SAFETY SERIES No. 50-P-3

SAFETY PRACTICES

safety series

Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing

A PUBLICATION WITHIN THE NUSS PROGRAMME

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1991

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DATA COLLECTION AND RECORD KEEPING FOR THE MANAGEMENT OF NUCLEAR POWER PLANT AGEING

A Safety Practice

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FOREWORD

The IAEA Nuclear Safety Standards (NUSS), which include 5 Codes and 55 Safety Guides, are a collection of internationally agreed basic and derived requirements for the safety of nuclear power plants with thermal neutron reactors. NUSS publications in the Safety Practices Category are intended to aid in the application and interpretation of individual concepts presented in the Codes and Safety Guides.

This Safety Practice is the first in a series of reports under the programme on the management of nuclear power plant ageing. The purpose of the programme is to facilitate the exchange of information and to promote co-operation among Member States towards understanding and managing the ageing degradation of components, with the aim of maintaining safe and reliable plant operation.

The availability and evaluation of appropriate data on nuclear power plant components are essential to safety and constitute a key factor in plant life extension considerations. The present publication provides guidance on data requirements and an effective and practical system for data collection and record keeping in relation to the evaluation and management of ageing and service life. This guidance is based on current practices. It is envisaged that the application of the guidance will contribute to the safe and reliable operation of nuclear power plants and will facilitate international information exchange on ageing related component failures, malfunctions and degradation, since data collected using the same ground rules would be easier to exchange and compare.

The guidance is intended primarily for the management, maintenance and technical staff of nuclear power plants, on whom the ultimate success of the recommended system and its associated benefits depend. Intended secondary audiences include utility management and central technical support organizations, regulatory bodies, standards organizations, design companies, and research and development institutes.

The work of all contributors in the drafting and review of this document is greatly appreciated. In particular, the IAEA would like to acknowledge the contributions of J. Pachner of Canada and J.S. Dukelow of the United States of America, who drafted most of the report.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The operation and maintenance of nuclear power plants requires the availability of timely, relevant, accurate and sufficiently complete information to make possible correct decisions which are essential for maintaining the safety and reliability of a plant throughout its service life.

The IAEA Nuclear Safety Standards (NUSS) Code on the Safety of Nuclear Power Plants: Operation (Safety Series No. 50-C-O (Rev. 1), hereinafter called the Operation Code) requires that the operating organization be in possession of all essential information relating to structures, systems and components important to safety, starting from the design phase and extending to the operational phase. Associated Safety Guides on in-service inspection (50-SG-O2), maintenance (50-SG-O7 (Rev. 1)) and surveillance (50-SG-O8 (Rev. 1)) provide further guidance on general types of records to be kept. The Safety Guide on maintenance also recommends appropriate retrievability and security of the records, and the Safety Guide on surveillance states that records of surveillance activities should be used as a basis for reviews carried out to detect trends indicating system or component deterioration. However, the scope of the Operation Code and of the associated Safety Guides does not cover in sufficient detail the data and record keeping requirements relating to the management of ageing[1] and the resulting degradation of plant components, systems and structures.

Reviews of nuclear power plant operating experience conducted in recent years have shown that existing records of baseline data (design, manufacturer, equipment qualification and commissioning), operational histories (operating performance, process/system and environmental conditions, etc.) and maintenance histories of plant components are often not sufficiently comprehensive or readily retrievable to allow:

(a) Trend analysis and prediction of component performance and remaining service life;
(b) Identification and evaluation of degradation, failures and malfunctions of components caused by ageing effects.

[1] In this publication, the term ageing is used to mean the continuing time dependent physical degradation of materials and components under normal service conditions, including expected extremes (transients) in operating requirements but excluding postulated accident and post-accident conditions. All materials in a nuclear power plant experience ageing degradation to a greater or lesser extent, leading to the functional degradation of plant components.

One of the main limitations of many existing record systems is the fact that they are primarily based on hard copy records (on paper or on microfilm), with the attendant slow retrieval and difficulty in processing or manipulation. Although computerization of record systems is extensive at many nuclear power plants, it has concentrated on computerized indexing of the hard copy records, rather than computerized delivery of the information.

The present Safety Practice publication supplements the Operation Code and associated Safety Guides by providing a synthesis of effective data collection and record keeping practices relating to the evaluation and management of nuclear power plant ageing and service life. It contains practical examples and methods which can be used in the implementation of certain safety requirements. The publication is intentionally placed at the hierarchial level of Safety Practices because the application of its content is recommended but not obligatory.

1.2. OBJECTIVES

The primary objective of this publication is to provide advice on data needs and on an effective and practical system for data collection and record keeping in connection with the evaluation and management of nuclear power plant ageing and service life [1].

The secondary objective of the publication is to facilitate the sharing and exchange of data on, and lessons learned from, ageing related degradation and failures of nuclear power plant components[2].

1.3. SCOPE

The data needs and the attributes of appropriate data collection and record keeping systems are determined by the scope of activities relevant to the above objectives.

In connection with the primary objective, the system for data collection and record keeping should provide information for the following activities:

- Prediction of future performance (i.e. functional capability and remaining service life) of components required for continued safe and reliable plant operation;
- Decision on the type and timing of preventive maintenance actions, including repair, refurbishment and replacement;

[2] In this document, the term component is used to mean a nuclear power plant component, system or structure.

