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Recordkeeping Needs to Mitigate the Impact of Aging Degradation

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Prepared for
U.S. Nuclear Regulatory Commission

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Abstract

This report discusses technical issues associated with the role of nuclear plant records systems in understanding and managing the aging of nuclear plant components, systems, and structures. It considers both the types of technical data useful for verifying continued safe operation and the use of new technology for upgrading records systems. Specific topics reviewed include the need for maintenance and reliability data, operational history data to support the assessment of remaining fatigue life, comprehensiveness and usability of the engineering design basis, improvement of the data input process, and conversion of existing records into machine-readable forms.

The report concludes that successful management of nuclear plant aging will require improvement of existing plant records systems; several generic and specific recommendations are provided. The computer-based technology for meeting this need and implementing these recommendations already exists and can be implemented at a reasonable cost.

Contents

Summary

This report documents work done for the U.S. Nuclear Regulatory Commission (NRC) as part of its Nuclear Plant Aging Research (NPAR) Program. This work is one task in a research program managed by the Electrical & Mechanical Engineering Branch of the NRC Office of Nuclear Regulatory Research. The NPAR Program focusses on aging assessments of electrical and mechanical components and systems. Complementary efforts are being conducted or supported by other organizations, including the Nuclear Management Resources Council, the Electric Power Research Institute, the U.S. Department of Energy, the Board of Nuclear Codes and Standards, the nuclear steam supply system vendors, the International Atomic Energy Agency, and industry and regulatory organizations in a number of foreign countries.

The objective of this work has been to ascertain if existing nuclear plant records systems are adequate to support the understanding and management of aging degradation mechanisms and, if necessary, to recommend enhancements to the records systems. Topics considered in this work were:

(1) the status of current nuclear plant records systems from the perspective of aging management,

(2) the results of NPAR Program research and other plant aging and life extension efforts,

(3) implications of the above for the understanding and management of aging,

(4) formulation of generic and specific recommendations for recordkeeping requirements in the context of aging management, and

(5) consideration of the techniques and technology available to implement those recommendations.

This work was conducted using a review of the literature and discussions with nuclear plant records managers. Conclusions are based on this information plus the author's experience as a user of records systems at an architect-engineering firm, a research reactor, a commercial nuclear utility system, a defense production reactor, and a high-level nuclear waste project. Conclusions regarding the capabilities of computer-based record-keeping tools are based on the author's experience with computer systems, software development, and as Lecturer in Computer Science.

Relevance of Records Systems to Nuclear Plant Aging Management

There are a number of reasons for a nuclear utility to maintain a comprehensive records system; these include NRC regulations, other regulatory requirements, and adherence to engineering and business good practices. U.S. nuclear utilities currently maintain extensive records systems, partly in response to 10 CFR 50.71, Regulatory Guide 1.28, Regulatory Guide 1.88, ANSI/ASME NQA-1, ANSI/ASME N45.2.9, and 10 CFR Part 50, Appendix B, and partly as an implementation of good business practices, as with the records the same utilities maintain to support their fossil plants.

From the standpoint of aging mechanisms, there are three reasons for recordkeeping:

(1) Maintenance and reliability records can be used to monitor the condition of equipment, to predict failures, and to design appropriately conservative predictive and preventive maintenance programs.

(2) Design, maintenance, operational history, and reliability records provide the basis for comparing the actual operating environment and operational stressors to the design assumptions. This comparison provides the justification for continuing to operate systems or components out to or beyond their original design lifetime.

(3) Maintenance and reliability records can support the decision to replace or refurbish systems, structures, or components (SSCs).

Extensive records of maintenance, equipment reliability, and plant operating status are maintained, but they have frequently been inadequate to support the desired analyses of past performance and predictions of future performance. In addition, at many nuclear plants, the records constituting the engineering design basis of the plant were incomplete at plant startup or they have not been kept current with the state of the plant. NRC implementation of Safety System Functional Inspections (SSFIs) and Safety System Outage Modification Inspections (SSOMIs), I & E Notice 85-66, and Systemic Assessment of Licensee Performance (SALP) have all highlighted the safety impact of failure to adequately document a plant's engineering design basis and to provide adequate configuration control and timely retrievability of the information in the plant's records system (Brackney et al. 1987). Approximately three dozen nuclear utilities have been upgrading their Configuration Management and Design Basis Documentation programs in response to these problems.

Existing records systems have exhibited a number of deficiencies, many of them related to the fact that they are primarily based on hard copy records (on paper or on microform), with the attendant slow retrieval and difficulty in processing or manipulating the records in any way. Computerized indexing of the hard copy records in plant records systems is extensive, but not computerized delivery of the information.

On the positive side, a number of utilities have implemented computer-assisted drafting systems for the storage and maintenance of plant drawing records, with the associated benefits in retrievability, legibility, and ease of modification and use. Also, several utilities have put procedures, technical specifications, and similar controlled documents on-line, thus benefiting from improved accessibility and reduced cost for controlling the distribution and managing the configuration of those documents.

NPAR Program Research Relevant to Recordkeeping

The Phase 1 Tasks of the NPAR Program have typically either characterized a particular aging degradation mechanism or have characterized all the mechanisms affecting a particular nuclear plant system or type of component. These reports frequently call for monitoring and surveillance to assess the impact of the degradation mechanisms; this represents a tacit recommendation for increased recordkeeping, since presumably the data resulting from the increased monitoring and surveillance will not simply be discarded. Few NPAR reports contain explicit recommendations regarding the data which should be collected, on what schedules, and to what purpose. On the other hand, there is a sense in several NPAR documents that to demonstrate that piping and large pressure vessels can continue to operate out to 60 years within their design fatigue life will require significant improvement in the characterization and records of irradiation history, operating pressure transients, and temperature transients.

The NPAR Program developed a basis to prioritize its own research by having a panel of experts determine, for each of fifty types of nuclear plant components, the change in total plant risk due to aging of the component as a function of 1) the risk importance of the component, 2) the increase in the component's failure rate as it ages, 3) the inspection interval, 4) the probability of successful detection of degradation, and 5) the conditional probability of successful repair, given that the degradation has been detected. The derivation of this functional relationship, called the RSCAAMP (for Risk Significance of Component Aging and Aging Management Practices) model, is described in a report by Levy

et al. (1988). The resulting prioritization has had additional benefits, including insights on which plant parameters are important to managing total plant risk and aging degradation.

To support prioritization and screening for aging management and to support the assessment of effectiveness of the maintenance program, utility records systems will need to provide information equivalent to the parameters described above. Most present systems do not provide all of this information. Therefore, recordkeeping enhancements are needed. The method used to prioritize, or screen, components and systems to determine which will require aging management will probably not be the RSCAAMP model, but it will require the development of similar information. The risk importance of a component would be determined using a plant probabilistic risk assessment, but the plant records system will have to support determination of the other four variables in the RSCAAMP model or determination of equivalent measures of the aging importance of plant components, systems, and structures.

Implications of NPAR Results for Utility Recordkeeping

Components having an expected lifetime on the order of the original design lifetime of the plant are those of most relevance and interest from a plant aging and life extension standpoint. They are reliable and long-lived enough that the operating history and failure records cannot be expected to support, with high degrees of confidence, statistical estimation of their residual life. Accordingly, if residual life assessment is chosen as one of the elements of an effective program to manage the aging of these components, the data from the design documentation, from the ISI program, and from NDE must be relied upon to assess the condition of such components and to estimate their residual life. Similarly, there may be components for which a careful assessment of the operating history and environment, particularly with respect to thermal and pressure transients, may be critical to an assessment of the remaining fatigue life of the component.

For components with an expected lifetime significantly less than forty years, the plant maintenance program will have already established a record of the efficacy of in-service inspection and monitoring to track aging degradation, so that the components can be replaced or refurbished in a timely fashion. The function of the records system in this context is to support the evaluation of aging degradation and determination of timely replacement or repair.

Finally, there should be consideration, on a plant-specific basis, of possible alternatives to expanded recordkeeping. These alternatives may include preventive maintenance, system or component refurbishment, or the development and implementation of testing and examination techniques capable of establishing the current condition of the system or component, without any need to consider its operating and maintenance history.

The ultimate criterion for evaluating the impact of aging degradation, together with the plant owner's program for mitigating that impact, is whether the plant will continue to meet the design adequacy acceptance criteria, as defined in the plant's licensing basis, throughout plant life. The nuclear plant records system must be capable of providing the information needed to support this conclusion.

Conclusions

The nuclear plant records system must provide access to the information needed 1) to prioritize SSCs according to their safety importance and their susceptibility to aging degradation, 2) to understand the actual course of aging degradation in the plant, and 3) to manage, by appropriate mitigation, that aging. The first of these goals is most strongly determined by the plant design and how that design has been implemented in the process of construction and

later modifications to the plant; that is, by the engineering design basis of the plant. The second and third goals represent the information needed to design and implement an effective maintenance program in the plant.

An effective data collection and recordkeeping system, supportive of aging management activities, should meet the following performance criteria:

- Provide sufficiently comprehensive and accurate information about the plant, including engineering baseline data, historical operational status, and maintenance history.
- Provide for flexible management of that information.
- Provide secure storage of the information.
- Provide for the integrity of the information over the life of the plant.
- Provide timely and accurate retrieval of the information.
- Provide adequate tools for data analysis, graphical display, and production of reports.

Expanded recordkeeping and enhanced databases will be necessary to manage aging in operating nuclear power plants. The records should be, wherever feasible, machine-readable, to facilitate later use of the information in ways not originally contemplated. The information should be integrated throughout the plant, using common formats, and centralized planning and management of the information systems function. The information should be carefully preserved and itself protected against aging. Finally, the plant databases and records system should include more than the "minimum necessary" to operate the plant, providing the engineering staff with the data and tools needed to minimize the impact of unexpected degradation phenomena.

The computer-based technology for meeting this need and implementing these recommendations already exists and the recommendations can be implemented at a reasonable cost. An appropriate computer-based system is likely to yield a substantial savings over the life of the plant, compared to a records system based on management of "hard copy" records.

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1 Introduction

The U.S. Nuclear Regulatory Commission (NRC) has established the Nuclear Plant Aging Research (NPAR) Program to study the safety-related technical issues associated with the aging of nuclear plant systems and components. The Program deals with issues related to the impact of aging degradation on the continued safe operation of the plants. The Nuclear Plant Aging Research Program Plan (USNRC 1991) describes the Program's goals and approach to meeting those goals.

More specifically, the NRC's Technical Integration Review Group for Aging and Life Extension (TIRGALEX) developed a Plan (USNRC 1987a) which identified "technical safety and regulatory issues related to reactor aging and life extension" and provided "a plan to integrate NRC and external activities to resolve the issues." One of the NRC action items described in the TIRGALEX Plan is the development of guidance for adequate recordkeeping to support license renewal.

