirable to have incipient failure detection technique to detect both old and new failure modes [2]	142, 159, & 160	23
Loss of operability.	Occasional	Plant maintenance	IEEE 741-1986 Section 7	Dagnostic techniques should be developed for use with physical inspections to determine condition of circuit breakers. [2]	142, 161, 162, & 163.	24

Document: NUREG/CR-4740, Nuclear Plant-Aging Research on Reactor Protection Systems
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Reactor Protection System	Pressure Transmitter	Seals	Ethylene propylene	Not stated	THERM, RAD, MOIST-EL	Leaks
2	Reactor Protection System	Pressure Transmitter	Fill-Oil	Silicon	Not stated	THERM & RAD	Oil degradation
3	Reactor Protection System	Pressure Transmitter	Electronic Components	Epoxy glass laminate, seats, & insulation materials	Not stated	THERM, RAD, MOIST-EL	Drift and subcomponent degradation
4	Reactor Protection System	Pressure Transmitter	Piping & Valves	Stainless steel	Not stated	CORR	Blockage, leaks
5	Reactor Protection System	Pressure Transmitter	Valve Packing	Not stated	Not stated	WEAR	Leaks
6	Reactor Protection System	Strain Gage Pressure Transduce	Bourdon Tube, Electronic Components, Seals & Wire	EDPM, Nylon, copper, tefzel, & steel	Not stated	RAD, THERM, MOIST-EL, & CONTAM	Resistance change, tube blockage, and shunting
7	Reactor Protection System	Pressure Switch	Bellows, Switch Contacts, Seals & Wire	Copper	Not stated	THERM, MOIST-EL, CONTAM, WEAR	Wear, tube blockage, and contact resistance change
8	Reactor Protection System	Resistance Temperature Device	Sensing Wire, Insulator & Sheath	Platinum, aluminum oxide powder, and inconel X750 or stainless steel sheath	Not stated	RAD, THERM, AND MOIST-EL	Resistance change and shunting
9	Reactor Protection System	Nuclear Instrument	Nuclear Sensitive Ion Chamber	Not stated	Not stated	THERMAL-CY AND MOIST-EL	Degrades sensor, low resistance, and erratic output
10	Reactor Protection System	Electronic Modules	Various Electronic Components	Not stated	Not stated	FAT & VIB	Loss of fatigue resistance
11	Reactor Protection System	Relays	Coils and Contacts	Not stated	Not stated	WEAR, CONTAM, CORR, AND CURSTR	Contacts wear, foreign material build up causes short ckt.
12	Reactor Protection System	Scram Breakers	Contacts, Under Volatge & Shunt Trip Attachments	Not stated	Westinghouse	WEAR	Contact wear, pin binding in uv attachent, lack of lubricant
13	Reactor Protection System	Control Cable	Conductor	#16 AWG copper except nuclear instruments sue RG11/CU Coax	Not stated	CORR, MOIST-EL, RAD, & WEAR	Mechanical damage & corrosion on terminations
14	Reactor Protection System	Control Cable	Insulation	Cross linked polyethylene and polyethylene	Not stated	MOIST-EL, RAD, & WEAR	Mechanical damage, insulaton degradation, and low ir

Document: NUREG/CR-4740, Nuclear Plant-Aging Research on Reactor Protection Systems
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Seal failure allows leaks leading to transmitter drift and moisture intrusion.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	15, 18, 61, 65, & 69	1
Degradation or loss of fill-oil causes transmitter drift and signal variance from other channels.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	18, & 62	2
Components are subject to drift of zero & span set points, and ultimate failure, resulting in loss of data channel.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	18, 65, & 70	3
Blockage causes degraded channel operation, components are subject to loss of calibration, resulting in loss of data channel.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	17, 19,28, 42, & 69	4
Components are subject to loss of calibration, resulting in loss of data channel.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	65	5
Sensing element resistance change due to radiation, seal failure allows moisture to get into connectors that lead to shunting signal, foreign material blocks sensing tube.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	15, 17, 48, & 69	6
Wear leads to switch failure, seal failure allows moisture to get into connectors that lead to shunting signal, foreign material blocks sensing tube.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	17, 34, 37, 49, & 65	7
Sensing element resistance change due to radiation, seal failure allows moisture to get into sensor and moisture causes shunting of signal.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	17. 19, 27, 32, & 70	8
Transmitter becomes noisy or erratic, also low insulation resistance (few problems reported).	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	19, 20, 27, 33, 65, & 66	9
Small system components such as transistors, capacitors, logic elements, terminals and wire connectors are subject to mechanical fatigue-related failures due to vibration, most failures are catastropic with unknown cause.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	27, 29-33, 35-37, 42-45, 47-49, 65, & 70	10
Sticking armature, open or short circuits in the coil of the electromagnet, and contact degradation causes failure to function.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	11, 13, B-7, & C-3	11
Increased friction, nicking of latch surfaces caused by repeated opeations, binding and friction causes degraded operation or failure to operate.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	66, 70, and Appendix B	12
Increase in series resistance and loose connections cause failure to accurately conduct current.	Rare	Not discussed in report	No specific program	Further research is needed to determine if improved maintenance and new predictive techniques are needed. [4]	20, 21, 23, 48, & 70	13
Decreased insulation resistance damage due to handling will accelerate aging and result in cable failing to accurately transmit voltage and current.	Rare	Not discussed in report	No specific program	Further research is needed to determine if improved maintenance and new predictive techniques are needed. [4]	20, 21, 23, 48, & 70	14

Document: NUREG/CR-4740, Nuclear Plant-Aging Research on Reactor Protection Systems
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15	Reactor Protection System	Control Cable	Jacket	Neoprene and galvanized steel except nuclear cable had PVC and galvanized steel	Not stated	CORR, MOIST-EL, RAD, EMBR, & WEAR	Loss of material, attrition, and insulation degradation
16	Reactor Protection System	Cable Penetrations	Assembly, Seals, Cable, Connectors, & Inert Gas	SS, brass, elastomer, insul. Matl, polysulfone, polyolefin, gold plated copper	Not stated	CORR, MOIST-EL, & RAD	Loss of material, insulation degradation, loss of fill gass
17	Reactor Protection System		Transmitters, Electronic Modules, Cables, Breakers	See components	B & W	CORR, RAD, VIB, CURSTR, THERM, & CONTAM	See components

Document: NUREG/CR-4747 V1, An Aging Failure Survey of LWR Safety Systems and Components
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Four Systems Covered (Same as Volume 2)			Not stated	Not stated	Not stated	

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Auxiliary Feedwater System	AC Circuit Breakers	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
2	Auxiliary Feedwater System	AC Circuit Breakers	Not stated	Not stated	Not stated	WEAR	Attrition
3	Auxiliary Feedwater System	AC Circuit Breakers	Not stated	Not stated	Not stated	VIBR	Loosening
4	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	CLOG	Flow blockage
5	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Loss of performance
6	Auxiliary Feedwater System	Flow Controllers	Not stated	Not stated	Not stated	Not stated	Drift, contact failure, module failure, or elect. failure
7	Auxiliary Feedwater System	Flow Control Recorders	Not stated	Not stated	Not stated	WEAR	Attrition
8	Auxiliary Feedwater System	Flow Control Recorders	Not stated	Not stated	Not stated	Not stated	Loss of performance
9	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	CONTAM	Buildup of deposites causing erroneous/erratic signals
10	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	Not stated	Out of calibration, drift, or module faulty

Document: NUREG/CR-4740, Nuclear Plant-Aging Research on Reactor Protection Systems
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to protect cable insulation and conductors.	Occasional	Not discussed in report	No specific program	Further research is needed to determine if improved maintenance and new predictive techniques are needed. [4]	20, 21, & 48	15
Radiation causes embrittlement and insulation degradation, corrosion causes material degradation and material build up, leaking seal allow loss of fill gas and then moisture intrusion resulting in failure to accurately transmit voltage and current.	Rare	Not discussed in report	No specific program	Further research is needed to determine if improved maintenance and new predictive techniques are needed. [2]	20 & 23	16
See components	Rare	Not discussed in report	IEE 338-1987, RG 1.118, ISA 67.06, Tech. Spec	Further research is needed to determine if improved maintenance and new predictive techniques are needed. [2]	IV, 69, & A-16	17

Document: NUREG/CR-4747 V1, An Aging Failure Survey of LWR Safety Systems and Components
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The aging information in Volume 1 is the same as that covered in the Volume 2 reveiw.	Not stated	Not discussed in report	N/A	Not stated		1

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fails to close	Rare	Not discussed in report	IEE 741-1986 Section 7	Not stated	F-20	1
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Occasional	Not discussed in report	IEE 741-1986 Section 7	Not stated	F-20	2
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not discussed in report	IEE 741-1986 Section 7	Not stated	F-20	3
Erroneous or erraric signals - erroneous or erraric signals are produced by the instrument because of foreign material intrusion.	Rare	Not discussed in report	IEEE 338-1987, Tech. Spec. requirements	Not stated	F-21	4
Erroneous or erratic signals - erroneous or erratic signals are produced by the instrument due to faulty module or loss of calibration.	Rare	Not discussed in report	IEEE 338-1987, Tech. Spec. requirements	Not stated	F-21	5
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, Tech. Spec. requirements	Not stated	F-21	6
Erroneous/erratic signals - erroneous erratic signals are produced by the instrument.	Rare	Not discussed in report	IEEE 338-1987, Tech. Spec. requirements	Not stated	F-22	7
Erroneous/erratic signals - erroneous erratic signals are produced by the instrument being out of calibration.	Rare	Not discussed in report	IEEE 338-1987, Tech. Spec. requirements	Not stated	F-22	8
Eroneous or erratic signals are produced by the instrument	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-23	9
Loss of performance	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-23	10

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	Auxiliary Feedwater System	Flow Transmitters	Not stated	Not stated	Not stated	WEAR	Attrition
12	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	Not stated	Erroneous/erratic signals
13	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
14	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	WEAR	Attrition
15	Auxiliary Feedwater System	Level Control Indicators	Not stated	Not stated	Not stated	Not stated	Loss of performance or end of life
16	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	Not stated	Erroneous/erratic signals
17	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
18	Auxiliary Feedwater System	Level Controllers	Not stated	Not stated	Not stated	Not stated	Loss of performance
19	Auxiliary Feedwater System	Pressure Switch	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
20	Auxiliary Feedwater System	Pressure Switch	Not stated	Not stated	Not stated	Not stated	Loss of performance
21	Auxiliary Feedwater System	Pressure Switch	Not stated	Not stated	Not stated	WEAR	Attrition
22	Auxiliary Feedwater System	Pressure Switch	Not stated	Not stated	Not stated	CORR	Loss of material
23	Auxiliary Feedwater System	Pressure Switch	Not stated	Not stated	Not stated	CURSTR	Arcing, material attrition, and carbon deposits
24	Auxiliary Feedwater System	Pressure Transmitter	Not stated	Not stated	Not stated	Not stated	Loss of performance

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-23	11
Out of calibration or faulty module related to aging.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-27	12
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-27	13
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-27	14
Failure to operate because of end of life or faulty module related to aging.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-27	15
Loss of performance due to out of calibration or faulty module	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-28	16
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-28	17
Failure to operate due to faulty module related to aging.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-28	18
Erroneous or erratic signals are produced by the instrument.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-38	19
Erroneous signals are produced by the instrument because of out of calibration	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-38	20
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-38	21
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-38	22
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-38	23
Erroneous signals are produced by the instrument due to out of calibration or faulty module.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-39	24

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
25	Auxiliary Feedwater System	Pressure Transmitter	Not stated	Not stated	Not stated	WEAR	Attrition
26	Auxiliary Feedwater System	Pressure Transmitter	Not stated	Not stated	Not stated	Not stated	Open circuit
27	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	WEAR	Attrition
28	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	Not stated	Loss of function
29	Auxiliary Feedwater System	Relays	Not stated	Not stated	Not stated	WEAR	Attrition
30	Chemical and Volume Control System	AC Circuit Breakers	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
31	Chemical and Volume Control System	Heat Tracing Heaters	Not stated	Not stated	Not stated	CORR	Loss of material
32	Chemical and Volume Control System	Heat Tracing Heaters	Not stated	Not stated	Not stated	Not stated	Abnormal resistance or aging related set point drift.
33	Chemical and Volume Control System	Level Controllers	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
34	Chemical and Volume Control System	Level Controllers	Not stated	Not stated	Not stated	Not stated	Loss of performance
35	Chemical and Volume Control System	Level Transmitters	Not stated	Not stated	Not stated	Not stated	Loss of performance
36	Class 1E DC Power Supply System	Batteries	Not stated	Not stated	Not stated	Not stated	Cause accelerated aging, not hold charge, or end of life
37	Class 1E DC Power Supply System	Battery	Not stated	Not stated	Not stated	WEAR	Attrition
38	Class 1E DC Power Supply System	Battery	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
39	Class 1E DC Power Supply System	Battery	Not stated	Not stated	Not stated	Not stated	Loss of performance
40	Class 1E DC Power Supply System	AC Circuit Breaker	Not stated	Not stated	Not stated	WEAR	Attrition
41	Emergency On-Site Power Supply System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Loss of performance

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to open - failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-39	25
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	F-39	26
Fails to open - failure of a normally closed relay to open upon demand because of binding, or wear	Rare	Not discussed in report	Vendor specific, NEMA PE 5, IEC 146-2	Not stated	F-40	27
Failure to operate because of drift or insulation breakdown related to aging.	Rare	Not discussed in report	Vendor specific, NEMA PE 5, IEC 146-2	Not stated	F-40	28
Failure to operate	Rare	Not discussed in report	Vendor specific, NEMA PE 5, IEC 146-2	Not stated	F-41	29
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not discussed in report	ANSI/IEEE 741-1986 Section 7	Not stated	F-47	30
Loss of function	Rare	Not discussed in report	No specific program	Not stated	F-48	31
Loss of function	Rare	Not discussed in report	No specific program	Not stated	F-48	32
Erroneous or erratic signals are produced by the instrument.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06	Not stated	F-49	33
Erroneous or erratic signals are produced by the instrument because of being out of calibration.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06	Not stated	F-49	34
Erroneous or erratic signals are produced by the instrument because of being out of calibration or faulty module.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06	Not stated	F-50	35
Loss of function - lack of specified output from batteries	Occasional	Not discussed in report	IEEE 450-1987, RG 1.129, Tech Spec Surveil.	Not stated	F-56	36
Loss of function - inability of the charging unit to perform its function to specifications.	Rare	Not discussed in report	Vendor specific, NEMA PE 5, IEC 146-2	Not stated	F-57	37
Loss of function - inability of the charging unit to perform its function to specifications.	Rare	Not discussed in report	Vendor specific, NEMA PE 5, IEC 146-2	Not stated	F-57	38
Loss of function - inability of the charging unit to perform its function to specifications because of set point drift or faulty module.	Frequent	Not discussed in report	Vendor specific, NEMA PE 5, IEC 146-2	Not stated	F-57	39
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Occasional	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-58	40
Failure to perform as expected because of aging related component drift or out of calibration.	Rare	Not discussed in report	Vendor specific, RG 1.108, Tech. Specs.	Not stated	F-61	41

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
42	Emergency On-Site Power Supply System	Diesel Generator	Not stated	Not stated	Not stated	Not stated	Loss of function
43	CLASS 1E Instrumentation, Uninterruptable Power Supply System	AC Circuit Breaker	Not stated	Not stated	Not stated	WEAR	Attrition
44	CLASS 1E Instrumentation, Uninterruptable Power Supply System	Inverter	Not stated	Not stated	Not stated	WEAR	Attrition
45	CLASS 1E Instrumentation, Uninterruptable Power Supply System	Inverter	Not stated	Not stated	Not stated	Not stated	Loss of function
46	CLASS 1E Instrumentation, Uninterruptable Power Supply System	Inverter	Not stated	Not stated	Not stated	Not stated	Loss of performance
47	High Pressure Injection System	AC Circuit Breakers	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
48	High Pressure Injection System	AC Circuit Breakers	Not stated	Not stated	Not stated	WEAR	Attrition
49	High Pressure Injection System	AC Circuit Breakers	Not stated	Not stated	Not stated	Not stated	Los of performance
50	High Pressure Injection System	Flow Transmitter	Not stated	Not stated	Not stated	Not stated	Cause accelerated aging
51	High Pressure Injection System	Flow Transmitter	Not stated	Not stated	Not stated	Not stated	Loss of performance
52	High Pressure Injection System	Flow Transmitter	Not stated	Not stated	Not stated	FAT	Cumulative fatigue damage
53	High Pressure Injection System	Flow Transmitter	Not stated	Not stated	Not stated	WEAR	Attrition
54	High Pressure Injection System	Heat Tracing Heaters	Not stated	Not stated	Not stated	CORR	Loss of material
55	High Pressure Injection System	Heat Tracing Heaters	Not stated	Not stated	Not stated	Not stated	Winding failure, open, short, or high resistance
56	High Pressure Injection System	Load Sequence Controllers	Not stated	Not stated	Not stated	Not stated	End of life
57	High Pressure Injection System	Load Sequence Controllers	Not stated	Not stated	Not stated	CONTAM	Builup of deposits
58	High Pressure Injection System	Load Sequence Controllers	Not stated	Not stated	Not stated	Not stated	Loss of performance
59	High Pressure Injection System	Level Transmitters	Not stated	Not stated	Not stated	Not stated	Loss of performance
60	High Pressure Injection System	Pressure Transmitter	Not stated	Not stated	Not stated	Not stated	Loss of performance
61	Service Water System	AC Breakers	Not stated	Not stated	Not stated	FAT	Fatigue accumulative damages

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure due to open circuit.	Rare	Not discussed in report	Vendor specific, RG 1.108, Tech. Specs.	Not stated	F-61	42
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-63	43
Loss of function - the inverter fails to perform its intended function to specified requirements.	Occasional	Not discussed in report	Vendor specific programs. Tech. Specs.	Not stated	F-64	44
The inverter fails to perform its intended function to specified requirements due to electrical failure, insulation breakdown, open or short circuit related to aging.	Occasional	Not discussed in report	Vendor specific programs. Tech. Specs.	Not stated	F-64	45
The inverter has degraded operation because of aging related drift or faulty modules.	Occasional	Not discussed in report	Vendor specific programs. Tech. Specs.	Not stated	F-64	46
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Occasional	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-66	47
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Occasional	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-66	48
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand because of a faulty module.	Rare	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-66	49
Erroneous or erratic signals are produced by the instrument	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-67	50
Erroneous or erratic signals are produced by the instrument because out of calibration.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-67	51
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-67	52
Failure to operate	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-67	53
Loss of function	Rare	Not discussed in report	No specific program	Not stated	F-71	54
Loss of function	Occasional	Not discussed in report	No specific program	Not stated	F-71	55
Erroneous or erratic signals	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-72	56
Failure to operate	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-72	57
Failure to operate because of faulty module	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-72	58
Erroneous or erratic signals because unit out of calibration.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-73	59
Erroneous or erratic signals are produced by the instrument because of set point drift due to aging.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-82	60
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-88	61

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
62	Service Water System	AC Breakers	Not stated	Not stated	Not stated	WEAR	Attrition
63	Service Water System	AC Breakers	Not stated	Not stated	Not stated	Not stated	Binding or out of adjustment
64	Service Water System	AC Breakers	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
65	Service Water System	AC Breakers	Not stated	Not stated	Not stated	Not stated	Coil failure
66	Service Water System	Flow Indicators	Not stated	Not stated	Not stated	Not stated	Loss of performance
67	Service Water System	Flow Swicthes	Not stated	Not stated	Not stated	CONTAM	Buildup of deposits
68	Service Water System	Flow Swicthes	Not stated	Not stated	Not stated	Not stated	Loss of performance
69	Service Water System	Pressure Indicators	Not stated	Not stated	Not stated	CLOG	Buildup
70	Service Water System	Pressure Indicators	Not stated	Not stated	Not stated	Not stated	Loss of performance

Document: NUREG/CR-4819 V1, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		SOV ASCO 3-Way Direct Acting	Coil	Class H insulation	ASCO	ELETEMP, CURSTR, & VOLSTR	Loss of dieletric strength and conductor short/open
2		SOV	Core	Stainless steel	ASCO	CONTAM	Friction between core and guide
3		SOV	Disk Holder Assy Seat	EPDRM OR Vitron	ASCO	ELETEMP	Degradation of elastomers
4		SOV	Disc Holder Spring	Steel	ASCO	CORR	Spring relaxation or failure
5		SOV	Core Spring	Stainless steel	ASCO	CORR	Spring failure
6		SOV	Disc Holder Assembly Seat	EPDM OR Viton	ASCO	CONTAM & ELETEMP	Seat degradation
7		SOV 3-Way Pilot Operated	Coil	Not stated	ASCO	ELETEMP, CURSTR, & VOLSTR	Insulation failure and conductor open/short
8		SOV	Core	Not stated	ASCO	CONTAM	Binding between core and guide
9		SOV	Disc Holder Assy Seat	Elastomers	ASCO	CORR ELETEMP	Valve disc adheres to oriface

Document: NUREG/CR-4747 V2, An Aging Failure Survey of Light Water Reactor Safety Systems and Components (Electrical)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-88	62
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Rare	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-88	63
Failure to operate - the circuit breaker does not function properly, either fails to open or fails to close on demand.	Occasional	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-88	64
Premature open - the opening of the circuit breaker prior to demand.	Rare	Not discussed in report	IEEE 741-1986 Section 7	Not stated	F-88	65
Failure to operate due to being out of calibration (aging related).	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-89	66
Erroneous or erratic signals	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-89	67
Erroneous or erratic signals due to set point drift, insulation breakdown or out of calibration.	Frequent	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-90	68
Erroneous or erratic signals	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-104	69
Erroneous or erratic signals because of being out of calibraton.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118	Not stated	F-104	70

Document: NUREG/CR-4819 V1, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valve does not operate	Occasional	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34-35. 41-43. 54	1
Partial/full failure of valve to change position	Occasional	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34-35. 41-43. 54	2
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34-35. 41-43. 54	3
Valve fails to operate as required	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34-35. 41-43. 54	4
Seat leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34-35. 41-43. 54	5
Seat leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34-35. 41-43. 54	6
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	7
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	8
Valve fails to operate as required	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	9

Document: NUREG/CR-4819 V1, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
10		SOV	Disc Holder Spring	Steel	ASCO	CORR	Spring relaxation or failure
11		SOV	Pressure Diaphragm Bleed Hole		ASCO	CONTAM	Blocked bleeder hole
12		SOV	Exhaust Diaphragm Bleed Hold		ASCO	CONTAM	Blocked bleeder hole
13		SOV	Core Spring	Stainless steel	ASCO	CORR	Spring failure
14		SOV	Disc Holder Assy Seat	EPDM	ASCO	CONTAM ELETEMP	Seat degradation
15		SOV	Pressure Diaphragm	EPDM OR Nomex fabric	ASCO	CONTAM ELETEMP	Continuous exhaust
16		SOV	Exhaust Diaphragm	EPDM OR Nomex fabric	ASCO	CONTAM ELETEMP	Leakage through exhaust port
17		SOV 2-Way Direct Operating	Coil	Class H insulation	Valcore	ELETEMP CURSTR VOLSTR	Insulation failure short/open conductors
18		SOV 2-Way Direct Operating	Coil	Not stated	Valcore	ELETEMP CURSTR VOLSTR	Insulation failure short/open conductors
19		SOV 2-Way Direct Operating	Plunger Spring	Stainless steel	Valcore	CONTAM CORR	Binding in guide. spring breakage
20		SOV 2-Way Direct Operating	Plunger Spring	Stainless steel	Valcore	CONTAM CORR	Binding in guide. spring breakage
21		SOV 2-Way Direct Operating	Pilot Spring	Not stated	Valcore	CORR	Spring failure
22		SOV 2-Way Direct Operating	Plunger	Stainless steel	Valcore	CONTAM	Binding in guide tube
23		SOV 2-Way Direct Operating	Plunger	Stainless steel	Valcore	CONTAM	Binding in guide tube
24		SOV 2-Way Direct Operating	Pilot Spring	Stainless steel	Valcore	CORR	Spring failure
25		SOV 2-Way Direct Operating	Position Reed	Not stated	Valcore	Not stated	Contact failure
26		SOV 2-Way Direct Operating	Poppet Seat	Elastomers	Valcore	ELETEMP CONTAM	Eroded seat

Document: NUREG/CR-4819 V1, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valve fails to operate as required	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	10
Valve slow to respond	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	11
Valve fails to operate as required	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	12
Valve leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	13
Valve leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	14
Valve leakage - valve failure to operate as required	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	15
Valve leakage - valve failure to operate as required	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	25-26. 34. 36. 41-43. 54	16
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	16. 25-28. 34. 37. 41-43. 54	17
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	18
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	16. 25-28. 34. 37. 41-43. 54	19
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	20
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	21
Valve sluggish or not operational	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	16. 25-28. 34. 37. 41-43. 54	22
Valve sluggish or no operation	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	23
Slow valve closure	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	24
No or constant position indication	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	25
Valve leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	16. 25-28. 34. 37. 41-43. 54	26

Document: NUREG/CR-4819 V1, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
27		SOV 2-Way Direct Operating	Poppet Seat	EPDM	Valcore	ELETEMP CONTAM	Eroded seat
28		SOV 2-Way Direct Operating	Pilot Seat Seal	EPDM	Valcore	ELETEMP CONTAM	Eroded seat
29		SOV 2-Way Direct Operating	Coil	Class H insulation	TRC	ELETEMP CURSTR VOLSTR	Insulation failure and short/open conductor
30		SOV	Coil Diode	Not stated	TRC	Not stated	Open diode
31		SOV	Core	Not stated	TRC	CONTAM	Binding in core tube
32		SOV	Pilot Disc Seat	Stainless steel	TRC	ELETEMP CONTAM	Degradation of elastomers
33		SOV	Main Disc	Stainless steel	TRC	CONTAM	Jammed disc
34		SOV	Position Switch	Not stated	TRC	WEAR	Contact failure
35		SOV	Position Relay	Not stated	TRC	Not stated	Coil conductor short/open
36		SOV	Return Spring	Stainless steel	TRC	CORR	Spring breakage
37		SOV	Main Disc Seat	Stainless steel	TRC	WEAR	Seat degradation

Document: NUREG/CR-4819 V2, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants, Vol. 2
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Solenoid-Operated Valves	Core Seat & Seals (Elastomeric Components)	Not stated	ASCO AND Skinner	THERM & AGR-CHEM	Prolonged temperatures degrades seals, chem attack by oils
2		Solenoid-Operated Valves	Solenoid Coil Insulation	Not stated	Not stated	THERM	Degraded insulation
3		Solenoid-Operated Valves	Core Spring	Not stated	Not stated	WEAR & CORR	Changes in mechanical propeties. binding, or corrsion contam
4		Solenoid-Operated Valves	Sliding Surfaces	Not stated	Not stated	WEAR & CORR	Loss of material and crud buidup

Document: NUREG/CR-4819 V1, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valve leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	27
Valve leakage	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	19. 25-28. 34. 38. 41-43. 54	28
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	29
Valve fails closed	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	30
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	31
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	32
Valve fails to operate	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	33
Loss of position indication	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	34
Position indication does not change	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	35
Valve remains open	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	36
Valve does not have a tight shutoff	Not stated	Not discussed in report	Vendor specific programs	R&D to develope test methods. Testing of proposed monitoring techniques. Develope baseline data. Evaluation of failures [4]	21. 25-28. 34. 39. 41-43. 54	37

Document: NUREG/CR-4819 V2, Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants, Vol. 2
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Chemical attack of elastomers by oil and degradation of elastomers resulting from prolonged operation at excessively high temperatures resulting in failure to operate.	Rare	Not discussed in report	Vendor specific programs	Determine the sensitivity with which degraded elestomeric valve seats can be determined from electrical measurements [2]	5, 7, 8, 11, & 44	1
Electrical failure of solenoid coil, caused by high-voltage turn-off transients in combination with insulation weakened by prolonged operation at high temperatures, electrical failure due to short circuit, conductor burnout.	Occasional	Not discussed in report	Vendor specific programs	Visual inspections and electrical resistance tests [2]	5, 7, 8, 11, & 44	2
Changes in mechanical properties of materials, binding in operation, hum or chatter, worn spring, & wear, change in valve operating time or in rush current.	Rare	Not discussed in report	Vendor specific programs	Visual inspections and electrical characterization of inrush currents [2]	5, 7, 8, 11, & 44	3
Mechanical binding and sluggish shifting caused by worn or improper parts or the presence of foreign materials inside the valve, increase in frictional force	Occasional	Not discussed in report	Vendor specific programs	Visual inspections and electrical characterization of inrush currents and valve actuation times. [2]	5, 7, 8, 11, & 44	4