- Identification and evaluation of degradation, failures and malfunctions of components caused by ageing effects;
- Optimization of operating conditions and practices that would reduce excessive ageing degradation;
- Identification of new emerging ageing effects before they jeopardize plant safety, production reliability and service life;
- Assessments concerning continued operation of nuclear power plants, including reviews of licence renewal applications.

In connection with the secondary objective, the guidance provided is also intended to serve as a basis for future development of an international database and information system on ageing and service life management. Data collected using the same ground rules and stored in an agreed format would be easier to compare and use in:

- Research and development aimed at the understanding of ageing processes;
- Development of new materials, technologies and designs less susceptible to ageing degradation (for use in both existing and new plants).

It should be noted that the aforementioned activities require timely and appropriate reporting and analysis of data identified in this publication to provide the input to relevant decisions. The subject of data analysis and evaluation (relating to predictions of future performance of components) is outside the scope of this publication.

1.4. STRUCTURE

General data needs for the evaluation and management of ageing and the service life of components are considered in Section 2, and the attributes of the effective data collection and record keeping system that is required to support the aforementioned activities are dealt with in Section 3. Section 4.1 identifies factors that may be used to prioritize the data requirements and to provide a basis for phased implementation of the system. The different design and implementation approaches required for plants in pre-operational and operational stages are discussed in Sections 4.2 and 4.3. Section 4.4 is concerned with the participation of the operating and maintenance staff of a nuclear power plant in the design of the data collection and record keeping system. Appendices cover component specific data needs, examples of effective data collection and record keeping systems, and guidance for the implementation of an advanced data collection and record keeping system.

2. GENERAL DATA NEEDS FOR THE EVALUATION AND MANAGEMENT OF AGEING

In this section, general data needs relating to the management of ageing degradation of nuclear power plant components are identified and their application in the evaluation and management of plant ageing is briefly discussed. These data needs apply to components that are safety related and/or are relevant to long term production reliability, i.e. a plant life management programme. (Plant life management refers to both plant life assurance and plant life extension programmes.)

In life management programmes for nuclear power plants, the data together with the respective evaluation techniques are used first to estimate the remaining service life of a component, and then, if applicable, to determine appropriate measures for mitigating the ageing degradation and for restoring lost component performance. Similarly, in the reviews of licence renewal applications, the regulatory agencies may assess the quality of plant data collection, record keeping and evaluation as a basis for an effective preventive maintenance programme, for component degradation assessments and for demonstrating adequate safety margins for extended service.

Already existing plant databases may partly provide the data needed for ageing evaluation and management and can be augmented to include the data that are lacking. The general data needs presented in this section have been derived from studies on plant life management and licence renewal, from operating performance evaluation programmes, and from experience with reliability centred maintenance (RCM). Implementation of these programmes requires good component baseline information together with good operation and maintenance histories records.

The safety and economic benefits of RCM programmes have been demonstrated by increased availability, fewer forced outages and reduced frequency of scheduled refurbishment or replacement. In relation to the benefits of life management programmes for nuclear plants, actual cost savings have not been demonstrated, but a number of studies have indicated that they may be substantial.

Data needs relating to ageing management are presented in Table I. The table is general in nature and is therefore subject to modification to satisfy needs specific to plants and components. The data are divided into three categories:

- Baseline information, consisting of design data and conditions at the beginning of the service life of a component;
- Operating history data, covering system and component level service conditions (including transient data) and component availability testing and failure data;
- Maintenance history data, including data on the monitoring and maintenance of component conditions.

The contents and intended utilization of these three data categories are described in Sections 2.1–2.3. Guidance for the selection of component specific data needs is given in Section 2.4; it is illustrated by examples given in Appendix I.

2.1. BASELINE INFORMATION

Baseline information is the broad category of nuclear power plant data which define a component and the plant and system in which it is located and describe its initial, undegraded material condition and functional capability, as well as a limiting operating envelope represented by the design service conditions and other operational limits. The baseline data determine the design service life of components. Together with the actual operating experience data, they provide essential information for developing effective ageing management strategies and for estimating remaining service life.

In general, nuclear power plant baseline information exists, but it is usually dispersed in numerous reports and is difficult to retrieve. To permit correlation of the baseline data with operating and maintenance history data, a clear identification of a component in the plant and the system in which it is located is essential. Furthermore, it is important to ensure that all pertinent baseline data are updated when the design is changed. (The baseline information file should provide a historical record of design changes.)

2.2. OPERATING HISTORY DATA

Operating history data describe the actual service conditions experienced by a component, including data on process conditions, chemistry, the ambient environment and transients (such as pressure–temperature (p–T) transients for pressure retaining components) and the component's availability, testing and failure data. Operating history data are essential to the effective management of ageing and its effect on plant safety and reliability for the following reasons:

(a) Operating history data enable the comparison of a component's design life usage and the rate of the usage with the design basis and the prediction of lifetime. Thus, they provide documentation of whether and by how much the design bases have been exceeded.
(b) Operating history data allow ageing related failures to be differentiated from other failures and specific environments favouring degradation and degradation mechanisms to be identified.