In support of that action item, Pacific Northwest Laboratory (PNL) established an NPAR Program Task during fiscal years (FYs) 1988 through 1990 to assess current nuclear utility recordkeeping practices and, if required, to formulate recommendations for changes needed to support aging management. Phase I NPAR Program research tasks aimed at identifying the aging degradation mechanisms affecting different classes of plant systems and components have typically recommended testing, surveillance, monitoring and trending, which implies some additional recordkeeping. The PNL NPAR Guidance for Recordkeeping Task has made recommendations regarding needed records, paying particular attention to any records (related to the engineering design basis of the plant or records of past plant, system, or component environment or performance) that may need to be reconstituted if they are not currently being maintained. In addition, it has assessed current nuclear plant recordkeeping practices and existing and developing technology in the areas of data acquisition, storage, database management, and data interpretation.

As with other NPAR Program components, the Guidance for Recordkeeping Task was conducted in a phased fashion. Phase I work during FY 1988 concentrated on the assessment of current utility practices, review of the recommendations resulting from other NPAR Program tasks, and an assessment of current and developing technology for dealing with recordkeeping needs. In addition, the tasks for Phase II of the effort were planned. The Phase II effort during FY 1989 and FY 1990 involved continuing review of current recordkeeping practices and NPAR Program research, and formulation of more extensive and explicit technical recommendations.

Section 2 of this report reviews current recordkeeping practices of U.S. nuclear utilities. Section 3 reviews those aspects of other NPAR Program tasks relevant to the role of records systems in the identification and management of aging degradation. Section 4 considers the recordkeeping implications of some of the other life extension programs. Section 5 contains recommendations for the use of records to support the management of aging degradation. Section 6 discusses the feasibility of implementing those recommendations and Section 7 summarizes the conclusions of the report.

2 Assessment of Current Utility Recordkeeping Practices

There are a number of reasons for a nuclear utility, like other business organizations, to maintain a comprehensive records system, including:

- understanding and maintaining an audit trail of the economic performance of the organization
- business and/or engineering good practices
- prevention of accidents or upsets
- defense against future liability claims
- regulatory requirements.

From the standpoint of aging management, there are three reasons for recordkeeping:

(1) Maintenance and reliability records are essential for the design and optimization of predictive and preventive maintenance programs.

(2) Design, maintenance, operational history, and reliability records provide the basis for comparing the actual operating environment and operational stressors with the design assumptions. This comparison may provide a justification for continuing to operate systems or components out to or beyond their original design lifetime.

(3) Maintenance and reliability records support decisions on when to replace or refurbish systems, structures, or components (SSC).

As the commercial nuclear industry has grown and matured, there has been a significant increase in the number of explicit regulatory requirements, including requirements for improved or increased recordkeeping. Much of this increase in regulatory requirements has been a result of the NRC's TMI-2 Action Plan (USNRC 1980), the identification of Unresolved Safety Issues and Generic Safety Issues, and the efforts to resolve those issues. Some of the impetus for additional recordkeeping comes from the need for information to support analytical, predictive models of various aspects of plant, equipment, and operator performance. An example is the desire to collect enough information from the monitoring and surveillance of major equipment to successfully estimate the residual life of that equipment. Additionally, there is a desire to provide sufficiently broad records of plant transients and equipment operating conditions to detect and understand previously unknown or unexpected phenomena (e.g., intergranular stress-corrosion cracking or pipe wall thinning due to erosion/corrosion).

Recordkeeping practices at U.S. nuclear utilities were reviewed using a combination of literature search and discussions with utility recordkeeping personnel. Discussions with members of the Nuclear Information and Records Management Association (NIRMA) and a review of NIRMA publications (NIRMA 1986, 1987, 1988) have been of particular value in assessing the efficacy of current recordkeeping practices. Some of the judgments expressed are based upon the author's experience as a user of records systems at an Architect-Engineering firm, a research reactor facility, a commercial nuclear reactor, a plutonium production reactor, and a high-level nuclear waste repository project.

U.S. nuclear utilities currently maintain extensive records systems, partly in response to 10 CFR 50.71, Regulatory Guide (R. G.) 1.28 (USNRC, 1985), Regulatory Guide 1.88 (USNRC, 1976), ANSI/ASME NQA-1 (ASME, 1986), ANSI/ASME N45.2.9 (ASME, 1979), and 10 CFR Part 50, Appendix B and partly as an implementation of good business practices, as with the records the same utilities maintain to support their fossil plants. Existing records systems are generally recognized to have a number of deficiencies, including the fact that they are primarily based on hard copy records (on paper, microfilm, or microfiche), with the attendant slow retrieval and difficulty in processing or manipulating the records in any way. Computerization of nuclear plant records systems is extensive (although not consistently so throughout the industry), but has concentrated on computerized indexing of the hard copy records. Although extensive records of maintenance, equipment reliability, and plant operating status are maintained, they have proved to be inadequate to support desired

analyses of past performance and predictions of future performance. At many nuclear plants, the records constituting the engineering design basis of the plant have been incomplete or have not been kept current with the state of the plant. In particular, the quality of trending and root-cause analysis at nuclear plants is generally considered to be inadequate.

On the positive side, a number of utilities have implemented computer-assisted drafting (CAD) systems for the storage and maintenance of plant drawing records, with the associated benefits in retrievability, legibility, and ease of modification and use. Also, several utilities have put procedures, technical specifications, and similar controlled documents on-line, with the benefits of improved accessibility and usability and reduced cost for controlling the distribution and managing the configuration of those documents.

A recent survey by Utility Data Institute compiled information on nuclear plant records systems at 56 separate plants at 33 reactor sites, comprising approximately half of U.S. nuclear plants (Nucleonics Week 1988). Table 2.1, adapted from the cited reference, summarizes the status of computerization of different types of plant record systems at the 33 sites. The report notes high levels of computerization of records systems for maintenance planning, radiation monitoring, and plant chemistry tracking, but far less in areas directly supporting operations and engineering, such as trending on operations history, safety system tagout control, and documentation of the engineering design basis of the plant. There is little standardization in the database systems used, because of a large number of vendors and a desire on the part of utility organizations to do at least part of the system development process themselves.

Table 2.1 Status of Selected Computerized Nuclear Information Systems

System Descriptions	Number of Reactor Sites with Systems		
	In Place	Under Development	No System
Radiation Exposure Monitoring	32	1	0
Process Monitoring Computer	31	0	2
Inventory Control	30	3	0
Maintenance Planning	29	0	2
Master Equipment List	24	2	3
Design Document Status	21	3	7
Radioactive Waste Management	21	2	10
Plant Radiation Monitoring	20	6	6
Plant Chemistry Tracking	20	4	9
Operator Assistance	19	2	12
Operations Log Trend Analysis	11	2	20
Tool Control Accountability	10	6	17
Safety System Tagout Control	9	9	14

Source of data: "Nuclear Plant Information Systems Survey," October 1987, prepared by the Utility Data Institute, Washington, D.C. (Nucleonics Week, 1988).

What standardization there is can be attributed to the predominance of mainframe computers of one particular computer vendor in the nuclear plant recordkeeping market. Utility involvement in the development of recordkeeping systems probably facilitates successful implementation by providing psychological "ownership" of the systems. Although there has been some consideration given to standardization in the records area and to formal cooperation between utilities, to date there has been almost no such interaction.

Records computerization has tended to favor areas related to finances, administrative support, and materials management, where it is easiest to show "hard dollar" savings. The term "hard dollar" refers to the ease with which the savings produced by automation of the record system can be quantified; typically, these are easily quantifiable savings in the recordkeeping process itself. "Soft dollar" savings arising from the increased productivity of records users or increased efficiency and safety of plant operation are much more difficult to quantify. Changes in the utility operating environment in recent years, including the trend toward deregulation and the appearance of "prudency" hearings have tended to increase the budget pressures on proposed upgrades of utilities' records systems. Discussions with NIRMA members and review of NIRMA Annual Symposia papers (NIRMA 1986, 1987, 1988) suggest strongly that hard dollar savings predominate in the utility planning and budgeting process and that improvements to records systems with the goal of increasing plant safety may require regulatory impetus.

Significant areas of ongoing record system improvements which have gotten such a regulatory push are Design Basis Documentation and the closely related area of Configuration Management. Personnel at one U.S. nuclear utility have been candid in describing the problems associated with poor recordkeeping, recognizing that fundamental management deficiencies are the root cause of these problems, and admitting the importance of regulatory impetus in persuading utility management to solve the problems (Cox and Filiak 1987, Guthrie et al. 1986). NRC implementation of Safety System Functional Inspections (SSFI) and Safety System Outage Modification Inspections (SSOMI), I&E Notice 85-66, and Systemic Assessment of Licensee Performance (SALP) have all contributed to current efforts by many utilities to upgrade their configuration management programs, in particular the description of the engineering design baseline.

A review of several SSFIs and SSOMIs provides the following description of common records system deficiencies (Brackney et al. 1987):

- High occurrence of inadequate availability and retrievability of design basis documents or data for inspected safety systems.
- A demonstrated lack of consideration of the original design basis (e.g., in the design and execution of plant modifications).
- Reliance on unsubstantiated or undocumented engineering judgments.
- Inadequate control of the design change process.
- Inadequate design verification.

> Further analysis of these findings reveals that the root cause of many of these deficiencies is the lack of availability or retrievability of original design documents or data.... In some situations where these documents were provided to the utility, the documents are poorly organized or indexed and, as a result, very difficult to retrieve in a timely manner.... Many program enhancements stress the reestablishment of the plant's baseline but do not pay adequate attention to improving the availability of baseline design information to support future plant modifications; ... the lack of prompt retrieval of records sometimes causes inappropriate conclusions to be drawn by NRC inspectors, quality auditing groups, and public utility regulators, or intervenors.... In addition to knowing the precise location of records, records must be retrievable to suit the information needs of potential users in a time period commensurate with the urgency of obtaining the information.

The NIRMA position paper on configuration management systems (NIRMA 1988) identifies some symptoms of additional programmatic problems with configuration management and recordkeeping systems:

- Outages are extended when problems surface during implementation or testing of changes (problems that could have been prevented if the design basis information in the records system were more usable).

- Multiple (databases) exist in different departments, which may contain conflicting data.

- Documents are not updated after a design change is completed.

- Personnel are not cognizant of changes that have been completed.

- Responses to operability questions are indeterminate because the design basis is unknown.

- System configuration problems result in LERs, NRC violations, NRC citations, and low SALP ratings.