Document: NUREG/CR-4928, Degradation of Nuclear Plant Temperature Sensors
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Temperature Sensors	RTD Sensing Wire or Film	Platinum	Not stated	OXIDAT, VIB, CONTAM, & ELE-TEMP	Platininum oxide build up, fat, ion migration, & strain
2		Temperature Sensors	RTD Insulation	Powder or cement (material not identified in report)	Not stated	MOIST-EL	Moisture decreases resistance
3		Temperature Sensors	RTD Sheath	Stainless steel	Not stated	VIB	Cold working in metals

Document: NUREG/CR-4939 V1, Improving Motor Reliability in Nuclear Power Plants - Performance Evaluation and Maintenance Practices
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electric Motors	Dielectric, Rotational, Mechanical	Not stated	Not stated	Not stated	Insulation is most affected by aging mechanisms

Document: NUREG/CR-4939 V2, Improving Motor Reliability in Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Motor	Insulation	Glass, mylar, dacron w/poly binder, epoxy, poly fibers & poly varnish	Westinghouse	ELETEMP	Slot wedge developed hole(s), arcing to ground
2		Motor	Bearing	Not stated	Westinghouse	ELETEMP WEAR	Bearing failure

Document: NUREG/CR-4939 V3, Failure Analysis and Diagnostic Tests on A Naturally Aged Large Electric Motor
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1			400HP, 2400 V Motor	Not stated	Not stated	VOLSTR	Insulation breakdown

Document: NUREG/CR-4967, Nuclear Plant Aging Research on High Pressure Injection Systems
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15	PWR high pressure injection system	Air Operated Valves		Not stated	Not stated	CONTAM	Parts degrade from oil in air supply
16	PWR high pressure injection system	HPI Nozzles and Thermal Sleeve		Stainless steel	Not stated	THERM FAT	Crack initiation and propagation
17	PWR high pressure injection system	I & C Electronics	Small Electronic Components	Not stated	Not stated	CORR	Opens, shorts, and loose connections
18	PWR high pressure injection system	PIPING		Stainless steel	Not stated	THERM FAT, WEAR, VIB, & MECHSTR	Cracking & abrasive wear
19	PWR high pressure injection system	Valve		Stainless steel	Not stated	WEAR & CONTAM	Leakage, blockage, & mechanical linkage faults
20	PWR high pressure injection system	Pump		Stainless steel	Not stated	THERM-CY, WEAR, VIB, & FAT	Wear on parts and seal leaks
21	PWR high pressure injection system	Pipe Supports		Not stated	Not stated	VIB AND FAT	Loosening of connections or breaking loose
22	PWR high pressure injection system	Motor Operated Valve		Stainless steel	Not stated	WEAR AND VOLSTR	Loose connections, wear on moving parts, motor failure

Document: NUREG/CR-4928, Degradation of Nuclear Plant Temperature Sensors
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Changes in resistance causes calibration changes	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987	Burn-in program for new sensors, develop a data base for degradation mechanisms, and simple tests to check sensor prob. [2]	A-9, and A-31 to A-36	1
Shunting of sensing element occurs when insulating powder gets wet. moisture intrusion occurs when the seals dry out, shrink, crack, or leak resulting in calibration shift or failure to function.	Not stated	Not discussed in report	No specific program	Burn-in program for new sensors, develop a data base for degradation mechanisms, and simple tests to check sensor prob. [2]	A-9, and A-31 to A-36	2
Mechanical shock and vibration can cause cold working in metal that leads to failure of the sheath and moisture intrusion.	Not stated	Not discussed in report	No specific program	Burn-in program for new sensors, develop a data base for degradation mechanisms, and simple tests to check sensor prob. [2]	A-9, and A-31 to A-36	3

Document: NUREG/CR-4939 V1, Improving Motor Reliability in Nuclear Power Plants - Performance Evaluation and Maintenance Practices
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
This report references a phase I study that investigated aging effects. This report only addresses motor evaluation and maintenance practices	Not stated	EPRI; IEEE 4,43,85,95,112,117, 286,429,432,522	EPRI; IEEE 4, 43, 85, 95, 112, 117, 286, 429,	Motors important to safety should undergo cost-effective PM programs [2]	1-6; 2-7; 4-1; 5-9,10,11,& 12; 7-1	1

Document: NUREG/CR-4939 V2, Improving Motor Reliability in Nuclear Power Plants
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Motor failure	Not stated	Not discussed in report	IEEE 334-1974 Section 14.2.3	The "plug reversal life test" is recommended for motor qualification. [2]	2-1, 6-1	1
Motor failure	Not stated	Not discussed in report	IEEE 334-1974 Section 14.2.3	Not stated	4-1, 5-1, 6-1	2

Document: NUREG/CR-4939 V3, Failure Analysis and Diagnostic Tests on A Naturally Aged Large Electric Motor
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Motor failure	Frequent	DC insulation &/or polarization tests	IEEE 334-1974 Section 14.2.3	Install effective grnd or grnd detectors on 3 Ph "capacitance" grnded (delta) PWR syst. [2]	3-4	1

Document: NUREG/CR-4967, Nuclear Plant Aging Research on High Pressure Injection Systems
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fail to operate	Rare	Not discussed in report	Vendor specific program. Tech Spec surveill.	Not stated	36	15
Nozzle leaks and loose parts resulting in degraded HPI system	Rare	Not discussed in report	Dye penetrant, ultrasonic, radiography	Not stated	36 & 53	16
Failure to operate	Occasional	Not discussed in report	IEEE 338-1987	Not stated	36	17
Through the pipe wall leakage resulting in HPIS degraded operation or failure to function.	Rare	Not discussed in report	Dye penentant, ultrasonic, radiography	Not stated	36 & 53	18
Failure to operate resulting in HPIS failure. Valve failure allowes cold water to flow back into primary system resulting piping cracks.	Rare	Not discussed in report	Vendor specific programs	Not stated	36 & 53	19
Fail to start or run	Rare	Not discussed in report	Vendor specific programs	Not stated	36	20
Lose of pipe supports stresses piping leading to potential pipe failure and HPIS failure.	Rare	Not discussed in report	Plant specific program	Not stated	36	21
Valve failure to operate results in HPIS failure.	Rare	Not discussed in report	Vendor specific programs	Not stated	36	22

Document: NUREG/CR-4992 V1, Aging and Servcie Wear of Multistage Switches Used in Safety Systems of Nuclear Power Plants
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Multistage Switches	General		GE, Westinghouse, Electro., Micro		
2		Multistage Switches	Cam Shaft	Steel, Al, brass	GE, Westinghouse, Electro., Micro	EXFORCE, WEAR	Bent or twisted shaft
3		Multistage Switches	Cam Shaft	Steel, Al, brass	GE, Westinghouse, Electro., Micro	MECHSTR, WEAR	Broken camshaft
4		Multistage Switches	Contacts	Silver or silver alloy	GE, Westinghouse, Electro., Micro	CORR, FAT, FAT/THERM, VIBR, CONTAM, ELETEMP, WEAR	Broken or distorted contact, sticking, loose contact
5		Multistage Switches	Contacts	Silver or silver alloy	GE, Westinghouse, Electro., Micro	ELETEMP, CURSTR, VOLSTR,	Pitted, worn, or welded contact
6		Multistage Switches	Contact Block	Phenolic	GE, Westinghouse, Electro., Micro	VIBR	Loose contact bank
7		Multistage Switches	Moving Contact Spring	Steel, Al, brass	GE, Westinghouse, Electro., Micro	FAT	Spring breaks
8		Multistage Switches	Moving contact Assembly	Not stated	GE, Westinghouse, Electro., Micro	FAT	Gear breaks
9		Multistage Switches	Moving Contact Pin	Not stated	GE, Westinghouse, Electro., Micro	ELETEMP, FAT, THERM-CY	Pin breaks
10		Multistage Switches	Cams	Polyphenylene oxide, acetal, phenolic	GE, Westinghouse, Electro., Micro	ELETEMP, RAD, THERM-CY, WEAR	Closing or opening cam failure
11		Multistage Switches	Cam Follower	Polycarbonate	GE, Westinghouse, Electro., Micro	ELETEMP, RAD, VIBR	Broken or warped follower
12		Multistage Switches	Cam Follower	Polycarbonate	GE, Westinghouse, Electro., Micro	WEAR	Slipping of cam follower
13		Multistage Switches	Switch Handle	Polycarbonate	GE, Westinghouse, Electro., Micro	VIBR	Broken or loose set screws
14		Multistage Switches	Shaft Bearings	Not stated	GE, Westinghouse, Electro., Micro	LOSLUB, WEAR, CONTAM	Bearing freezes up
15		Multistage Switches	Gear	Not stated	GE, Westinghouse, Electro., Micro	FAT, WEAR	Gear failure
16		Multistage Switches	Detent Mechanism	Steel, Al, brass, vulcanized fiber	GE, Westinghouse, Electro., Micro	FAT, WEAR	Worn detent mechanism, loose detent roller pin
17		Multistage Switches	Detent Stop Arm	Steel, Al, brass	GE, Westinghouse, Electro., Micro	EXFORCE	Bent stop arm

Document: NUREG/CR-4992 V1, Aging and Servcie Wear of Multistage Switches Used in Safety Systems of Nuclear Power Plants
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
	Not stated	Not discussed in report	No specific/vendor specific programs	Operators provide feedback on problems, failures should be analyzed,no further consideraton by NPAR [2]	2, 10, 52	1
Bent or twisted shaft causes incorrect contact alignment and failure to operate as required	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	2
Switch will not change state resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	3
Contacts do not close or change state, open or short circuit, high electrical resistnace resulting in failure to operate	Frequent	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	4
High contact resistance resulting in failure to operate as required	Frequent	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	5
Contacts do not mate properly resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	6
No positive return of cam followers, contacts may open or close randomly resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	7
Contacts to not change state resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	8
Contacts will tend to remain closed during opening cam action resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	9
Contacts to not change state resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	10
Contacts do not change state resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	11
Incomplete contact closure resulting in failure to operate as required	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	12
Switch will not change state resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	13
Switch will not change state resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	14
Switch will not maintain position resulting in failure to operate	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	15
False indication of position change, contacts do no properly line up resulting in failure to operate as required	Frequent	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	16
Overtravel of cams at end stop resulting in failure to operate as required	Not stated	General - none specifically for switches	No specific/vendor specific programs	Not stated	2, 10, 31-37, 41-44, 52	17

Document: NUREG/CR-5008, Development of A Testing and Analysis Methodology to Determine the Functional Condition of Solenoid Operated Valves
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Solenoid Valves	General		Not stated		
2		Solenoid Valves	Spring	Not stated	Not stated	Not stated	Weakened spring
3		Solenoid Valves	Valve Seat	Not stated	Not stated	CONTAM	Not stated
4		Solenoid Valves	Plunger	Not stated	Not stated	Not stated	Sticking plunger

Document: NUREG/CR-5051, Detecting and Mitigating Battery Charger and Inverter Aging
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Inverter	Automatic Transfer Switch (Two Pairs of SCR's)	Not stated	Not stated	ELETEMP & CURSTR	Degraded component or burn out
2		Battery	Electrolytic Capacitors	Not stated	Not stated	ELETEMP	Reduced capacitor life
3		Battery	Semi-Conductors		Not stated	VIB, THERM, & CURSTR	Vibration loosens connections & heat degrades operation
4		Battery	Magnetics - Transformers	High permeability alloys, copper windings, & insulation	Not stated	ELETEMP AND CURSTR	Aging degradation resulting from over heating & elec. stress
5		Battery	Complete Assembly	Enclosures and electrical components	Seven listed	ELETEMP & CURSTR,	Overheating & electrical transients from stresses

Document: NUREG/CR-5053, Operating Experience and Aging Assessment of Motor Control Centers
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Motor Control Center	General				
2		Motor Control Center	Molded Case Circuit Breakers	Lubr., adhes., neoprene, silicone, polyester, phenolic, rubber, silver alloy, copper, stainless steel	Not stated	FAT, WEAR, CONTAM, CORR, CORR/PIT,	Mech. stress, sticking, surface deterioration, low torque
3		Motor Control Center	Molded Case Circuit Breakers	Lubr., adhes., neoprene, silicone, polyester, phenolic, rubber, silver alloy, copper, stainless steel	Not stated	WEAR,	Out of adjustment, defective latch, short/ground, stresses
4		Motor Control Center	Relay	Phenolic, vulcanized rubber, silver alloy, copper, steel	Not stated	ELETEMP, CORR, CORR/PIT	Breakdown of insulation, contact surface degradation
5		Motor Control Center	Relay	Phenolic, vulcanized rubber, silver alloy, copper, steel	Not stated	CONTAM, CORR, CORR/PIT, VIBR, FAT	Foreign mat'l accumulation, surface degradation, misalign.
6		Motor Control Center	Relay	Phenolic, vulcanized rubber, silver alloy, copper, steel	Not stated	WEAR	Out of calibration
7		Motor Control Center	Transformer	Phenolic, fiberglass, copper wire, teflon	Not stated	ELETEMP, CURSTR, VOLSTR	Overheating, deterioration and breakdown of insulation

Document: NUREG/CR-5008, Development of A Testing and Analysis Methodology to Determine the Functional Condition of Solenoid Operated Valves
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
This report is not an aging assessment of sovs. The report investigates testing and analysis methodologies.	Not stated	Not discussed in report	Vendor specific programs	Explore alternative analytical techniques. Further develop and validate coherency model [2]	23	1
Not stated	Not stated	Not discussed in report	Vendor specific programs	Not stated	13	2
Not stated	Not stated	Not discussed in report	Vendor specific programs	Not stated	13	3
Not stated	Not stated	Not discussed in report	Vendor specific programs	Not stated	13	4

Document: NUREG/CR-5051, Detecting and Mitigating Battery Charger and Inverter Aging
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inverter fails and vital bus loads are automatically transferred to alternate source if failure occurs.	Not stated	Not discussed in report	Vendor specific programs	Not stated	3-15 TO 3-22	1
Aging due to high temperature leads to capacitor failure resulting in improper output.	Frequent	Not discussed in report	Vendor specific programs	Improve thermal efficiency by using forced air cooling. Manufacture improvements such as adding a fuse module. [2]	3-4 TO 3-6	2
Aging due to local heat buildup results in short circuit of the SCR and an inverter failure.	Occasional	Not discussed in report	Vendor specific programs	Improved maintenance and testing done more often. [2]	3-7, 4-13, & 5-7	3
Transformer aging caused by over heating, electrical transients, and personnel error results in charger/invertor failure.	Not stated	Not discussed in report	Vendor specific programs	Improved maintenance and testing done more often. [2]	XIII, 1-6, 3-9, & 5-6	4
Electrolytic capacitors, fuses, magnetics (inductors and transformers) and semiconductors failure results in charger/invertor failure.	Not stated	Plant maintenance	Vendor specific programs	Establish a comprehensive maintenance program that addresses inspection, testing, predictive and corrective maintenance [2]	XIII, 4-15, & 7-4	5

Document: NUREG/CR-5053, Operating Experience and Aging Assessment of Motor Control Centers
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
	Not stated	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Detailed survey of PM, surveillance techniques, and oper. exp. review maintenance data. PRA to determine importance [2]	5-1 thru 5-13, 6-5 thru 6-7	1
Failure to open or failure to close	Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-20, 4-21, 5-1 thru 5-13	2
Inadvertent trip, failure to trip	Occasional to Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-20, 4-21, 5-1 thru 5-13	3
Open circuits	Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-20, 4-21, 5-1 thru 5-13	4
Failure to open or failure to close	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-20, 4-21, 5-1 thru 5-13	5
Response on incorrect signal	Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-20, 4-21, 5-1 thru 5-13	6
Open or short circuits	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-22, 5-1 thru 5-13	7

Document: NUREG/CR-5053, Operating Experience and Aging Assessment of Motor Control Centers
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
8		Motor Control Center	TERMINAL BLOCK	Phenolic	Not stated	VIBR, WEAR	Mechanical stresses
9		Motor Control Center	Terminal Block	Phenolic	Not stated	ELETEMP	Conduction paths are formed
10		Motor Control Center	Thermal Overloads	Phenolic, silver plating, copper, vulcanized rubber	Not stated	ELETEMP, FAT	Overheating
11		Motor Control Center	Thermal Overloads	Phenolic, silver plating, copper, vulcanized rubber	Not stated	CORR, CORR/PIT	Surface degradation
12		Motor Control Center	Thermal Overloads	Phenolic, silver plating, copper, vulcanized rubber	Not stated	WEAR, CONTAM	Out of calibration, sticking
13		Motor Control Center	Starter/Contactor	Lubricant, adhesive, neoprene, silicone, polyester, phenolic, rubber, silver alloy, coppper, stainless steel	Not stated	FAT, CORR, CORR/PIT, CONTAM	Mech. stresses, surface degradation, foreign substance
14		Motor Control Center	Fuse	Not stated	Not stated	Not stated	Material degradation causes open circuits
15		Motor Control Center	Coils	Phenolic, fiberglass, copper wire, teflon	Not stated	CURSTR	Overcurrent causes overheating and insulation breakdown
16		Motor Control Center	Trip and Control	Not stated	Not stated	Not stated	Drifting of setpoint, out of calibration
17		Motor Control Center	Trip and Control	Not stated	Not stated	CONTAM	Degradation of contact surfaces, buildup of grease and dirt
18		Motor Control Center	Cabinets	Steel	Not stated	Not stated	Not stated

Document: NUREG/CR-5141, Aging and Qualification Research on Solenoid Operated Valves
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		SOV - ASCO	Coils	Elastomers	ASCO	MOIST-EL, ELETEMP	Decreased insulation and coil resistance
2		SOV - ASCO	Core Disc	Buna-N, EPDM	ASCO	ELETEMP, RAD	Hardening, decreased elongation
3		SOV - ASCO	Seat	Buna-N and nylon metal and EP	ASCO	ELETEMP, RAD	Hardening, decreased elongation
4		SOV - ASCO	Body O-Rings	Buna-N, EPDM	ASCO	ELETEMP, RAD	Hardening, decreased elongation

Document: NUREG/CR-5053, Operating Experience and Aging Assessment of Motor Control Centers
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Poor connection/open circuit	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-22, 5-1 thru 5-13	8
Ground/short	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-22, 5-1 thru 5-13	9
Open circuit	Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-23, 4-24, 5-1 thru 5-13	10
Would not operate	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-23, 4-24, 5-1 thru 5-13	11
Tripped and response on incorrect signal	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-23, 4-24, 5-1 thru 5-13	12
Failure to open or close	Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-23, 4-24, 5-1 thru 5-13	13
Premature operation	Frequent	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	4-6, 4-23, 5-1 thru 5-13	14
Open circuit, short/ground	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 4-6, 4-24, 5-1 thru 5-13	15
Response on incorrect signal	Occasional	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	4-6, 4-24, 5-1 thru 5-13	16
Sticking and material degradation result in falure to operate	Rare	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	4-6, 4-24, 5-1 thru 5-13	17
Not stated	Not stated	IEEE 308,279,317; RG 1.106,1.63; NEMA; UL	IEEE 308, 279, 317; RG 1.106, 1.63; NEMA; UL	Not stated	3-4, 5-1 thru 5-13	18

Document: NUREG/CR-5141, Aging and Qualification Research on Solenoid Operated Valves
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Water enters during MSLB/LOCA conditions. Failure to operate	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 9, 28-31, 41-48, 75-78	1
Leakage	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 9, 28-31, 73, 75-78	2
Leakage. Laquer like organic deposits surrounding the metal to metal seats caused failure to transfer.	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 9, 28-31, 75-78	3
Failure to transfer	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 9, 28-31, 74, 75-78	4

Document: NUREG/CR-5141, Aging and Qualification Research on Solenoid Operated Valves
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5		SOV - ASCO	Housings, Washers, Core Spring, Gaskets	Not stated	ASCO	Not stated	Not stated
6		SOV - VALCOR	Coils	Elastomers	Valcor	MOIST-EL, ELETEMP	Decreased coil and insulation resistance
7		SOV - VALCOR	Seats	EPR	Valcor	ELETEMP, RAD	Hardening and decreased elongation
8		SOV - VALCOR	Shaft Seal O-Ring	EPR	Valcor	ELETEMP, RAD	Hardening and decreased elongation
9		SOV - VALCOR	Upper Assembly Seal O-Ring	EPR	Valcor	ELETEMP, RAD	Hardening and decreased elongation
10		SOV - VALCOR	Shaft, Cage, Ports	Not stated	Valcor	Not stated	Not stated

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	1E Power	General					
2	1E Power	Transformer	General				
3	1E Power	Transformer	Insulating Oil	Mineral oil, systhetic chlorinated aromatic hydrocarbon	Not stated	MOIST-EL, ELETEMP	Degraded insulation value
4	1E Power	Transformer	Core (Magnetic Circuit and Windings)	Copper, aluminum, silicon steel, cellulose, phenolics, fiberglass, varnish, epoxy	Not stated	FAT, ELETEMP	Magnetic core deformation
5	1E Power	Transformer	Core (Magnetic Circuit and Windings)	Copper, aluminum, silicon steel, cellulose, phenolics, fiberglass, varnish, epoxy	Not stated	ELETEMP, VIBR, MOIST-EL, VOLSTR, CURSTR, CORR/OX	Arcing, hot spots, winding insulation degradation
6	1E Power	Transformer	Case (Tank)	Structural steel, paints	Not stated	FAT	Failure of tank welds, moisture seal cracking
7	1E Power	Transformer	Insulating Gas	Nitrogen, air, flourocarbon	Not stated	MOIST-EL	Insulation breakdown
8	1E Power	Transformer	Core (Magnetic Circuit and Windings)	Copper, aluminum, silicon steel, cellulose, phenolics, figerglass, varnish, epoxy	Not stated	FAT, ELETEMP	Magnetic core deformation
9	1E Power	Transformer	Core (Magnetic Circuit and Windings)	Copper, aluminum, silicon steel, cellulose, phenolics, figerglass, varnish, epoxy	Not stated	MOIST-EL, ELETEMP, CORR/OX, CURSTR, VIBR, VOLSTR	Arcing, hot spots, winding insulation degradation
10	1E Power	Transformer	Case (Tank)	Structural steel, paint	Not stated	FAT	Failure of tank welds, moisture seal cracking

Document: NUREG/CR-5141, Aging and Qualification Research on Solenoid Operated Valves
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	9	5
Water enters during MSLB/LOCA conditions. Failure to operate	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 11, 20-28, 41-48, 75-78	6
Not stated	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 11, 20-28, 41-48, 75-78	7
O-rings adhered to the guide tube - caused sticking and failure to transfer	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 11, 20-28, 41-48, 73-78	8
O-rings adhered to seat - caused sticking and failure to transfer	Frequent	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	6-7, 11, 20-28, 41-48, 73-78	9
Not stated	Not stated	Not discussed in report	10 CFR 50.49 if EQ'd, plant specific programs	Not stated	11	10

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
	Not stated	RG 1.118, IEEE-338, IEEE,943	RG 1.108, 1.118, 1.129; IEEE 338, 387, 450	Eval. surveillance & monitoring practices. Determine which components contribute most to system unavailability [4]	49, 51, 54, 71	1
	Not stated	Representative plant	Vendor specific programs	Industry continue developing monitoring techniques. Transf. and surge suppressor aging studies should be performed [4].	66, 70	2
Reduction in dielectric strength resulting in internal shorts and winding failures	Not stated	Not discussed in report	Vendor specific programs	Not stated	20, 21, 22	3
Vibration and excessive temperature cause the magnetic core circuit to become deformed and loosen and can result in failure of the windings	Not stated	Not discussed in report	Vendor specific programs	Not stated	20, 21, 22	4
Winding-to-winding short circuit, winding-to-case short circuit	Not stated	Not discussed in report	Vendor specific programs	Not stated	20, 21, 22	5
Leakage, moisture instrusion resulting in degradation of the insulating oil	Not stated	Not discussed in report	Vendor specific programs	Not stated	21, 22	6
Reduction in dielectric strength resulting in internal shorts and winding failures	Not stated	Not discussed in report	Vendor specific programs	Not stated	21, 22	7
Deformation and loosening of the magnetic core resulting in winding failures	Not stated	Not discussed in report	Vendor specific programs	Not stated	21, 22	8
Winding-to-winding short circuit, winding-to-case short circuits	Not stated	Not discussed in report	Vendor specific programs	Not stated	21, 22	9
Moisture intrusion and leakage of the gas coolant/insulation resulting in failure of the winding insulation	Not stated	Not discussed in report	Vendor specific programs	Not stated	21, 22	10

Table A.2 Gall Report for NPAR Reports

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	1E Power	Cable	Insulation	XLPE, EPR, silicon or butyl rubber, Kapton, PE, PVC, teflon, CSP	Not stated	ELETEMP, RAD, MOIST-EL, AGRCHEM	Embrittlement of insulation, treeing
12	1E Power	Cable	Jacket	CSP	Not stated	ELETEMP, RAD, MOIST-EL, AGRCHEM	Embrittlement of insulation
13	1E Power	Connections and Terminations	Not stated	Not stated	Not stated	FAT	Cracking
14	1E Power	Electrical Cable	Cable Clamp	Stainless steel	Not stated	Not stated	Not stated
15	1E Power	Electrical Cable	Terminal Strip Assembly	Glass filled phenolic	Not stated	Not stated	Not stated
16	1E Power	Electrical Cable	Shrink Tubing	Polyolefin	Not stated	Not stated	Not stated
17	1E Power	Electrical Cable	Plug Sleeve and Coupling Ring	Bronze	Not stated	Not stated	Not stated
18	1E Power	Electrical Cable	O-Ring Seal	Elastomer	Not stated	Not stated	Not stated
19	1E Power	Electrical Cable	Contact Socket	Copper	Not stated	Not stated	Not stated
20	1E Power	Electrical Cable	Interfacial Seal	Dow Corning Sylgard	Not stated	Not stated	Cracking
21	1E Power	Electrical Cable	Insulator, Plug Skirt	Polysulfone	Not stated	Not stated	Cracking
22	1E Power	Electrical Cable	Washer	Stainless steel	Not stated	Not stated	Not stated
23	1E Power	Electrical Cable	Module Assembly	Brass	Not stated	Not stated	Not stated
24	1E Power	Circuit Breaker	Insulation	Polyester, glassfiber-filled epoxy resins, phenolic	Not stated	ELETEMP	Reduced insulation value
25	1E Power	Circuit Breaker	Contacts	Silver alloy in copper base	Not stated	CURSTR, VOLSTR	Poor electrical contact
26	1E Power	Circuit Breaker	Arc Chutes	Not stated	Not stated	ELETEMP	Structural damage to the arc chutes
27	1E Power	Circuit Breaker	Overload Mechanism	Not stated	Not stated	ELETEMP	Reduced overload rating
28	1E Power	Circuit Breaker	Connections	Not stated	Not stated	VIBR	Loose connections
29	1E Power	Circuit Breaker	Lubricant	Not stated	Not stated	ELETEMP, AGRCHEM, CONTAM	Hardening of the lubricant
30	1E Power	Circuit Breaker	Frame	Painted or electroplated steel	Not stated	Not stated	Not stated

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Embrittlement results in cracking which permits moisture to enter and result in conductor-to-conductor and conductor-to-ground shorts. Treeing results in conductor-to-conductor and conductor-to-ground shorts	Occasional	Not discussed in report	No specific program	Not stated	22, 23, 25, 41	11
Embrittlement results in cracking and moisture instrusion	Occasional	Not discussed in report	No specific program	Not stated	22, 23, 25, 41	12
Not stated	Not stated	Not discussed in report	Plant specific progarms	Not stated	23,24	13
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	22, 25, 49, 56	14
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	15
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	16
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	17
Pressure leak	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	18
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	19
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	20
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	21
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	22
Not stated	Not stated	RG 1.63, IEEE-317	10 CFR 50.49, Vendor specific programs	Not stated	24, 25, 49, 56	23
Excessive temperature caused by poor contact, large currents, or elevated environment degrades the insulation resulting in shorts and arcing	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	24
Degraded/poor contacts result in degraded or open circuits	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	25
Flashover/arcing, failure to extinguish the arc	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	26
Premature trip at low current	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	27
Improper operation and open circuits	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	28
Improper operation, failure to open or close	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	29
Not stated	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	30