(c) Operating history data allow the age dependent reliability of components with lifetimes much shorter than the plant lifetime to be tracked and related to the service conditions experienced, transients, materials and the root causes of failures. They also provide feedback on the effectiveness of preventive maintenance programmes to maintain component functional capability.
(d) Operating history data permit periodic assessments of the effects of operating and availability testing practices on ageing degradation.
(e) The data on system service conditions are also intended to permit the identification of emerging ageing phenomena such as intergranular stress corrosion cracking (IGSCC) or pipe wall thinning by erosion–corrosion. A periodic evaluation of a broad collection of such data may provide opportunities for the early identification and characterization of unexpected phenomena and thus for the prevention of potentially significant operational or maintenance problems.

In addition to these direct applications of plant specific operating history data, it is useful to compare some of these data and derived reliability parameters (e.g. failure rate, unavailability) with appropriate external information. For example, operating experience from sister units and various generic incident reporting systems, such as those of the IAEA, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) and the World Association of Nuclear Operators (WANO), may provide useful information in support of root cause analyses of specific component failures. Also, comparisons of plant specific component failure rates with those from sister units or from applicable generic reliability databases can provide a useful check on the component performance. (If generic reliability data are used, it should be ensured that the component boundary definitions are identical.) Plant specific failure rates that exceed the 'standards' provided by the generic data or the failure rates from the sister units may indicate the onset of wear-out or other ageing degradation.

Many of the operating history data listed in Table I are currently being collected. However, they are generally difficult to retrieve from the existing records. In addition, there are areas where data collection should be improved, such as for operating transient data. For example, assessing fatigue usage of pressure retaining components requires good records of actual pressure–temperature transients experienced. Also, more attention should be paid to the root cause analysis of failures. A classification of root causes into time dependent causes (e.g. wear, corrosion) and random causes (accidental damage, design deficiency) would assist in the analysis of ageing.

2.3. MAINTENANCE HISTORY DATA

Maintenance history data consist of condition monitoring data (generated by test, inspection and surveillance activities that provide information on the degree of material and functional degradation), repair or modification history of components and the overall maintenance cost history. These data may be used in conjunction with appropriate models to predict the future rate of material and functional degradation and to decide on the timing and the most appropriate type of maintenance actions (i.e. repair, refurbishment or replacement). Together with the failure data and derived reliability parameters, they facilitate the evaluation of the effectiveness of preventive maintenance in preventing component failures.

Tracking of the cost of maintenance at the plant and possibly the system level may indicate an overall increase in age dependent degradation of plant components; its causes may include operating conditions exceeding the design specifications or improper maintenance practices. The increase in the cost of maintenance could trigger a more detailed assessment of the root causes of the increase, including a review of operating conditions and operating and maintenance practices.

Many of the requisite maintenance records are already available. However, the availability and quality of condition monitoring data are usually limited. For example, sophisticated technology for monitoring vibration and wear particles for rotating equipment does exist but its use is limited. Condition monitoring techniques and evaluation methods for other plant components (e.g. electrical motor windings) are only now being developed.

TABLE I. GENERAL DATA NEEDS FOR THE MANAGEMENT OF AGEING DEGRADATION

Baseline information

- Component identification (ID) (including component type and location)[a]
- Number or amount (e.g. length) of similar components
- Expected degradation mechanisms
- Design specifications (including design service conditions and design service life cycles)
- Equipment qualification (EQ) specifications (qualified life, normal service conditions and postulated accident and post-accident conditions; procurement, storage, installation, operation and maintenance specifications)
- EQ test conditions (e.g accident test profile)
- Manufacturer's data (including materials data, history docket for pressure retaining components (PRCs))
- Commissioning data (e.g. data on the startup test, on baseline vibrations and the inaugural inspection)
- Date of component installation
- Information on design modifications

TABLE I. (cont.)

Operating history data

System service conditions

- System ID
- Process conditions (e.g. temperature, flow, pressure)
- Chemistry data (including radioactivity)
- Noise data (e.g. neutron, audio, electrical)
- System transient data: dates and profiles of system loading, cycling or startup (e.g. p–T records and chemistry excursions)
- Mode of operation (continuous, stand-by, intermittent)
- Information on major changes in system operation

Component service conditions

- Component ID[a]
- Environmental conditions (ambient temperature, humidity, radiation, etc.)
- Transient data: dates and profiles of component loading, cycling or startup (e.g. mechanical stresses, p–T records for PRCs)
- Mode of operation (continuous, stand-by, intermittent)
- Downtime periods
- Information on changes in component use

Availability testing data

- Component ID[a]
- Test description (including test frequency)
- Date of test
- Test result (success or failure)

Component failure data

- Component ID[a]
- Date of failure
- Failure time (hours or cycles of operation before failure)
- Method of failure discovery
- Failure mode and description
- Failure cause: (a) perceived; (b) root (at failure mechanism level)
- Failed parts (if the component can be divided into subcomponents)
- Relevant system conditions (e.g. unusual loading, power or signal conditions)
- Relevant environmental conditions

Maintenace history data

Component condition monitoring data

- Component ID[a]
- Parameter(s) to be monitored/tracked (e.g. vibration, temperature, chemistry)
- Component condition indicator data (test, inspection and surveillance results, including incipient failures, their dates and operational time/cycles)
- Information on changes in condition monitoring

TABLE I. (cont.)