The Nuclear Construction Issues Group (NCIG) and the Task Group on Technical Data Requirements, in cooperation with the Electric Power Research Institute (EPRI), have conducted a review of nuclear plant records requirements (as laid out in ANSI/ASME NQA-1, Regulatory Guide 1.28, and ANSI/ASME N45.2.9). This review was recently published as a EPRI Report (EPRI 1988c), subsequently referred to as the Guidelines. The intent of this review is signalled by the opening paragraph of the Abstract:

> The record systems at many nuclear power plant sites are becoming overloaded with unnecessary and superfluous records. The reason for this overload is that although the Codes and Standards list the record types to be retained, there is no definition for the contents of the records. This encourages varied interpretations which often lead to the approach of "save everything."

The approach NCIG used was to perform an engineering review of each record type to identify which data are "essential data," in the sense of being of "significant value" in:

- demonstrating capability for safe operation

- maintaining, reworking, repairing, replacing, or modifying an item

- determining the cause of an accident or malfunction of an item

- providing required baseline data for in-service inspection.

This engineering review classified each type of data as either 1) essential data contained in lifetime records, 2) verification data contained in lifetime records, or 3) non-permanent records. The distinction drawn between essential data and verification data was that verification data demonstrate that the as-built plant meets the quality requirements laid out in the regulations, the engineering design basis, and the plant's Quality Assurance program. It should be noted that some verification data, particularly that verifying in-process quality rather than the quality of the final product, were classified as non-permanent records. Verification data are viewed by the Guidelines as helpful for resolving questions and for conducting root cause evaluations, but are of secondary importance to essential technical data. In addition to the above classification, the engineering review attempted to identify alternate sources for essential technical data, for use in the event of missing or incorrect data.

Considerations related to possible plant renewed license term were specifically excluded from the scope of the NCIG engineering review and the resulting Guidelines. That noted, the author of this report concludes that several of the record types classified as non-permanent records in the Guidelines would be, in fact, of considerable value in assessing the capability of safety-related SSC to perform their function during a license extension period. On the other hand, many of these classifications as non-permanent records agreed with similar classifications in current recordkeeping standards, such as R.G. 1.28 or ANSI/ASME N45.2.9. Examples of such record types classified as non-permanent in the Guidelines are provided in Table 2.2.

Table 2.2 Record Types Classified as "Non-Permanent" in EPRI Guidelines Document (1988c)

Record Type	Classification in R.G. 1.28	Classification in ANSI/ASME N45.2.9
Radiographs not required by ASME Section XI	10 year	Lifetime storage required for some radiographs
Manufacturing test procedures	3 year	Some are lifetime records
Design Review Reports	10 year	During warranty period
Construction phase welding test procedures	3 year	Until Operating License or during warranty period
Concrete/cement composition reports	10 year	Until Operating License or during warranty period
Pressure test results	Lifetime (manufacturing) 3 year (installation) Lifetime (?) (pre-op)	Lifetime
Calibration procedures and reports	3 year	Until recalibration
Meeting minutes of plant nuclear safety committee and company nuclear review board	---	Lifetime
Licensee Event Reports	---	Per regulatory requirements

3 Review of NPAR Program Tasks Relevant to Recordkeeping

Research on specific components and systems conducted to date by the NPAR Program was reviewed with particular emphasis on explicit recommendations for recordkeeping for aging management.

The Phase I tasks of the NPAR Program Plan have typically either characterized a particular aging degradation mechanism or have characterized all of the mechanisms affecting a particular nuclear plant system or type of component. The NPAR Task reports will list or, less frequently, evaluate the in-service inspection (ISI) techniques which have the potential for tracking the degree of component or system degradation due to the mechanisms considered. A frequent generic recommendation is for increased monitoring and surveillance to mitigate the impact of the degradation mechanisms; this represents a tacit recommendation for increased recordkeeping, since presumably the data resulting from the increased monitoring and surveillance should not simply be discarded.

Many of the NPAR Program tasks have attempted to characterize aging mechanisms and ascertain their prevalence by the use of the national reliability and operating experience databases such as the Nuclear Plant Reliability Data System (NPRDS) and the Licensee Event Report (LER) database. These databases share all of the quality problems described in Section 5.2 of this report plus, for NPRDS, the additional difficulty that, although the information required has been reasonably well defined, the actual submittal of data was voluntary until 1984, when U.S. nuclear utilities made a commitment to the Institute for Nuclear Power Operations (INPO) to provide complete reporting of both engineering and failure data. Even since 1984, NPRDS reporting obligations have been subject to varying interpretations by utilities involved, although INPO does employ three data "auditors" to review input to the database and has some ability to compell corrections or enhancements to the data submittals. Therefore, conclusions drawn regarding operating experience using the national databases tend to be significantly different from the conclusions obtainable when the investigators are able to talk candidly one-on-one with plant engineering and maintenance personnel and review actual plant records. See, for example, the experience of Jarrell et al. (1989), in attempting to use the generic national databases to assess aging degradation mechanisms of safety-related plant service water systems. They note:

> The generic data analysis results did not appear reasonable in light of the investigator's previous plant experience. Subsequently, a broader search for information led the researcher to specific plant data bases and final[ly] to the system expert. . . . It is important for the investigator to understand the intended purpose, features, and limitations of the data base being considered.

Other NPAR Program Tasks (Hoopingarner and Zaloudek 1989) have been able to use the national generic databases, in combination with data from proprietary equipment history databases and with subjective interpretation of the data by experts, to successfully assess and characterize the aging mechanisms impacting a particular plant system.

In a few NPAR Task reports there are explicit recommendations regarding the data that should be collected, on what schedules, and to what purpose. The example that stands out is the report by Hoopingarner and Zaloukek (1989) on emergency diesel generator (EDG) aging. Hoopingarner and Zaloudek propose periodic EDG tests consisting of a slower start and load sequence (e.g., 30 second start and 2 minute load sequence) followed by fairly extensive monitoring and logging of EDG operational parameters, comprising an engine "health check." In Appendix A of their report, they propose logging of about 30 parameters, chosen to provide confirmation of the operability and stability of the EDG and its subsystems. In addition to these periodic (but still monthly) slow start and load operability tests, they propose less frequent (every 6 to 12 months) fast start and load tests, with each such test followed by a 2 hour run at full power to monitor operational parameters and relieve the stresses created by the rapid start. The report also proposes less frequent complete overhauls combined with somewhat more extensive post-overhaul testing than current practice, again with the emphasis on operability and stability rather than fast

start and load. Important operability variables collected in the proposed program would be subjected to statistical analysis and trending much more extensively than that currently practiced, with the goal of optimizing (with respect to safety and economics) the preventive maintenance program.

Another example of detailed consideration of increased monitoring and surveillance (and, implicitly, increased recordkeeping) is found in a variety of studies on electrical cable aging mechanisms and the efficacy of nondestructive examination (NDE) and in situ ISI techniques (Ahmed et al. 1985; Mopsick et al. 1988; EPRI 1984). The general conclusion of these reports is that existing techniques for in situ ISI of electrical cable are not capable of characterizing the condition of the cable and require additional research and development. In particular, they are not capable of predicting that the cable will fulfill its function for some length of time into the future and be able to continue to fulfill its safety function during and after a design basis accident occurring at that future date.

There is a general sense throughout many of the NPAR Program documents (and in the documents of other organizations investigating plant life extension) that assuring piping and pressure vessels can continue to operate within their design fatigue life will require significant improvement in the characterization and records of operating pressure and temperature transients. Beyond this general sense, there are few explicit recommendations. One of the exceptions is the report compiled by Shah and MacDonald (1986) which reviews in Chapters 11-14 the state-of-the-art in nondestructive examination and ISI and the prospects for advanced techniques still under development. Chapter 15 then makes explicit recommendations, including some directly impacting recordkeeping needs.

4 Recordkeeping Implications of Other Life Extension Initiatives

In addition to NPAR and other aging-related NRC activities, the nuclear industry, under the aegis of the Nuclear Management Resources Council (NUMARC), and with the support of EPRI and the U.S. Department of Energy (DOE), has undertaken a number of programs investigating the feasibility of plant life extension. Results of these programs as reported to date offer a number of insights and recommendations regarding the place of records systems in supporting aging management, plant life extension (PLEX), and license renewal. Specifically, EPRI supported two Pilot Plant Studies, one at a BWR and the other at a PWR. Results of the Pilot Plant Studies have been published in a series of EPRI reports.

4.1 Monticello BWR Pilot Plant Study

The Interim Phase 2 report on the BWR Pilot Plant Study (EPRI 1988a) reviews the Monticello Phase 1 and Phase 2 Programs, gives Component Evaluation Summaries for 15 components (some safety-related, some not), discusses the Monticello PLEX Implementation Plan, provides conclusions of the Phase 2 Program, and, in an appendix (EPRI 1988b), gives a database printout of 336 different PLEX follow-on activities. There is much in the report with interesting implications for nuclear plant recordkeeping.

To summarize some of the main highlights and conclusions of the report:

- The component, system, and structure (SSC) prioritization was done in Phase 1 using the Delphi Method and criteria based on safety, availability, and replacement/refurbishment cost.
- Phase 1 evaluated the "critical components," arbitrarily taken to be the 27 highest ranked.
- Phase 2 expanded the Component Evaluations from the 27 "critical" components to all 120 SSC and supplemented the Phase 1 Component Evaluations with in-plant condition assessment and testing of the 27 critical components.
- The 93 new Component Evaluations produced more than 400 recommended actions aimed at improving component life; half of these are relevant not only to life extension, but also to assuring that the plant can reach its design life of 40 years.
- Phase 1 concluded that "a major part of a successful life extension program must include a major rethinking of maintenance practices and equipment monitoring." Phase 2 confirmed that and other Phase 1 conclusions.
- "Procedures generally do not provide sufficient space for recording data, observations or part replacements listings."
- It is necessary "to ensure that all maintenance observations and data needed for PLEX and for long-term preventive maintenance are obtained."
- "Data obtained when components are found in acceptable condition may be as important to future PLEX evaluations as data suggesting immediate refurbishment."
- "As the plant ages and the amount of field data grows, a well developed computerized system for maintenance and for supporting major component replacement/refurbishment studies will be essential."
- Regarding vendor maintenance manuals: "...these supplier manuals have initial deficiencies both in format and content and as they age, they tend to become more deficient and technically outdated regardless of supplier efforts to revise them. The PLEX issue which deserves further evaluation is whether or not the operating plant should continue to rely on supplier manuals as primary maintenance procedures for the long term."
- "Recording of maintenance observations and data for PLEX should be improved."

- "A component based documentation system for the storage and retrieval of maintenance history should be developed."
- "the large percentage of maintenance (34%) and testing/surveillance/ISI (29%) improvements recommended [of the 505 total recommended follow-on activities] for Monticello show that a successful justification for license renewal will be very dependent on a good quality maintenance program with trended data collection and analysis, to support degradation studies and demonstrate adequate margins for extended service."