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
31	1E Power	Circuit Breaker	Housing, Doors	Painted sheet steel	Not stated	Not stated	Not stated
32	1E Power	Circuit Breaker	Mechanisms	Cast bronze and steel, stamped steel	Not stated	CORR, AGRCHEM, WEAR, VIBR, FAT, CONTAM	Reduced force, increased friction, embrittled mat.
33	1E Power	Relays	Coil Insulation	Not stated	Not stated	VOLSTR, ELETEMP	Reduced insulation value
34	1E Power	Relays	Moving Parts	Not stated	Not stated	WEAR, FAT	Increased friction, binding
35	1E Power	Relays	Contacts	Not stated	Not stated	WEAR, CORR, VIBR, CONTAM	Poor electrical contact
36	1E Power	Relays	Connections	Not stated	Not stated	VIBR, ELETEMP	Loose or poor electrical connections
37	1E Power	Relays	Coil Bobbin	Not stated	Not stated	ELETEMP	Accelerate aging
38	1E Power	Chargers and Inverters	Circuit Breaker	Not stated	Not stated	CONTAM, LOSLUB, WEAR, CORR/PIT	Increased friction, binding, loss of continuity
39	1E Power	Chargers and Inverters	Fuse	Not stated	Not stated	THERM-CY, FAT	Metal fatigue, melting of link
40	1E Power	Chargers and Inverters	Relay	Not stated	Not stated	CORR/PIT, CORR/OX	Loss of continuity
41	1E Power	Chargers and Inverters	Electrolytic Capacitors	Not stated	Not stated	ELETEMP, VIBR	Loss of electrolyte, failure of leads
42	1E Power	Chargers and Inverters	Oil Filled Capacitors	Not stated	Not stated	ELETEMP, VIBR	Dielectric breakdown, failure of leads
43	1E Power	Chargers and Inverters	Magnetics (Transformer, Inductor)	Not stated	Not stated	ELETEMP, LOW TEMP, VOLSTR, VIBR	Degraded insulation, cracked moisture seals, broken wires
44	1E Power	Chargers and Inverters	Silicon Controlled Rectifiers	Not stated	Not stated	ELETEMP	Over voltage or over current caused by transients
45	1E Power	Chargers and Inverters	Resistor	Not stated	Not stated	VIBR, ELETEMP	Decrease in resistance, lead fails
46	1E Power	Chargers and Inverters	Printed Circuit Boards	Not stated	Not stated	TEMP, THERM-CY, CORR, VIBR	Cracking of circuit lines, open circuits, loose connections

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	31
Improper operation, failure to oper or close	Not stated	Not discussed in report	ANSI/IEEE 741-1986 Section 7, vendor specific	Not stated	25, 26, 27	32
Excessive temperture from ohmic heating or the environment causes insulation failure and results in failure of the relay to operate	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987	Not stated	25, 26, 27, 28	33
Misopertion, failure to operte, slow or sluggish operation, inadvertant contact closure	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987	Not stated	25, 26, 27, 28	34
Open circuit, failure to close, arcing, increased temperature due to ohmic heating	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987	Not stated	25, 26, 27, 28	35
Open circuit, heating at the socket/pin interface	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987	Not stated	25, 26, 27, 28	36
Coil failure	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987	Not stated	25, 26, 27, 28	37
Failure to operate, failure to open	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	38
Fails open (opens prematurely)	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	39
Open circuit or coil, contacts open	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	40
Loss of capacitance or open circuit causes the charger/inverter to have improper output	Frequent	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	41
Loss of capacitance or open circuit causes the charger/inverter to have improper output	Frequent	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	42
Failure of device due to short circuit (turn-to-turn or turn-to-ground) or change in inductance	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	43
Failure of device due to open or short circuits	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	44
Failure of device due to open circuit or change in value of resistor	Rare	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	45
Output changes from desired value	Frequent	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	46

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
47	1E Power	Chargers and Inverters	Surge Suppressor	Not stated	Not stated	VOLSTR, CURSTR	Semiconductor breakdown
48	1E Power	Chargers and Inverters	Connections	Not stated	Not stated	MECHSTR	Fatigue failure of wire at terminals
49	1E Power	Chargers and Inverters	Meters	Not stated	Not stated	CONTAM	Increase in bearing friction
50	1E Power	Chargers and Inverters	Switch	Not stated	Not stated	CORR, CORR/PIT	Loss of continuity across contacts
51	1E Power	Chargers and Inverters	Potentiometer	Not stated	Not stated	ELETEMP	Loss of continuity
52	1E Power	Batteries	Grids/Plates	Lead-calcium alloy	Not stated	OVERCHG, ELETEMP, CONTAM	Accelerates corrosion and oxidation
53	1E Power	Batteries	Active Material	Lead dioxide and lead sulfate	Not stated	GAS	Dislodges active material
54	1E Power	Batteries	Separator	Rubber/glass matt	Not stated	ELETEMP	Accelerates deterioration of electrical insulation
55	1E Power	Batteries	Electrolyte	Sulfuric acid and water	Not stated	CONTAM	Hydrolysis of the water and loss of electrolyte
56	1E Power	Batteries	Vent	Fused alumina	Not stated	MECHSTR	Vent breaks allowing contamination to enter
57	1E Power	Batteries	Top Connectors	Lead-calcium alloy	Not stated	ELETEMP, CORR, EMBR	Low electrolyte level causes corrosion and embrittlement
58	1E Power	Batteries	Terminals	Lead-calcium alloy	Not stated	CORR/OX, CORR	Poor electrical contact with external busses
59	1E Power	Batteries	Container and Top Cover	Polycarbonate, styrene acryolonitrile, acrylo-butadiene styrene	Not stated	MECHSTR, CORR/OX	Oxidation of lead causes plate growth

Document: NUREG/CR-5192, Testing of A Naturally Aged Nuclear Power Plant Inverter and Battery Charger
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Inverter	Resistors	Carbon conposition	Not stated	ELETEMP & MOIST	Ohms decrease - temperature, & ohms increase - moisture
2		Inverter	Wire	Not stated	Not stated	Not stated	Turns contact

Document: NUREG/CR-5181, Nuclear Plant Aging Research: The 1E Power System
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Semiconductor breakdown due to overheating causes short circuits and improper output	Rare	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	47
Improper output due to open or short circuits	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944,	Not stated	29-36, 55, 60-64	48
Improper indication	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944	Not stated	29-36, 55, 60-64	49
Improper output due to switch failing open or closed	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944	Not stated	29-36, 55, 60-64	50
Improper output due to open or short circuit	Occasional	IEEE-446, NEMA PE5, IEC 146-2, ANSI/IEEE-944	IEEE 446, NEMA PE5, IEC 146-2, ANSI/IEEE 944	Not stated	29-36, 55, 60-64	51
Corrosion/oxidation causes plate growth resulting in reduced capacity and stresses the container	Frequent	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	52
Dislodging active material from the plates causes loss of capacity	Not stated	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	53
Loss of electrical insulation between plates causes short circuits and loss of capacity	Not stated	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	54
Loss of electrolyte results in loss of capacity	Not stated	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	55
Contaminates in the electrolyte result in reduced capacity	Not stated	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	56
Embrittled top conductors are susceptible to breaking and causes loss of capacity	Frequent	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	57
Poor electrical contact results in loss of capacity and may result in total battery failure	Not stated	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	58
Plate growth and handling stresses results in cracked containers which allow electrolyte to escape resulting in reduced capacity or total failure	Frequent	RG 1.129, IEEE-450	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Not stated	30, 31, 36, 37, 38, 50, 54, 62-65	59

Document: NUREG/CR-5192, Testing of A Naturally Aged Nuclear Power Plant Inverter and Battery Charger
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Resistance change causes improper output.	Not stated	Not discussed in report	Vendor specific, Tech. Spec., IEEE 446, NEMA	Individual fusing of filter capacitors to preclude a capacitor failure in the short circuit mode [2]	3-23	1
When turns of wire in resisor make contact it decreases total resistance of resistor resulting in improper output.	Not stated	Not discussed in report	Vendor specific, Tech. Spec., IEEE 446, NEMA	Not stated	3-23	2

Document: NUREG/CR-5192, Testing of A Naturally Aged Nuclear Power Plant Inverter and Battery Charger
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3		Inverter	Electrolytic Capacitors	Not stated	Not stated	Not stated	Capacitance decreases with age
4		Inverter	Ceramic Capacitor	Not stated	Not stated	Not stated	Unstable capacitance value
5		Inverter	Silicon Controlled Rectifiers	Silicon	Not stated	ELETEMP	Deterioration of the thermal joint compound
6		Inverter	Various Electrical Components	Not stated	Not stated	Not stated	No aging effects noted for 12 year old equipment
7		Battery	Various Electrical Components	Not stated	Not stated	Not stated	No aging effects noted for 12 year old equipment

Document: NUREG/CR-5280 V1, Age-Related Degradation of Westinghouse 480-Volt Circuit Breakers
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		DS-206/DS-416 Circuit Breakers	Power Operated Mechanisms	Spring steel	Westinghouse	WEAR, LOSLUB, CORR/UA	Wear out, loss of material, friction, & corr product buildup
2		DS-206/DS-416 Circuit Breakers	Contacts	Contacts mounted on high strenght insulating base and steel arm	Westinghouse	WEAR, CURSTR, & CORR/UA	Wear from operation, pitting, & erosion from arcs
3		DS-206/DS-416 Circuit Breakers	Arc Chutes	Steel and arc resisting plastic plates	Westinghouse	WEAR, & CURSTR	Erosion & burned splitter plates
4		DS-206/DS-416 Circuit Breakers	Amptector Trip Unit (Electronic Components)	Not stated	Westinghouse	VIB, CURSTR, & VOLSTR	Loose parts, component burn out or degraded operation
5		DS-206/DS-416 Circuit Breakers	Current Magnitude and Direction Sensors	Current transformers	Westinghouse	CURSTR, & VOLSTR	Dielectric properties degraded from electrical stresses
6		DS-206/DS-416 Circuit Breakers	Optional Accessories	Electro-mechanical devices, switch, and solid state device	Westinghouse	VIB, CURSTR, & VOLSTR	Not stated
7		DS-206/DS-416 Circuit Breakers	Electrical and Mechanical Components in General	Not stated	Westinghouse	VIB, CURSTR, VOLSTR, LOSLUB, & WEAR	Coil burnings, binding of linkage, wear, overheating, & dust

Document: NUREG/CR-5280 V2, Age-Related Degradation of Westinghouse 480-Volt Circuit Breakers (Mechanical Cycling)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		DS-416 Breaker/480 V	Structural Components	Steel	Westinghouse	VIB & CORR	Vibration will loosen parts, corrosion degrades metals
2		DS-416 Breaker/480 V	Contact Assembly	Insulating material and stainless steel	Westinghouse	WEAR & CURSTR	Wear & loss of material from arcing.

Document: NUREG/CR-5192, Testing of A Naturally Aged Nuclear Power Plant Inverter and Battery Charger
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Distortion of signals to SCRs may result in improper putput.	Not stated	Not discussed in report	Vendor specific, Tech. Spec., IEEE 446, NEMA	Not stated	3-23	3
Not stated	Not stated	Not discussed in report	Vendor specific, Tech. Spec., IEEE 446, NEMA	Not stated	3-23	4
Over heating of SCRs may result in SCR failure and loss of output.	Not stated	Not discussed in report	Vendor specific, Tech. Spec., IEEE 446, NEMA	Not stated	4-1	5
None	Not stated	Not discussed in report	Vendor specific, Tech. Spec., IEEE 446, NEMA	Not stated	4-3	6
None.	Not stated	Not discussed in report	Vendor specific progarm, Tech. Spec. Surveil.	Not stated	3-1, 4-1, & 4-3	7

Document: NUREG/CR-5280 V1, Age-Related Degradation of Westinghouse 480-Volt Circuit Breakers
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Excessive force or rubbing causes distortion & wear out, rust on pivotal parts & trip gears can cause hang up, hardened or improper lubricants or lubricant application can cause sluggish operation.	Occasional	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Twelve recommendations given relating to three separate issues covering reliability, pole shaft welds, and maintenance. [2]	2-7, 6-2, & 7-4	1
Contacts wear from repeated operations, arcing causes pitting, contacts become mottled, dirty, and eroded due to arc burning. Contacts over heat from resistance due to weak springs.	Occasional	Maintenance per owner's group MPM WORGTSDS416	Vendor specific , IEEE 741-1986 Section 7	Filing or dressing with abrasive cloth is not recommended [2]	2-9, 6-2, & 7-6	2
Slots in arc chute gradually erode with arc interruptions, fault currents cause heavy erosion, and throat of the arc chute enclosure becomes burned and coated with soot from arc interruptions.	Frequent	Maintenance per owner's group MPM WORGTSDS416	Vendor specific , IEEE 741-1986 Section 7	Life of the DS-16 breaker should be 5000 cycles or 20 years. [2]	2-9, 6-3, & 7-6	3
Vibration may loosen parts, voltage and current stress may cause part burn out or insulation damage. Electrical stress reduces dielectric properties	Occasional	Maintenance per owner's group MPM WORGTSDS416	Vendor specific , IEEE 741-1986 Section 7	Life of the DS-16 breaker should be 5000 cycles or 20 years. [2]	2-9, 6-3, & 7-6	4
Not stated	Not stated	Maintenance per owner's group MPM WORGTSDS416	Vendor specific , IEEE 741-1986 Section 7	Not stated	2-12	5
Not stated	Not stated	Maintenance per owner's group MPM WORGTSDS416	Vendor specific , IEEE 741-1986 Section 7	Not stated	2-12 & 2-13	6
Most breaker problems result from control problems involving contacts, coil burnings, and trip device bindings, followed by operating mechanism problems. Loss of lubrication, erosion of contacts, burning of arc chutes, & loss of adjustment are from aging	Occasional	Owner's group recommended maintenance	Vendor specific , IEEE 741-1986 Section 7	Twelve recommendations given related to reliability, weld failures, and maintenance [2]	2-1, 7-1, & 7-4.	7

Document: NUREG/CR-5280 V2, Age-Related Degradation of Westinghouse 480-Volt Circuit Breakers (Mechanical Cycling)
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to operate	Rare	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Not stated	3-2 & 6-2	1
Unreliable contact	Not stated	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Not stated	3-2 & 6-2	2

Document: NUREG/CR-5280 V2, Age-Related Degradation of Westinghouse 480-Volt Circuit Breakers (Mechanical Cycling)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3		DS-416 Breaker/480 V	Power Operated Mechanism	Steel	Westinghouse	WEAR, FAT, & EX FORCE	Wear, fracture, and distortion.
4		DS-416 Breaker/480 V	Pole Shaft	Steel	Westinghouse	FAT, & EX FORCE	Cracking, misalignment, & binding due to poor welds
5		DS-416 Breaker/480 V	Charging System (Rachet, Motor, Brushes, Oscillator., Spring)	Steel, carbon brush in motor, insulation varnish on motor windings	Westinghouse	WEAR, FAT, & CURSTR	Wear on moving parts & electric motor burn out
6		DS-416 Breaker/480 V	Electrical Coils (UVTA, STA, AND Closing Coil)	Not stated	Westinghouse	CURSTR	Extended duration of current flow caused burn out
7		DS-416 Breaker/480 V	Sensors, Amptector Trip Unit, & Arc Chutes	Not stated	Westinghouse	Not stated	Extended energization of coils.

Document: NUREG/CR-5334, Severe Accident Testing of Electrical Penetration Assemblies
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		D. G. O'Brien Electrical Penetration	SEALS	Silicon O-ring	D. G. O'Brien	ELETEMP, MOIST-EL, AND RAD	Seal cracks and moisture intrusion.
2		D. G. O'Brien Electrical Penetration	Electrical Components (Wire, Insulation, and Connectors)	Not stated	Not stated	ELETEMP, MOIST-EL, AND RAD	Moisture or contaminants caused electrical shorts to ground
3		Westinghouse Electrical Penetration	Seals	Silcion O-ring	Westinghouse	ELETEMP, MOIST-EL, AND RAD	Seal cracks and moisture intrusion
4		Westinghouse Electrical Penetration	Electrical Components (Wire, Insulation, and Connectors)	Not stated	Westinghouse	ELETEMP, MOIST-EL, AND RAD	Insulation degradation
5		CONAX Electrical Penetration	Seals	Viton O-rings	Conax	ELETEMP, MOIST-EL, AND RAD	Seal cracks and moisture intrusion
6		CONAX Electrical Penetration	Electrical Components (Wire, Insulation, and Connectors)	Not stated	Conax	THERM, MOIST-EL, AND RAD	Embrittlement and cracking

Document: NUREG/CR-5383, Effect of Aging on Response Time of Nuclear Plant Pressure Sensors
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Pressure Transmitter	Diaphragm	Not stated	Not stated	VIBR FAT PRESS	Deformation, cracking, and hysteresis of diaphragm
2		Pressure Transmitter	Mechanical Linkages	Not stated	Not stated	PRESS CORR CORR/OX	Changes in system restoration ability
3		Pressure Transmitter Electronics	Seals	Not stated	Not stated	EMBR	Moisture on electronics

Document: NUREG/CR-5280 V2, Age-Related Degradation of Westinghouse 480-Volt Circuit Breakers (Mechanical Cycling)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Aging degradation in parts between the motor and the poles redistributes the force transmitted from the charging motor causing large unbalanced stresses in subcomponents & wear	Occasional	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Monthly inspection and every 50 to 100 cycles inspect parts vulnerable to aging, maintenance & lubrication at 250 cycles [2]	6-2 & 6-5	3
Once cracks grow to a quarter the size of an effective weld the five levers connecting the pole contacts become misaligned and caused excesssive movement leading to fracture, binding and other problems.	Not stated	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Monthly inspection and every 50 to 100 cycles inspect parts vulnerable to aging, maintenance & lubrication at 250 cycles [2]	6-2 & 6-5	4
Wear of ratchet wheel, holding pauls, motor crank, and handle dominated the aging of the charging system. Carbon brushes needed frequent maintenance.	Not stated	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Assure design adequacy by inspection, enhanced inspections and maintenance & install cycle counter. [2]	6-2, 6-4	5
Sluggish operation, binding, failure to operate,	Freq when mechanism binding	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Assure design adequacy by inspection, enhanced inspections and maintenance & install cycle counter. [2]	4-18	6
Not stated	Not stated	Not discussed in report	Vendor specific , IEEE 741-1986 Section 7	Not stated	3-2	7

Document: NUREG/CR-5334, Severe Accident Testing of Electrical Penetration Assemblies
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Cracks in the seals from high temperature and radiation allows moisture to leak into penetration resulting in electrical faults.	Rare	IEEE 317-1976 AND IEEE 323-1974 DESIGN STD	10 CFR 50.49, vendor specific	Each design should be tested. The leak potential is highly dependent on the temperatures to which the EPA is subject. [2]	4-1, 4-16, and 7-1	1
Short to ground and electrical faults due to moisture intrusion.	Not stated	IEEE 317-1976 AND IEEE 323-1974 DESIGN STD	10 CFR 50.49, vendor specific	Not stated	C-1, 4-16, and 7-1	2
Seal cracks allow moisture intrusion into penetration resulting in electrical faults.	Rare	IEEE 317-1976 AND IEEE 323-1974 DESIGN STD	10 CFR 50.49, vendor specific	Each design should be tested. The leak potential is highly dependent on the temperatures to which the EPA is subject. [2]	1-3, 5-1, 5-15, and 7-1	3
Decreased insulation resistance results in excessive leakage currents.	Rare	IEEE 317-1976 AND IEEE 323-1974 DESIGN STD	10 CFR 50.49, vendor specific	Not stated	4-1, 4-16, and 7-1	4
Seal cracks allow moisture intrusion resulting in electrical faults.	Rare	IEEE 317-1976 AND IEEE 323-1974 DESIGN STD	10 CFR 50.49, vendor specific	Each design should be tested. The leak potential is highly dependent on the temperatures to which the EPA is subject. [2]	6-1, 6-13, and 7-1	5
Electrical faults due to moisture intrusion through connectors.	Occasional	IEEE 317-1976 AND IEEE 323-1974 DESIGN STD	10 CFR 50.49, vendor specific	Look at types of cables and connectors rather than penetration design to improve future electrical penetrations. [2]	6-1, 6-13, and 7-1	6

Document: NUREG/CR-5383, Effect of Aging on Response Time of Nuclear Plant Pressure Sensors
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Response time degradation for pressure transmitter	Not stated	RG 1.118, IEEE 338, & ISA Standard 67.06	RG 1.118, IEEE 338, Tech Spec surveillance	Revise RG and standards to take into account recent advances in testing technology and other available information. [2]	23, 115	1
Response time degradation for pressure transmitter	Not stated	RG 1.118, IEEE 338, & ISA Standard 67.06	RG 1.118, IEEE 338, Tech Spec surveillance	Revise RG and standards to take into account recent advances in testing technology and other available information. [2]	23, 115	2
Response time degradation for pressure transmitter	Not stated	RG 1.118, IEEE 338, & ISA Standard 67.06	RG 1.118, IEEE 338, 10 CFR 50.49, Tech Specs	Revise RG and standards to take into account recent advances in testing technology and other available information. [2]	23, 115	3

Document: NUREG/CR-5383, Effect of Aging on Response Time of Nuclear Plant Pressure Sensors
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4		Pressure Transmitter Electronics	Electronic Components	Not stated	Not stated	ELETEMP RAD MOIST-EL	Changes in value of electronic components

Document: NUREG/CR-5448, AGING EVALUATION OF CLASS 1E BATTERIES: SEISMIC TESTING
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1			Batteries	Not stated	Not stated	SEISMIC	Plate movement or breakup

Document: NUREG/CR-5461, Aging of Cables, Connections, and Electrical Penetration Assemblies Used in Nuclear Power Plants
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Cable	Insulation	EPR, CSPE, EPDM, XLPE, silicon rubber, butyl rubber, polyethylene, and 13 others used less often	Ten manufactures listed	MOIST-EL, ELETEMP, AND RAD	Insulation degradation, short and open circuits
2		Cable	Jacket	Neoprene, hypalon, XLPO, CSPE, & CPE,	Ten manufactures listed	MOIST-EL, ELETEMP, AND RAD	Jacket degradation, cracks, and discoloration
3		Connections	Terminal Blocks	Phenolic with glass or cellulose filler with metal terminals	Seven listed	ELETEMP, RAD, & VIB	Loose connections, cracks and short circuits
4		Connections	Splices	Crimp type ring lugs, copper conductor, nylon or kynar insulation, and Raychem heat shrink tubing	Raychem	ELETEMP, VIB, AND RAD	Loose connections and loss of dielectric isolation
5		Connections	Coax Connectors	Metal with organic insulation such as teflon	Not stated	ELETEMP AND RAD	Insulation degradation
6		Electrical Penetrations	Seal Material	Steel tubes, seal materials are polysulfone, metal-glass, and epoxy	Conax, O'Brien, and Westinghouse	ELTEMP & RAD	Seal leaks and cracking
7		Electrical Penetrations	Electrical Wire or Cable	Insulations (XLPE, EPR, EPDM & Polymide) and jacket(CSPE, SPE, Hypalon, FR, and fiberglass)	Ten manufacturers listed	ELETEMP AND RAD	Change in dieletric properties, embrittlement, and cracking

Document: NUREG/CR-5546, An Investigation of The Effects of Thermal Aging on the Fire Damageability of Electric Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electrical Cables	Insulation	XPE, and interstitial material (Nylon & paper)	Rockbestos	ELETEMP	Not stated
2		Electrical Cables	Jacket	Neoprene	Rockbestos	ELETEMP	Embrittlement and cracking
3		Electrical Cables	Insulation	EPR, and interstitial material (Nylon & paper)	Boston Insulated Wire	ELETEMP	Not stated
4		Electrical Cables	Jacket	Hypalon	Boston Insulated Wire	ELETEMP	Embrittlement, dielectric loss and forms cracks

Document: NUREG/CR-5383, Effect of Aging on Response Time of Nuclear Plant Pressure Sensors
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Response time degradation for pressure transmitter	Not stated	RG 1.118, IEEE 338, & ISA Standard 67.06	RG 1.118, IEEE 338, Tech Spec surveillance	Revise RG and standards to take into account recent advances in testing technology and other available information. [2]	23, 115	4

Document: NUREG/CR-5448, AGING EVALUATION OF CLASS 1E BATTERIES: SEISMIC TESTING
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
No effect on bat capability if maintained to IEEE Std 450, RG 1.1.29 and MFG recommendations	Not stated	IEEE STD 450, RG 1.129, & Mfg recommendations	RG 1.129, IEEE 450-1987, Tech Spec Surveil.	Batteries not maintained per IEEE 450, RG1.129, & MFG rec. need adv.monitoring tech. to determine seismic capability. [2]	35	1

Document: NUREG/CR-5461, Aging of Cables, Connections, and Electrical Penetration Assemblies Used in Nuclear Power Plants
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Thermal and radiation effects cause insulation degradation leading to cracking which allows moisture to intrude and then shorts or current leakage results. Jacket/insulation interaction effect was also noted.	Not stated	EQDB, IEEE 323-1974 & IEEE 383-1974 testing	No specific program	Not stated	8, 24, & 40	1
Thermal and radiation effects cause jacket material degradation leading to cracking which allows moisture to intrude into the insulation, jacket/insulation interaction effect was also noted in the sandia report.	Not stated	EQDB, IEEE 323-1974 & IEEE 383-1974 testing	No specific program	Not stated	8, 24, & 40	2
Loss of dielectric isolation or loose connections to disrupt a circuit, leakage paths through moisture films, and insulation resistance decrease in presents of steam.	Not stated	Not discussed in report	Plant specific programs	Not stated	11, 27, & 41	3
Insulaton vulnerable to aging, loss of dielectric isolation sufficient to disrupt a circuit, or loose connections	Not stated	Not discussed in report	10 CFR 50.49	Not stated	11, 27, & 42	4
Decreased insulation resistance results in excesive leakage current.	Not stated	Not discussed in report	Plant specific programs	Not stated	27	5
Seal cracks and leaks result in moisture intrusion and electrical faults.	Not stated	Not discussed in report	10 CFR 50.49, vendor specific program	Not stated	14, 28, & 42	6
Insulation degradation and jacket cracking leading to short or open circuits and degraded signals.	Not stated	Not discussed in report	10 CFR 50.49, vendor specific program	Not stated	14, 28, & 42	7

Document: NUREG/CR-5546, An Investigation of The Effects of Thermal Aging on the Fire Damageability of Electric Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
None	Not stated	Not discussed in report	No specific program	Not stated	10, 13, and 32	1
Failure to protect conductors and insulation.	Not stated	Not discussed in report	No specific program	Not stated	21, 24, and 32	2
Reduced the thermal damage threshold.	Not stated	Not discussed in report	No specific program	Not stated	21, 24, and 32	3
Reduced thermal damage threshold.	Not stated	Not discussed in report	No specific program	Not stated	21, 24, and 32	4

Document: NUREG/CR-5560, Aging of Nuclear Plant Resistance Temperature Detectors
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Resistance Temperature Detector (RTD)	Seal	Not stated	Five Companies Listed	ELETEMP, MOIST-EL, VIB, & THERM-CY	Dry out, shrink, & crack
2		Resistance Temperature Detector (RTD)	Insulation	MgO	Five Companies Listed	MOIST-EL	Moisture degrades insulation
3		Resistance Temperature Detector (RTD)	Sensing Element	Platinum	Five Companies Listed	ELETEMP, MOIST-EL, VIB, & THERM-CY	Noisy, cal shift, & degraded element
4		Resistance Temperature Detector (RTD)	Sheath	Stainless steel	Five Companies Listed	ELETEMP, VIB, & THERM-CY	Not stated

Document: NUREG/CR-5619, The Impact of Thermal Aging on the Flammability of Electric Cables
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1			Electric Cables	Neoprene jacket, cross-linked polyethylene (XPE) insulated	Rockbestos	ELETEMP	Not stated
2			Electric Cables	Hypalon jacket, ethylene-propylene rubber (EPR) insulated	Boston Insulated Wire	ELETEMP	Not stated

Document: NUREG/CR-5643, Insights Gained From Aging Research
Reviewed by: Jerry Edson, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electrical Components					