Component maintenance data

— Component ID[a]
— Reason for maintenance action (including the decision criteria)
— Type of maintenance (corrective, preventive)
— Date and duration of maintenance
— Description of maintenance work (repair, refurbishment, replacement)
— Information on changes in maintenance methods and intervals

Cost of maintenance

— Total cost of repairs, refurbishments and replacements at plant and possibly system level
— Total radiation dose associated with maintenance

[a] The purpose of including component ID (identification code) under each of the data categories is to indicate that the collected baseline information, operating and maintenance history data must be cross-referenced in the evaluation and management of component ageing effects.

2.4. COMPONENT SPECIFIC DATA NEEDS

Table I can serve as a basis for deriving component specific data needs. Not all data listed in this general table are necessarily needed for a given component; the level of detail is dependent on the depth of knowledge and understanding of significant age related degradation mechanisms.

The component specific data needs vary according to the different component types and categories (e.g. concrete structures, PRCs and mechanical, electrical, instrumentation and control equipment). For each component type, the individual data needs should be carefully identified in order that only the relevant data are collected and the required accuracy is ensured. Here it is appropriate to emphasize that for the evaluation and management of nuclear power plant ageing, the quality of the data is often more important than the quantity. (The quality refers to both the appropriate choice of information to be collected and the accuracy of the actually recorded information and measured parameters.)

The following screening questions are suggested for use when selecting the component specific data needs from the list in Table I:

— Is this information item a necessary input for the ageing evaluation and management activities listed in Section 1?
— Can this information item be measured with sufficient accuracy to permit the evaluation or management of the component ageing effects?

As examples of component specific data needs, Appendix I gives the data to be collected for the reactor pressure vessel, emergency diesel generator and electrical cables.

3. ATTRIBUTES OF AN EFFECTIVE DATA COLLECTION AND RECORD KEEPING SYSTEM

This section describes performance objectives of an effective data collection and record keeping system and provides general principles and further guidance for achieving those objectives.

3.1. SYSTEM PERFORMANCE OBJECTIVES

An effective data collection and record keeping system, supportive of the ageing management activities identified in Section 1, should meet the following performance objectives:

(a) To provide sufficiently comprehensive and accurate information about the components of the plant, including baseline information and operation and maintenance history data;
(b) To provide for flexible management of the information;
(c) To provide for secure storage of the information;
(d) To provide for the integrity of the stored information over the required period of time;
(e) To provide for timely and accurate retrieval of the information (the 'timeliness' requirement will vary according to the use of the information);
(f) To provide adequate tools for data analysis, graphical display and the production of reports.

A variety of data collection and record keeping systems can satisfy these performance objectives. These systems may range from hard copy records and mechanical retrieval to an advanced record keeping system using computers and optical disk storage technology. Examples of various data collection and record keeping systems that have been used effectively in nuclear power plants are described in Appendix II.

3.2. SYSTEM DESIGN PRINCIPLES

To meet the system performance objectives, three general principles for the design of a data collection and record keeping system can be established:

(a) Data should, to the extent possible, be entered by maintenance and operations personnel directly in a machine readable form in order to improve the quality of the data input and permit the use of modern computer techniques in data storage, retrieval and manipulation. The data entry should include an appropriate quality control mechanism.
(b) Databases distributed throughout the plant should have common organization and format and central indexing, and should be stored and archived digitally on stable media so as to facilitate data retrieval and manipulation.
(c) The integrity of data in plant records should be carefully managed, with attention given to the possibility of ageing degradation of the records themselves.

Underlying all three general design principles is the emphasis on the storage and manipulation of data in a machine readable and digital form. The basic rationale for this emphasis is that digital data: can be stored compactly and inexpensively; can be 'backed up' easily; can be stored redundantly (using error correcting codes) so that errors introduced by degradation of the storage media can be detected and corrected without compromising the integrity of the data; and can be manipulated quickly and inexpensively. In addition, digital representation of analog data permits the application of noise reduction, pattern recognition, image enhancement and other advanced analytical techniques. Appendix III gives more detailed guidance for system design and implementation using modern data collection and record keeping technologies.

4. GENERAL RECOMMENDATIONS FOR IMPLEMENTING THE PROPOSED DATA COLLECTION AND RECORD KEEPING SYSTEM

The implementation of an effective data collection and record keeping system at a nuclear power plant is a major task which requires significant resources. However, the attendant benefits and the decreasing cost and increasing capability of computation are expected to make the proposed improvements feasible and economic.

The general data needs and the attributes of a data collection and record keeping system for the management of ageing degradation and the service life of components have been described in Sections 2 and 3. Specifications for a data collection and record keeping system for a given nuclear power plant should be derived from the plant specific conditions, such as the stage in a plant life cycle (i.e. the design, construction, commissioning or operating stage), the existing data collection and record keeping system, and available resources. Since the general data needs given in Section 2 are quite extensive, it may be appropriate to meet these needs by introducing the proposed data collection and record keeping system in phases. Section 4.1 identifies factors that may be used to prioritize the data requirements and to provide a basis for phased implementation of the system. Appendix III gives guidance on the implementation of an advanced data collection and record keeping system.

The different design and implementation approaches required for plants in a pre-operational stage and in an operational stage are discussed in Sections 4.2 and 4.3. Section 4.4 recommends the participation of the operating and maintenance staff of a nuclear power plant in the design of the data collection and record keeping system.