Appendix A summarizes some of the component-specific recordkeeping recommendations from the report. In addition to the recommendations summarized in Appendix A, each of the 15 Component Evaluation Subsections of the report also describes the aging degradation mechanisms relevant to that component and contains a table evaluating the significance of each of the degradation mechanisms for each of the components treated in that subsection.

4.2 PWR Pilot Plant Life Extension Study at Surry Unit 1

The NUMARC/EPRI/DOE-supported PWR Pilot Plant Study identified in Phase 1 and partially implemented in Phase 2 a number of records system enhancements intended to improve "both the near-term effectiveness and efficiency of records management, and the long-term integrity and availability of records necessary to support life extension evaluation" (EPRI 1989b). The project team "evaluated the completeness, accuracy, availability, and retrievability of records pertinent to future PLEX analyses." This evaluation identified the following shortcomings of the Surry recordkeeping system:

- Some data required to perform life extension evaluations are not available.
- Some data are difficult to retrieve.
- Some data are recorded on media (e.g., radiographs) that will degrade over the life of the plant.
- Nuclear Steam Supply System (NSSS) vendor stress reports and detailed drawings, and other data are retained by the NSSS vendor and Architect-Engineering (A-E) firms and are, thus, not under the direct control of the licensee (Virginia Power).
- Certain data are not prepared in a format that enables storage in the current data format (e.g., computer data files).
- During the 2-year interval between receipt of data for storage and actual archiving (i.e., microfilming), records can potentially be lost, misfiled, or damaged.
- The manual indices used for the current (records) system are cumbersome and time consuming, and will become more so over time.
- The recordkeeping system is designed to meet regulatory requirements rather than operations needs.

This record systems review identified the need for a records database that would tie records to the plant system number, component mark number, document type, date, keywords appearing in the record, and other operationally useful sorting parameters. An investigation of new recordkeeping technologies led to the decision to implement, on a pilot project basis, a records system upgrade based upon capture of the image of a record page in digitized form (using an optical scanner) followed by indexing and storage of the digitized image on optical disks. Storage on optical disks was chosen because of enhanced security, data integrity, and retrievability.

4.3 Sandia Study of Operational Data Collection and Analysis to Support Nuclear Plant Life Extension

Personnel from Multiple Dynamics Corp. and Northern States Power with the support of Sandia National Laboratories and the Department of Energy have been evaluating the results of the Monticello and Surry PLEX Pilot Plant programs to define the operational data needed to support nuclear plant life extension (USDOE 1989; Berg et al. 1989). They have developed a series of

"PLEX Aging Indicators," have considered how current industry databases can be used to support PLEX, and have considered what improvements should be made in data collection, preservation, and dissemination to improve plant life extension prospects. The report on this study, "Operational Data Collection and Analyses for Nuclear Plant Life Extension" (Berg at al. 1989), defines 291 operational data types, covering 11 classes of data, such as transient, water chemistry, testing, surveillance, and environmental data. The data identified in the report are associated with only fifteen critical components and structures, identified during the course of the Pilot Plant programs.

The highest priority data consisted of those items required to evaluate a degradation mechanism that will definitely affect component life. Of the high priority data items, 10.5% are not currently being collected by the Pilot Plants; Appendix B summarizes these items. The report also identifies potential PLEX Aging Indicators (USDOE, 1989), including

- ISI examination results
- pressure/temperature transient history
- water chemistry transient history
- reactor pressure vessel beltline material radiation sample test results
- primary containment vessel wall thickness test results
- carbon steel piping wall thickness test results
- concrete crack mapping and growth history
- concrete core sample compressive test results
- results of destructive testing on removed electrical cable

The report includes specific recommendations on data measurements and recording methods, suggested enhancements to commercial databases, and suggested improvements in the collection and dissemination of chemistry data, summarized here in Appendix C.

4.4 IAEA (draft) Guidelines for Data Collection and Record Keeping

The International Atomic Energy Agency (IAEA) Advisory Group on Nuclear Power Plant Ageing and Life Extension recommended in June 1988 that guidelines for data collection and recordkeeping of baseline, operational, and maintenance data for nuclear power plant components be drafted. An IAEA Consultants Panel met in Vienna during July 1989 to prepare the draft, which was subsequently reviewed at a Technical Committee meeting in Vienna in November 1989. A second draft was prepared during a Consultants Meeting in March 1990. After further review and revision the guidelines were published in December 1991 as the Safety Series report *Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing* (IAEA 1991).

The report treats the following topics: 1) general data needs for the evaluation and management of aging, 2) the attributes of an effective data collection and recordkeeping system, 3) factors that may be used to prioritize the data requirements and provide the basis for phased implementation of the records systems, 4) the need for differing approaches to records system implementation in planned plants and existing plants, and 5) participation of the operations and maintenance staff of the plant in the design and implementation of the records systems. Appendix I of the report provides specific examples of data needs for the management of aging of the reactor pressure vessel, the emergency diesel generators, and electrical cables. Appendix II provides some examples of effective data collection and recordkeeping systems and Appendix III offers some guidance for the implementation of an advanced data collection and recordkeeping system.

5 Recordkeeping Approaches Supporting Aging Management

We suggest two criteria for determining which SSCs and which aging mechanisms need to be treated to support aging management. The first is determination that a particular SSC is important to safety, a determination made using the plant's current licensing basis. The second criterion is the expected lifetime of the SSC under the influence of specific aging mechanisms. If the SSC needs to be repaired, refurbished, or replaced several times during the plant's design lifetime due to the effects of a particular aging mechanism, then by definition that mechanism becomes a problem that the plant owner has had to deal with during the original life of the plant license in the context of the plant maintenance program. On the other hand, if the expected lifetime of a SSC under the influence of a specific aging mechanism is on the order of the design/licensed lifetime of the plant, then, again by definition, neither the plant owner nor vendors will have an extensive experience base of SSC failures to support aging management for that SSC. It is these combinations of plant SSC and aging mechanisms that the life extension effort must characterize. Note that a SSC may be at the same time a maintenance concern with respect to one aging degradation mechanism and a life extension concern with respect to another degradation mechanism.

As a conceptual model for deciding, on a plant-specific basis, what types of data need to be collected, maintained, and analyzed in support of an aging management effort, consider a matrix (or table) indexed on one side by the collection of safety-significant plant systems and component types (as determined by the plant's current licensing basis) and indexed on the other side by the aging degradation mechanisms (as determined by NRC and industry supported research projects and by plant operational experience). The ij-th entry in this matrix represents the assemblage of information related to the impact of the j-th aging degradation mechanism on the i-th plant system or component. In order to complete the ij-th entry, the plant owner should collect and evaluate, as part of the aging management effort, information answering the following questions:

(1) Is the j-th aging degradation mechanism relevant to the i-th system in this specific plant?

(2) If relevant, what is the condition of the i-th system (with respect to the j-th degradation mechanism), again, in this plant?

(3) What are the plans for mitigating any i-th system degradation due to the j-th mechanism, as well as plans for managing and controlling the impact of that mechanism on the system?

The specific information required will vary from plant to plant, depending on the type of reactor, details of the original design, how the plant has been modified, maintained, and operated, any significant operational transients experienced by the plant systems, and the specific refurbishment strategies chosen by the applicant. Plant owners may discover that they need to replace or refurbish plant systems for which detailed and comprehensive records would have supported continued operation without major modifications.

The ultimate acceptance criterion for evaluating the impact of aging mechanisms together with the licensee's program for mitigating that impact is whether the plant will continue to meet the design adequacy acceptance criteria specified in the plant's licensing basis, throughout the life of the plant.

5.1 Screening and Prioritization of Components, Systems, and Structures for Aging Management

Methodologies proposed for the screening and prioritization of SSCs for aging management generally involve consideration of some or all of the following factors:

- the risk or safety significance of the SSC
- the effectiveness of the inspection and maintenance programs
- the expected lifetime of the component or structure
- the feasibility of replacing or refurbishing the SSC.

The NPAR Program developed a methodology to prioritize SSC for its own research by having a panel of experts determine values (using available data or their engineering judgment) of the parameters in the following equation for each of fifty types of nuclear plant components.

$$R = N \cdot A \cdot \left(\frac{1}{2}\right) \cdot \left\{\frac{L}{P(D) \cdot P(M|D)}\right\}^2 \qquad (5.1)$$

where R = the increment in total plant risk due to aging of the component

N = the Birnbaum Risk Importance of the component

A = the derivative of the failure rate of the component with respect to time (i.e., a measure of the increase or decrease in the failure rate with aging of the component)

L = the standard inspection interval for the component

P(D) = the probability of detecting aging degradation at the time of inspection

P(M|D) = the conditional probability of correcting or mitigating the aging degradation, given that it has been detected.

The derivation of this equation, called the RSCAAMP (for Risk Significance of Component Aging and Aging Management Practices) model, is described in a report by Levy et al. (1988).

The method used to prioritize, or screen, components and systems to determine which will require detailed evaluation in an aging management program may not be the RSCAAMP model, but, in any event, will require the development of similar information. The risk importance of a component is determined using a plant probabilistic risk assessment, but the plant records system will have to support determination of the other four parameters on the right hand side of the RSCAAMP model or of equivalent data.

5.2 Determination of the Expected Lifetime of Components, Systems, and Structures

One of the major applications of plant records is to enable the estimation of the failure distributions for particular systems and components. These estimates allow:

- incorporation into existing or planned probabilistic risk assessments of failure data reflecting actual plant experience and aging impact
- a legitimate basis for the design of preventive maintenance programs and surveillance and testing requirements
- predictions of remaining component or system life in support of continued operation of the plant to or beyond the current license termination date.

One factor which must be taken into account in formulating recommendations for nuclear utility recordkeeping systems (on the basis of the results from the NPAR Program) is the effect of the expected lifetime of a system or component as a function of its original design and fabrication, together with the preventive maintenance program. Plant systems and components can be roughly divided into three categories:

- Category 1 - Systems and components with expected lifetimes significantly less than the plant lifetime. Examples are batteries, most of the valves, and many of the "active" plant components.
- Category 2 - Systems and components with expected lifetimes significantly greater than the plant lifetime. By this we mean that at the end of the plant design lifetime, such systems or components still fulfill their design function with unused design margins. Possible examples are structural concrete and "passive" components subject to mild environments.
- Category 3 - Systems and components with lifetimes of the same order as the lifetime of the plant. Examples of these might be some of the electrical

cabling, containment penetration seals, some of the piping, and, in general, "passive" components of the plant which are subject to aggressive environments or have smaller design margins.

Aging mechanisms and techniques for detecting and mitigating them are relevant to all three categories, but the proper use of the knowledge gained varies from category to category.