Document: NUREG/CR-5655, Submergence and High Temperature Steam Testing of Class 1E Electrical Cables
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1			Electrical Cable	EPR, XLPO, silicone, kapton, kerite, coaxial	12 Mfg	ELETEMP RAD MOIST-EL	Insulation failure
2			Electrical Cable	EPR, XLPO, silicone, kapton, kerite, coaxial	12 Mfg	ELETEMP RAD MOIST-EL	Some insulation failure
3			Electrical Cable	EPR, XLPO, silicone, kapton, kerite, coaxial	12 Mfg	ELETEMP RAD MOIST-EL	Some insulation failure

Document: NUREG/CR-5700, Aging Assessment of Reactor Instrumentation and Protection System Components
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Instrumentation System	Indicator	Not stated	Not stated	ELETEMP VIBR	Indicator failure

Document: NUREG/CR-5560, Aging of Nuclear Plant Resistance Temperature Detectors
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Seal may dry out, shrink, or crack allowing moisure intrusion and degraded performance of RTD.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	25, & 27	1
Moisure intrusion from a leaking seal will degrade the insulation.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	28	2
Long term high temp exposure affects material properties, vibration may cause response time degradation, and therm-cy can cause calibration shift.	Occasional	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Calibrate RTDs and perform response time tests prior to installation in a plant. [2]	28, 167, 180, and A8	3
Sheath not normally effected by aging during qualified life of RTD.	Rare	Not discussed in report	IEEE 338-1987, RG 1.118, ISA 67.06, Tech Spec	Not stated	15, 25 & 27	4

Document: NUREG/CR-5619, The Impact of Thermal Aging on the Flammability of Electric Cables
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Reduction in flammability	Not stated	Not discussed in report	No specific program	No further investigation needed	21	1
Reduction in flammability	Not stated	Not discussed in report ·	No specific program	No further investigation needed	21	2

Document: NUREG/CR-5643, Insights Gained From Aging Research
Reviewed by: Jerry Edson, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
For electrical components, this report contains information identical to that in other NPAR reports. See the following NUREG/CR reports: 4457, 5448, 4564, 5051, 5192, 5461, 5655, 4156, 4939, 4234 v1 & v2, 5141, 4819 v1 & v2, 5181, 4747 v1, 4967, 4740	Not stated	Not discussed in report	Component specific programs	Not stated		1

Document: NUREG/CR-5655, Submergence and High Temperature Steam Testing of Class 1E Electrical Cables
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	IEEE 383	No specific program	Not stated	2, 35	1
Not stated	Not stated	IEEE 383	No specific program	Not stated	2, 35	2
Not stated	Not stated	IEEE 383	No specific program	Not stated	2, 35	3

Document: NUREG/CR-5700, Aging Assessment of Reactor Instrumentation and Protection System Components
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Frequent	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Develop methods to prevent infant mortality. Testing for synergistic effects of aging. Develop industry wide data base [2]	11 ,24 ,38 ,65	1

Document: NUREG/CR-5700, Aging Assessment of Reactor Instrumentation and Protection System Components
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2		Instrumentation System	Sensor	Not stated	Not stated	ELETEMP VIBR PRESS-CY MOIST-EL	Sensor failure, response time degradation, drift
3		Instrumentation System	Controller	Not stated	Not stated	ELETEMP VIBR MOIST-EL	Failure, response time degradation, drift
4		Instrumentation System	Controller	Not stated	Not stated	ELETEMP VIBR MOIST-EL	Calibration shift slow responce time
5		Instrumentation System	Annunciators	Not stated	Not stated	ELETEMP VIBR MOIST-EL	Visual unit failure sound alarm failure
6		Instrumentation System	Recorders	Not stated	Not stated	ELETEMP VIBR MOIST-EL	Failure to record

Document: NUREG/CR-5762, Comprehensive Aging Assessment of Circuit Breakers and Relays
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1			Protective Relay - 10, 13, & 24 Years Old(GE)	Not stated	General Electric	Not stated	Oxidation on contacts, increased operating temperatures
2			Control Relay	Not stated	Klockner Moeller	Not stated	None
3			Control Relay - 2 & 12 Years Old	Not stated	Struthers Dunn	Not stated	Slight discoloration of armature and contact conn. fingers
4			Control Relay	Not stated	Westinghouse	Not stated	None
5			Electronic Relay	Not stated	Blaser Electric	Not stated	Not stated
6			Auxilliary Relay	Not stated	General Electric	Not stated	Worn contacts and dust inside case
7			Auxilliary Relay	Not stated	Westinghouse	Not stated	Contact worn, discolored and pitted with age
8			Timing Relay	Not stated	Agastat	Not stated	Increased pickup voltage and op. temp. with age
9			Molded Case Circuit Breakers	Not stated	Square D	Not stated	None - 6 year old
10			Molded Case Circuit Breakers	Not stated	Westinghouse	Not stated	None - 18 & 30 year old
11			Molded Case Circuit Breakers	Not stated	Klockner Moeller	Not stated	Overheating (discoloration) of case & spliting of tubing
12			Molded Case Circuit Breakers	Not stated	ITE	Not stated	Overheating/distoration/damage to thermal element & trip mec

Document: NUREG/CR-5700, Aging Assessment of Reactor Instrumentation and Protection System Components
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Develop methods to prevent infant mortality. Testing for synergistic effects of aging. Develop industry wide data base [2]	11, 13, 26 ,41 ,65	2
Not stated	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06	Develop methods to prevent infant mortality. Testing for synergistic effects of aging. Develop industry wide data base [2]	11, 13, 26 ,43 ,65	3
Not stated	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Develop methods to prevent infant mortality. Testing for synergistic effects of aging. Develop industry wide data base [2]	11, 13, 26 ,47 ,65	4
Not stated	Frequent	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06	Develop methods to prevent infant mortality. Testing for synergistic effects of aging. Develop industry wide data base [2]	11, 13, 26 ,48 ,65	5
Not stated	Occasional	Not discussed in report	RG 1.118, IEEE 338-1987, ISA 67.06, Tech Spec	Develop methods to prevent infant mortality. Testing for synergistic effects of aging. Develop industry wide data base [2]	11, 13, 26 ,48 ,65	6

Document: NUREG/CR-5762, Comprehensive Aging Assessment of Circuit Breakers and Relays
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Higher contact resistance, differences in induction pickup, significant variation in time/current charateristic.	Frequent	Yes - not specifically identified	IEEE 741-1986 Section 7	Modify current practices to include the addition of infrared temperature measurement with cover off and relay energized. [2]	3-1 & 7-3	1
None	NONE	Yes - not specifically identified	IEEE 741-1986 Section 7	Modify current practices to include the addition of infrared temperature and vibration measurements. [2]	3-18 & 7-3	2
Contact resistance increased with age	Rare	Yes - not specifically identified	IEEE 741-1986 Section 7	Modify current practices to include the addition of infrared temperature and vibration measurements. [2]	3-18 & 7-3	3
None	Not stated	Yes - not specifically identified	IEEE 741-1986 Section 7	Modify current practices to include the addition of infrared temperature and vibration measurements. [2]	3-18 & 7-3	4
Not stated	Not stated	Yes - not specifically identified	IEEE 741-1986 Section 7	Not stated	3-32 & 7-3	5
Pickup voltage exceeded acceptance criteria	Not stated	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. [2]	3-36 & 7-3	6
Increased contact resistance	Not stated	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. [2]	3-36 & 7-3	7
Timing accuracy not within typical required accuracy	Not stated	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement, inrush current and vibration testing to current plant practices. [2]	3-52 & 7-3	8
None	Not stated	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. modify instantaneous trip test. [2]	3-65 & 7-3	9
Exceeded typical accept. criteria for instantaneous trip (125%) time.	Rare	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. modify instantaneous trip test. [2]	3-65 & 7-3	10
300% overcurrent trip delay exceeded acceptance criteria. Damaged/misaligigned trip pin caused overheating and failure to perform instantaneous trip when required.	Occasional	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. modify instantaneous trip test. [2]	3-65 & 7-3	11
Instantaeous trip inoperable/out of tolerance on 2 phases. 300% overcurrent trip does not meet acceptance ctiteria.	Frequent	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. modify instantaneous trip test. [2]	3-65 & 7-3	12

Document: NUREG/CR-5762, Comprehensive Aging Assessment of Circuit Breakers and Relays
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13			Metal Clad Circuit Breakers	Not stated	Westinghouse	Not stated	Main/arcing contacts pitted, insulation, split, damaged parts
14			Metal Clad Circuit Breakers		General Electric	Not stated	Back connections oxidized. binding of dashpot

Document: NUREG/CR-5772 V1, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - insulation resistance (IR)
2		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - capacitance & diss. factor
3		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - polarization index
4		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - elongation & tens. strength
5		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - hardness
6		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - indenter modulus
7		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - bulk density
8		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - mandrel bend test
9		600 V, Single Conductor Cables	Insulation	Cross linked polyethylene and cross linked polyolefin	Four Suppliers Listed	MOIST-EL	Moisture absorbed into a cable acts as a plasticizer
10		600 V, Single Conductor Cables	Jacket	Neoprene, chlorosulfonated polyethylene (CSPE), & CPE	Four Suppliers Listed	ELETEMP, RAD, & OXIDAT	Jacket - elongation & tensil strength
11		600 V, Single Conductor Cables	Jacket	Neoprene, chlorosulfonated polyethylene (CSPE), & CPE	Four Suppliers Listed	ELETEMP, RAD, & OXIDAT	Jacket - hardness and indenter modulus

Document: NUREG/CR-5772 V2, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		600 V I&C Cables	Single and Multiconductor Cable Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - insulation resistance (IR)
2		600 V I&C Cables	Single and Multiconductor Cable Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - polarizaton index

Document: NUREG/CR-5762, Comprehensive Aging Assessment of Circuit Breakers and Relays
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Long time delay varied between 110% and 150% of setting	Rare	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. modify instantaneous trip test. [2]	3-89 & 7-3	13
One phase failed to trip on long time delay overcurrent. Short timedelay overcurrent trip not within acceptance criteria.	Frequent	Yes - not specifically identified	IEEE 741-1986 Section 7	Add infrared temperature measurement and vibration testing to current plant practices. modify instantaneous trip test. [2]	3-89 & 7-3	14

Document: NUREG/CR-5772 V1, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	6, 27, 40, and App C	1
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	6, 28, & App D.	2
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	6, 28, and App C	3
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	6, 30-33, 39, and App E.	4
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	6, 34, 56, and App F.	5
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	33, 38, & 39	6
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	35 & 56	7
Not determined since report only addressed detection methods	Not stated	Testing per IEEE 383-1974	No specific program	Not stated	47 TO 54, & 57.	8
Not determined since report only addressed detection methods	Not stated	Testing per IEEE 383-1974	No specific program	Not stated	54 & 57	9
Not determined since report only addressed detection methods	Not stated	Testing per IEEE 383-1974	No specific program	Not stated	33, 39, & 56	10
Not determined since report only addressed detection methods	Not stated	Not discussed in report	No specific program	Not stated	39 & 56	11

Document: NUREG/CR-5772 V2, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	31, 32, 52 TO 58, 73, 74, & Appendix I	1
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	The electrical measurements were not effective for monitoring aging	13, 32, 46, & 73	2

Document: NUREG/CR-5772 V2, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3		600 V I&C Cables	Single and Multiconductor Cable Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Aging effects on capacitance and dissipation factor
4		600 V I&C Cables	Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - elongation & tens. strength
5		600 V I&C Cables	Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - hardness
6		600 V I&C Cables	Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - indenter modulus
7		600 V I&C Cables	Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - bulk density
8		600 V I&C Cables	Insulation	Ethylene propylene	Five Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - cracking
9		600 V I&C Cables	Insulation	Ethylene propylene	Five Suppliers Listed	MOIST-EL	Moisture absorbed into a cable acts as a plasticizer
10		600 V I&C Cables	Jacket	CSPE and CPE	Five Suppliers Listed	ELETEMP, RAD, & OXIDAT	Jacket - elongation & tensil strength
11		600 V I&C Cables	Jacket	CSPE, & CPE	Five Suppliers Listed	ELETEMP, RAD, & OXIDAT	Jacket - hardness and indenter modulus

Document: NUREG/CR-5772 V3, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - insulation resistance (IR)
2		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - capacitance & diss. factor
3		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in electrical property - polarization index
4		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - elongation & tens. strength
5		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - hardness
6		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - indenter modulus
7		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - bulk density
8		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	ELETEMP, RAD, AND OXIDAT	Changes in mechanical property - brittleness
9		Miscellaneous Cable Types	Insulation	FR insulation, coax, silicon rubber, & polymide (Kapton)	Three Suppliers Listed	MOIST-EL	Moisture absorbed decreases insulation resistance
10		Miscellaneous Cable Types	Jacket	FR & fiberglass braided	Three Suppliers Listed	ELETEMP, RAD, & OXIDAT	Jacket - elongation & tensil strength
11		Miscellaneous Cable Types	Jacket	FR & fiberglass braided	Three Suppliers Listed	ELETEMP, RAD, & OXIDAT	Jacket - hardness and indenter modulus

Document: NUREG/CR-5772 V2, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	33, 36, & 46	3
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	36 TO 41, & 46	4
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	43, 46, and Appendix F	5
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	The Franklin indenter is recommended because it is a good indicator of aging for jacket and EPR materials. [4]	17, 42, & 46	6
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	43, 46, & Appendix F	7
Not determined since report only addressed detection methods.	Not stated	Testing per IEEE 383-1974	No specific program	Follow IEEE 383-1974 requirements. [4]	66, 74, & 75	8
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	58 & 74	9
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	73 & 75	10
Not determined since report only addressed detection methods.	Not stated	Not discussed in report	No specific program	Not stated	46 & 73	11

Document: NUREG/CR-5772 V3, Aging, Condition Monitoring, and Loss-of-Coolant Accident (LOCA) Tests of Class 1E Electrical Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	30, 38, 40, & 51	1
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	32, 38, & Appendix D	2
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	31, 38, & Appendix C.	3
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	34, 35, & Appendix E	4
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	36 & Appendix G	5
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	The indenter is a good indicator of aging for silicon rubber and Kerite jacket materials, but not for coax jackets [4]	36, & Appendix F	6
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	36 & Appendix G	7
Not determined since report only addressed detector methods.	Not stated	Testing per IEEE 383-1974	No specific program	IEEE 383-1974 requirements. [4]	45 TO 48, & 52.	8
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	52	9
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	6, 13, & 35	10
Not determined since report only addressed detector methods.	Not stated	Not discussed in report	No specific program	Not stated	16 & 36	11

Document: NUREG/CR-6095, Aging, Loss-of-Coolant Accident (LOCA), and High Potential Testing of Damaged Cables
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		#12 AWG, 1C, Cables	Insulation	Ethylene propylene	Okonite	RAD, ELTEMP, & MOIST-EL, & VOLTSTR	Cracks, degraded insulation resistance for damaged cable
2		#12 AWG, 1C, Cables	Jacket	Chlorosulfonated polyethylene (CSPE)	Okonite	RAD, ELTEMP, & MOIST-EL, & VOLTSTR	Cracks
3		#12 AWG, 1C, Cables	Insulation	Silicon rubber	Rockbestos	RAD, ELTEMP, & MOIST-EL, & VOLTSTR	Fragile & cracks
4		#12 AWG, 1C, Cables	Jacket	Figerglass braid	Rockbestos	RAD, ELTEMP, & MOIST-EL, & VOLTSTR	Not stated
5		#12 AWG, 1C, Cables	Insulation	Cross linked polyethylene with no jacket	Brand Rex	RAD, ELTEMP, & MOIST-EL, & VOLTSTR	Voltage breakdown and moisture and high temp degradation

Document: SAND--88-0754, Time-Temperature-Dose Rate Superpositions: A Methodology for Predicting Cable Degradation Under Ambient Nuclear Power Plar
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electrical Cable	Jacket	Neoprene	Not stated	THERM & RAD	Drop in elongation
2		Electrical Cable	Jacket	Hypalon	Not stated	THERM & RAD	Drop in elongation
3		Electrical Cable	Jacket	PVC	Not stated	THERM & RAD	Elongation reduced from initial value
4		Electrical Cable	Insulation	Low density polyethylene	Not stated	THERM & RAD	Embrittlement & discoloration
5		Electrical Cable	Insulation	Chemically Cross linked polyethylene	Not stated	THERM & RAD	Elongation decrease

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electrical Switchgear	Metal Housing System	Not stated	GE, Westinghouse, ITE/BB	FAT, MECHSTR	Cracked welds, deformation of circuit breaker rails
2		Electrical Switchgear	Metal Housing System	Not stated	GE, Westinghouse, ITE/BB	CONTAM, CORR	Rust, pitting, and corr of structural members and fasteners
3		Electrical Switchgear	Primary Insulating System	Not stated	GE, Westinghouse, ITE/BB	EMBR	Insulation failure
4		Electrical Switchgear	Primary Insulating System	Not stated	GE, Westinghouse, ITE/BB	CONTAM, EMBR	Decrease in surface resistance
5		Electrical Switchgear	Primary Insulating System	Not stated	GE, Westinghouse, ITE/BB	ELETEMP, CONTAM, EMBR	Decrease in volumetric and surface resistance
6		Electrical Switchgear	Horizontal Racking Mechanism	Not stated	GE, Westinghouse, ITE/BB	WEAR	Binding of drawout unit
7		Electrical Switchgear	Vertical Racking Mechanism	Not stated	GE, Westinghouse, ITE/BB	WEAR	Lifting motor failure

Document: NUREG/CR-6095, Aging, Loss-of-Coolant Accident (LOCA), and High Potential Testing of Damaged Cables
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Longitudinal cracks were through to conductor and adjacent to damaged area, insulaton resistance degrades until failure occurs.	Occasional	Not discussed in report	No specific program	Not stated	4, 5, 10, & 18	1
Jacket cracking can propagate to the insulation	OCASSIONAL	Not discussed in report	No specific program	Not stated	4, 5, 10, & 18	2
Some cables showed degradation during accident tests, on one cable a crack was found adjacent to the damaged area.	Rare	Not discussed in report	No specific program	Not stated	4 & 16	3
Not stated	Rare	Not discussed in report	No specific program	Not stated	4 & 16	4
No high potential effects found when insulation remaining was 7 mills, no cracks developed from aging. Failure of cables during LOCA testing were at damaged locations	Rare	Not discussed in report	No specific program	Not stated	4	5

Document: SAND--88-0754, Time-Temperature-Dose Rate Superpositions: A Methodology for Predicting Cable Degradation Under Ambient Nuclear Power Plant A
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Jacket failed to provide protection from moisture.	Rare	Not discussed in report	No current programs	Not stated	28 to 34	1
Jacket failed to provide protection from moisture.	Rare	Not discussed in report	No current programs	Not stated	34 to 38	2
Jacket failed to provide protection from moisture.	Occasional	Not discussed in report	No current programs	Not stated	43	3
Embrittlement causes cracking and allows moisture intrusion resulting in failure to accurately transmit voltage or current.	Frequent (for 1960 cable)	Not discussed in report	No current programs	Not stated	44	4
Embrittlement causes cracking and allows moisture intrusion resulting in failure to accurately transmit voltage or current.	Rare	Not discussed in report	No current programs	Not stated	12 & 54	5

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Structural degradation caused by material fatigue can lead to the loss of structural integrity.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-7	1
Contaminants and moisture can cause corrosion/rust of the metal housing system, resulting in a loss of structural integrity.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-7	2
Insulation deterioration results from ambient temperatures with ohmic heating and can result in a loss of insulating properties and flashover of insulation.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-7	3
Normal voltage in combination with humidity, dirt, and contaminants can lead to surface current tracking which can result in insulation failure and flashover	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-7	4
Normal voltage in combination with thermal deterioration, humidity, dirt, and contaminants can lead to a decrease in volumetric and surface resistance which can result in bus insulation failure and flashover.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-7	5
Wear from many racking cycles can lead to a binding of the drawout unit which can result in the inability to connect the breaker for operation.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-7	6
Wear from many racking cycles can lead to a lifting motor failure which can result in the breaker not being able to be connected for operation.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-8	7

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
8		Electrical Switchgear	Arcing Contacts	Not stated	GE, Westinghouse, ITE/BB	CURSTR	Arcing contact burn up and vaporization
9		Electrical Switchgear	Main Contacts	Not stated	GE, Westinghouse, ITE/BB	CURSTR	Contact burning or welding
10		Electrical Switchgear	Main Contacts	Not stated	GE, Westinghouse, ITE/BB	VIBR, WEAR	Contact burning or welding
11		Electrical Switchgear	Stored Energy Spring and Solenoid Operated Mech	Not stated	GE, Westinghouse, ITE/BB	CONTAM, ENVIR	Deterioration of greases
12		Electrical Switchgear	Stored Energy Spring and Solenoid Operated Mech	Not stated	GE, Westinghouse, ITE/BB	ENVIR, MECHSTR, WEAR	High friction between moving parts
13		Electrical Switchgear	Stored Energy Spring and Solenoid Operated Mech	Not stated	GE, Westinghouse, ITE/BB	VIBR, WEAR	Movement of components and loss of tolerances
14		Electrical Switchgear	Stored Energy Spring and Solenoid Operated Mech	Not stated	GE, Westinghouse, ITE/BB	FAT, CONTAM	Broken welds
15		Electrical Switchgear	Stored Energy Spring and Solenoid Operated Mech	Not stated	GE, Westinghouse, ITE/BB	WEAR	Wear of spring charging mechanism components
16		Electrical Switchgear	Stored Energy Spring and Solenoid Operated Mech	Not stated	GE, Westinghouse, ITE/BB	ELETEMP	Trip or close coil burn out
17		Electrical Switchgear	Solenoid Operated Mechanism	Not stated	GE, Westinghouse, ITE/BB	ELETEMP	Solenoid coil burnout
18		Electrical Switchgear	Solenoid Operated Mechanism	Not stated	GE, Westinghouse, ITE/BB	CURSTR, ELETEMP	Insulation deterioration
19		Electrical Switchgear	Arc-Chute	Not stated	GE, Westinghouse, ITE/BB	ELETEMP, EMBR	Material degradation
20		Electrical Switchgear	Primary Disconnect	Not stated	GE, Westinghouse, ITE/BB	WEAR	Disconnect wear, spring relaxation
21		Electrical Switchgear	Secondary Disconnect	Not stated	GE, Westinghouse, ITE/BB	WEAR	Spring relaxation

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
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Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fault current operation can cause contact deterioration and lead to contact burn up and vaporization which degrades the breaker's function.	Not stated	Various recommendations made for maintenance	IEEE 308-1980 Section 7.4 & 7.5	Not stated	4-8	8
Fault current operation can lead to contact deterioration which can result in the breaker's function being degraded.	Not stated	Various recommendations made for maintenance	IEEE 308-1980 Section 7.4 & 7.5	Not stated	4-8	9
Movement of components and loss of tolerances from mechanical cycling can lead to high resistance at the contact interface which in turn can lead to contact burning or welding. This can result in degraded breaker function.	Not stated	Various recommendations made for maintenance	IEEE 308-1980 Section 7.4 & 7.5	Not stated	4-8	10
Ambient temperatures can cause greases to deteriorate leading to binding of latches and high friction in mechanism. These can result in slow or no open or close operation.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-8	11
Mechanical cycling of the stored energy spring can cause mechanical wear of mechanism parts which leads to high friction between moving parts. This can result in binding of mechanism and latches, slow or no open or close operation.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-8	12
Mechanical cycling can cause a loss of tolerances and movement of components. This can result in binding and/or failure to operate.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-8	13
Mechanical cycling can lead to pole shaft weld fatigue which can lead to broken welds. This can result in jamming, slowing, or failure to operate.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-9	14
Mechanical cycling can lead to wear of spring charging mechanism components which can result in failure to charge closing springs and failure to close.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-9	15
Prolonged energization of the control coils can lead to elevated temperatures which can lead to trip or close coil burn out. This can result in failure to open, failure to close, or failure to operate.	Not stated	Various recommendations made for maintenance	No specific program for this sub component	Not stated	4-9	16
Prolonged energization of solenoid coil can cause elevated temperatures in the coil which can lead to solenoid coil burnout. This can result in the breaker failing to close.	Not stated	Various recommendations made for maintenance	No specific program for this sub component	Not stated	4-9	17
Electrical cycling can cause insulation deterioration which can lead to solenoid coil burn out. This can result in a failure to close.	Not stated	Various recommendations made for maintenance	No specific program for this sub component	Not stated	4-9	18
Fault current operation can cause elevated temperatures in the arc-chute which can lead to material degradation of the arc-chute. This can result in degraded function of the arc-chute.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-9	19
Many racking cycles can cause disconnect wear and spring relaxation which can lead to high resistivity connections. This can result in degraded disconnect function.	Not stated	Various recommendations made for maintenance	No specific program for this mechanism	Not stated	4-9	20
Many racking cycles can cause spring relaxation which can lead to high resistivity connections. This can result in degraded disconnect function.	Not stated	Various recommendations made for maintenance	No specific program for this mechanism	Not stated	4-10	21

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
22		Electrical Switchgear	Mechanical Interlock	Not stated	GE, Westinghouse, ITE/BB	WEAR	Wear/damage of mechanical interlock
23		Electrical Switchgear	Auxiliary Switch	Not stated	GE, Westinghouse, ITE/BB	WEAR, MECHSTR	Burnt contacts
24		Electrical Switchgear	Current and Potential Transformers	Not stated	GE, Westinghouse, ITE/BB	EMBR, ELETEMP	Insulation deterioration
25		Electrical Switchgear	Undervoltage Trip Attachment	Not stated	GE, Westinghouse, ITE/BB	ELETEMP, EMBR	Insulation deterioration
26		Electrical Switchgear	Undervoltage Trip Attachment	Not stated	GE, Westinghouse, ITE/BB	WEAR	Wear of latch
27		Electrical Switchgear	Undervoltage Trip Attachment	Not stated	GE, Westinghouse, ITE/BB	WEAR	High friction between moving parts
28		Electrical Switchgear	Control Wiring	Not stated	GE, Westinghouse, ITE/BB	ELETEMP, MECHSTR, VIBR	Loss of electrical and mechanical properties
29		Electrical Switchgear	Shunt Trip Attachment	Not stated	GE, Westinghouse, ITE/BB	ELETEMP	Coil deterioration
30		Electrical Switchgear	Shunt Trip Attachment	Not stated	GE, Westinghouse, ITE/BB	VIBR, WEAR	Loss of tolerances
31		Electrical Switchgear	Overcurrent Trip Device (Electro-Mechanical)	Not stated	GE, Westinghouse, ITE/BB	WEAR, FAT	Spring relaxation
32		Electrical Switchgear	Overcurrent Trip Device (Electro-Mechanical)	Not stated	GE, Westinghouse, ITE/BB	WEAR, ENVIR	Armature mechanical wear
33		Electrical Switchgear	Overcurrent Trip Device (Electro-Mechanical)	Not stated	GE, Westinghouse, ITE/BB	CONTAM, MECHSTR	Seal degredation

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Many racking cycles can cause wear/damage from friction. This can make it possible to remove or insert the cb into compartment with main contacts closed. This could jeopardize personnel safety.	Not stated	Various recommendations made for maintenance	Vendor specific - Mechanism not safety rel.	Not stated	4-10	22
Mechanical cycling of the auxiliary switch can cause contact deterioration which can lead to burnt contacts. This can result in contact failure.	Not stated	Various recommendations made for maintenance	Vendor specific - Mechanism not safety rel.	Not stated	4-10	23
Temperature and electrical cycling can cause insulation deterioration which can lead to shorted windings. This can result in degraded function of the transformer which can cause failure of undervoltage and control functions.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-10	24
Constant coil energization can cause elevated temperatures which can lead to insulation deterioration. This can result in the breaker tripping open due to coil failure.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-10	25
Mechanical cycling can cause wear of latch which can lead to latch failure. This can result in a failure to trip on undervoltage condition.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-10	26
Mechanical cycling can cause high friction between moving parts which can lead to a lack of adequate force to trip the breader in an undervoltage condition.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-10	27
High resistance connections, damage due to maint, and vibr can cause a loss of elect and mech properties, leading to elevated temp and mech damage. This can result in insulation deterioration and short to ground resulting in failure to operate.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-10	28
Prolonged energization can cause elevated temperatures in the coil which can lead to coil deterioration. This can cause coil failure and result in a failure of the shunt trip to operate.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-11	29
Cycling and vibration can cause a loss of tolerances on its mounting leading to loosening or misalignment. This could result in the device not actuating the trip mechanism.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-11	30
Prolonged spring compression can cause spring relaxation leading to metal fatigue in the spring. This could result in setpoint/time delay drift which could cause the overcurrent trip device to have improper operation or failure to operate.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-11	31
Mechanical cycling and elevated temperatures can cause friction or degraded lubricant which can lead to mechanical wear in the armature. This can result in setpoint/time delay drift with the potential loss of overcurrent protection.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-11	32
Mechanical cycling in conjunction with dirt or contaminants can lead to seal degradation which can result in dashpot leakage and setpoint/time delay drift. This can result in the potential loss of overcurrent protection.	Not stated	Various recommendations made for maintenance	IEEE 308-1980 Sections 7.4 & 7.5	Not stated	4-11	33