4.1. PRIORITIZATION OF REQUIREMENTS FOR DATA COLLECTION AND RECORD KEEPING

The amount of resources available at a given nuclear power plant may dictate a phased introduction of the proposed system. A prioritization of plant components or systems furnishes the basis for prioritizing the data collection and record keeping requirements in relation to the component/system importance. The resources required for the system implementation could thus be divided and spread over time. The following factors may be used for this prioritization and definition of the data collection and record keeping requirements for each phase:

(a) Safety significance of a component based upon deterministic and/or probabilistic criteria related to predicted consequences of failure;
(b) Possibility and cost of a component replacement or refurbishment;
(c) Susceptibility to ageing degradation;
(d) Probability of a catastrophic as compared with a 'mild' failure (e.g. pipe rupture or pipe leak);
(e) Capability of the existing surveillance programme to detect component degradation before failure;
(f) Usefulness of collected data to the evaluation and management of ageing;
(g) Expected service life of a component in comparison with a plant design life or the operating licence period (components with an expected service life of the same order as the plant design life or the operating licence period are expected to have very few failures; consequently, their condition monitoring and maintenance histories will be more important for the evaluation of remaining service life and for the determination of appropriate ageing management measures).

This listing is not necessarily in order of importance.

4.2. SYSTEM IMPLEMENTATION IN THE PRE-OPERATIONAL PHASE

With a nuclear power plant in the pre-operational stage there exists the opportunity to build the proposed data collection and record keeping system as part of an integrated, computerized plant information system together with the necessary sensors, monitors and instrumentation for surveillance purposes. If possible, such a system should employ direct entry of information in a digital machine readable form and provide for digital storage, retrieval and manipulation of the data.

An integrated plant information system containing the data needed for operation, maintenance and engineering also provides the capability for an effective configuration management[3] of both the plant records and the plant systems. Configuration management can ensure that different units of the plant organization are using the same data reflecting the current plant status. When the plant or records configuration changes as a result of system modifications or new information, a single data entry in an integrated database is needed rather than a number of entries in multiple databases.

For a new nuclear power plant, an integrated database is the best solution for the purposes of plant safety and reliability as well as cost effectiveness over the plant lifetime. Such databases already exist. Examples include the Plant Information Model supported by the Electric Power Research Institute (EPRI) and the Plant Configuration Model of Construction Systems Associates [2] .

4.3. SYSTEM IMPLEMENTATION IN THE OPERATIONAL PHASE

The implementation of the recommended system at an operational plant will generally require the upgrading or replacement of the existing data collection and record keeping system.

The existing record system will most probably be heavily based upon 'hard copy' records (paper, radiographs, etc.) with some computerized indexing and a variety of single purpose computerized databases spread around the plant. Such a system may have limitations related to slow retrieval and difficulty in ensuring agreement between the data appearing several times in various parts of the record system.

A phased introduction of the recommended system appears to be the best approach for an operational plant. The choice of the implementation approach and the actual implementation plan should be plant specific and should take into account:

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[3] A configuration is a functional arrangement of interrelated items, for example the records or plant systems, for a specific purpose. Configuration management is a controlled management of change; for example, changes in the plant records or plant systems.

(a) the benefits of conversion of different parts of the existing records system; (b) the costs of that conversion, including the associated quality assurance/quality controls; (c) the available resources, including the personnel to monitor, interpret and make recommendations for corrective actions and feedback of information based on analysis of the data.

The prioritization of the data requirements outlined in Section 4.1 is intended to help in the establishment of a phased implementation plan. In addition, practical matters such as regulatory requirements, the characteristics and capabilities of the existing system, and operating and maintenance practices and constraints should be considered when formulating the implementation plan.

4.4. PARTICIPATION OF OPERATING AND MAINTENANCE STAFF IN THE SYSTEM DESIGN

When a decision is made to implement the proposed system, it is of the utmost importance that plant operating and maintenance (O&M) personnel participate in the system design. This is to give them a sense of ownership of the system, which is necessary to obtain the desired benefits from its use. The design of the system should take into account the needs of O&M personnel and the constraints imposed by their working environment and should provide them with useful information and capabilities.

Appendix I

COMPONENT SPECIFIC DATA NEEDS

I.1. REACTOR PRESSURE VESSEL

The data needs identified below are partially based on information contained in Ref. [3].

I.1.1. Baseline information

- — Manufacturer, dimensions;
- — Expected degradation mechanisms (irradiation embrittlement, fatigue, stress corrosion cracking (SCC), wear, erosion–corrosion);
- — Design specifications (expected neutron fluence for design service life, base material and weld metal specifications, forecast for evolution of the toughness of irradiated material, reference defects and reference p–T transients postulated in the safety analysis to determine margin of safety, results of the safety analysis);
- — Original stress report;
- — Manufacturer's data (fabrication records, including mechanical and chemical characteristics of the 'as-built' vessel, such as composition levels of Cu, Ni and P and pre-service inspection results);
- — Commissioning test data (e.g. pressure test data).

I.1.2. Operating history data

- — Transient data (p–T transients, records of events exceeding the design basis);
- — Neutron fluence (inside and outside the reactor pressure vessel (RPV));
- — Process conditions (temperature, pressure, flow rates within the vessel, operating time at temperature);
- — Primary water chemistry (concentrations of oxygen, hydrogen and boron and conductivity for control of IGSCC);
- — Containment environment (e.g. temperature, humidity);
- — Material surveillance data (Charpy and tensile test data).