For Category 1 components, information about aging mechanisms is used to design preventive maintenance programs that will maintain an acceptable level of the required function of the system or component. Indeed, predicting and mitigating aging of Category 1 components is a major goal of the nuclear plant maintenance program. The only aging management concerns are (1) to confirm that such a program has been in place and will continue in place, (2) to verify that equipment spares will continue to be available, and (3) to assess whether technology advancement makes replacement/redesign desirable from an economic or safety viewpoint. For Category 1, aging management is not essentially different from the earlier operation of the plant and the continuation of a demonstrated effective program should be adequate to maintain safety and availability.

For Category 2 components, failure data will be scarce or non-existent. Information on the impact of aging mechanisms will necessarily consist mostly of in-service surveillance and monitoring information using destructive and nondestructive examination techniques. This information should verify that the condition of the components shows no unexpected or undue deterioration and that the operational environment remains within the design envelope of the component.

Category 3 components are those of most relevance and interest from an aging management standpoint. They are reliable and long-lived enough that the operating history and failure records cannot be expected to provide statistically strong guidance to assess their residual life and expected performance during the renewed license period. Accordingly, data from ISI and NDE may be relied upon to assess the condition of the component and estimate its residual life. Similarly, there may be components for which a careful assessment of the operating history and environment, particularly with respect to thermal and pressure transients, may be critical to an assessment of the remaining fatigue life of the component.

Consideration was given to the quantity and quality of data required to make reliable estimates of failure distributions, particularly in the case of most interest for aging management, where we want to estimate the end-of-life parameters for systems or components which have exhibited few failures to date. The quality of reliability data for nuclear plant components and systems imposes significant uncertainties upon attempts to estimate residual life of SSC for reasons partially explained by Fussell and Arendt (1979):

> Reliability data are unlike other data such as nuclear cross sections. The basis of cross-section data is a large finite number of nuclei, all with identical properties. The basis of reliability data is stochastic, involving ever-changing components and environmental conditions. In addition, reliability data have the property of describing a statistical distribution rather than a fixed but unknown value. In other words, even under perfect measurement conditions, reliability data for a single event cannot be determined by a single test but rather must be determined from years of observation of equipment in various environments during which time the equipment designs may change. In addition, it is frequently easy to determine how many components of a certain type failed in a certain way during a known time period. Unfortunately, it is often not known how many identical components did not fail during this time interval; i.e., the population of components in use is not known. Collecting and evaluating reliability data is very frustrating.

In addition to the difficulties with collecting high quality reliability data described in the quotation, difficulties which apply to all three categories of components and systems, there are additional problems associated with the long-lived Categories 2 and 3. These additional problems are a result of the rarity of failures for components and systems with expected lifetime on the order of 40 years or more. For a reliability engineer to successfully characterize the ability of a system or component

to fulfill its required function out to 60 years based on data from the first 30 years of life would be similar to a statistician trying to build an annuity table for the U.S. population based only on data about people no more than 30 years old. Such estimates can be made by assuming a particular shape for the failure distribution (more specifically, by assuming a failure distribution belonging to a particular parametric family of distributions), but the estimation process is ill-conditioned and the resulting confidence intervals will tend to be large. On the other hand, when relevant information is available from accelerated aging tests and equipment qualification programs, ISI, and in service testing, it may be possible to supplement the statistical estimation or to eliminate the need for it altogether.

5.3 Generic Recordkeeping Approaches to Manage Plant Aging

In the context of aging management, the nuclear plant records system must provide access to the information needed (1) to prioritize SSC according to their safety importance and their susceptibility to aging degradation, (2) to understand the actual course of aging degradation in the plant, and (3) to manage, by appropriate mitigation, that aging. The first of these goals is most strongly determined by the plant design and how that design has been implemented in the process of construction and later modifications to the plant; that is, by the engineering design basis of the plant. The second and third goals represent the information needed to design and implement an effective maintenance program in the plant.

An effective data collection and recordkeeping system, supportive of aging management activities, should meet the following performance elements:

- Provide sufficiently comprehensive and accurate information about the plant, including engineering baseline data, historical operational status, and maintenance history.
- Provide for flexible management of that information.
- Provide secure storage of the information.
- Provide for the integrity of the information over the (possibly extended) life of the plant.
- Provide timely and accurate retrieval of the information.
- Provide adequate tools for data analysis, graphical display, and production of reports.

At the same time, there should be full consideration of the alternatives to recordkeeping requirements for specific components or systems. For some safety significant components, systems, and structures, a conservative preventive maintenance program, based upon equipment history, may provide for aging management, without the need for extensive records of the operating environment. A commitment to refurbishment or replacement of a plant system may reduce the need for records documenting the earlier operating environment of that equipment. Similarly, techniques for "de novo" condition assessment (that is, determining the adequacy of a system or component, as if it were new and did not have an operating history) may permit continued operation without the need for extensive records of the past operating environment.

5.4 Specific Recordkeeping Approaches to Manage Plant Aging

Specific recommendations flowing from the generic performance criteria described in the preceding section emphasize two basic design principles:

(1) To the extent possible, data should be entered by maintenance and operations personnel directly in a machine readable form.

(2) Databases distributed throughout the nuclear plant should have common organization, format, and central indexing and should be stored and archived digitally on stable and usable media.

5.4.1 A Specific Example of the Recommended Approach

Consider an example of the recommended approach to recordkeeping in the context of the framework for EDG

testing, monitoring, and trending proposed by Hoopingarner and Zaloukek (1989).

On the first point, the preferred method for direct input of machine readable data would involve replacement of paper forms filled out by the maintenance personnel with a program running on a portable computer. This program, to be used by the maintenance and test personnel during the test, would request the desired data in the appropriate order, perform input validation, and immediately calculate operational parameters of interest (i.e., heat exchanger performance parameters could be calculated once the input and output temperatures and the flows are known). Such a program could produce hard copy reports as needed and could enable easy transfer of the data into the preferred long-term database format. Another approach to direct data input for some of the desired data is to have the portable computer or a portable terminal directly interrogate the machinery. This requires vendor cooperation, but is an approach widely used in the computer, instrument, machine tool, and automobile industries. Hoopingarner and Zaloukek (1989) recommend this approach for the collection of data verifying the integrity of EDG control circuitry and control logic. Alternative, but less desirable, approaches include (1) the collection of data on paper forms which are machine readable in some fashion or (2) business-as-usual with the maintenance personnel filling out a form, which may or may not be transcribed later into a machine-readable form and may or may not be centrally-indexed in machine readable form. These approaches offer several additional opportunities for introducing errors into the database, while providing no opportunity for validity checking while remeasurement is still possible.

The primary reason for utilities to move quickly toward the direct capture of plant information in a machine readable form is to enable straightforward utilization of evolving analytical and data processing capabilities without the formidable barrier of having to recover and convert information that is only available in hard copy form.

On the second point, for some utilities, various databases relevant to a particular plant system or piece of equipment are spread throughout the organization, on different media or data processing equipment, with different formats, and no central coordination or indexing. In some cases data are archived in unwieldy formats, on suspect media, or under inappropriate environmental conditions. As a practical matter, many plant records, although archived, are not sufficiently retrievable to be usable by the plant staff. Among developing storage technologies, optical disk storage, particularly in the write-once, read-many-times (WORM) format, seems to offer the best combination of large storage capacity, good retrievability, a built-in audit trail, and good permanent archiving characteristics. The Plant Life Extension Pilot Project at Surry is investigating optical disks as a storage media for plant records. Pacific Gas & Electric and Northern States Power are each involved in what appear to be cooperative demonstration projects exploring the utility of optical disks and related technologies. Papers by Ruiz (1988), Minkler (1988), and Lancaster (1986) discuss some of the important issues related to possible uses of optical disks in nuclear plant records systems.

In addition to these major points, the Hoopingarner and Zaloukek report (1989) suggests more consistent and informative collection of data related to equipment procurement, installation, and reliability. Explicitly excluded from the recommendations are data that support analysis of the spectral signature of EDG vibration. Although of proven value to maintenance of pumps, turbines, etc., for EDGs it amounts to too much of a good thing. The day-to-day and even minute-to-minute variations in EDG vibration, due to reciprocating components and a variable power source in each [illegible], are too great to permit the timely selection of appropriate action.

5.4.2 Recordkeeping to Support Maintenance

Good maintenance records, supported by root cause analysis and usable engineering design baseline documentation, are necessary to enable the reliability engineering analysis used to design a Reliability-Centered Maintenance (RCM) program. Additional data are needed on operator error probabilities and inspection efficiencies to support development of an RCM program (Smith 1987). The report by Jarrell et al. (1989) contains specific recommendations for types of data needed to support root cause analysis and to enable determination of equipment failure rates and estimation of residual life.

Reliability-Centered Maintenance programs have been widely used during the last 20 years for both commercial and military aircraft and for U.S. Navy submarines and surface vessels. RCM uses reliability engineering (in some cases, a fault tree analysis of the system) to characterize the dominant failure modes for a system, to order them according to their relative importance to the preservation of system function, and to prioritize and evaluate the preventive maintenance actions with potential impact on a dominant failure mode. The preventive maintenance actions are evaluated according to their efficacy in reducing the probability of system failure and also with respect to their cost-efficiency. The net effect of this analysis tends to shift preventive maintenance tasks away from scheduled overhaul or replacement and toward condition monitoring used to track degradation and predict incipient failure. The economic and safety benefits of a well designed RCM program are substantial, as a result of improved availability, fewer forced outages, and reduced levels of scheduled overhaul or replacement. EPRI has supported pilot studies of RCM in nuclear plants and is supporting technology transfer to other utilities through the auspices of an RCM Users Group (Smith 1987; Brauer and Brauer 1987).

Implementation of RCM Programs requires thorough documentation of the engineering design basis of a plant, together with good records of its operational history and equipment histories. The RCM focus on continuous or frequent periodic condition monitoring of equipment requires sufficient recordkeeping to facilitate trending of equipment condition parameters and prediction of maintenance needs.

5.4.3 Reconstitution of Missing Data

A particular attempt has been made to identify those situations requiring utilities to "reconstruct" missing data from the early years of plant operation, e.g., plant transient conditions logging to provide a basis for estimating the remaining fatigue lifetime of critical components. Any such requirement needs to be carefully considered because of the expense and difficulty of such records reconstruction.

Indeed, the only such data identified are those of the example, transients occurring during the plant operating history and other data relevant to assessing the impact of those transients on the low-cycle fatigue design basis for piping and pressure vessels. There are several initiatives under way to develop methodologies for reconstructing such information (when missing) and also for re-analyzing more realistically the impact of the plant transient history on low-cycle fatigue limits.

5.4.4 Aging of Archival Records

One of the major data integrity issues with potential impact on license renewal is the adequacy of weld radiograph storage. Even under ideal storage conditions, the proven archival lifetime of photographic media is on the order of the original 40 year license period. In many cases, actual storage practice is not ideal. Testing of residual sodium thiosulphate may not have been performed adequately; radiographs may be stored in facilities that are too warm or moist; they may be stacked horizontally, rather than stored on end; acid-free interleaving paper may not have been used; the radiographs may be handled at times without gloves. Any of these conditions may result in significant degradation of the original radiographs (Anderson 1988).