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
34		Electrical Switchgear	Overcurrent Trip Device (Solid State)	Not stated	GE, Westinghouse, ITE/BB	ELETEMP, CURSTR, MECHSTR	Electrical component aging

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	CORR	Contact pitting
2		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	FAT	Cumulative fatigue damage
3		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	WEAR	Attrition
4		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	ENVIR	Chemical or physical degradation
5		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	THERM-CY, ELETEMP,	Deterioration of insulation, chemical or physical degradatio
6		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	CURRSTR	Equip temp rise, equipment degradation,
7		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	ELETEMP	Chemical or physical degradation
8		Battery Chargers, Inverters, & UPS's	Transformer	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
9		Battery Chargers, Inverters, & UPS's	Circuit Boards	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
10		Battery Chargers, Inverters, & UPS's	Switches	Not stated	Not stated	CORR	Contact pitting
11		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	CORR	Contact pitting
12		Battery Chargers, Inverters, & UPS's	Potentiometer	Not stated	Not stated	CORR	Contact pitting
13		Battery Chargers, Inverters, & UPS's	Switches	Not stated	Not stated	FAT	Cumulative fatique damage

Document: SAND93-7027, Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Switchgear
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Elevated temperature, electrical transients and mechanical shock result in material degradation from component aging. This can result in erroneous solid-state device output/operation and potential loss of overcurrent protection.	Not stated	Various recommendations made for maintenance	IEEE 308-1980 Sections 7.4 & 7.5	Not stated	4-11	34

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Corrosion can result in high contact impeadance, heat build-up, and signal transmission failure.	Not stated	Cleaning, visual inspection, IR scanning	No specific program for this mechanism	Not stated	4-19, 5-15	1
Fatigue due to high cyclic operation and vibration, resulting in contact degradation, loose connections, reduced force output and component failure.	Not stated	Tactile inspection, vibration observation, IR scanning	No specific program for this mechanism	Not stated	4-20, 5-16	2
Physical deterioration due to the cyclic operation caused by routine operation and periodic testing and adjustment, results in rubbing surfaces, binding of linkages, erosion of contacts and metal surfaces, burning of arc chutes, and loss of adjustment.	Not stated	Tactile inspection	No specific program for this mechanism	Not stated	4-21, 5-16	3
Drifting of the electronic setpoint can cause misoperation or component failure.	Not stated	Calibration, operational surveillance	No specific program for this mechanism	Not stated	4-21, 5-14	4
Continuous load coupled with poor contact mating, and fault currents can cause deterioration of contact support insulation, and possible phase-to-ground faults	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-22, 5-15	5
Damage to contacts and arc chutes occurs regularly due to normal fault interruption.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-22, 5-15	6
Coil heating due to continuous, long-term energizing of the coil, causing material degradation due to accelerated chemical reactions/reduced dielectric strength.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-22, 5-15	7
Temperature and moisture create environmental stresses on transformers which could result in corrosion of the windings. A reduction of the dielelctric strength or insulation resilience may occur, causing the transformer to ultimately fail.	Not stated	Visual inspection	Vendor specific programs	Not stated	4-19, 5-14	8
Temp and moisture create environmental stresses, and deposited contaminants may affect electronics such as printed circuit boards, resistors, and capacitiors, resulting in corrosion of these components, which may lead to open/short circuits at the termin	Not stated	visual inspection, on-line monitoring	Vendor specific programs	Not stated	4-19, 5-15	9
Corrosion can result in high contact impeadance, heat build-up, and signal transmission failure.	Not stated	Cleaning, visual inspection	No specific program	Not stated	4-19, 5-16	10
Corrosion can result in high contact impeadance, heat build-up, and signal transmission failure.	Not stated	Cleaning, visual inspection	No specific program	Not stated	4-19, 5-14	11
Corrosion can result in high contact impeadance, heat build-up, and signal transmission failure.	Not stated	Cleaning, visual inspection	No specific program	Not stated	4-19, 5-16	12
Fatigue due to high cyclic operation and vibration, resulting in contact degradation, loose connections, reduced force output and component failure.	Not stated	Tactile inspection, vibration observation, IR scan	Vendor specific surveillance	Not stated	4-20, 5-16	13

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
14		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	FAT	Cumulative fatique damage
15		Battery Chargers, Inverters, & UPS's	Potentiometer	Not stated	Not stated	FAT	Cumulative fatique damage
16		Battery Chargers, Inverters, & UPS's	Switches	Not stated	Not stated	WEAR	Attrition
17		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	WEAR	Attrition
18		Battery Chargers, Inverters, & UPS's	Potentiometer	Not stated	Not stated	WEAR	Attrition
19		Battery Chargers, Inverters, & UPS's	Potentiometer	Not stated	Not stated	ENVIRO	Chemical or physical degradation
20		Battery Chargers, Inverters, & UPS's	Surge Suppressors	Not stated	Not stated	ENVIRO	Chemical or physical degradation
21		Battery Chargers, Inverters, & UPS's	Circuit Boards	Not stated	Not stated	ENVIRO	Chemical or physical degradation
22		Battery Chargers, Inverters, & UPS's	Electronics	Not stated	Not stated	ENVIRO	Chemical or physical degradation
23		Battery Chargers, Inverters, & UPS's	Electronics	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
24		Battery Chargers, Inverters, & UPS's	Wire	Not stated	Not stated	CORR	Loss of material; corrosion product buildup
25		Battery Chargers, Inverters, & UPS's	Cooling Fans and Cooling Fan Motors	Not stated	Not stated	CORR/OX	Loss of material; corrosion product buildup;internal damage
26		Battery Chargers, Inverters, & UPS's	Cabinet	Not stated	Not stated	CORR/OX	Loss of material; corrosion product buildup;internal damage

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fatigue due to high cyclic operation and vibration, resulting in contact degradation, loose connections, reduced force output and component failure.	Not stated	Tactile inspection, vibration observation, IR scan	Vendor specific surveillance	Not stated	4-20, 5-14	14
Fatigue due to high cyclic operation and vibration, resulting in contact degradation, loose connections, reduced force output and component failure.	Not stated	Tactile inspection, vibration observation, IR scan	Vendor specific surveillance	Not stated	4-20, 5-16	15
Physical deterioration due to the cyclic operation caused by routine operation and periodic testing and adjustment, results in rubbing surfaces, binding of linkages, erosion of contacts and metal surfaces, burning of arc chutes, and loss of adjustment.	Not stated	Tactile inspection	No specific program	Not stated	4-21, 5-16	16
Physical deterioration due to the cyclic operation caused by routine operation and periodic testing and adjustment, results in rubbing surfaces, binding of linkages, erosion of contacts and metal surfaces, burning of arc chutes, and loss of adjustment.	Not stated	Tactile inspection	No specific program	Not stated	4-21, 5-14	17
Physical deterioration due to the cyclic operation caused by routine operation and periodic testing and adjustment, results in rubbing surfaces, binding of linkages, erosion of contacts and metal surfaces, burning of arc chutes, and loss of adjustment.	Not stated	Not discussed in report	No specific program	Not stated	4-21, 5-16	18
Drifting of the setpoint can cause misoperation or componenet failure.	Not stated	Calibration, Tech Spec, I/O logging, output	IEEE 308-1980 Section 7, Tech Spec surveil.	Not stated	4-21, 5-16	19
Drifting of the electronic setpoint can cause misoperation or componenet failure.	Not stated	Calibration	No specific program	Not stated	4-21, 5-15	20
Drifting of the electronic setpoint can cause misoperation or componenet failure.	Not stated	Calibration, Tech Spec, I/O logging, output	Tech Spec. required surveillance	Not stated	4-21, 5-15	21
Drifting of the electronic setpoint can cause misoperation or componenet failure.	Not stated	Calibration, Tech Spec, I/O logging, output	Tech Spec. required surveillance	Not stated	4-21, 5-15	22
Temp and moisture create environmental stresses, and deposited contaminants may affect electronics such as printed circuit boards, resistors and capacitors resulting in corrosion of the components, which may lead to open/short circuits at the terminals.	Not stated	Visual inspection, output	Vendor specific programs	Not stated	4-19, 5-15	23
Temp and moisture create environmental stresses, and deposited contaminants may corrode shields or conductor strands, terminations, etc. eventually causing failure of the circuit due to overheating or dielectric insulation breakdown.	Not stated	Visual inspection, output	No specific program	Not stated	4-19, 5-16	24
Temp and moisture create environmental stresses, and deposited contaminants may increase contact resistance. Vibration can promote loosening connectons resulting in localized heating and more oxidation.	Not stated	Visual inspection	IEEE 334-1974 Section 14.2.3	Not stated	4-19, 5-16	25
Temp and moisture create environmental stresses, and deposited contaminants may over time can degrade and give way to oxidation corrosion.	Not stated	Visual inspection	No specific program	Not stated	4-20, 5-17	26

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
27		Battery Chargers, Inverters, & UPS's	Transformer	Not stated	Not stated	FAT	Cumulative fatigue damage
28		Battery Chargers, Inverters, & UPS's	Inductors	Not stated	Not stated	FAT	Cumulative fatigue damage
29		Battery Chargers, Inverters, & UPS's	Capacitor	Not stated	Not stated	FAT	Cumulative fatigue damage
30		Battery Chargers, Inverters, & UPS's	SCR's	Not stated	Not stated	FAT	Cumulative fatigue damage
31		Battery Chargers, Inverters, & UPS's	Diodes	Not stated	Not stated	FAT	Cumulative fatigue damage
32		Battery Chargers, Inverters, & UPS's	Surge Suppressors	Not stated	Not stated	FAT	Cumulative fatigue damage
33		Battery Chargers, Inverters, & UPS's	Circuit Boards	Not stated	Not stated	FAT	Cumulative fatigue damage
34		Battery Chargers, Inverters, & UPS's	Electronics	Not stated	Not stated	FAT	Cumulative fatigue damage
35		Battery Chargers, Inverters, & UPS's	Wire	Not stated	Not stated	FAT	Cumulative fatigue damage
36		Battery Chargers, Inverters, & UPS's	Cooling Fans and Cooling Fan Motors	Not stated	Not stated	FAT	Cumulative fatigue damage

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	Vendor specific program	Not stated	4-20, 5-14	27
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	Vendor specific program	Not stated	4-20, 5-14	28
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	Vendor specific program	Not stated	4-20, 5-14	29
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	No specific program	Not stated	4-20, 5-15	30
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	No specific program	Not stated	4-20, 5-15	31
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	No specific program	Not stated	4-20, 5-15	32
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	Vendor specific program	Not stated	4-20, 5-15	33
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	Vendor specific program	Not stated	4-20, 5-15	34
High frequency vibration caused by ferromagnetic resonance can cause fatigue resulting in loose parts, open circuits causing loss of signal or sporatic operation. Regular maint also moves/bends wires/connectors causing conductor or insulation failure.	Not stated	Tactile/audible inspection, vibration observation, IR scan	No specific program	Not stated	4-20, 5-16	35
Vibration induced fatigue in motor mounts can occur due to improper sheave alignment and dynamic imbalances.	Not stated	Tactile/audible inspection, vibration observation, IR scan	IEEE 334-1974 Section 14.2.3	Not stated	4-20, 5-17	36

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
37		Battery Chargers, Inverters, & UPS's	Cooling Fans and Cooling Fan Motors	Not stated	Not stated	WEAR	Attrition
38		Battery Chargers, Inverters, & UPS's	Transformer	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR	Deterioration of insulation, chemical or physical changes
39		Battery Chargers, Inverters, & UPS's	Inductors	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
40		Battery Chargers, Inverters, & UPS's	Capacitor	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
41		Battery Chargers, Inverters, & UPS's	Diodes	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
42		Battery Chargers, Inverters, & UPS's	Surge Suppressors	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
43		Battery Chargers, Inverters, & UPS's	Circuit Boards	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
44		Battery Chargers, Inverters, & UPS's	Electronics	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
45		Battery Chargers, Inverters, & UPS's	SCR's	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
46		Battery Chargers, Inverters, & UPS's	Switches	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR	Deterioration of insulation, chemical or physical changes
47		Battery Chargers, Inverters, & UPS's	Wire	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR, EMBR	Deterioration of insulation, chemical or physical changes
48		Battery Chargers, Inverters, & UPS's	Cooling Fan Motors	Not stated	Not stated	THERM-CY, ELETEMP, VOLSTR, CURSTR, EMBR	Deterioration of insulation, chemical or physical changes
49		Battery Chargers, Inverters, & UPS's	Transformer	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
50		Battery Chargers, Inverters, & UPS's	Inductors	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
51		Battery Chargers, Inverters, & UPS's	SCR's	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Shafts and bearings are susceptible to normal wear, and wear due to misalignment, imbalances, and inherent eccentricity of the rotor. On dc motors, brushes and commutators are also subject to wear.	Not stated	Noise observation	IEEE 334-1974 Section 14.2.3	Not stated	4-21, 5-17	37
Overvoltage or turn-to-turn shorts can cause high internal tempreratures, causing insulation to fail, causing local heating and deterioration of material resulting in dielectric failure.	Not stated	Cleaning, visual/tactile/audible inpection	Vendor specific program	Not stated	4-22, 5-14	38
Overvoltage or turn-to-turn shorts can cause high internal tempreratures, causing insulation to fail, causing local heating and deterioration of material resulting in dielectric failure.	Not stated	Cleaning, visual/tactile/audible inpection	Vendor specific program	Not stated	4-22, 5-14	39
Overvoltage can cause voltage stress causing loss of capacitance, breakdown of dielectric,	Not stated	Cleaning, visual inspection, measuement, part replacement	Vendor specific program	Not stated	4-22, 5-14	40
Heat due to overcurrent conditions and internal stresses can cause dielectric breakdown resulting in change in output signal.	Not stated	Cleaning, visual inspection, temperature & input/output	Vendor specific program	Not stated	4-22, 5-15	41
Heat due to overcurrent conditions and internal stresses can cause dielectric breakdown and misoperation or failure of the device.	Not stated	Cleaning, visual inspection, temperature & input/output	No specific program	Not stated	4-22, 5-15	42
Heat due to overcurrent conditions and internal stresses can cause dielectric breakdown and misoperation or failure of components, open/shorts of circuits.	Not stated	Cleaning, visual inspection, temperature & input/output	Vendor specific program	Not stated	4-22, 5-15	43
Heat due to overcurrent conditions and internal stresses can cause dielectric breakdown and misoperation or failure of components, open/shorts of circuits.	Not stated	Cleaning, visual inspection, temperature & input/output	Vendor specific program	Not stated	4-22, 5-15	44
Heat due to overcurrent conditions and internal stresses can cause dielectric breakdown and misoperation or failure of components, open/shorts of circuits.	Not stated	Cleaning, visual inspection, temperature & input/output	Vendor specific program	Not stated	4-22, 5-15	45
Heat due to overcurrent conditions and normal operations, and due to contact resistance, can cause dielectric breakdown of supports and insulation, and misoperation or failure of components.	Not stated	Cleaning, visual inspection, temperature logging	No specific program	Not stated	4-23, 5-16	46
Thermal effects on wire and cable leading to embrittlement, and insulation failure. Ohmic heating and heat from surrounding environment degrades insulation, resulting in short circuits.	Not stated	Cleaning, visual inspection, temperature & input/output	No specific program	Not stated	4-23	47
Heat due to overcurrent conditions and normal operations, can cause dielectric breakdown and failure.	Not stated	Cleaning, visual inspection, temperature & input/output	IEEE 334-1974 Section 14.2.3	Not stated	4-23, 5-16	48
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-23, 5-14	49
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-23, 5-14	50
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 5-15	51

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
52		Battery Chargers, Inverters, & UPS's	Diodes	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
53		Battery Chargers, Inverters, & UPS's	Capacitor	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
54		Battery Chargers, Inverters, & UPS's	Surge Suppressors	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
55		Battery Chargers, Inverters, & UPS's	Circuit Boards	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
56		Battery Chargers, Inverters, & UPS's	Electronics	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
57		Battery Chargers, Inverters, & UPS's	Wire	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
58		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
59		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
60		Battery Chargers, Inverters, & UPS's	Switches	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
61		Battery Chargers, Inverters, & UPS's	Potentiometers	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
62		Battery Chargers, Inverters, & UPS's	Cooling Fan Motoers	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
63		Battery Chargers, Inverters, & UPS's	Relay	Not stated	Not stated	LOSLUB	Viscosity change, loss of lubricicty
64		Battery Chargers, Inverters, & UPS's	Circuit Breakers	Not stated	Not stated	LOSLUB	Viscosity change, loss of lubricicty

Document: SAND93-7068, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Transformer	Metal Enclosure (Tank) and Cover	Low-alloy steel	Not stated	ENVIR	Chemical/physical degradation
2		Transformer	Metal Enclosure (Tank) and Cover	Low-alloy steel	Not stated	CORR	Loss of material; corrosion product buildup

Document: SAND93-7046, Aging Management Guideline for Commerical Nuclear Power Plants - Battery Chargers, Inverters and Uninteruptable Power Supplies
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 5-15	52
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-23, 5-14	53
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 5-15	54
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-23, 5-15	55
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 5-15	56
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 5-16	57
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-23, 4-24, 5-14	58
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	Vendor specific programs	Not stated	4-23, 4-24, 5-15	59
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 4-24, 5-16	60
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	No specific programs	Not stated	4-23, 4-24, 5-16	61
Fouling due to accumulation of insects, dirt, and dust, can reduce heat dissipation, cause overheating, and eventual failure of components.	Not stated	Cleaning, visual inspection	IEEE 334-1974 SECTION 14.2.3	Not stated	4-24, 5-17	62
Material set occurs when the organic materials used as lubricants in those subconponents harden, gel, or adhere to adjacent materials, which can cause binding of the devices, resulting in faulty operation.	Not stated	Tactile inspection, operational	Vendor specific programs	Not stated	4-24, 5-14	63
Material set occurs when the organic materials used as lubricants in those subconponents harden, gel, or adhere to adjacent materials, which can cause binding of the devices, resulting in faulty operation.	Not stated	Tactile inspection, operational	Vendor specific programs	Not stated	4-24, 5-14	64

Document: SAND93-7068, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Chipping, cracking, or peeling of the enclosure's protective coating	Not stated	Visual inspection, cleaning, pressure testing	Vendor specific surveillance, IEEE 308-1980	Not stated	4-7, 5-3, 5-15	1
Exposed metal develops rust and corrosion	Not stated	Visual inspection, cleaning, pressure testing	Vendor specific surveillance, IEEE 308-1980	Not stated	4-7, 5-3, 5-15	2

Document: SAND93-7068, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3		Transformer	Metal Enclosure (Tank) and Cover	Low-alloy steel	Not stated	ENVIR, EMBR	Deterioration of organic components
4		Transformer	Metal Enclosure (Tank) and Cover	Low-alloy steel	Not stated	FAT	Cumulative damage from cyclic vibration or thermal stress
5		Transformer	Primary and Secondary Windings, Liquid-Immersed	Not stated	Not stated	ELETEMP	Chemical or physical degradation: thermal distortion
6		Transformer	Primary and Secondary Windings, Liquid-Immersed	Not stated	Not stated	VIBR, VOLSTR, EXFORCE	Loosening, reduced tolerances, distortion or bending
7		Transformer	Primary and Secondary Windings, Dry-Type	Not stated	Not stated	ELETEMP	Chemical or physical degradation; thermal distortion
8		Transformer	Primary and Secondary Windings, Dry-Type	Not stated	Not stated	VIBR, VOLSTR, EXFORCE	Loosening, reduced tolerances, distortion or bending
9		Transformer	Magnetic Core	Not stated	Not stated	VIBR, MECHSTR, EXFORCE	Loosening, distortion, deterioration of mech function
10		Transformer	Magnetic Core	Not stated	Not stated	EMBR/TE	Loss of fracture toughness
11		Transformer	Insulation	Not stated	Not stated	ELETEMP, VOLSTR	Chemical or physical degradation, degradation of insulation
12		Transformer	Insulation	Not stated	Not stated	MOIST-EL, CONTAM	Loss of dielectric properties, buildup of deposits
13		Transformer	Insulation	Not stated	Not stated	Not stated	High acidity resulting in more water retention
14		Transformer	Insulation	Not stated	Not stated	CORR/OX	Loss of material; corrosion product buildup;internal damage

Document: SAND93-7068, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Gaskets and other organic seals used in construction of the enclosure degrade due to exposure to heat, ultraviolet radiation, moisture, or chemicals, while under mechanical stress or compression. polymeric seal materials embrittle and harden	Not stated	Visual inspection, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-7, 5-15	3
Can affect areas of high local stress such a welds, tank edges, etc., resulting in tank leaks (oil or gas-filled units) and potentially a loss of structural intergrity.	Not stated	visual inspection, cleaning, pressure testing	Vendor specific surveillance, IEEE 308-1980	Not stated	4-7, 4-8, 5-3, 5-15	4
May induce accelerated degradiation of surrounding organic materials.	Not stated	Electrical testing, visual inspection, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-8, 5-4, 5-15	5
Movement and vibration allow windings to change clearances/tolerances required for maintaining satisfactory dielectric strength, which can result in dielectric breakdown and localized discharge. Can cause mechanical stress on electrical connections	Not stated	Electrical testing, visual inspection, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-9, 5-4, 5-15	6
May induce accelerated degradation of surrounding organic materials. Degradation of winding conductor connections due to high resistance connections causing localized heating.	Not stated	Electrical testing, visual inspection, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-9, 5-4, 5-15	7
Movement and vibration allow winding to change clearances/tolerances required for maintaining satisfactory dielectric strength, which can result in deilectric breakdown and localized discharge. Can cause mechanical stress on electrical connections.	Not stated	Electrical testing, visual inspection, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-9, 5-4, 5-15	8
Loosining of the core due to vibration, shock, or severe electrical transients, can cause wear or deterioration of the insulation once dislocation occurs may lead to sufficient insulation damage to allow electrical failure	Not stated	Electrical testing, visual inspection	Vendor specific surveillance, IEEE 308-1980	Not stated	4-10, 5-4, 5-15	9
A result of relatively high thermal exposure resulting from core and winding losses, causing weakening or failure of the laminations, causing increased eddy currents and core losses.	Not stated	Electrical testing, visual inspection	Vendor specific surveillance, IEEE 308-1980	Not stated	4-10, 4-11, 5-4, 5-15	10
Partial or localized breakdown of the dielectric capacity of the material, which may in turn produce other eleterious effects such as the formation of additional gaseous byproducts, decomposition of the surrounding insulating fluid.	Not stated	Sampling and analysis, cleaning, replacement	Vendor specific surveillance, IEEE 308-1980	Recommended laboratory and/or in-situ analysis to detect impending breakdown of dielectric [2]	4-11, 5-5, 5-15, 5-22	11
Particulates contaminants and moisture may result in blockage of passages leading to hot spots. Chemical contaminants may have adverse effects on the material properties, water reduces dielectric strength causing partial discharge or dielectric breakdown	Not stated	Sampling and analysis, cleaning, replacement	Vendor specific surveillance, IEEE 308-1980	Recommended laboratory and/or in-situ analysis to detect impending breakdown of dielectric [2]	4-12, 5-5, 5-16, 5-22	12
High acidity results in more water being held in solution and therefore reduced dielectric strength. Also affects the deterioration and decomposition of solid insulating materials reducing the dielectric strenth	Not stated	Sampling and analysis, cleaning, replacement	Vendor specific surveillance, IEEE 308-1980	Recommended laboratory and/or in-situ analysis to detect impending breakdown of dielectric [2]	4-12, 5-5, 5-16, 5-22	13
Formation of sludge which can impead circulation creating hot spots. Dielectric properties associated with the sludge may also differ. oxygen will also increase the acidity of the insulating fluid	Not stated	Sampling and analysis, cleaning, replacement	Vendor specific surveillance, IEEE 308-1980	Recommended laboratory and/or in-situ analysis to detect impending breakdown of dielectric [2]	4-12, 5-5, 5-16, 5-22	14

Document: SAND93-7068, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: Michael W. Vaughn, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15		Transformer	Insulation	Not stated	Not stated	ELETEMP	Chemical or physical degradation; thermal distortion
16		Transformer	Bushings	Not stated	Not stated	THERM-CY	Degradation due to exposure to elements and temp cycles
17		Transformer	Bushings	Not stated	Not stated	CONTAM	Buildup of deposits:loss of desired surface properties
18		Transformer	Bushings	Not stated	Not stated	ENVIRO	Chemical or physical degradation
19		Transformer	Bushings	Not stated	Not stated	VOLSTR	Dielectric stress causing degradation of insulation
20		Transformer	Cooling System, Liquid-Immersed and Dry-Type	Not stated	Not stated	FAT, WEAR	Attrition and cumulative fatigue damage over time
21		Transformer	Cooling System, Liquid-Immersed and Dry-Type	Not stated	Not stated	CONTAM	Buildup of deposits; loss of desired surface properties
22		Transformer	Oil Preservation and Sampling System	Not stated	Not stated	ENVIRO, ELETEMP	Chemical or physical degredation
23		Transformer	Oil Preservation and Sampling System	Not stated	Not stated	WEAR	Attrition
24		Transformer	Tap Changers	Not stated	Not stated	WEAR	Attrition
25		Transformer	Tap Changers	Not stated	Not stated	VIBR, MECHSTR	Loosening, deterioration of mechanical function
26		Transformer	Tap Changers	Not stated	Not stated	ELTEMP, THERM-CY	Chemical or physical degradation, insulation deterioration
27		Transformer	Protection and Monitoring Systems	Not stated	Not stated	ENVIRO, EMBR	Chemical or physical degradation, loss or fracture toughness
28		Transformer	Protection and Monitoring Systems	Not stated	Not stated	THERM-CY	Deterioration of insulation

Document: SAND93-7068, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: Michael W. Vaughn, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The elevated temperatures cause thermal deterioration and dielectric breakdown	Not stated	Visual inspection, insulation resistance testing, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-13, 5-7, 5-16	15
Breakdown of gaskets and seals, and all organic materials due to heat caused by current in the conductor, solar radiation, etc.	Not stated	Visual inspection, power factor testing, cleaning	Vendor specific surveillance, IEEE 308-1980	Manage bushing flashover by controling airborne dust and/or salt spray accumulation in combination with rain/humidity [2]	4-14, 5-7, 5-16, 5-22	16
The combination of dirt, dust, salt, and other contaminants, alone or with water or other liquid can form a conductive path leading to flashover of the bushing.	Not stated	Visual inspection, power factor testing, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-14, 5-7, 5-17	17
Factors such as ultraviolet radiation, humidity, etc. can cause degradation over time	Not stated	Visual inspection, power factor testing, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-14, 5-7, 5-17	18
Improper storage or loss of insulating oil, or voltage transients, can degrade the dielectric properties. Dielectric stress from potential gradient between the central conductor and other surfaces.	Not stated	Visual inspection, power factor testing, cleaning	Vendor specific surveillance, IEEE 308-1980	Not stated	4-14, 5-7, 5-17	19
Bearings and other parts wear over time due to friction and other stresses placed on them. This is accelerated by such stresses as frequent motor starting and stopping, undue vibration or transverse/longitudinal load placed on the driven unit.	Not stated	Visual inspection, monitor, adjust, lubricate, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-15, 5-8, 5-17	20
Fouling of heat transfer surfaces such as radiators due to dirt, debris, or other materials	Not stated	Visual inspection, monitor, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-16, 5-8, 5-17	21
Elevated temperatures and exposure to the elements can cause thermal and wear degradation to components.	Not stated	Visual inspection, adjust, repair/replace, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-16, 5-9, 5-17	22
Wear to components such as sampling and isolation valves, fittings, and pressure regulating valves, can result in leakage of fluids, binding and/or malfunctioning of devices.	Not stated	Visual inspection, adjust, repair/replace, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-17, 5-9, 5-18	23
Wear to components due to friction.	Not stated	Visual inspection, adjust, repair/replace, lubricate, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-18, 5-9, 5-18	24
Vibration and mencanical stresses can result in a loss of adjustment in parts	Not stated	Visual inspection, adjust, repair/replace, lubricate, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-18, 5-10, 5-18	25
Degradation of organic insulating materials in motor windings, insulators on main contacts, and materials used in related electrical components which can reduce their dielectric as well as mechanical properties.	Not stated	Visual inspection, adjust, repair/replace, clean	Vendor specific surveillance, IEEE 308-1980	Not stated	4-18, 5-10, 5-18	26
Degradation of organic materials used to seal the relay, can embrittle and harden the gaskets allowing leakage, possibly leading to the component failure.	Not stated	Visual inspection, functional testing	Vendor specific surveillance, IEEE 308-1980	Not stated	4-19, 5-11, 5-18	27
Repeated heating and cooling of the temperature indicator elements due to load variation induces thermal stresses which may eventually result in open-circuit failure of the element.	Not stated	Visual inspection, functional testing	No specific program	Not stated	4-20, 5-10, 5-19	28