I.1.3. Maintenance history data

- — Component condition indicator data (result of in-service inspections used to monitor SCC, corrosion, mechanical wear or fatigue crack growth; detected leaks from RPV seal areas);
- — Date, type and description of maintenance.

I.2. EMERGENCY DIESEL GENERATOR

The following description of data needs is largely based on Refs [4, 5], which detail different approaches to the monitoring of emergency diesel generators (EDGs).

I.2.1. Baseline information

— EDG identification (ID) (type and size in horsepower, manufacturer, starting system type (compressed air or electric starter motor));
— Quantity (number of the same EDGs at plant, number of similar EDGs at other plants);
— Design specifications (diesel performance requirements and generator rating);
— Expected degradation mechanisms (the instrumentation and control system is vulnerable to age related failures, especially vibration loosening; moving parts susceptible to mechanical wear and fatigue; starting system susceptible to adverse environmental conditions, including moisture induced corrosion, fouling and other damage);
— Date of installation of EDG.

I.2.2. Operating history data

— Process conditions (engine operating temperature, oil pressure, fuel pressure);
— Noise data (vibration from loose parts);
— Environmental conditions (ambient air temperature, barometric pressure and relative humidity);
— Downtime (time out of service noted);
— Test description (type and frequency of tests);
— Date of test;
— Emergency use (time and duration of use);
— Test results (success or failure);
— Date and type of failure (startup or running);
— Cause of failure (vibration, manufacturing error, etc.);
— Failed parts (parts of instrument and control system, governor, sensors, etc.).

I.2.3. Maintenance history data

— Parameters to be monitored (depending on type of monitor): cranking speed, fuel pressure, governor position, water temperature and pressure, oil temperature and pressure, alternator winding temperature and alternator bearing temperatures, starting air pressure, fuel temperature;

— Data from the diesel generator condition indicator (test and surveillance results and their dates);
— Date and type of maintenance (corrective, preventive);
— Cost of maintenance.

I.3. ELECTRICAL CABLES

I.3.1. Baseline information

— Cable ID (identification code designating a system and possibly circuit in which the cable is installed);
— Cable type (power, control or instrumentation; low, medium or high voltage; insulation and jacket material; manufacturer);
— Cable location (inside or outside containment);
— Quantity (number of similar cables or cable runs, total length);
— Expected degradation mechanisms (for example: embrittlement of insulation polymer due to radiation and heat; progressive partial breakdown or 'treeing' for medium voltage cables, i.e. ≥ 2 kV; possible moisture and chemical attack in wet locations);
— Design specifications (design or qualified life; voltage and current ratings);
— Equipment qualification (EQ) specifications (assumed ambient and postulated accident environment);
— EQ test conditions (accelerated ageing conditions; applied voltage and current; simulated accident conditions);
— Manufacturer's data (test data, designation of materials);
— Commissioning data (results of tests and inspections during installation);
— Date of cable installation.

I.3.2. Operating history data

— Cable ID;
— Mode of operation (continuous or stand-by);
— Environmental conditions (ambient temperatures, radiation, moisture; results from environmental mapping programme, including identification of hot spots);
— Date of failure;
— Method of failure discovery;
— Description of failure;
— System and environmental conditions relevant to the failure (e.g. abnormal loading or signal conditions, high ambient temperature);
— Cause of failure (service conditions and failure mechanism responsible);
— Failed parts (which part of cable failed, i.e. insulation, jacket or conductor).

I.3.3. Maintenance history data

- Cable ID;
- Component condition indicator data (cable indentor data, visual inspection results);
- Reason for maintenance action;
- Description of maintenance work (repair or replacement).

Appendix II

EXAMPLES OF EFFECTIVE DATA COLLECTION AND RECORD KEEPING SYSTEMS

A wide range of data collection and record keeping systems is commonly used at nuclear power plants. The information may be recorded and stored in the form of cards, drawings, chart recordings, radiographs, microfiches or optical disks. Different forms of data/record indexing and retrieval may be employed, including mechanical and computerized versions.

This appendix presents some examples of actual record keeping systems used at nuclear power plants that may be employed to facilitate ageing studies. As shown by the examples, a wide range of record keeping technologies is currently available. The specific choice depends on the availability of technology; cost considerations and other aspects are beyond the scope of this publication. Guidance for implementation of the more advanced record keeping system described in Section II.6 is presented in more detail in Appendix III.

II.1. INDEX CARDS FOR MANAGEMENT OF AGEING

One nuclear power plant electrical maintenance group uses colour coded index cards for electrical buses, switchgear, motor control centres and transformers, with coloured tabs designating the calendar periodicity of the action required. The various cards record the basic design parameters of a component, its maintenance and refurbishment history, design or operating changes, failures and sometimes root cause data. Operating cycle data are also recorded. The cards are totally manual in nature, but very effective for component history trend and failure analysis and for prompting maintenance group actions.

II.2. TRAVELLING RACKS FOR DRAWINGS AND FILES

One plant records system uses a chain/wire driven system of hanging folders and clamps to suspend documents and files several deep on a closed loop moving system. A file is retrieved by entering a computer code for location (obtained from a hard copy ledger book at the counter). The system rotates the desired file to stop at the front by the counter, where it is unclamped.