Some vendors are offering microfilming of original radiographs as a way of solving the problems cited. This raises the question of loss of resolution in the copying process and avoids the issue of the ultimate archival lifetime of film media.

Another possible solution enabled by evolving computer technologies uses digital scanners to digitize the information in critical radiographs. If necessary, it is possible to apply image enhancement algorithms to the digitized data. The digitized information can then be stored on compact, archival media (such as optical disks or optical digital tape) using data compression and error-correcting codes. The stored data could be reread periodically and reconstituted exactly if the error-correcting codes indicated any degradation of the stored data. Subsequent use of the data for comparison with on-going ISI can be based upon exact, verified copies of the master disks, using processes imposing minimal risk on the integrity of the original data.

Other types of records may also be subject to age-induced deterioration. Utility records from the design and construction period may be copies of originals

produced by vendors, architect-engineer, or constructor. From the author's personal experience, such copies may be subject to considerable fading and legibility problems after a few years of storage, particularly those made using "wet" copying techniques prior to the widespread use of xerography. Data stored on magnetic tape requires careful control of environmental conditions, periodic rewinding, and, perhaps, periodic recopying to maintain data integrity. In addition to these problems of physical deterioration, design and construction records particularly may suffer from loss of the original context of supporting assumptions in which they were generated. At the time of their generation, that context was provided mostly by the memory of the individuals involved. Many years later, with those individuals unavailable (or their memory faded), it may be extremely difficult to reconstruct all of the information in the original record in its original context.

5.4.5 Avoiding Surprises

Particular attention was paid to the types of records required to identify "unexpected" physical and operational phenomena with the intent of enabling early identification of phenomena such as intergranular stress-corrosion cracking, steam generator tube thinning and denting, and pipe wall thinning due to erosion/corrosion. By definition, a "surprising" physical or chemical phenomenon is unexpected. As such, it is difficult to predict what information should be collected and evaluated to permit early identification and characterization of the unexpected phenomenon. Experience suggests, however, that broad collection of data on (1) plant water chemistry; (2) plant temperatures, pressures, and flows; and (3) noise data--neutron, pressure, temperature, and audio noise--even if no immediate need for the data is seen, will provide opportunities to predict some "surprises." Further, it is important not to discard unexplained or "outlying" data. The British scientists who discovered the annual formation each winter of an ozone "hole" over Antarctica delayed for some time reporting their results because they didn't understand why the American satellite measuring global ozone levels had not already seen this phenomenon. Upon publication by the British, American scientists revisited their data and discovered the ozone "hole" had been in their raw data all along, but the computer program processing the raw data contained instructions to ignore such "unrealistically low" ozone levels.

5.4.6 Specific Recommendations from the Monticello Pilot Plant Study

The reports documenting the Monticello Pilot Plant Life Extension Studies (EPRI 1988a, 1988b, 1989b; Berg 1989) are the richest single source of specific types of operational data of value for plant life extension. Some of this material has been included in this report as Appendixes A, B, and C. Some of the judgments and recommendations are specific to BWRs or to Monticello in particular, but many are of generic interest.

6 Techniques and Technologies for the Improvement of Recordkeeping

One of the reasons for existing limitations and deficiencies in plant recordkeeping has been the high personnel, software, and hardware costs associated with maintaining a comprehensive record of plant performance, operating history, and equipment maintenance. Indeed, recordkeeping systems have always been strongly driven by the capabilities of the available technologies, going all the way back to the beginnings of written history. Many of the early innovations in written language and mathematics were impelled by a need for more efficient or secure methods for maintaining commercial and cultural records (e. g., cuneiform script, arabic numbers, papyrus, and movable type).

The striking reduction in the effective cost of computation and data storage and the coming of age of machine pattern recognition and expert systems during the last decade may make feasible and economic what could not be done at a reasonable cost in the past.

Techniques and technologies impacting the feasibility of recordkeeping improvements will be described in the following sections.

6.1 Enhanced Forms Design

One of the ways of improving the quality of data in plant records systems is to eliminate errors at the data input stage. The use of human factors design principles can create data input forms less subject to misinterpretation. The need for a procedure prescribing how to fill out a form, which the author has seen in several organizations, is prima facie evidence of poor forms design.

6.2 Direct Input of Data

The direct input of data in a machine-readable form, using on-line "help" facilities, has a great potential for improving the quality of initial data input as well as essentially eliminating errors due to transcription of hard-copy data into a machine readable form. This report is being written using a fairly complex word processing program, which has 45 half screens of on-line documentation, any of which can be accessed in no more than 2 or 3 seconds, practically eliminating the need to use the written manual. Direct input of data in machine-readable form can be achieved using portable (even hand-held) terminals and/or computers, FM modems, bar code readers, passive and active transponders, FM transmission of data on normal plant AC power lines, and write-once laser card technologies. These may not be cost-effective for backfit application, but should be carefully considered as new data collection needs arise. Southern California Edison has joined with Radix of Salt Lake City in a pilot study of the use of hand-held computers to automate the data logging required by the San Onofre plant's Control Room Surveillance procedure (Electric Light and Power 1988).

6.3 Integrated Plant Databases

Already available are integrated plant databases, providing a single, coherent database which can be used to support plant construction, produce drawings, manage maintenance, prepare licensing submittals, and support plant operation. Examples of such databases are the EPRI-supported Plant Information Model and the Plant Configuration Model of Construction Systems Associates (Smith 1989).

6.4 Expert System Control of Data Input

Expert systems can be created to assist primary data collectors, i.e., the plant maintenance, engineering, and administrative staff, with the input process. The purpose of the expert system would be to capture the expertise of the plant's most knowledgeable and experienced personnel. For example, this technique has been used to build "expert assistants" for the creation of input files for complex thermohydraulic computer codes.

6.5 Optical Disk Storage and Dissemination of Data

Optical disks offer many significant advantages for nuclear records applications, including low cost per bit stored; a stable archival media; access to massive amounts of data, even on desktop machines; and, in the case of compact disk-read only memory (CD-ROM) and write-once read-many (WORM) systems, a secure audit trail and assurance that configuration managed data have not been subject to unauthorized changes. CD-ROM is most suitable for "publishing" applications where the cost of creating a master disk can be spread over a number of copies. There is currently a strong move toward publishing machine-readable vendor manuals on CD-ROM, mixing both text and graphics (and soon the capability of mixed text, graphics, and audio).

6.6 Digital Scanners and Optical Character Recognition

Conversion of existing records to machine-readable formats can be achieved using digital scanners to directly capture text and graphics as an image which can be stored digitally. Such an image cannot be directly manipulated by word processors or database software until the textual content of the image has been captured using optical character recognition (OCR) software, producing an ASCII (or other format) text file which can be manipulated by other computer programs. Although conversion of many types of existing hard copy records using scanners and OCR software is possible, it may require a substantial QA/QC effort to catch errors made by the scanner and/or the OCR software. Both scanners and OCR have improved substantially over the last 5 years and can be expected to continue to do so.

6.7 Enhanced Retrievability of Data

Associative memory, pattern recognition techniques, hypertext software, optical disk "jukeboxes," and database "engines" (computer hardware specialized by architecture for the storage and retrieval of data) all offer potential for significantly enhanced data retrievability. For example, the U.S. Environmental Protection Agency has recently produced a hypertext version of its regulations on leaking underground storage tanks (Foskett 1990). Entitled "Reg-in-a-Box," it has been widely distributed at nominal or no cost in versions suitable for the two commonest types of microcomputers. Hypertext incorporates links between sections of text which reflect the document's logical relationships, offer footnotes, give parenthetical information, and trace cross-references through the regulations and the underlying laws. It allows the reader to navigate freely through the document following logical "threads" and backtracking to pick up previous paths.

6.8 Simulation, Multivariate Statistical Analysis, and Related Techniques

One of the ways of attacking "missing data" problems is to construct simulations which can be used to solve an inverse problem (and thus estimate the value of the missing data). An example along these lines is work by Structural Integrity Associates to construct Green's Functions which transform their input values, existing coolant system temperatures and pressures, directly into fatigue usage factors for vessel locations for which the necessary local temperature records are not available.

A Brookhaven National Laboratory report by Samanta et al. (1989) examines four different multivariate statistical analysis tools for their applicability to the analysis of nuclear plant operational data. The tools considered are correlation analysis, principal component analysis, cluster analysis, and regression analysis (using Cox's proportional hazard model). They are considered for applicability to operational event traces (that is, the collection of operational variable time series which characterizes the event), to safety system acuations, and to component level failure prediction. The evaluation performed was preliminary, using computer codes and operator training simulators rather than actual plant data.

Some of the potential benefits adduced:

- uncovering the underlying structure of the operational data discovering (perhaps previously unknown) interrelationships between operational data variables

- reduction of dimensionality - that is, the ability to replace a set of operational data variables with a much smaller set of variables incorporating most of the information available in the larger set
- enhancing the sensitivity of the analysis - replacing the existing operational variables with combination variables which more sensitively reflect degradation and incipient failure processes
- classification - the use of cluster analysis to identify combinations of operational data values associated with degraded plant condition and incipient failures or transients.

The authors emphasize the preliminary nature of their evaluation and the iterative, exploratory nature of the statistical techniques described. These tools are powerful, but their use is sensitive to the weighting and scaling of variables. For this reason, use of these tools requires a strong feedback between the results of statistical analysis and the engineering reality represented by the underlying data.

7 Conclusions

Virtually all parties involved in consideration of aging management have recognized the likelihood that nuclear plant records systems would need to be upgraded.

Although current records systems are extensive (NCIG argues that they are too extensive), they are not implemented consistently throughout the industry and have a number of recognized deficiencies. Indeed, many utilities are currently upgrading the documentation of their engineering design basis, in response to deficiencies identified during SSFI, SSOMI, or SALP reviews. NPAR Program Phase I tasks have identified aging degradation mechanisms relevant to safety-significant nuclear plant systems and types of components. Most of these tasks have also tentatively identified surveillance or monitoring programs which can be used to assess and trend equipment condition. Any additional surveillance or monitoring carries with it a need for additional recordkeeping.

One of the goals of the Phase II NPAR tasks, including the Guidance for Recordkeeping task, is the development of functional requirements in the area of equipment condition assessment trending and prediction of residual life. Many systems and components have expected lifetimes significantly less than the 40 years of the original plant license. For these SSCs, the plant owner has already had to develop a maintenance program which manages the relevant aging mechanisms. For aging management of such SSCs, continuation of the existing maintenance program is not sufficient; there must also be assurance of the continued availability of spares, an evaluation of the desirability of system upgrades, and an assessment to assure that there are no additional aging degradation mechanisms operating during extended life.