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Motor Control Center	Motor	Not stated	GE, Westinghouse, C-H, KM	THEM-CY, EMBR	Loss of electrical and mechanical properties of insulator
2		Motor Control Center	Motor	Not stated	GE, Westinghouse, C-H, KM	MOIST-EL, CONTAM, ENVIR	Loss of surface insulating properties
3		Motor Control Center	Motor	Not stated	GE, Westinghouse, C-H, KM	MOIST-EL, CONTAM, ENVIR	Loss of volumetric insulating properties
4		Motor Control Center	Motor	Not stated	GE, Westinghouse, C-H, KM	WEAR, CORR/OX, CONTAM	High resistance electrical connections
5		Motor Control Center	Motor	Not stated	GE, Westinghouse, C-H, KM	MECHSTR, VIBR	Loosening/loss of fasteners
6		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	CURSTR	Contact surface deterioration
7		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	FAT, MECHSTR	Fatigue of various circuit breaker components
8		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	WEAR, CONTAM	Wear of internal components
9		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	ELETEMP, CORR/OX, VIBR	Loose or high resistance elect connections or terminations
10		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	CURSTR	Thermal trip setpoint variations
11		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	CONTAM, ENVIR	Deterioration of lubricants
12		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	ENVIR	Current limiting fuse failure

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Power and Distribution Transformers
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Exposure to ambient temps and ohmic heating can lead to loss of insulating properties and thermally induced cracking. This has the potential of causing a flashover of the component insulation and loss of structural integrity.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-4, 4-5, 5-15	1
Voltage and humidity can affect energized insulation that is dirty or deteriorated and cause surface tracking paths on the insulator. This can lead to flashover.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-6, 4-7, 5-15	2
Simultaneous exposure of thermally deteriorated insulation to temp, voltage, humidity, dirt and contaminants can result in loss of volumetric insulating properties, leading to increased surface and volumetric leakage currents and possible flashover	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-6, 4-7, 5-15	3
Poor mating surface contact or sharp bends/current flow restrictions near crimps or terminations can cause high resistance elec connections which can result in excessive heating and potentially fire.	Not stated	Various recommendations made for maintenance	Vendor specific program	Not stated	4-5, 4-8, 5-15	4
Over-torquing of fasteners, and fasteners loosened by various external stresses (non-seismic) could cause loss of structural integrity or affect electrical connections.	Not stated	Various recommendations made for maintenance	Vendor specific program	Not stated	4-8, 5-15	5
High temps that accompany fault currents may cause contact material to vaporize, inducing a loss of contact surface material and pitting. This could cause the contacts to burn or weld together and result in breaker failure.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-9, 5-15	6
Cyclic stress can cause fatigue failure of various circuit breaker components such as contact assemblies, operating mechanisms, breaker housing. Fatigue may be evidenced by progressive cracking and ultimate failure of the component.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-9, 5-15	7
Inadequate or degraded lubrication, normal component wear, or wear caused by contaminants (from other degraded material or from external sources) can cause the breaker to malfunction.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-9, 5-15	8
Operation of the breaker and non-seismic vibration cause loose connections. oxidation or contamination of contact surfaces and sharp bends in wiring near terminations can cause high resistance connections. These can cause excessive heating or fire.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-9, 5-15	9
Exposure to fault currents can cause variations in the thermal trip setpoint of a circuit breaker. This can cause the CB to trip at progressively lower current levels, potentially causing nuisance tripping.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-10, 5-15	10
Contamination, aging, evaporation, and ambient temperatures can cause lubricants to deteriorate. this can slow or completely prevent operation of a breaker.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-10, 5-15	11
Fuses degrade slowly over time until eventually the current-carrying capability of the fuse is reached during normal/transient load operation, resulting in nuisance current interruptions.	Not stated	Various recommendations made for maintenance	Replace when inoperative	Not stated	4-10, 5-15	12

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Notor Control Centers
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	CURSTR, CONTAM	Surface current tracking/loss of insulating properties
14		Motor Control Center	Molded-Case Circuit Breakers	Case-phenolic or glass polyester, contact- silver or tungsten	GE, Westinghouse, C-H, KM	CURSTR, ELETEMP	Thermally induced degradation
15		Motor Control Center	Magnetic Contactors/Starters	Not stated	GE, Westinghouse, C-H, KM	ELETEMP	Insulation deterioration
16		Motor Control Center	Magnetic Contactors/Starters	Not stated	GE, Westinghouse, C-H, KM	ELETEMP	Organic component breakdown
17		Motor Control Center	Magnetic Contactors/Starters	Not stated	GE, Westinghouse, C-H, KM	VIB, WEAR	Cyclic fatigue
18		Motor Control Center	Magnetic Contactors/Starters	Not stated	GE, Westinghouse, C-H, KM	WEAR, VIB, CONTAM	Wear of contactor and starter subcomponents
19		Motor Control Center	Magnetic Contactors/Starters	Not stated	GE, Westinghouse, C-H, KM	CONTAM	Contact surface degradation
20		Motor Control Center	Thermal Overload Relays	Not stated	GE, Westinghouse, C-H, KM	WEAR, CURSTR	Degradation of heater or bimetallic elements
21		Motor Control Center	Thermal Overload Relays	Not stated	GE, Westinghouse, C-H, KM	CONT, WEAR	Binding of mechanical components
22		Motor Control Center	Thermal Overload Relays	Not stated	GE, Westinghouse, C-H, KM	CONT	Contact surface degradation
23		Motor Control Center	Thermal Overload Relays	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, EMBR	Thermal degradation of organic materials

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Notor Control Centers
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Voltage and humidity can affect energized insulation that is dirty or deteriorated and cause surface tracking paths on the insulator. Breaker arc-chute insulation is especially susceptible to surface current tracking. This can lead to flashover.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-10, 5-15	13
Fault currents can produce high temperatures and currents that can rapidly damage contacts, arc-chute surfaces and other organic materials. Continuous load currents can produce ohmic heating in poor connections. These can cause cb failure.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-11, 5-15	14
During operation, the heat generated in the coil during energization could cause insulation deterioration of the coil itself. This can lead to coil failure.	Not stated	Various recommendations made for maintenance	Vendor specific program	Not stated	4-12, 5-16	15
Prolonged coninuous energization of the contactor coil could result in excessive temperatures that cause the organic compounds that encapsulate the contactor to degrade. This could shorten life and lead to coil burnout.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-12, 5-16	16
Cyclic fatigue can occur in magnetic contactors if subjected to extremely high cycle operation. This can lead to heat generation because of higher resistivity, misalignment of contact, binding of armature, preventing full contact mating and arcing.	Not stated	Various recommendations made for maintenance	Vendor specific program	Not stated	4-13, 5-16	17
Binding of the contactor assembly, binding of contactor armature, binding of the contactor mechanism are all caused by wear, vibration and contamination. These can result in poor contactor/starter operation and failure.	Not stated	Various recommendations made for maintenance	Vendor specific program, replace when failed	Not stated	4-13, 5-16	18
Dust, dirt, and foreign material can lead to coil burnout, pitting of contact surfaces, and breakdown of adhesives and lubricants. They can also prevent the contact from closing. All the above can cause the contactor or starter to fail.	Not stated	Various recommendations made for maintenance	Vendor specific program	Not stated	4-13, 5-16	19
In bimetallic devices, variations in the current flowing through the heater will result in variations in device setpoint. These variations may be caused by changes in the characteristics of the heater element	Not stated	Various recommendations made for maintenance	Vendor specific program, replace when failed	Not stated	4-14, 5-16	20
Mechanical interference, dirt and friction may cause mechanical interference resulting in binding of mechanical components.	Not stated	Various recommendations made for maintenance	Replace when failed	Not stated	4-14, 5-17	21
Dust, dirt, and foreign material can lead to coil burnout, pitting of contact surfaces, and breakdown of adhesives and lubricants. They can also prevent the contact from closing. All the above can cause the relay to fail.	Not stated	Various recommendations made for maintenance	Vendor specific program, replace when failed	Not stated	4-14, 5-17	22
Elevated temperatures caused by the heaters cause aging of the heater element support material. Failure of the support block results in possible failure of the overload relay to perform its required function.	Not stated	Various recommendations made for maintenance	Vendor specific program, replace when failed	Not stated	4-14, 5-17	23

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Notor Control Centers
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
24		Motor Control Center	Thermal Overload Relays	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, CORR/OX, VIBR	Loose or high resistance elec connections or terminations
25		Motor Control Center	Miscellaneous Relays	Not stated	GE, Westinghouse, C-H, KM	ELETEMP	Thermal breakdown of organic materials
26		Motor Control Center	Miscellaneous Relays	Not stated	GE, Westinghouse, C-H, KM	CONT	Contact surface degradation
27		Motor Control Center	Miscellaneous Relays	Not stated	GE, Westinghouse, C-H, KM	WEAR, VIBR	Wear of mechanical parts
28		Motor Control Center	Miscellaneous Relays	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, CORR/OX, VIBR	Loose or high resistance elect connections or terminations
29		Motor Control Center	Miscellaneous Relays	Not stated	GE, Westinghouse, C-H, KM	VOLTSTR	Coil dielectric breakdown
30		Motor Control Center	Control Transformers	Not stated	GE, Westinghouse, C-H, KM	ELETEMP	Winding insulation degradation
31		Motor Control Center	Control Transformers	Not stated	GE, Westinghouse, C-H, KM	CURSTR	Winding conductor failure
32		Motor Control Center	Control Transformers	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, CORR/OX, VIBR	Loose or high resistance elect connections or terminations
33		Motor Control Center	Terminal Blocks	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, CORR/OX, VIBR	Loose or high resistance elect connections or terminations
34		Motor Control Center	Terminal Blocks	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, EMBR, ENVIR	Degradation or organic materials

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Notor Control Centers
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Operation of the relay and non-seismic vibration cause loose connections. Oxidation or contamination of contact surfaces and sharp bends in wiring near terminations can cause high resistance connections. These can cause excessive heating or fire.	Not stated	Various recommendations made for maintenance	Vendor specific program	Not stated	4-15, 5-17	24
Prolonged continuous energization of the relay could result in excessive temperatures that cause the organic compounds that encapsulate the contactor to degrade. This could shorten life and lead to coil burnout.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-12, 5-17	25
Dust, dirt, and foreign material can lead to coil burnout, pitting of contact surfaces, and breakdown of adhesives and lubricants. They can also prevent the contact from closing. All the above can cause the relay to fail.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-15, 5-17	26
Wear can lead to setpoint drift, mechanical fatigue, surface burning caused by arcing, and insulation deterioration. These can result in reduced mechanical tolerances, jamming and binding of moving parts.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-17, 5-17	27
Operation of the relay and non-seismic vibration cause loose connections. Oxidation or contamination of contact surfaces and sharp bends in wiring near terminations can cause high resistance connections. These can cause excessive heating or fire.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-17, 5-17	28
Inductive voltage surges resulting from current interruptions can stress the relay coil. The inductive surge may cause coil dielectric breakdown at the weak points in the insulation, which can rapidly lead to insulation failure.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-18, 5-17	29
Ohmic heating and breaker internal ambient conditions cause elevated temperatures which lead to winding insulation degradation. This can produce shorted transformer winding, resulting in faulty voltage/current transformation or open circuit conditions.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-18, 5-17	30
Primary or secondary winding failure can result from continuous use for extended periods or from excessive current drawn through the winding from attached control power loads.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-18, 5-17	31
Non-seismic vibration can cause loose connections. oxidation or contamination of contact surfaces and sharp bends in wiring near terminations can cause high resistance connections. These can cause excessive heating or fire.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-18, 5-17	32
Operation of motor control center components and non-seismic vibration cause loose connections. Oxidation or contamination of surfaces and sharp bends in wiring near terminations cause high resistance connections. These can lead to heating or fire.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-19, 5-17	33
Terminal blocks and the organic glue or agent used to mount them may degrade because of ohmic heating, ambient temperature, humidity and vibration. This can result in embrittlement of the terminal blocks and loosening from their mounting surfaces.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-19, 5-17	34

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Notor Control Centers
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
35		Motor Control Center	Terminal Blocks	Not stated	GE, Westinghouse, C-H, KM	EXFORCE, MECHSTR	Degradation of terminal block hardware
36		Motor Control Center	Terminal Blocks	Not stated	GE, Westinghouse, C-H, KM	MOIST-EL, CONTAM, ENVIR	Loss of surface insulating properties
37		Motor Control Center	Terminal Blocks	Not stated	GE, Westinghouse, C-H, KM	MOIST-EL, CONTAM, ENVIR	Loss of volumetric insulating properties
38		Motor Control Center	Control Wiring	Copper wire insulated by ethylene propylene rubber or X-linked poly	GE, Westinghouse, C-H, KM	ELETEMP, EMBR	Insulation degradation
39		Motor Control Center	Control Wiring	Copper wire insulated by ethylene propylene rubber or X-linked poly	GE, Westinghouse, C-H, KM	ELETEMP	Conductor degredation
40		Motor Control Center	Control Wiring	Copper wire insulated by ethylene propylene rubber or X-linked poly	GE, Westinghouse, C-H, KM	VIBR, CORR/OX, ELETEMP, CONT, EXFORCE	Loose or high resistance elect connections or terminations
41		Motor Control Center	Fuse	Not stated	GE, Westinghouse, C-H, KM	FAT	Cyclic failure
42		Motor Control Center	Fuse	Not stated	GE, Westinghouse, C-H, KM	CORR/OX, CONT	High resistance contact surfaces
43		Motor Control Center	Fuse	Not stated	GE, Westinghouse, C-H, KM	ELETEMP, CORR/OX, VIBR, CONT	Loose or high resistance elect connections or terminations

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Battery	Container	Polycarbonate, styrene acrylonitrile, butadiene, styrene	C&D, GNB, Exide	CORR/SCC, ELOTEMP, FAT	Cracks in container
2		Battery	Electrolyte	Sulfuric acid and water	C&D, GNB, Exide	CONTAM	Electrolyte consumed, water loss

Document: SAND93-7069, Aging Management Guideline for Commercial Nuclear Power Plants - Notor Control Centers
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Terminal block hardware degrades primarily as a result of stresses produced during normal use. Improper maintenance techniques exacerbates this degredation.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-19, 5-17	35
Voltage and humidity can affect energized insulation that is dirty or deteriorated and cause surface tracking paths on the insulator. This can lead to flashover.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-20, 5-17	36
Simultaneous exposure to thermally deteriorated insulation to temp, voltage, humidity, dirt and contaminants can result in loss of volumetric insulating properties, leading to increased surface and volumetric leakage currents and possible flashover.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-20, 5-17	37
Insulation degradation can occur with exposure to elevated ambient temperature, ohmic heating of the conductor, and excessive ohmic heating that accompanies high resistivity connections.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-20, 5-17	38
Conductor degradation may result from bending, pulling, or crimping of the conductor or from localized heating (either from an external heat source or ohmic heating within the wire).	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-20, 5-17	39
Loose or high resistance connections or terminations may occur from bending or pulling on wire, vibration of components, inadequate torquing of fasteners, or oxidation/corrosion/contamination of contact surfaces.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-21, 5-17	40
Cyclic fatigue of the fuse holder is primarily associated with the installation or removal of fuse elements; usually some sort of frictional arrangement is employed to keep the fuse secure and properly connected.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-21, 5-18	41
High resistance contact surfaces may result from corrosion, oxidation, or contamination of the surfaces in contact with the fuse element itself. This condition may result in a loss of continuity or increased localized heating.	Not stated	Various recommendations made for maintenance	Vendor specific programs	Not stated	4-21, 5-18	42
Loose or high resistance connections or terminations may occur from vibration of components, inadequate torquing of fasteners, or oxidation/corrosion/contamination of contact surfaces.	Not stated	Various recommendations made for maintenance	No specific program for this subcomponent	Not stated	4-21, 5-18	43

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Cracks in container caused by mishandling during maintenance/installation, seismic events, plate growth and improper use of grease or cleaning solvents lead to electrolyte leakage resulting in reduced capacity.	Not stated	IEEE Std-450,535, 10 CFR 50.49,NMAC TR-100248	Tech Spec. surveillance, RG 1.129, IEEE 450	Not stated	4-17, 21, 25, 26	1
Sulfation caused by undercharging & impurities consume electrolyte and results in reduced capacity.	Not stated	IEEE Std-450,535, 10 CFR 50.49,NMAC TR-100248	Tech Spec. surveillance, RG 1.129, IEEE 450	Not stated	4-23	2

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3		Battery	Electrolyte	Sulfuric acid and water	C&D, GNB, Exide	GAS, ELETEMP	Gassing causes water loss from electrolyte
4		Battery	Plates	Lead antimony, lead calcium, lead	C&D, GNB, Exide	FAT, ELETEMP, MECHSTR	Increased mechanical stress on plates
5		Battery	Plates	Lead antimony, lead calcium, lead	C&D, GNB, Exide	GAS	Active material shedding from plates
6		Battery	Plates	Lead antimony, lead calcium, lead	C&D, GNB, Exide	CORR/OX	Increase in battery internal resistance
7		Battery	Plates	Lead antimony, lead calcium, lead	C&D, GNB, Exide	CONTAM	Local action at plates
8		Battery	Cell Top Straps	Not stated	C&D, GNB, Exide	CORR/OX	Increased battery internal resistance
9		Battery	Cell Top Straps	Not stated	C&D, GNB, Exide	FAT	Increased mechanical stress on cell top straps
10		Battery	Separators	Rubber/glass mat, polyethylene	C&D, GNB, Exide	Not stated	Hydration caused by electrolyte low specific gravity
11		Battery	Separators	Rubber/glass mat, polyethylene	C&D, GNB, Exide	ELETEMP	Thermal aging caused by excessive electrolyte temperature
12		Battery	Terminal Posts	Lead alloy, copper inserts	C&D, GNB, Exide	CORR	High connection resistance and embrittlement of material
13		Battery	Terminal Posts	Lead alloy, copper inserts	C&D, GNB, Exide	FAT	Cracked or broken terminal posts

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Gassing and electrolyte evaporation occur from overcharging and excessive temperatures. Gassing and evaporation main cause of water loss in electrolyte. Results in reduced capacity.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. surveillance, RG 1.129, IEEE 450	Not stated	4-23	3
Repeated thermal and mechanical stresses from battery charge/discharge cycles and seismic events can cause loss of active material or loss of electrical continuity, resulting in reduced battery capacity or total loss of battery output.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. Surveillance, IEEE 450-1987	Not stated	4-22	4
Active material shedding from plates results in sediment buildup at the bottom of cell. this can cause short circuits between the positive and negative plates, resulting in reduced capacity and eventually the inability to hold a charge.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. Surveillance, IEEE 450-1987	Not stated	4-23	5
Corrosion caused by oxidizing environment that exists at the positive plates. Plates become brittle and break down, decreasing their cross sectional area and increasing resistance. This leads to seismic vulnerability and decreased battery capacity.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. Surveillance, IEEE 450-1987	Not stated	4-22	6
Electrochemical reactions due to impurities in the electrolyte cause local action at the plates resulting in decreased battery capacity and potential overcharging of the positive plates.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. Surveillance, IEEE 450-1987	Not stated	4-21	7
Corrosion caused by oxidizing environment that exists at the positive plates. Straps become brittle and break down, decreasing their cross sectional area and increasing resistance. This leads to seismic vulnerability and decreased battery capacity.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. Surveillance, IEEE 450-1987	Not stated	4-22	8
Repeated thermal and mechanical stresses from battery charge/discharge cycles and seismic events can cause fatigue failure. This can cause loss of electrical continuity, resulting in reduced battery capacity or total loss of output.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech Spec. Surveillance, IEEE 450-1987	Not stated	4-22	9
Hydration causes material chemical changes in separators. Formation of metallic lead on surface of separators builds numerous short circuit paths between pos & neg plates, resulting in inability to hold charge.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	No program specific to this material	Not stated	4-21	10
Excessive electrolyte temp caused by overcharging or excessive ac ripple on the charger output reduces dielectric strength of separator mat'l and causes structural deterioration, resulting in reduced battery capacity or inability to hold charge.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	No program specific to this material	Not stated	4-23	11
High connection resistance and embrittlement of material in terminal posts results in decreased battery output and overheating of the posts.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-22	12
Repeated or improper torquing of connections during instal/maint can result in cracked or broken terminal posts. This results in increased connection resistance or loss of electrical continuity, resulting in reduced capacity or loss of battery output.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-22	13

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
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Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
14		Battery	Terminal Posts	Lead alloy, copper inserts	C&D, GNB, Exide	CORR	Fouling of terminal posts
15		Battery	Intercell Connectors	Lead plated copper bars	C&D, GNB, Exide	CORR	High connection resistance, embrittlement
16		Battery	Intercell Connectors	Lead plated copper bars	C&D, GNB, Exide	FAT	Cracked or broken intercell connectors
17		Battery	Intercell Connectors	Lead plated copper bars	C&D, GNB, Exide	CORR	Fouling of intercell connectors
18		Battery	Terminal Post Seals	Not stated	C&D, GNB, Exide	FAT	Cracking of the terminal post seals
19		Battery	Battery Racks	Steel	Not stated	CORR, FAT	Rack structure weakened
20		Battery	Container	Polypropylene	C&D, GNB, Exide	CORR/SCC, FAT	Cracks in container
21		Battery	Container	Polypropylene	C&D, GNB, Exide	FAT	Fatigue cracking of cover
22		Battery	Electrolyte	Potassium Hydroxide	C&D, GNB, Exide	Not stated	Decreased conductivity of electrolyte
23		Battery	Electrolyte	Potassium Hydroxide	C&D, GNB, Exide	GAS	Gassing causes water loss from electrolyte
24		Battery	Plates	Nickel hydroxide, cadmium hydorxide	C&D, GNB, Exide	Not stated	Aging of active material

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fouling of terminal posts can occur due to accumulation of dirt, dust, and leaked electrolyte. This can cause corrosion at the electrical connections, short circuits, and battery grounding, resulting in degraded battery output, discharge or overheating.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-24	14
Excessive ambient humidity, external dust and dirt, electrolyte leaks and spills can cause corrosion of connectors. This results in high connection resistance and embrittlement resulting in decreased battery output and overheating of connectors.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-22	15
Repeated or improper torquing of connections during install/maint can result in cracked or broken intercell connectors. This results in increased connection resistance or loss of elec continuity, resulting in reduced capacity or loss of battery output.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-22	16
Fouling of intercell connectors can occur due to accumulation of dirt, dust, and leaked electrolyte. This can cause corrosion at the electrical connections, short circuits, and battery grounding, resulting in degraded output, discharge or overheating.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-24	17
Fatigue failures can occur in post seals due to improper handling, plate growth, excessive corrosion which stresses the seals and covers. This can cause a loss of electrolyte and venting of gases, resulting in reduced capacity or loss of output.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-23	18
Electrolyte leaks or spills, humidity and high temp can cause corrosion of battery rack which can weaken the structure. This can cause structural failure and loss of supported battery.	Not stated	IEEE Std-450,535,10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-22	19
Damage to container is caused by improper use of greases and cleaning solvents which react with container material or weaken the structure. This can lead to reduced capacity.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. surveillance, IEEE 1106-1987	Not stated	4-25	20
Thermal expansion and improper handling introduce stresses to container cover which can cause cracking. This can result in gas release, possible air intrussion, and loss of electrolyte which may result in conductive paths to ground and loss of capacity.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. surveillance, IEEE 1106-1987	Not stated	4-25	21
Material chemical changes occur due to carbonation of potassium hydroxide electrolyte when exposed to carbon dioxide in air, which decreases conductivity of electrolyte. This increases battery internal resistance and decreases capacity.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. surveillance, none for this comp.	Not stated	4-24	22
Gassing & electrolyte evaporation is due to overcharging and elevated temp. These cause electrolyte water loss, which will reduce battery capacity. Evaporation also contributes to water loss.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. surveillance, IEEE 1106-1987	Not stated	4-26	23
Recrystallization of the nickel hydroxide in the positive plates causes gradual aging of the active material. This results in reduced capacity.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. surveillance, none for this comp.	Not stated	4-24	24

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
25		Battery	Separators	Plastic	C&D, GNB, Exide	ELETEMP	Reduced delectric strength of separator material
26		Battery	Terminal Posts	Not stated	C&D, GNB, Exide	CORR	Failure of terminal posts
27		Battery	Terminal Posts	Not stated	C&D, GNB, Exide	FAT	Cracked or broken terminal posts
28		Battery	Terminal Posts	Not stated	C&D, GNB, Exide	CORR	Corrosion, short ckts and grounding caused by fouling
29		Battery	Intercell Connectors	Nickel-plated copper bars with stainless steel hardware	C&D, GNB, Exide	CORR	Failure of intercell connectors
30		Battery	Intercell Connectors	Nickel-plated copper bars with stainless steel hardware	C&D, GNB, Exide	FAT	Cracked or broken intercell connectors
31		Battery	Intercell Connectors	Nickel-plated copper bars with stainless steel hardware	C&D, GNB, Exide	CORR	Corrosion, short ckts, grounding caused by fouling
32		Battery	Terminal Post Seals	Not stated	C&D, GNB, Exide	FAT	Fatigue cracking of post seals
33		Battery	Battery Racks	Steel	Not stated	CORR, FAT	Rack structure weakened
34		Battery	Pressure Relier Valve	Not stated	Not stated	Not stated	Malfunction of valve
35		Battery	Electrolyte	Not stated	Not stated	Not stated	Dryout of electrolyte
36		Battery	Electrolyte	Not stated	Not stated	ELETEMP	Thermal runaway

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Overcharging or excessive ac ripple on charger output cause excessive electrolyte temp which reduces the dielectric strength of separator mat'l & deteriorates mech strength. This results in reduced capacity & eventual inability to hold charge.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	No program specific to this subcomponent	Not stated	4-26	25
Humidity, dust, and elevated temperatures can lead to corrosion of the terminal posts. This can lead to failure of terminal posts.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	4-25	26
Repeated or improper torquing of connections can result in cracked or broken terminal posts. This results in increased connection resistance or loss of continuity. This results in reduced capacity or total loss of output.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	2-25	27
Fouling of terminal posts caused by accumulation of dirt, dust, and leaked electrolyte can cause corrosion, short circuits between pos and neg posts, and battery grounding. This results in degraded output, batt discharge, or overheating of connections.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	4-24	28
Humidity, dust, and temperature can lead to corrosion of intercell connectors. This can lead to failure of the intercell connectors.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	4-25	29
Repeated or improper torquing of connections can result in cracked or broken intercell connectors. This results in increased connection resistance or loss of continuity which reduces battery capacity or results in total loss of battery output.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	4-25	30
Dirt, dust, and leaked electrolyte cause fouling of intercell connectors. fouling coupled with moisture condensation leads to corrosion, which causes current paths to ground. This results in degraded batt output, discharge or overheating of connections.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	4-26	31
Excessive stresses caused by thermal expansion, corrosion of terminal posts, and improper handling can lead to fatigue cracking of terminal post seals, leading to gas release, air intrusion, loss of electrolyte. Results in conductive paths to ground.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	Tech. Spec. required surveillance. IEEE 1106	Not stated	4-25	32
Humidity, dust accumulation, and temperature can lead to corrosion in the battery racks. This can cause structural failure and loss of supported battery.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	IEEE 1106-1987	Not stated	4-25	33
Wear occurs due to relative movement between contacting internal parts and can cause malfunction of valve. This can allow gases and vapors to escape, resulting in lowered gas recombination efficiency. This can lead to dryout.	Not stated	IEEE Std-1106,10 CFR 50.49,EPRI NMAC TR-10248	No program specific to this subcomponent	Not stated	4-27	34
Overcharging, elevated temperatures, failed pressure relief valve or cracked container or seal can lead to dryout of electrolyte. This can result in battery failure.	Not stated	IEEE PAR 1188, 10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450 & 1106	Not stated	4-27	35
Elevated temperature, improper (high) float voltage, or excessive ac ripple from battery charger can cause thermal runaway. This can result in battery failure.	Not stated	IEEE PAR 1188, 10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-28	36