II.3. CHART RECORDING STORAGE

One plant uses multiple wooden hinged storage shelves to store rolled strip chart paper from control room recorders. Any strip chart can be recovered if the recorder number is known. However, the paper is ageing and becoming brittle in rolled condition after 15 years of storage. The plant is seeking to replace the system with one using microfilm, or to extract the pertinent cycle/operating data and then destroy the originals.

II.4. MICROFILM REPRODUCTION/STORAGE OF RADIOGRAPHS

Original radiographic films at a particular nuclear power plant were deteriorating owing to inappropriate early storage and chemical changes in the plastic and dyes of the film. These radiographs were of piping and vessel welds at the time of plant construction and initial inspections, and will be necessary for use as baseline information to compare with conditions pertaining in the future. In order to preserve the information, the original radiographs were microfilmed and other information, including the radiograph number, contractor and film techniques, was recorded in an associated records management system for easy retrieval. The microfilm rolls were duplicated for storage both on and off the site.

II.5. MECHANICAL MICROFICHE RECOVERY

Another plant uses a computer records management system (minicomputer based) with record storage, search and indexing routines available at a backlit terminal. However, retrieval of the document for viewing on the same terminal screen is from a mechanical carousel of fiche with 'fingers' that lift the fiche from a cartridge, move it and position it for viewing on the backlit screen, and allow direct printing. This system is very convenient in concept, but does not function well owing to the high degree of precision and maintenance needed for the fingers, the sticking together of the fiches and poor imaging. This system is being evaluated for possible replacement with an optical disk storage system.

II.6. ADVANCED RECORD KEEPING SYSTEM

Figure 1 illustrates an advanced nuclear power plant record keeping system that is useful for ageing management and life extension as well as licensing and design basis documentation, configuration management and safety evaluations. The system consists of a scanner to capture text and graphics directly as images that can be stored digitally. The textual content of the image is captured using optical character recognition (OCR) software to produce a file that can be manipulated by other computer programs. The data in the file are permanently stored on optical disks that can be accessed by the control computer. Images can be manipulated on high resolution monitors to improve readability and can be electronically transmitted to remote locations. A laser printer can produce high quality copies of the records needed.

Such a system is currently being implemented at some nuclear power plants as a significant improvement in record keeping technology. It is substantially faster than manual systems, and the volume of records is reduced by a factor of 3000 or more (up to 60 000 pages of hard copy can be stored on a single optical disk 30 cm in diameter). Guidance for implementation of such a system is detailed in Appendix III.

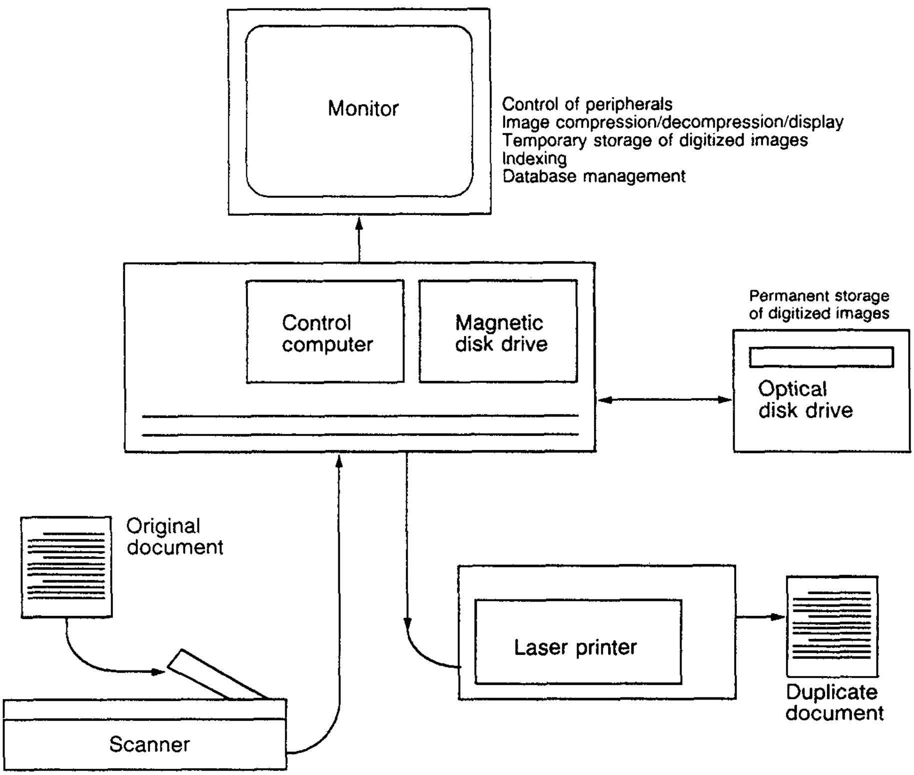

FIG. 1. Modern nuclear power plant record keeping system. [Grove Engineering, Rockville, MD, USA.]

Appendix III

GUIDANCE FOR IMPLEMENTATION OF AN ADVANCED DATA COLLECTION AND RECORD KEEPING SYSTEM

Appendix II describes data collection and record keeping systems of various capabilities and levels of technology, as used at several nuclear plants. One of the systems described uses the latest computer technology, including optical disk data storage. These data collection and record keeping systems, used in the evaluation and management of component ageing and service life, may be part of an integrated plant database or an add-on to an existing system.