For Category 2 and 3 SSCs, records establishing the engineering design baseline, records documenting the operating environment and transients experienced, and maintenance records detailing both failures and successful operation of the SSC are recommended to support the plant-specific "matrix" approach described in Section 5.0 of this report.

In response to additional recordkeeping needs and as part of a continuing program to upgrade the usability and archival integrity of existing records, there is a need to evaluate, on a plant-specific basis, the new and more cost effective recordkeeping technologies discussed in Section 6.0 of this report.

8 References

Ahmed, S., S. P. Carfagno, and G. J. Toman, 1985, *Inspection, Surveillance, and Monitoring of Electrical Equipment Inside Containment of Nuclear Power Plants - With Applications to Electrical Cables*, NUREG/CR-4257, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The American Society of Mechanical Engineers, 1986, *Quality Assurance Program Requirements for Nuclear Facilities*, ANSI/ASME NQA-1, 1986 Edition, New York.

The American Society of Mechanical Engineers, 1979, *Requirements for Collection, Storage, and Maintenance of Quality Assurance Records for Nuclear Power Plants*, ANSI/ASME N45.2.9-1979, New York.

Anderson, Craig E., 1988, "*Microfilming Radiographs*," paper in NIRMA (1988).

Berg, R. M., J. E. Lewis, S. A. Skay, and T. L. Bailey, 1989, *Operational Data Collection and Analysis for Nuclear Plant Life Extension*, SAND88-7111, Sa: dia National Laboratories, Albuquerque, New Mexico.

Brackney, J., H. Cheatheam, R. Vecchiarello, and B. Kallander, 1987, "*Configuration Management and the Role of the Records/Information Manager*," paper in (NIRMA 1987).

Brauer, D. C. and G. D. Brauer, 1987, "*Reliability-Centered Maintenance*", IEEE Transactions on Reliability, Vol. R-36, No. 1, April 1987, pp. 17-24.

"*Configuration Management Program--A Position Paper*," 1988, developed by the NIRMA Configuration Management Committee, paper in (NIRMA 1988).

Cox, J. and P. Filiak, "*Design Baseline Reconstitution*," Nuclear Plant Journal, September-October 1987, pp. 40 ff.

Electric Light and Power, 1988, "*SoCalEd automates data gathering at San Onofre*," Vol. 66, No. 11 (November 1988).

Electric Power Research Institute, 1984, *Condition Monitoring of Nuclear Plant Electrical Equipment*, EPRI NP-3357, Palo Alto, Calfiornia.

Electric Power Research Institute, 1988a, *BWR Pilot Plant Life Extension Study at the Monticello Plant: Interim Phase 2*, EPRI NP-5836M, Palo Alto, California.

Electric Power Research Institute, 1988b, *BWR Pilot Plant Life Extension Study at the Monticello Plant: Interim Phase 2*, Appendices, Volumes 1, 2, and 3, EPRI NP-5836S, Palo Alto, California.

Electric Power Research Institute, 1988c, *Guidelines for the Content of Records to Support Nuclear Power Plant Operation, Maintenance, and Operation* (NCIG-08), EPRI NP-5653, Palo Alto, California.

Electric Power Research Institute, 1989a, *PWR Pilot Plant Life Extension Study at Surry Unit 1: Phase 2*, EPRI NP-6232-M, Palo Alto, California.

Electric Power Research Institute, 1989b, *BWR Pilot Plant Life Extension Study at the Monticello Plant: Phase 2*, EPRI NP-6541m, Palo Alto, California.

Foskett, W. H., February 1990, "*Reg-in-a-Box: A Hypertext Solution*," AI Expert, 5(2):38-45.

Fussell, J. B. and J. S. Arendt, 1979, "*System Reliability Engineering Methodology: A Discussion of the State of the Art*," Nuclear Safety, v. 20, pp. 541- 550, 1979.

Guthrie, R. D., M. B. Holland, M. McGuire, and W. J. Pattison, 1986, "*Configuration Management at Browns Ferry Plant*," paper in NIRMA (1986).

Hoopingarner, K. R. and F. R. Zaloudek, 1989, *Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators,* NUREG/CR-5057, Pacific Northwest Laboratory, Richland, Washington.

International Atomic Energy Agency, 1991, "*Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing,*" Safety Series No. 50 - p. 3, Vienna, Austria.

Jarrell, D. B., A. B. Johnson, Jr., P. W. Zimmerman, and M. L. Gore, 1989, *Nuclear Plant Service Water System Aging Degradation Assessment*, NUREG/CR- 5379, Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

Lancaster, T. C., 1986, "*Optical Disk Storage and Retrieval Systems--What Records Managers Should Know,*" paper in NIRMA (1986).

Levy, I. S., J. Wreathall, G. DeMoss, A. Wolford, E. P. Collins, and D. B. Jarrell, 1988, *Prioritization of TIRGALEX-Recommended Components for Further Aging Research,* NUREG/CR-5248, Pacific Northwest Laboratory, Richland, Washington.

Minkler, W. S., 1986, "*Realistic Look at Laser-Optics and Micrographics Technology at Nuclear Generating Plants*", paper in NIRMA (1986).

Mopsick, F. I., E. F. Kelley, and F. D. Martzloff, 1988, *A Review of Candidate Methods for Detecting Incipient Defects Due to Aging of Installed Cables in Nuclear Power Plants,* NBSIR 88-3774, National Institute of Standards and Technology (formerly the National Bureau of Standards), Washington, DC.

Nuclear Information and Records Management Association, Inc., 1986, *Ten Years of Progress - Current and Evolving Trends,* Tenth Annual Symposium Proceedings, held at Denver CO, September 7-10, 1986, NIRMA, New York.

Nuclear Information and Records Management Association, Inc., 1987, *Coping with Technology - The Big Squeeze,* Eleventh Annual Symposium Proceedings, held at Long Beach, CA, August 23-26, 1987, NIRMA, New York.

Nuclear Information and Records Management Association, Inc., 1988, *Managing Information - The Hidden Asset,* Twelfth Annual Symposium Proceedings, held at Chicago, IL, August 21-24, 1988, NIRMA, New York.

Nucleonics Week, May 5, 1988, "*Utility Records Computerization is Uneven and Very Individual*", pp. 7-9.

Ruiz, D. E., 1988, "*Document Workflow Automation - Beyond Storage and Retrieval*", paper in NIRMA (1988).

Samanta, P. K., T. Teichmann, M. M. Levine, and W. Y. Kato, 1989, *A Multivariate Statistical Study on a Diversified Data Gathering System for Nuclear Power Plants,* NUREG/CR-5325, Brookhaven National Laboratory, Upton, New York.

Shah, V. N. and P. E. MacDonald (eds.), 1986, *Residual Life Assessment of Major Light Water Reactor Components,* Volume 1 (DRAFT), NUREG/CR-4731, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

Smith, A. M., 1987, "*Using Reliability-Centered Maintenance to Optimize PM Programs*", Nuclear Plant Journal, September-October 1987, pp. 20 ff.

Smith, P., 1989, "*Configuration Management of Nuclear Power Plants*", Transactions of the American Nuclear Society, vol. 59, Transactions of a meeting held at Atlanta, Georgia on June 4-8, 1989, American Nuclear Society, Lagrange, Illinois.

U.S. Department of Energy, 1989, "*Operational Data Collection and Analysis for PLEX*", NUPLEX News, May 1989, p. 2.

U.S. Nuclear Regulatory Commission, 1976, *Collection, Storage, and Maintenance of Nuclear Plant Quality Assurance Records,* Regulatory Guide 1.88, Rev. 2, Office of Standards Development, Washington, DC.

U.S. Nuclear Regulatory Commission, 1980, *Clarification of TMI Action Plan Requirements,* NUREG-0737, Office of Nuclear Reactor Regulation, Washington, DC.

U.S. Nuclear Regulatory Commission, 1985, *Quality Assurance Program Requirements (Design and Construction),* Regulatory Guide 1.28, Rev. 3, Office of Nuclear Regulatory Research, Washington, DC.

U.S. Nuclear Regulatory Commission, 1987b, *Plan for Integration of Aging and Life-Extension Activities, Technical Integration Review Group for Aging and Life Extension,* Washington, DC.

U.S. Nuclear Regulatory Commission, 1991, *Nuclear Plant Aging Research (NPAR) Program Plan,* NUREG-1144, Rev. 2, Office of Nuclear Regulatory Research, Washington, DC.

Appendix A

Component-Specific Recordkeeping Recommendations

Appendix A

(from EPRI 1988a)

Component-Specific Recordkeeping Recommendations

Component or Component Type	Recordkeeping Recommendation
Main Turbine	Obtain (from vendor) or reconstruct turbine design basis and material specification information. Update the stress analysis.
	Trend oil test data
	Trend results of LP Turbine Casing inspections.
	Improved vibration monitoring.
Main Generator	Install monitoring equipment for all generator water-cooled armature winding RTD's and thermocouples.
	Perform NDT of generator retaining rings and rotor every five years to detect SCC ...[perform] borosonic inspection of the rotor shaft.
	Evaluate implementation of monitoring devices to detect fatigue cracking and water erosion of copper stator conductors, including radio frequency and particulate sensors, and advanced temperature sensors such as sacrificial coatings and optical fibers
Main Condenser	Internal inspection and thickness testing of shell, tube support plates, and lagging ... Thickness testing can be trended to determine material loss rates
	Water box thickness testing and trending of results is necessary to verify corrosion rates and estimate service life.
	Monitoring of condenser conductivity near each tubesheet ... to evaluate increases in tubesheet to tubesheet leakage.
	Track number of plugged tubes
Control Rod Drive Hydraulic Control Units	Trending failure data ... Failure of certain HCU components can be expected to occur in a predictable manner.

Component or Component Type	Recordkeeping Recommendation
Underground Piping	Additional testing/surveillance should be periodically performed such that improved accuracy may be obtained in the life predictions.
	Water quality testing and a biological assay should be performed on river water and groundwater to better assess the general corrosion and MIC (microbiologically induced corrosion) potential.
Main Steam Valves (MSIV, SRV, TSV, TCV)	The steam valves should be included in an overall valve trending program. Information on specific performance indicators (primarily test results), subcomponent replacement histories and data on contributing effects (e.g., number of cycles) would be included. This data would help schedule maintenance, predict life and establish an experience record to justify life extension.
Inboard Isolation Valves	Study the available valve diagnostic programs to ascertain their value in identifying incipient degradation of motor-operated valves by monitoring key operating parameters.
	To provide assurance that actual corrosion rates conform to predicted rates, it is recommended that wall thicknesses be measured and trended.
	A [database] for valve data is recommended. ... to increase valve reliability by monitoring key valve operating and inspection data and scheduling maintenance on the basis of reliability and cost benefit considerations.
Moisture Separators	Minimum vessel wall thickness should be determined and the effects of erosion and corrosion be monitored to establish a wall thinning rate.
	Proper documentation of inspection findings and test results is required if extension of the service life of moisture separators is to be assured. ...including results from visual inspections ...thickness measurements of problem areas should be documented and trended.
Large Heat Exchangers	Thickness measurements of the shells [should] be performed every three to five years, and results be trended to establish the rate of corrosion.
	Plugged tubes should be trended and compared with allowables.
	Failure data, operating and maintenance records, tests, and inspections [at the plant should] be maintained through the use of a [database].
	Instrumentation, controls, and acoustic monitoring systems ... to detect damaging vibration should be investigated
	Compile data of existing and potential heat exchanger materials and their causes of corrosion.