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
37		Battery	Electrolyte	Not stated	Not stated	Not stated	Memory effect

Document: TIRGALEX, Plan for Integration of Aging and Life-Extension Activities
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Cable	Not stated	Not stated	Not stated	ELETEMP, RAD, MOIST-EL, & VIB.	Not stated
2		Conectors	Not stated	Not stated	Not stated	ELETEMP, RAD, MOIST-EL, & VIB.	Not stated
3		Switchgear	Not stated	Not stated	Not stated	WEAR & LOSLUB	Not stated
4		Relays	Not stated	Not stated	Not stated	CORR, WEAR, & ELETEMP	Not stated

Document: WYLE 60103-1, Test Plan of Molded Case Circuit Breakers for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Pla
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Molded Case Circuit Breakers	5 Relay Types and 3 Types of Circuit Breakers	Not stated	Three mfg. listed	Not stated	Not stated

Document: WYLE 60103-2, Test Plan of Metal Clad Circuit Breakers for the Comprehensive Aging Assessment of Circuit Breakers and Relays for ----- NPAR Pı
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Metal Clad Circuit Breakers	Not stated	Not stated	GE & Westinghouse	Not stated	Not stated

Document: WYLE 60103-3, Test Plan of Auxiliary Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for ---- (NPAR) Program Pha
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Auxiliary Relays	Not stated	Not stated	Westinghouse	Not stated	Not stated

Document: WYLE 60103-4, Test Plan of Control Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for ----- (NPAR) Program, Phe
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Control Relays	Not stated	Not stated	Three mfg.s listed	Not stated	Not stated

Document: WYLE 60103-5, Test Plan of Protective Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant Aging Res
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Protective Relays	Not stated	Not stated	GE & Westinghouse	Not stated	Not stated

Document: SAND93-7071, Aging Management Guideline for Commercial Nuclear Power Plants - Stationary Batteries
Reviewed by: K. D. McCarthy, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Successive small discharge cycles can lead to a memory effect in a sintered plate nickel-cadmium battery. This can result in reduced capacity.	Not stated	IEEE PAR 1188, 10 CFR 50.49, NMAC TR-100248	Tech. Spec. surveillance, IEEE 450-1987	Not stated	4-28	37

Document: TIRGALEX, Plan for Integration of Aging and Life-Extension Activities
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	IBE79-01, NUREG-0588, 10CFR 50.49, & RG 1.89	No specific program	Five recommendations are given for resolving aging and life extension issues [4]	A31-A36	1
Not stated	Not stated	IBE79-01, NUREG-0588, 10CFR 50.49, & RG 1.89	No specific program	Five recommendations are given for resolving aging and life extension issues [1]	A31-A36	2
Not stated	Not stated	Generic Letter 83-28 concerns and Tech Specs	IEEE 741-1986 Section 7	Three issues requiring followup are listed. [1]	A51 & A53	3
Not stated	Not stated	Generic Letter 83-28 concerns and Tech Specs	Dependent upon type and function of the relay	Followup on calibration frequency for protective relays, seismic fragility, and effect of common mode failure on safety [1]	A52 & A53	4

Document: WYLE 60103-1, Test Plan of Molded Case Circuit Breakers for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	No specific program, application dependent	Not stated	1-1	1

Document: WYLE 60103-2, Test Plan of Metal Clad Circuit Breakers for the Comprehensive Aging Assessment of Circuit Breakers and Relays for —— NPAR Pro
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	RG 1.118, IEEE 338-1987, TECH. SPEC. MAINT. &	Not stated	4-1	1

Document: WYLE 60103-3, Test Plan of Auxiliary Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for —— (NPAR) Program Phase
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	Dependent upon application, Tech. Spec. maint	Not stated	1-1, 1-2, & 4-1	1

Document: WYLE 60103-4, Test Plan of Control Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for —— (NPAR) Program, Phas
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	No specific program	Not stated	3-1	1

Document: WYLE 60103-5, Test Plan of Protective Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant Aging Rese
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	Tech Spec surveillance	Not stated	4-1	1

Document: WYLE 60103-6, Test Plan of Timing Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant Aging Rese
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Timing Relays	Not stated	Not stated	Agastat	OXIDAT	Degradation caused by oxidation surfaces

Document: WYLE 60103-7, Test Plan of Electronic Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant Aging Re
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Electronic Relays	Not stated	Not stated	Basler	Not stated	Not stated

Document: WYLE 60103-6, Test Plan of Timing Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant Aging Researc
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Relay failure due to contact oxidation caused by low current application of silver alloy contacts.	Occasional	Not discussed in report	Application dependent, Tech Spec Surveill.	Not stated	4-1	1

Document: WYLE 60103-7, Test Plan of Electronic Relays for the Comprehensive Aging Assessment of Circuit Breakers and Relays for Nuclear Plant Aging Rese
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	Application dependent, likely no program	Not stated	4-1	1

Document: GL 91-15, Operating Experience Feedback Report, Solenoid-Operated Valve Problems at U.S. Reactors
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Not stated	Not stated	Solenoid Operated Valves	Not stated	Not stated	Not stated	Not stated

Document: GL 91-15, Operating Experience Feedback Report, Solenoid-Operated Valve Problems at U.S. Reactors
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Reference to case report study NUREG-1275, volume 6, "Operating Experience Feedback Report--Solenoid-Operated Valve Problems," February 1991	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		1

Document: IN NO. 89-07, Failures of Small-Diameter Tubing in Control Air, Fuel Oil, and Lube Oil Systems Which Render Emergency Diesel Generators Inoper
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Emergency diesel generators		Small Diameter Tubing	Stainless Steel	Not stated	VIBR	Cracks, breaks, & holes in tubing

Document: IN NO. 89-17, Contamination and Degradation of Safety-Related Battery Cells
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2			Battery Cells Connections	Copper	Not stated	CONTAM	Electrolytic transfer of copper to battery lead term/plates

Document: IN NO. 89-20, Weld Failures in A Pump of Byron-Jackson Design
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3		Pump	Welds	Not stated	Byron Jackson	VIBR	Weld cracks

Document: IN NO. 89-42, Failure of Rosemount Models 1153 and 1154 Transmitters
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4			Pressure Transmitters	Not stated	Rosemount	Not stated	Loss of oil from sensing module

Document: IN NO. 89-43, Permanent Deformation of Torque Switch Helical Springs in Limitorque SMA-Type Motor Operators
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5		Torque Switch	Helical Springs	Not stated	Limitorque	MECHSTR	Permnent deformation of helical spring

Document: IN NO. 89-64, Electrical Bus Bas Failures
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
6		Electrical Bus	Noryl Insulation	Not stated	Not stated	CONTAM EMBR	Electrical ground fault, short to ground

Document: IN NO. 89-66, Qualification Life of Solenoid Valves
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7		Duel-Coil Solenoid Valve	Elastomer Seat	Ethylene Propylene Dimer (EPDM)	Automatic Switch Co.	CONTAM ELETEMP	Sticky and deformed seats

Document: IN NO. 89-79, Degraded Coatings and Corrosion of Steel Containment Vessels
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
8		Containment Vessels	Coatings	Not stated	Not stated	MOIST-EL	Coating failure

Document: IN NO. 89-84, Failure of Ingersoll Rand Air Start Motors as A Result of Pinion Gear Assembly Fitting Problems
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9	Diesel Generator	Air Starter Pinion Gear	Tang and Retainer Bolts	Not stated	Ingersoll Rand	WEAR VIBR	Cracking of retainer ring and loosening of bolts

Document: IN NO. 89-07, Failures of Small-Diameter Tubing in Control Air, Fuel Oil, and Lube Oil Systems Which Render Emergency Diesel Generators Inoperativ
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inoperability of EDG	Not stated	Not discussed in report	Vendor specific, RG 1.108, IEEE 387, IEEE 749	Review info and take actions as appropriate. [4]		1

Document: IN NO. 89-17, Contamination and Degradation of Safety-Related Battery Cells
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of battery capacity	Not stated	Tech. spec requires exam, clean, & test connections	Tech. Spec., RG 1.129, IEEE 450-1987	Review info and take actions as appropriate [4]		2

Document: IN NO. 89-20, Weld Failures in A Pump of Byron-Jackson Design
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Broken ring and impeller - fasteners in recirculation loop	Not stated	Not discussed in report	Vendor specific, may have Tech. Spec. surveil	Review info and take actions as appropriate [4]		3

Document: IN NO. 89-42, Failure of Rosemount Models 1153 and 1154 Transmitters
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Transmitter failure	Not stated	Not discussed in report	Bul 90-1 Suppl. 1	Review info and take actions as appropriate [4]		4

Document: IN NO. 89-43, Permanent Deformation of Torque Switch Helical Springs in Limitorque SMA-Type Motor Operators
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Operability problem with valve motor operator	Not stated	Not discussed in report	Vendor specific, NUREG-1352	Not stated		5

Document: IN NO. 89-64, Electrical Bus Bas Failures
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inoperable electrical bus	Not stated	Not discussed in report	IEEE 338-1987, RG 1.118, IEEE 741-1986	Review info and take actions as appropriate [4]		6

Document: IN NO. 89-66, Qualification Life of Solenoid Valves
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valves fail to operate as required	Frequent	Not discussed in report	Application dependent, may have Tech Spec req	Review info and take actions as appropriate [4]		7

Document: IN NO. 89-79, Degraded Coatings and Corrosion of Steel Containment Vessels
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Oxidation and pitting of steel tanks	Not stated	Not discussed in report	Vendor specific	Review info for applicability and take actions as appropriate [4]		8

Document: IN NO. 89-84, Failure of Ingersoll Rand Air Start Motors as A Result of Pinion Gear Assembly Fitting Problems
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Diesel generators would not start	Frequent	Not discussed in report	RG 1.108,IEEE 387,IEEE 749,Tech. Spec. maint.	Review info and consider actions as appropriate [4]		9

Document: IN NO. 90-41, Potential Failure of General Electric Magne-Blast Circuit Breakers and AK Circuit Breakers
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
10		Circuit Breakers	Prop Reset Spring	Not stated	General Electric	FAT	Broken spring

Document: IN NO. 90-51, Failures of Voltage-Resistors in the Power Supply Circuitry of Electric Governor Systems
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	Emergency Diesel Generator	Governor Control Power Supply	Voltage Dropping Resistor	Not stated	Pacific Resistor	ENVIR ELTEMP	Loss of resistance value

Document: IN NO. 90-51-01, Failures of Voltage-Resistors in the Power Supply Circuitry of Electric Governor Systems
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
12	Emergency Diesel Generator	Governor Control Power Supply	Voltage Dropping Resistor	Not stated	Not stated	CURSTR & ELETEMP	Loss of resistance value

Document: IN NO. 90-80, Sand Intrusion Resulting in Two Diesel Generators Becoming Inoperable
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13	Diesel Generatrors	Cylinders	Liners and Piston Rings	Not stated	Not stated	CONTAM ADH	Scoring of liners and piston rings

Document: IN NO. 91-20, Electric Wire Insulation Degradation Caused Failure in A Safety-Related Motor Control Center
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
14		Motor Control Center	Wire	PCV - Vegatable oil plasticierR	Not stated	ELTEMP	Cond cover emits liquid which hardens on electrical contact

Document: IN NO. 91-45, Possible Malfunction of Westinghouse ARD, BFD, and NBFD Relays, and A200 DC and DPC 250 Magnetic Contactors
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15		Relays	Coils	Epoxy	Westinghouse	ELTEMP	Epoxy becomes fluid when coil is energized for ext. period

Document: IN NO. 91-46, Degradation of Emergency Diesel Generator Fuel Oil Delivery Systems
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
16	Diesel Generators		Filters and Injectors	Not stated	Not stated	CONTAM	Excessive particulate, fouled filters and injectors

Document: IN NO. 91-62, Diesel Enging Damage Caused by Hydraulic Lockup Resulting From Fluid Leakage Into Cylinders
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
17	Emergency Diesel Generator	Diesel Engine	Head Gasket	Not stated	Not stated	Not stated	Water leaks into cylinder

Document: IN NO. 91-78, Status Indication of Control Power for Circuit Breakers Used in Safety-Related Applications
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
18		Indicator Lights	Fuse Holders	Not stated	Not stated	FAT	Fuse holder fingers deformed resulting in poor elect contact

Document: IN NO. 90-41, Potential Failure of General Electric Magne-Blast Circuit Breakers and AK Circuit Breakers
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Breaker would attempt to close but would trip free	Frequent	Not discussed in report	RG 1.108,IEEE 387,IEEE 749,Tech. Spec. maint	Review info and consider actions as appropriate [4]		10

Document: IN NO. 90-51, Failures of Voltage-Resistors in the Power Supply Circuitry of Electric Governor Systems
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Edg loses speed control	Frequent	Scheduled Replacement	RG 1.108, IEEE 387, IEEE 749	Review info and consider actions if applicable [4]		11

Document: IN NO. 90-51-01, Failures of Voltage-Resistors in the Power Supply Circuitry of Electric Governor Systems
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure of resistor leads to governor power supply. Failure in original design. resistor failure in new replacement assembly results in a backup mechanical governor taking control of speed.	Frequent - old; Rare - new	Scheduled Replacement	RG 1.108, IEEE 387, IEEE 749	Review info and consider actions if applicable [4]	1 & 2	12

Document: IN NO. 90-80, Sand Intrusion Resulting in Two Diesel Generators Becoming Inoperable
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inoperable diesel generators - maintenance activity introduced sand into diesel cylinders	Not stated	Not discussed in report	No specific program	Review info and consider actions if applicable [4]		13

Document: IN NO. 91-20, Electric Wire Insulation Degradation Caused Failure in A Safety-Related Motor Control Center
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Insulates electrical contacts	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		14

Document: IN NO. 91-45, Possible Malfunction of Westinghouse ARD, BFD, and NBFD Relays, and A200 DC and DPC 250 Magnetic Contactors
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Degrades or delays relay function	Not stated	Not discussed in report	No specific program	Review info and consider actions if applicable [4]		15

Document: IN NO. 91-46, Degradation of Emergency Diesel Generator Fuel Oil Delivery Systems
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inoperable diesel generator	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		16

Document: IN NO. 91-62, Diesel Enging Damage Caused by Hydraulic Lockup Resulting From Fluid Leakage Into Cylinders
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Damage to engine will cause EDG failure	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		17

Document: IN NO. 91-78, Status Indication of Control Power for Circuit Breakers Used in Safety-Related Applications
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Improper indication of motor operation	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		18

Document: IN NO. 91-81, Switchyard Problems That Contribute to Loss of Offsite Power
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19		Swithcyard Control System	Zener Diodes	Not stated	Not stated	VOLSTR	Zenor diode failure

Document: IN NO. 91-83, Solenoid-Operated Valve Failures Resulted in Turbing Overspeed
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
20	Turbine		Soleniod- Operated Valves	Not stated	Parker Hannifin	Not stated	Pilot valve assy mechanically bound

Document: IN NO. 91-85, Potential Failures of Thermostatic Control Valves for Diesel Generator Jacket Cooling Water
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
21	Diesel Generator	Cooling Water System	Thermostatic Control Valve	Not stated	Not stated	Not stated	Valve failure

Document: IN NO. 91-87, Hydrogen Embrittlement of Raychem Cryofit Couplings
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
22		Gas Space Sampling Line	Cryofit Coupling	Tinel (50% Titanium and 50% Nickel)	Raychem	EMBR/HY & ELETEMP	Circumferential fracture at the midpoint of coupling

Document: IN NO. 92-04, Potter & Brumfield Model MDR Rotary Relay Failures
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
23		Rotary Relay	Rotor Coil	Varnish	Potter & Brumfield	CORR	Deposits on rotor

Document: IN NO. 92-27, Thermally Induced Accelerated Aging and Failure of ITE/GOULD A.C. Relaty Used in Safety-Related Applications
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
24		Relay	Plastic Armature Carrier and Coil Insulation	Not stated	ITE/Gould	ELETEMP	Brittleness and cracking

Document: IN NO. 92-44, Problems With Westinghouse DS-206 Type Circuit Breakers
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
25		Circuit Breaker	Reset Spring	Not stated	Westinghouse	FAT	Weakened spring

Document: IN NO. 92-48, Failure of Exide Batteries
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
26		DC Power	Battery cells	Not stated	Exide	CORR	Cracking of battery face

Document: IN NO. 92-78, Piston to Cylinder Liner Tin Smearing On Cooper=Bessemer KSV Diesel Engines
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
27	Diesel Generator	Cylinders	Walls	Not stated	Cooper Bessemer KSV	CORR	Transfer of tin from cyl. walls and breakdown of lubrication

Document: IN NO. 91-81, Switchyard Problems That Contribute to Loss of Offsite Power
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of switchyard control	Not stated	Not discussed in report	RG 1.118, IEEE 741-1986 Section 7	Review info and consider actions as appropriate [4]		19

Document: IN NO. 91-83, Solenoid-Operated Valve Failures Resulted in Turbing Overspeed
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valves failed to close allowing steam to cause turbine overspeed	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		20

Document: IN NO. 91-85, Potential Failures of Thermostatic Control Valves for Diesel Generator Jacket Cooling Water
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Overheating of diesel generator	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		21

Document: IN NO. 91-87, Hydrogen Embrittlement of Raychem Cryofit Couplings
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The fractured coupling allowed a reactor coolant system leak that exceded the 1.0 gpm technical specification limit.	Rare	Not discussed in report	No specific program	Not stated	1 & 2	22

Document: IN NO. 92-04, Potter & Brumfield Model MDR Rotary Relay Failures
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Mechanical binding of rotor and failure of relay to operate properly within 2 to 5 years after installation	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as applicable [4]		23

Document: IN NO. 92-27, Thermally Induced Accelerated Aging and Failure of ITE/GOULD A.C. Relaty Used in Safety-Related Applications
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Coil shorts and relay fails to operate	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		24

Document: IN NO. 92-44, Problems With Westinghouse DS-206 Type Circuit Breakers
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Breaker fails to open when required	Not stated	Not discussed in report	Vendor specific program	Review info and consider action as appropriate [4]		25

Document: IN NO. 92-48, Failure of Exide Batteries
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leakage of electrolytic and battery cell failure	Not stated	Not discussed in report	RG 1.129, IEEE 450-1987, Tech. Spec. Surveil.	Review info and consider action as applicable [4]		26

Document: IN NO. 92-78, Piston to Cylinder Liner Tin Smearing On Cooper=Bessemer KSV Diesel Engines
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Crankcase explosions and diesel failure	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		27

Document: IN NO. 93-05, Storm-Related Loss of Offsite Power Events Due to Salt Buildup on Switchyard Insulators
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
28		Switch Yard	Insulators	Not stated	Not stated	CONTAM	Arcing across salt-lading insulators

Document: IN NO. 93-22, Tripping of Klockner-Moeller Molded-Case Circuit Breakers due to Support Lever Failure
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
29		Mold-Case Circuit Breakers	Support Lever (Spring Arm)	Polycarbonate & Glass fiber composite	Klockner Moeller	CORR FAT	Fractured support lever

Document: IN NO. 93-23, Weschler Instruments Model 252 Switchboard Meters
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
30		Indicating Meters	Meter Movement	Not stated	Weschler	ADH	Sticking movement

Document: IN NO. 93-26, Grease Solidification Causes Molded-Case Circuit Breaker Failure to Close
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
31		Mold-Case Circuit Breakers	Grease	Soap-based or clay-based grease	General Electric	ENVIR	Drying out of grease, friction, gouging of metal-to-metal

Document: IN NO. 93-33, Potential Deficiency of Certain Class 1E Instrumentation and Control Cables
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
32			Cables	Not stated	Not stated	REFERENCE NUREG/CR-5772	Reference nureg/cr-5772

Document: IN NO. 93-64, Periodic Testing and Preventive Maintenance of Modled Case Circuit Breakers
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
33			Circuit Breakers Type EB and EHB	Not stated	Westinghouse	Not stated	Thermal and instantaneous trip not within specifications

Document: IN NO. 94-04, Digital Integrated Circuit Sockets With Intermittent Contact
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
34		Digital Board	Socket Contacts	Tin-lead	Augat	CORR/OX	Contact failure

Document: IN NO. 94-33, Capacitor Failures in Westonghouse Easge 21 Plant Protection Systems
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
35	Westinghouse Eagle 21 plant protection system	ASTEC America DC Power Supply	Electrolytic Capacitors	Epoxy module	AVX	ELTEMP	Capacitor failure

Document: IN NO. 93-05, Storm-Related Loss of Offsite Power Events Due to Salt Buildup on Switchyard Insulators
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of offsite ac power	Not stated	Not discussed in report	IEEE 765-1983, Plant specific program	Review info and consider actions as appropriate [4]		28

Document: IN NO. 93-22, Tripping of Klockner-Moeller Molded-Case Circuit Breakers due to Support Lever Failure
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Breakers tripped without cause	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		29

Document: IN NO. 93-23, Weschler Instruments Model 252 Switchboard Meters
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inaccurate meter indications	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		30

Document: IN NO. 93-26, Grease Solidification Causes Molded-Case Circuit Breaker Failure to Close
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Breaker fails to close	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		31

Document: IN NO. 93-33, Potential Deficiency of Certain Class 1E Instrumentation and Control Cables
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
References the result of the NUREG report to evaluate plant cables	Not stated	Not discussed in report	No specific program	Review info and consider actions as appropriate [4]		32

Document: IN NO. 93-64, Periodic Testing and Preventive Maintenance of Modled Case Circuit Breakers
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Age, failure to excercise, and lack of maintenance caused breakers trips to go out of specifications	Not stated	Not discussed in report	Vendor specific program, Tech. Spec.	Review info and consider actions as appropriate [4]		33

Document: IN NO. 94-04, Digital Integrated Circuit Sockets With Intermittent Contact
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Not stated	Not stated	Not discussed in report	No specific program	Review info and consider action as appropriate [4]		34

Document: IN NO. 94-33, Capacitor Failures in Westonghouse Easge 21 Plant Protection Systems
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Power supply failure	Not stated	Not discussed in report	Vendor specific program	Review info and consider actions as appropriate [4]		35

Document: LER 88-011-282, Auto-Start of Train A of Auxiliary Building Special Ventilation System as a result of a Radiation Monitor Spike
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1	Ventilation System	Radiation Monitor	Not stated	Not stated	Not stated	Not stated	Rad monitor spike - attributed to age of rad mon equipment

Document: LER 88-033-02-327, Unplanned Reactor Trip Signal Due to a Reactor Protection System (RPS) Channel 1 Instrument Failure During RPS Channel 2
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
2	Reactor Protection System	Not stated	Not stated	Not stated	Foxboro	Not stated	Two transistors shorted and bridge assembly open circuited

Document: LER 89-001-280, Unplanned Auto Start of #3 EDG Due to Failed Diode
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
3	Diesel Generator	Control Circuit	Diode	Not stated	GM Electro-Motive Division	Not stated	Failed diode caused start relay to actuate

Document: LER 89-002-331, Age-Related Failure of a Governor Printed Circuit Board Results in High Pressure Coolant Injection System Inoperability
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
4	High Pressure Injection System	Turbine Governor	Printed Circuit Board Component	Not stated	Woodward Governor Company	ELETEMP	Intermitant electronic componet output

Document: LER 89-003-263, Isolation of Reactor Water Cleanup System Due to Capacitor Failure in Filter/Demineralizer Inlet Temperature Indication Switch
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
5	RWCU	Electronic Circuit Filter	Capacitor	Not stated	Seimans	Not stated	Capacitor failed

Document: LER 89-006-261, Reactor Trip Due to Loss of Turbine E-H Control Power Supplies
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
6	Turbine Control	Power Supply	Transistor	Not stated	Solid State Controls Inc.	CURSTR & VOLSTR	Transistors developed leakage current

Document: LER 89-010-362, Fuel Handling Isolation System Train "A" Actuation Due to Power Supply Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
7	Fuel Handling Isolation System	Power Supply	Regulator	Not stated	Nuclear Meaurement Corp.	ELETEMP	Nylon screw broken due to thermal aging

Document: LER 88-011-282, Auto-Start of Train A of Auxiliary Building Special Ventilation System as a result of a Radiation Monitor Spike
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Auto-start of aux building ventilation system when not called for. The electronics was 16 years old. Root cause of spike unknown. rad monitor upgrade pursued.	Not stated	10 CFR 50.73	Vendor specific program	Not stated	1-3	1

Document: LER 88-033-02-327, Unplanned Reactor Trip Signal Due to a Reactor Protection System (RPS) Channel 1 Instrument Failure During RPS Channel 2 C
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure of a rcs channel 1 delta T/Tavg loop instrument caused an unplanned reactor trip signal. Component aging was referenced as a possible failure mechanism.	Not stated	10 CFR 50.73	Tech. Spec. surveillance, RG 1.118, IEEE 338	Not stated	1-4	2

Document: LER 89-001-280, Unplanned Auto Start of #3 EDG Due to Failed Diode
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The failure of the diode was attributed to normal aging. the start relay iniated the air start motors and started the diesel when no emergency existed.	Not stated	10 CFR 50.73	No specific surveillance for this component	Not stated	1-3	3

Document: LER 89-002-331, Age-Related Failure of a Governor Printed Circuit Board Results in High Pressure Coolant Injection System Inoperability
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure to operate, reason was unanticipated age-related response of the printed circuit board's components due to long term constant energization and possibly environmental factors. Vendor indicated that long term constant current flow could reduce life	Rare	10 CFR 50.73	Tech. Spec. Surveillance req'd for HPI	Change out the governor printed circuit boards every eight years [4]	1-4	4

Document: LER 89-003-263, Isolation of Reactor Water Cleanup System Due to Capacitor Failure in Filter/Demineralizer Inlet Temperature Indication Switch
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Unexpected capacitor failure caused circuit to actuate a portion of the ESF system. Aging was given as the cause of the capacitor failure	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-3	5

Document: LER 89-006-261, Reactor Trip Due to Loss of Turbine E-H Control Power Supplies
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Transistor leakage current caused increased gain resulting in higher voltage on the output stage of the power supply. the over voltage protective circuitry was triggered causing the fuse to blow. degraded transistors attributed to aging.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	6

Document: LER 89-010-362, Fuel Handling Isolation System Train "A" Actuation Due to Power Supply Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Lost power from the power supply when the regulator shifted due to the broken screw and allowed a burr on the metal heat sink to penetrate the mica insulation. a short circuit resulted blowing a fuse.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-5	7

Document: LER 89-014-271, Reactor Core Isolation Cooling System Inoperable Due to Motor Burn Out
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
8	Reactor Core Isolation Cooling System	Motor Operated Valve	Motor	Not stated	Not stated	CURSTR	Failed armature winding

Document: LER 89-015-327, Control Room Isolation Resulting From a Worn Set of Contacts in the 480V Motor Starter for a Main Control Room Ventilation Intake
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
9	Control Room Isolation	Motor Starter	Contacts	Not stated	Not stated	WEAR	Increased contact resistance causing arcing

Document: LER 89-019-01-325, Failure of Service Water System to Meet Design Requirements
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
10	Service Water System	Pump	Winding Insulation	Not stated	General Electric	ELETEMP	Degraded insulation on motor winding

Document: LER 89-020-01-528, Apparent Ground Causes Control Element Assembly Slip
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
11	Control Element Assembly	Coil	Coil Lead Wire	Not stated	Combustion Engineering	Not stated	Not aging related

Document: LER 89-031-01-302, Failure of "A" 480V Engineered Safeguards Transformer Causes Temporary Interruption of Decay Heat Cooling and a Plant Ope
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
12	ESFAS	Transformer	Transformer Insulation	Not stated	Not stated	Not stated	Insulation degradation

Document: LER 90-007-01-388, ESF Actuations Due to RPS EPA Breaker Spurious Trip
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
13	Reacotr Protection System	Electrical Protection Assembly	Logic Card	Not stated	General Electric	Not stated	Logic card failed

Document: LER 90-018-244, Dropped Control Rod During Rod Control Exercise Causes Automatic Actuation of RPS
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
14	Control Rod Drive System	Power Bridge	Capacitor	Not stated	Westinghouse	ELETEMP	Degraded capacitor

Document: LER 90-022-01-344, Degraded Fire Penetration Seals as a Result of Inadewuate Construction Technique
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
15	Various	Cable Penetrations	Seal	Silicon foam	Not stated	WEAR	Degradation of foam, splits and gaps.