Component or Component Type	Recordkeeping Recommendation
Containment Coatings	Perform [an] analysis of the effects of complete loss of containment coatings into the torus ... This analysis includes a complete inventory of coating type, thickness, and surface area.
Reactor Vessel	Monitoring of water chemistry parameters important to Internals IGSCC, especially in plants using hydrogen water chemistry.
	Use of plant specific in-reactor sensors to develop crack growth rate data.
Power and Control Cables	Generic cable life expectancy is difficult to predict due to a lack of appropriate in situ monitoring test and accurate artificial aging methods.
	Power cables will require more extensive monitoring than control cables ...
	Destructive testing of cable currently provides the best assessment of cable condition.
	Actual replacement will be based on the results of periodic inspections and destructive testing.
Control Room 1E Components	A computerized maintenance [database] for control room commodity groups should be developed, for better trending of component maintenance, failure and refurbishment activities, and for refining service life assessments.
Active Electrical Components	Revise inspection and maintenance procedures to observe and record data concerning degradation of metal clad enclosures, bus work, mounting bolts and structures, and other passive electrical subcomponents. Trend and analyze results for service life assessment.
	Perform periodic infrared thermal scanning of switchgear and MCC's and record and trend results.
	Selectively remove, analyze and test low voltage/current protective relays to determine actual aging characteristics, and trend failure/replacement rates.
	Develop O&M parts assurance program.

Appendix B

High Priority PLEX Data Requirements Not Currently Being Collected by the Pilot Plants

Appendix B

(from Berg et al. 1989)

High Priority PLEX Data Requirements Not Currently Being Collected by the Pilot Plants

Category of Data	Component	Description of Data Not Currently Collected
Inspection	RPV	VT and UT examination of CRD housing, stub tube, weld and adjacent base metal
	RPV	RPV sliding foot assemblies, VT or on-line monitoring
	RPVI	Inspection of radial keys, clevis inserts, and alignment pins
	RPVI	UT of diffuser to adaptor weld region of jet pump diffuser assembly
	PC	Visual inspection of reinforced concrete containments
	PC, CCS	Concrete crack mapping and growth monitoring
	PC, CCS	Evaluation of waterproofing membrane
	M-G	Inspection results of main generator thermosetting insulation
	M-G	Boresonic inspection results of generator rotor shaft
Transient	RCS	Temperature and pressure vs. time for charging and safety injection nozzles
	SG	Steam outlet temperature
	SG	SG feedwater inlet temperature
	SG	SG girth weld inner diameter temperature
Surveillance	CABLE	Temperature and radiation levels in proximity to selected electrical cables in containment.
	M-G	Full load motor input currents
	M-G	Generator radio frequency signal monitoring

Category of Data	Component	Description of Data Not Currently Collected
Surveillance	CABLE	Power cable conductor and insulation temperatures within trays
	EDG	Machine vibration measurements
	EDG	Measurements of EDG parts subject to wear
	EDG	Engine temperature
Materials Testing	PC, CCS	Concrete core sampling and compressive strength testing
	PC	Containment component thickness testing
	MC	Water box thickness measurements
	MC	Condenser shell thickness measurements
	ELECT	Testing and analysis of removed low current, low voltage protective relays
	CABLE	Destructive examination results of removed cables
	MCP	Boat sample analysis of MC pump casing
Chemistry	RPV, RPVI	RWCU inlet and outlet isotopics
	HCU	CRD cooling water oxygen content
Abnormal	PC, CCS	Heavy loads data
	CABLE	Occurrence of unusual events of cable submergence, chemical exposure, excessive heat, power surges, and similar incidents

Appendix C

Summary of Recommendations for Operational Data Collection Related to Aging Management

Appendix C

(from Berg et al. 1989)

Summary of Recommendations for Operational Data Collection Related to Aging Management

1. Utilities contemplating a PLEX program for their plant, or wishing to preserve the option for PLEX, should compare the PLEX data needs defined in Appendix A [of Berg et al.] with their current data gathering and records storage programs, to define areas of improvement. This will represent a major step towards ensuring the future success of a life extension program.

2. Utilities should improve methods used to record maintenance, surveillance and inspection data, to provide quantitative and qualitative descriptions of as-observed or as-failed conditions. This improvement is necessary to support use of the PLEX workbook concept for component degradation trending and continuous service life evaluations. It would also provide a statistical [database] for justification of a license renewal application.

3. Industry [databases] should be reviewed to determine if failure codes need to be added or expanded [if existing], to better support aging assessments and more precisely define aging-related failures.

4. Owners of existing [databases] which currently record failures and significant outages should be contacted to determine if they wish to expand their [database] to support PLEX. Of the [relevant databases], one would be selected for expansion to include significant preventive maintenance events which are performed to preclude a failure or influence significant day-to-day events affecting service life. In addition, the frequency of activities, the service life and hours of operation prior to the preventive maintenance or failure would also be added to the [database] to enhance PLEX evaluations.

5. A future phase of this program should survey plant maintenance, surveillance, testing, non-Section XI ISI and materials records and data collection practices. Pilot plant studies revealed that records in these areas probably are not adequate to support PLEX, particularly for large passive components and structures.

6. The industry should examine the need for additional R&D to develop special tools and methods for PLEX data collection vs. currently available practices ....

7. Plants should implement improvements in current data collection practices identified in Table 4 [of Berg et al.], to support a life extension program.

8. A future phase of this program should examine the candidate aging indicators identified in Table 5 [of Berg et al., Section 4.3 of this report], and possibly others, to assess their validity and usefulness in developing utility self-assessment tools for PLEX.

9. Improve PLEX chemistry data dissemination among utilities by creating an industry [database] for chemistry parameters, or by revising the scope and application of the NSSS vendor [databases]. Additional software may be needed to pool and trend the raw data for dissemination.

10. Improve collection of BWR secondary system chemistry data and PWR tertiary system chemistry data to support component degradation analysis and service life evaluation ....

11. Expand the initial operational [database] to include the scope of safety system components and subcomponents to be examined in the License Renewal Lead Plant Program.

12. Expand the extent of validation for PLEX operational data capture and preservation to other BWR's and PWR's to determine the level of consistency among the domestic plants.

Appendix D

Acronyms and Abbreviations

Appendix D

Acronyms and Abbreviations

A-E	architect-engineering
AC	alternating current
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
ASME	American Society of Mechanical Engineers
BWR	boiling water reactor
SSC	systems, structures, and components
CAD	computer-assisted drafting
CCS	critical concrete structures
CD-ROM	compact disk-read only memory
CFR	Code of Federal Regulations
CRD	control rod drive
DOE	U.S. Department of Energy
EDG	emergency diesel generator
EPRI	Electric Power Research Institute
FM	frequency modulation
FY	Fiscal Year
HCU	h[illegible] control unit
I & E	[illegible]n & Enforcement (formerly a [illegible] of NRC)
IBM	[illegible]ational Business Machines
IEEE	Ins[illegible]tute for Electrical and Electronics Engineers
IGSCC	inter-granular stress corrosion cracking
INPO	Institute for Nuclear Power Operations
ISI	In-service inspection
LER	Licens[illegible]ports
LP	low pres[illegible]
LR	license re[illegible]
MC	main condenser, or main coolant
MCC	motor control centers
MCP	main coolant pumps
M-G	main generator
MIC	microbiologically-induced corrosion
MSIV	main steam isolation valve
MVS	operating system software for IBM mainframe computers
NCIG	Nuclear Construction Issues Group
NDE	nondestructive examination
NDT	nondestructive testing
NIRMA	Nuclear Information and Records Management Association
NPAR	Nuclear Plant Aging Research
NPRDS	Nuclear Plant Reliability Data System
NRC	Nuclear Regulatory Commission
NSSS	nuclear steam supply system
NUMARC	Nuclear Management Resources Council
NUPLEX	nuclear plant life extension
OCR	optical character recognition
PC	primary containment
PLEX	plant life extension
PM	preventive maintenance
PNL	Pacific Northwest Laboratory
PWR	pressurized water reactor
Q-List	list of safety-related equipment
QA	Quality Assurance
QC	quality control
R. G.	Regulatory Guide
RCM	Reliability-Centered Maintenance
RCS	reactor cooling system
RPV	reactor pressure vessel
RPVI	reactor pressure vessel internals
RSCAAMP	Risk Significance of Component Aging and Aging Management Practices

RTD	resistance thermometer devices
RWCU	reactor water cleanup
SALP	Systemic Assessment of Licensee Performance
SCC	stress corrosion cracking
SG	steam generator
SRP	Standard Review Plan (NUREG-0800)
SRV	safety relief valve
SSC	system, structure, or component
SSCs	systems, structures, or components
SSFI	Safety System Functional Inspection
SSOMI	Safety System Outage Modification Inspection
TCV	turbine control valve
TIRGALEX	Technical Integration Review Group for Aging and Life Extension
TMI-2	Three Mile Island - 2 nuclear power plant
TSV	turbine stop valve
TVA	Tennessee Valley Authority
USNRC	U. S. Nuclear Regulatory Commission
UT	ultrasonic testing
VSLIC	very large-scale integrated circuit
VT	visual testing
WORM	write-once, read-many-times optical disk drives

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

This report discusses technical issues associated with the role of nuclear plant records systems in understanding and managing the aging of nuclear plant components, systems, and structures. It considers both the types of technical data useful for verifying continued safe operation and the use of new technology for upgrading records systems. Specific topics reviewed include the need for maintenance and reliability data, operational history data to support the assessment of remaining fatigue life, comprehensiveness and usability of the engineering design basis, improvement of the data input process, and conversion of existing records into machine-readable forms.

The report concludes that successful management of nuclear plant aging will require improvement of existing plant records systems; several generic and specific recommendations are provided. The computer-based technology for meeting this need and implementing these recommendations already exists and can be implemented at a reasonable cost.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

Nuclear plant aging
Recordkeeping
Nuclear plant records

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