Document: LER 89-014-271, Reactor Core Isolation Cooling System Inoperable Due to Motor Burn Out
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valve failed to close because of failed motor. An incorrect upper bearing gasket thickness resulted in a motor current 20% above full rated load which is believed to have contributed to premature aging.	Rare	10 CFR 50.73	Vendor specific testing	Not stated	1-4	8

Document: LER 89-015-327, Control Room Isolation Resulting From a Worn Set of Contacts in the 480V Motor Starter for a Main Control Room Ventilation Intake F
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Contacts not conducting properly and current was arcing over introducing EMI into the circuitry resulting in a spurious high radiation signal that initiated the control room isolation.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-3	9

Document: LER 89-019-01-325, Failure of Service Water System to Meet Design Requirements
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Inadequate air flow through the motor winding over a period of time resulted in thermally aged insulation that resulted in a turn to turn failure.	Rare	10 CFR 50.73	IEEE 334-1974 Section 14.2	Not stated	1-4	10

Document: LER 89-020-01-528, Apparent Ground Causes Control Element Assembly Slip
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Manufacturing defect	Rare	10 CFR 50.73	Vendor specific program	Not stated	4 & 5	11

Document: LER 89-031-01-302, Failure of "A" 480V Engineered Safeguards Transformer Causes Temporary Interruption of Decay Heat Cooling and a Plant Opera
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Transformer failed causing a cooling pump to de-energize and loss of decay heat cooling. Power was also interrupted to various plant ventilation systems. Event compounded by personnel error.	Rare	10 CFR 50.73	RG 1.118, IEEE 338-1987, IEEE 741-1986	Not stated	1 & 3	12

Document: LER 90-007-01-388, ESF Actuations Due to RPS EPA Breaker Spurious Trip
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The logic card failure caused the trip breaker to operate and initiated other esf actuations. The card failure was attributed to aging and the aging process was found to be applicable when the epa logic card was both in service and in storage.	Occasional; (12 times/6 Y)	10 CFR 50.73	RG 1.118, IEEE 338-1987	Not stated	1-5	13

Document: LER 90-018-244, Dropped Control Rod During Rod Control Exercise Causes Automatic Actuation of RPS
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Noisy incoming power to the control rod J-10 (caused the rod to drop) was attributed to the degraded capacitor. Elevated temperature at the power supply location was the cause of the decreased service life of the capacitor.	Rare	10 CFR 50.73	Vendor specific program	Not stated	1-8	14

Document: LER 90-022-01-344, Degraded Fire Penetration Seals as a Result of Inadewuate Construction Technique
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Degradation of foam is attributed to aging and wear as noted under other defects	Occasional	10 CFR 50.73	Vendor specific program	Not stated	1-6	15

Document: LER 90-023-325, Partial Group 6 Isolation Resulting From Failure of Relay I-CAC-3A
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
16	Containment Isolation Control	Isolation Logic	Coil	Not stated	General Electric	Not stated	Coil burned up

Document: LER 90-023-424, Transformer Failure Results in Loss of Steam Generator Level and Manual Reactor Trip
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
17	Non 1-E Power System	Transformer	Not stated	Not stated	General Electric	Not stated	Internal fault in the "b" phase high side windings

Document: LER 90-029-01-325, CBEAF SYSTEM Actuation Resulting From the Failure of the 1-D22A-K2 Relay Coil.
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
18	Control Building Emergency Air Filtration System	Arm Logic	Relay	Not stated	General Electric	Not stated	Cracks on epoxy coating, relay burned up (probably shorted)

Document: LER 91-001-293, Automatic Closing of the Primary Containment System Group 5 Isolation Valves During Sruveillance Testing
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
19	Primary Isolation Control System	Electric Governor	Transistor	Not stated	Not stated	Not stated	Transistor failed
20	Primary Isolation Control System	Electric Governor	Cable Insulation	Not stated	Woodward Governor Company	ELETEMP, MOIST, & EMBR	Embrittlement due to past exposure to heat and humidity

Document: LER 91-002-01-327, EGTS Inoperable Because of a Train EGTS Being Out of Service for Filter Testing and B Train Diesel Generator Being Declarec
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
21	Emergency Gas Treatment System (EGTS)	Diesel Generator	Fuse	Not stated	Not stated	THERM-CY	Fuse failed

Document: LER 91-006-530, ESF Actuation Due to Loss of Power to 4.16 KV Bus
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
22	1E Power	Circuit Breaker	Trip Circuit	Not stated	Not stated	MOIST	Moisture induced short circuit in trip circuit

Document: LER 91-007-456, Rod Control System Failure Causes Shutdown Bank Control Rods to be in a Condition Prohibited by Technical Specifications
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
23	Rod Control System	Circuit Card	Transistor	Not stated	Not stated	Not stated	Transistor failed

Document: LER 90-023-325, Partial Group 6 Isolation Resulting From Failure of Relay I-CAC-3A
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Relay failure resulted in partial loss of cac logic and subsequent partial group 6 isolation. This normally energized coil burned up as a result of normal end of life failure due to aging.	Occasional; (3 in 18 Mo)	10 CFR 50.73	RG 1.118, IEEE 338-1987, Tech Spec. surv.	Not stated	1-3	16

Document: LER 90-023-424, Transformer Failure Results in Loss of Steam Generator Level and Manual Reactor Trip
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Transformer failed resulted in loss of power to speed control circuitry of the 1B main feedwater pump. Possible premature aging of transformer.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	17

Document: LER 90-029-01-325, CBEAF SYSTEM Actuation Resulting From the Failure of the 1-D22A-K2 Relay Coil.
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
CBEAF system actuation resulted from the failed relay. This normally energized relay failed due to cracks in the epoxy coating on the coil. This was called a normal end of life failure due to aging.	Occasional	10 CFR 50.73	No specific surveillance for this component	Not stated	1-3	18

Document: LER 91-001-293, Automatic Closing of the Primary Containment System Group 5 Isolation Valves During Sruveillance Testing
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Circuit failed to control governor leading to automatic closure of isolation valves.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	19
Cable embrittlement due to thermal aging was listed as the cause. handling of cable during maintenance and surveillance activities may have contributed to the cable failure.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	20

Document: LER 91-002-01-327, EGTS Inoperable Because of a Train EGTS Being Out of Service for Filter Testing and B Train Diesel Generator Being Declared I
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failed fuse resulted in train B EGTS being declared inoperable. Frequent cycling on and off of the air start system due to an air leak is believed to be have degraded the fuse resulting in fuse failure.	Rare	10 CFR 50.73	Tech Spec. required surveillance	Not stated	1-5	21

Document: LER 91-006-530, ESF Actuation Due to Loss of Power to 4.16 KV Bus
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Breaker opened when it was supposed to be closed. A degraded seal around an air conditioning duct penetration allowed moisture from a rain storm to enter the plant multiplexer cabinets causing the short circuit.	Rare	10 CFR 50.73	RG 1.118, IEEE 338-1987, IEEE 741-1987 SECTIO	Not stated	1-5	22

Document: LER 91-007-456, Rod Control System Failure Causes Shutdown Bank Control Rods to be in a Condition Prohibited by Technical Specifications
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Transistor failure caused the circuit to fail resulting in no motion control for the group 1 control rods. Aging degradation was given as the cause of the transistor failure.	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	23

Document: LER 91-008-260, Unplanned Engineered Safety Features Actuation Due to a Failed PCIS Relay
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
24	Primary Containment Isolation System	Logic Relay	Coil	Not stated	General Electric	Not stated	Burned coil

Document: LER 91-010-01-155, Reactor Protection System Pressure Switches Experiencing Setpoint Drift, Revision 1
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
25	Reactor Protection System	Switches		Not stated	Foxboro	CORR	Corrosion caused switch setpoint drift

Document: LER 91-014-01-498, Erratic Containment Extended Range Pressure Channel Output
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
26	Containment Extended Range Pressure Channel	Pressure Transmitter	Thermisitor	Not stated	Barton	Not stated	Erratic behavior of instrument

Document: LER 91-016-260, Unplanned Engineered Safety Features Actuation Due to a Blown Fuse Caused by a Failed Relay
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
27	ESFAS	Relay	Coil	Not stated	General Electric	ELETEMP	Relay coil failed

Document: LER 91-016-424, Failure to Complete Technical Specification Required Action for Battery Cell Low Voltage
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
28	Various	Battery	NA	Not stated	C & D Batteries	Not stated	Low cell voltage while single cell charging

Document: LER 91-020-237, Reactor Building Ventilation Isolation and Automatic Standby Gas Treatment Initiation Due to Radiation Monitor Power Supply Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
29	Reactor Building Ventilation System	Power Supply	Wire	Not stated	General Electric	WEAR	Insulation worn and spark caused power supply failure

Document: LER 91-021-254, RCIC Declared Inoperable Due to High Pump Flow in ISI Required Action Range
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
30	RCIC System	Tachometer	NA	Not stated	Not stated	Not stated	Instrument drift

Document: LER 91-028-254, Loss of Power to 1A RPS Bus Caused by EPA 1A-1 Tripping on Undervoltage Due to Low M-G Set Output
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
31	M-G Set	Voltage Regulator	Voltage Rheostat	Insulation	General Electric	Not stated	Low voltage from m-g set

Document: LER 91-008-260, Unplanned Engineered Safety Features Actuation Due to a Failed PCIS Relay
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The burned coil cause the normally energized relay to fail resulting in loss of logic power and an unplanned actuation of the esfas. This was called a thermally aged relay coil failure.	Occasional	10 CFR 50.73	Tech Spec. required surveillance	Not stated	1-3	24

Document: LER 91-010-01-155, Reactor Protection System Pressure Switches Experiencing Setpoint Drift, Revision 1
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The drift would adversly effect the RPS operation. Found during refueling outage calibration.	Rare	10 CFR 50.73	Tech Spec. required surveillance	Not stated	1-2	25

Document: LER 91-014-01-498, Erratic Containment Extended Range Pressure Channel Output
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
A cracked thermistor was found on the control card, however the erratic behavior of the pressure transmitter cannot be positively attributed to this thermistor.	Rare	10 CFR 50.73	Tech Spec. surveillance, RG 1.118, IEEE 338	Not stated	1-4	26

Document: LER 91-016-260, Unplanned Engineered Safety Features Actuation Due to a Blown Fuse Caused by a Failed Relay
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Unplanned ESFAS actuation due to failed relay. The failed relay coil was 15 years old and the service life for a normally-energized coil relay of this type is 15 to 20 years. This was an end of life failure.	Rare	10 CFR 50.73	Tech Spec. surveillance, not specific	Not stated	1-3	27

Document: LER 91-016-424, Failure to Complete Technical Specification Required Action for Battery Cell Low Voltage
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Battery failed to meet technical specification while charging. This was considered to be related to battery aging phenomena.	Rare	10 CFR 50.73	Tech Spec. surveillance, RG 1.118, IEEE 450	Not stated	1-4	28

Document: LER 91-020-237, Reactor Building Ventilation Isolation and Automatic Standby Gas Treatment Initiation Due to Radiation Monitor Power Supply Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The ventilation system and gas treatment system actuation resulted from the power supply failure.	Occasional	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	29

Document: LER 91-021-254, RCIC Declared Inoperable Due to High Pump Flow in ISI Required Action Range
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure due to instrument drift caused by aging	Rare	10 CFR 50.73	No specific surveillance for this component	Not stated	1-4	30

Document: LER 91-028-254, Loss of Power to 1A RPS Bus Caused by EPA 1A-1 Tripping on Undervoltage Due to Low M-G Set Output
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Cause of dip is unknown, but normal wear of the voltage adjustment rheostat was supected. It was believed to have developed a flat spot or corrosion at the point of the previous adjustment due to normal wear at that point over a long period of time.	Occasional	10 CFR 50.73	Vendor specific program	Not stated	1-6	31

Document: LER 91-028-325, Component Failure of a Reactor Water Cleanup System Isolation Logic Relay Resulted in an Unplanned Engineered Safety Featur
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
32	RWCU	Relay	Coil	Insulation	General Electric	Not stated	Relay coil failed after insulation breakdown

Document: LER 91-030-423, Motor Control Center Auxiliary Control Relay Failure Due to Thermal Aging
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
33	Motor Control Center	Relay	Coil	Insulation	ITE Gould	ELETEMP & EMBR	Relay coil insulaton embrittlement and failure

Document: LER 92-001-155, Brittle Motor Lead Wires Discovered in VOP-7050 (Main Steam Isolation Valve-MSIV)
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
34	Main Steam	Isolation Valve Motor	Lead Wire Insulation	Butyl rubber	Limitorque	ELETEMP & EMBR	Brittle and cracked insulation

Document: LER 92-001-263, Shutdown Required by Technical Specification Due to Inoperable Bellows Leak Detection System for Safety Relief Valves
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
35	Bellows Leak Detection System	Valve	Seating Material	Cast urethane	Automatic Switch Company	ELETEMP	Urethane seat material degraded due to high temperature

Document: LER 92-001-296, Engineered Safety Feature Actuation Caused by a Failed Relay Coil
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
36	Engineered Safety Feature Actuating System (ESFAS)	Relay	Coil	Not stated	General Electric	ELETEMP	Degraded insulation causing coil failure

Document: LER 92-001-339, Reactor Trip Caused by MFRV Closure Upon Failure of Driver Card
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
37	Feedwater system	Main Feed Regulating Valve	Power Supply	Not stated	Not stated	Not stated	Power supply failed on driver card

Document: LER 92-002-247, Reactor Trip Due to Main Feedwater Regulating Valve Going Closed
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
38	Feedwater system	Feedwater Regulating Valve	Solenoid Valve	Not stated	Not stated	Not stated	Solenoid valve failed

Document: LER 92-004-389, Manual Reactor Trip Due to Low Steam Generator Water Level Caused by a Failed Circuit in the 2A Feedwater Regulating Control S
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
39	Feedwater Regulatiog Valve Control System	Power Supply	Capacitor	Not stated	Not stated	Not stated	Capacitor failed

Document: LER 91-028-325, Component Failure of a Reactor Water Cleanup System Isolation Logic Relay Resulted in an Unplanned Engineered Safety Feature A
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
ESFAS actuation resulted from the relay failure. Component failure determined to be a normal end of life failure due to aging. This was a normally energized relay.	Occasional	10 CFR 50.73	Tech Spec. not specific for this component	Not stated	1-4	32

Document: LER 91-030-423, Motor Control Center Auxiliary Control Relay Failure Due to Thermal Aging
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Elevated temperature from continuous operation of relays caused embrittlement and failure. Heat also discolored other plastic parts near the coil.	Occasional	10 CFR 50.73	Vendor specific program	Not stated	1-5	33

Document: LER 92-001-155, Brittle Motor Lead Wires Discovered in VOP-7050 (Main Steam Isolation Valve-MSIV)
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Loss of isolation capability, the degraded wire insulation was found in the limit switch housing as a result of planned maintenance during a scheduled refueling outage.	Rare	10 CFR 50.73	Vendor specific progarm, GL 89-10, NUREG-1352	Not stated	1-4	34

Document: LER 92-001-263, Shutdown Required by Technical Specification Due to Inoperable Bellows Leak Detection System for Safety Relief Valves
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Valve failed to seat due to degradation of the seating material from exposure to temperatures near manufacturers rated temperature.	Rare	10 CFR 50.73	Vendor specific program	Not stated	1-6	35

Document: LER 92-001-296, Engineered Safety Feature Actuation Caused by a Failed Relay Coil
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The coil failure iniated partial actuation of the ESFAS system.	OCCAIONAL	10 CFR 50.73	Vendor specific program, Tech. Spec. Surveil.	Not stated	1-5	36

Document: LER 92-001-339, Reactor Trip Caused by MFRV Closure Upon Failure of Driver Card
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Power supply failure caused the MFRV valve to fail closed isolating normal feedwater and causing a reactor trip.	Occasional	10 CFR 50.73	No specific program	Not stated	1-3	37

Document: LER 92-002-247, Reactor Trip Due to Main Feedwater Regulating Valve Going Closed
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Solenoid valve failued relieving air pressure to the diaphragm of the regulating valve which caused it to go to the closed position.	Rare	10 CFR 50.73	No specific program	Not stated	1-3	38

Document: LER 92-004-389, Manual Reactor Trip Due to Low Steam Generator Water Level Caused by a Failed Circuit in the 2A Feedwater Regulating Control Sy
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Because of the capacitor failure the lead lag circuit output current was low and the steam regulating valve closed. The reactor was manually tripped.	Rare	10 CFR 50.73	Vendor specific program	Not stated	1-3	39

Document: LER 92-006-331, Emergency Safety Feature Actuation During Modification Acceptance Testing Due to Damaged Switchyard Cable
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
40	1E Power	Cable	Insulation	Ethylene propylene rubber	Not stated	WEATH, CORR, & MOIST	Insulation degraded, galvanic corrosion rusted wire cores

Document: LER 92-006-354, Reactor Shutdown to Comply With Technical Specification 3.6.1.1, Due to Failure of Suppression Chamber to Drywell Vacuum Bre
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
41	Various	Drywell Vacuum Breakers	Seal	Not stated	Not stated	Not stated	Seal degraded due to aging

Document: LER 92-007-01-33, Failure of Analog Transmitter Trip System (ATTS) Trip Relays Due to Thermal Aging
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
42	Analog Transmitter Trip System	Relay	Coil	Not stated	Amerace	ELETEMP	Relay coil wire insulation embrittlement

Document: LER 92-009-01-499, Missed Technical Specification Required Surveillance Due to a Faulty Toxic Gas Monitoring System Modem
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
43	Emergency Response ---- Display System (ERFDADS)	Modem	NA	Not stated	Black Box Corporation	Not stated	Modem failed

Document: LER 92-011-325, Primary Containment Monitoring System Inoperability Due to Relay Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
44	Containment Atmospheric Control (CAC) System	Containment Control – Logic	Relay	Not stated	General Electric	Not stated	Relay failed (end of life)

Document: LER 92-021-237, Automatic Isolation of Reactor Building Ventilation Due to Radiation Monitor Trip Relay Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
45	Reactor Building Ventilation System	RBV Radiation Monitor	Relay	Not stated	General Electric	Not stated	Burned out coil

Document: LER 92-034-01-333, Engineered Safety Feature Actuations Due to Transformer Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
46	ESFAS	Transformer	NA	Not stated	General Electric	ELETEMP	Insulation degradation in transfomer

Document: LER 92-006-331, Emergency Safety Feature Actuation During Modification Acceptance Testing Due to Damaged Switchyard Cable
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
A tear or crack in the insulation exposed wires to ambient conditions and moisture intrusion with continuous dc potential on wires may have contributed to galvanic corrosion leading to an open circuit. The failed circuit caused sf actuation during test.	Rare	10 CFR 50.73	No specific program	Not stated	1-8	40

Document: LER 92-006-354, Reactor Shutdown to Comply With Technical Specification 3.6.1.1, Due to Failure of Suppression Chamber to Drywell Vacuum Break
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Leak in vacuum breakers was too large and violated the technical specifications resulting in reactor shut down. Two of the three leaking breakers also had seal and pallet alignment problems.	Rare	10 CFR 50.73	No specific program	Not stated	1-5	41

Document: LER 92-007-01-33, Failure of Analog Transmitter Trip System (ATTS) Trip Relays Due to Thermal Aging
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Debris from the embrittled coil spool was inhibiting movement of the relay plunger resulting in sticking relay and excessive delay time. The relay had been in service 4 years which exceeded the recommended service life of 3 years	Occasional	10 CFR 50.73	Tech Spec. required surveillance	Not stated	1-5	42

Document: LER 92-009-01-499, Missed Technical Specification Required Surveillance Due to a Faulty Toxic Gas Monitoring System Modem
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Garbled data sent to erfdads computer. Failure of modem attributed to aging. Operators were unable to meet technical specifications requiring the each chemical detection system be demonstrated operable every 12 hours.	Rare	10 CFR 50.73	No specific program	Not stated	1-5	43

Document: LER 92-011-325, Primary Containment Monitoring System Inoperability Due to Relay Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure of this relay resulted in loss of power to various containment isolation valves and inoperability of the cac system.	Occasional	10 CFR 50.73	Tech Spec. required surveillance	Not stated	1-3	44

Document: LER 92-021-237, Automatic Isolation of Reactor Building Ventilation Due to Radiation Monitor Trip Relay Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Failure of relay coil caused the RBV system to actuate.	Rare	10 CFR 50.73	No specific program	Not stated	1-4	45

Document: LER 92-034-01-333, Engineered Safety Feature Actuations Due to Transformer Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Fault in middle phase b winding due to dielectric breakdown of insulation caused transformer failure resulting in ESFAS actuations. The dielectric breakdown due to aging resulted in multiple faults.	Rare	10 CFR 50.73	RG 1.118, IEEE 338-1987	Not stated	1-16	46

Document: LER 92-038-255, Reactor Trip Caused by a Loss of the Preferred AC BUS Y-20 Coincident With a Blown Fuse in a Second Channel of the Reactor P
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
47	Reactor Protection System	Inverter	Transformer	Not stated	Sola	ELETEMP	Transformer coils failed

Document: LER 93-002-249, Control Valve Fast Closure Half-Scram Pressure Switches Out-of Calibration Due to Setpoint Drift
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
48	Reactor Protection System	Pressure Switch	NA	Not stated	Barksdale	VIB	Wear of face of the plunger

Document: LER 93-003-530, Emergency Diesel Generator Unable to Start and Run in Manual Test Mode
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
49	Emergency Diesel Generator	Starting System	Relay	Not stated	Agastat	Not stated	Relay failed by fault of a suppression varistor across coil

Document: LER 93-005-01-275, Medium Voltage Cable Failures Due to Chemical Degradation and Undkown Causes
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
50	Various	Cable	12KV Underground Cable	Ethylene-propylene=rubber (EPR) and neoprene jacket	Okonite	CHEM, CONTAM, & CORR	Chemical degradation of jacket and corrosion of shield
51	Various	Cable	12KV Underground Cable	Ethylene-propylene=rubber (EPR) and neoprene jacket	Okonite	Not stated	Anomalies occurred over time

Document: LER 93-005-01-305, Annual Transmitter Calibration Finds a Shift in the Pressurizer High Pressure Reactor Trip Signal Initiation Due to Instrument Dri
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
52	Reactor Protection System	Pressure Transmitter	NA	Not stated	Foxboro	Not stated	Transmitter drift

Document: LER 93-007-249, Yarway Reactor Water Level Switch Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
53	High PRessure Coolant Injection System (HPCI)	Level Switch	NA	Not stated	Yarway	MECHSTR	Spring force degradation

Document: LER 93-008-237, Yarway Reactor Water Level Switch Failure
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
54	High PRessure Coolant Injection System (HPCI)	Level Switch	NA	Not stated	Yarway	MECHSTR	Spring force degradation

Document: LER 92-038-255, Reactor Trip Caused by a Loss of the Preferred AC BUS Y-20 Coincident With a Blown Fuse in a Second Channel of the Reactor Pro
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The transformer failure resulted from accelerated aging due to improper inernal wiring in the inverter. Only one primary winding was connected resulting in operation at a higher temperature. the Y-20 bus power failure tripped the reactor.	Rare	10 CFR 50.73	Tech. Spec. required surveillance, RG 1.118	Not stated	1-8	47

Document: LER 93-002-249, Control Valve Fast Closure Half-Scram Pressure Switches Out-of Calibration Due to Setpoint Drift
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Vibration contributed to the drift of the set point because of wear on the plunger face.	Rare	10 CFR 50.73	Tech Spec. required surveillance	Not stated	1-6	48

Document: LER 93-003-530, Emergency Diesel Generator Unable to Start and Run in Manual Test Mode
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The starting system check circuitry relay shorted and the resulting current surge damaged other electrical components on the fiber optics card in the EDG starting circuit. The EDG would not start in the manual test mode. Component aging was the cause	Rare	10 CFR 50.73	RG 1.108, IEEE 387-1984 Section 7.5, IEEE 749	Not stated	1-9	49

Document: LER 93-005-01-275, Medium Voltage Cable Failures Due to Chemical Degradation and Undkown Causes
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
A ground fault developed at the cable jacket degradation location (insulation breakdown). Excess chlorides and a fatty acid, ethyl ester compound, were identified as the chemical that attacked the cable jacket. Water carried chemical into conduit.	Rare	10 CFR 50.73	No specific program	Not stated	1-16	50
Ground fault occurred on cable. water was in conduit (cable was designed for wet conditions) cable removed from conduit and no root cause identified from inspections or tests conducted by utility and manufacturer.	Rare	10 CFR 50.73	No specific program	Not stated	1-16	51

Document: LER 93-005-01-305, Annual Transmitter Calibration Finds a Shift in the Pressurizer High Pressure Reactor Trip Signal Initiation Due to Instrument Drift
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
The transmitter would not initiate a trip signal at the required point. The method of calibration was most probable cause and aging was the next most likely cause.	Occasional	10 CFR 50.73	RG 1.118, IEEE 338-1987	Not stated	1-5	52

Document: LER 93-007-249, Yarway Reactor Water Level Switch Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Switch tripped outside of technical specification limits. Excessive set point drifts were also found.	Frequently	10 CFR 50.73	RG 1.118, IEEE 338-1987	Not stated	1-5	53

Document: LER 93-008-237, Yarway Reactor Water Level Switch Failure
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Out of tolerance	Frequently	10 CFR 50.73	RG 1.118, IEEE 338-1987	Not stated	1-6	54

Document: LER 93-009-498, Technical Specification 3.0.3 Entry Due to Potentially Undersized Fuses in the Solid State Protection System
Reviewed by: L. C. Meyer, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
55	Solid State Protection System	Fuse	NA	Not stated	Not stated	Not stated	Fuse failed

Document: LER 93-009-498, Technical Specification 3.0.3 Entry Due to Potentially Undersized Fuses in the Solid State Protection System
Reviewed by: L. C. Meyer, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
An independent laboratory determined that the fuse did not open as the result of a high current fault. It was not possible to determine whether the fuse had a defect. LER states that the event was caused by the random age related failure of a ssps fuse.	Rare	10 CFR 50.73	No specific program	Not stated	1-5	55

Document: BL 90-01, Loss of Fill-Oil in Transmitters Manufactured by Rosemount
Reviewed by: E. W. Roberts, INEL

Item	System	Structure/Comp	Subcomponent	Materials	Manufacturer	ARD mechanism	ARD effects
1		Pressure Transmitters Model 1153 & 1154	O-Ring	Metal	Rosemount	Not stated	Loss of transmitter oil

Document: BL 90-01, Loss of Fill-Oil in Transmitters Manufactured by Rosemount
Reviewed by: E. W. Roberts, INEL

Effect of Aging on Component Function	Contrib to Failure	Reported progs	Rel.progs	Report Recommendations	Page No.	Item
Transmitter drift, slow response, inability to respond over full range, sustained zero/span drift, or total failure	Frequent	Not discussed in report	Bul 90-01 Suppl 1, RG 1.118, IEEE 338-1987	Identify transmitters and take appropriate corrective action [4]		1

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10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

Argonne National Laboratory and Idaho National Engineering Laboratory in support of the License Renewal Project Directorate of the U.S. Nuclear Regulatory Commission (NRC) performed a comprehensive review of literature pertaining to nuclear power plant aging effects. This generic aging lessons learned (GALL) effort was a systematic review of plant aging information in order to assess materials and component aging issues related to continued operation and license renewal of operating reactors. Literature on mechanical, structural, thermal-hydraulic, and electrical components and systems reviewed consisted of 163 Nuclear Plant Aging Research Reports, 31 NRC Generic Letters, 265 Information Notices, 82 Licensee Event reports, 5 Bulletins, and 10 Nuclear Management and Resources Council Industry Reports. The results of these reviews were systematized using a standardized GALL tabular format and standardized definitions of aging related degradation mechanisms and effects. A computerized data base has also been developed for all review tables and can be used to search for information on structures, components, and relevant aging effects. A survey of the GALL tables reveals that all significant component and structure aging issues are currently being addressed by the regulatory process. However, aging of what are termed passive components and structures has been highlighted for continued scrutiny.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

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