This appendix gives details of the features and implementation of an advanced data collection and record keeping system at a nuclear power plant. It includes information on the main implementation steps of: (1) direct input of data; (2) data storage; (3) data retrieval and manipulation. Also discussed are quality assurance in data collection and database security. One of the major reasons for implementing an advanced computer based data collection and record keeping system is to facilitate the evaluation and management of plant ageing and plant service life.

III.1. DATA COLLECTION

A data collection and record keeping system should be implemented at a nuclear power plant starting at the front end of the record keeping process, that is with the initial collection of the data and their inputting into the record system.

III.1.1. Direct input of data

Errors in the transcription of hard copy data into a machine readable form can be essentially avoided by having the plant operations and maintenance staff collect the data directly in a machine readable form. This direct collection can be effected by providing the operating staff with direct or indirect links with the computerized part of the record keeping system. Once this link has been established, a side benefit is the possibility of providing on-line 'help' facilities to assist the operating staff during this data collection activity. Many complex computer programs now offer extensive, context sensitive help.

The preferred method for direct input of machine readable data would require replacement of paper forms filled out by the maintenance and operations personnel with a program running on a portable computer or a portable terminal. This program would request the desired data in the appropriate order, perform input validation and immediately calculate operational parameters of interest to the station technical staff (for example, heat exchanger performance parameters could be calculated once the input and output temperatures and the flows were 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 co-operation, but is an approach widely used in the computer, instrument, machine tool and automobile industries. Hoopingarner et al. [6] recommend this approach for the collection of data for monitoring the functional capability and degradation of an emergency diesel generator.

Direct input of plant data in machine readable form can be achieved by using combinations of: portable (even hand-held) terminals and computers; short distance frequency modulation (FM) radio modems; bar code readers; passive and active transponders; FM transmission of data via normal plant alternating current power lines; and write-once laser card technologies. These may not be cost effective for backfit application, but should be carefully considered when new data collection requirements arise.

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

III.1.2. Enhanced form design

Another way to minimize errors at the data input stage is to put more careful effort into the design of data input forms less subject to misinterpretation. The need for a written procedure prescribing how to complete a form is telling evidence of its poor design. Detailed instructions, if needed, should be an integral part of the form rather than given in a separate written procedure.

III.1.3. Optical character recognition and digital scanners

Existing records can be converted to machine readable formats with digital scanners to capture text and graphics directly as an image that 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 OCR software to produce a file with a text in ASCII or other format which can be manipulated by other computer programs.

It should be noted that although conversion of many types of existing hard copy records using scanners and OCR software is possible, its practicality has not been demonstrated. It depends on the quality of existing records and may require a substantial quality assurance/quality control effort to catch errors made by the scanner and/or the OCR software. Both scanners and OCR have improved substantially over the past five years and can be expected to continue to do so.

III.1.4. Expert system control of the data input

Artificial intelligence techniques, specifically 'expert' or 'knowledge based' systems, may be used in the future to assist primary data collectors, i.e. the plant maintenance, operations and technical staff, with the data input process. The purpose of the expert system would be to capture the expertise of the plant's most knowledgeable and experienced personnel in a form useful to less experienced personnel. (The technique has been used to build 'expert assistance' for the creation of input files for complex thermal hydraulic computer codes.)

III.2. DATA STORAGE

The design of the record keeping system and the storage media used will affect the comprehensiveness of the record keeping system (performance objective 1 in Section 3.1) and the ability to maintain data integrity over the life of the plant (performance objective 4). One aspect of data integrity is ensuring that multiple databases throughout the plant all have the same value for a datum that appears in several of them. Another aspect of data integrity, sometimes overlooked, is the need to control and mitigate the physical deterioration of the data storage media.

III.2.1. Optical disk storage and dissemination of data

Optical disks offer many significant advantages for nuclear power plant records applications, including: low cost per bit stored; a stable archival medium; access to very large 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 data have not been subject to unauthorized changes. CD-ROM is most suitable for 'publishing' applications for which the cost of creating a master disk can be spread over a number of copies. There is currently a strong move towards the publishing of machine readable vendor manuals on CD-ROM, combining both text and graphics (and soon probably mixed text, graphics and audio). WORM disks, in contrast, are well suited to the storage of data which need to be modified by the operating staff from time to time, but without losing the audit trail of historical data.

Still awaited is the advent of optical digital tape (first as a medium for the recording and storage of audio information for consumer electronics), which will offer an archival storage medium of extremely high data density and high total storage capacity, at the expense of significantly slower retrieval of information than is possible with optical disks.

Although the characteristics and performance of the various types of optical disks favour their use for nuclear plant applications, an understanding of their suitability for use as a legal record of various kinds of transactions is still evolving. The consensus is that optical media will be a suitable archival medium; in particular, since data storage on optical media is digital and can (and, in fact, must) be combined with the use of error correcting codes, it will be possible to check the media from time to time for deterioration and, in the event of such deterioration (assuming that it has not proceeded too far), to reconstitute the original data without error using the error correction capability of the encoding.

III.2.2. Ageing deterioration of archival records

One of the major data integrity issues with possible implications in licence renewals of nuclear power plants is the adequacy of storage of weld radiographs. These radiographs provide the baseline for interpreting the results of weld in-service inspections (ISI) during the life of the plant. Detailed standards and regulatory guidance exist for the production, processing and storage conditions for radiographs, but, as with all other analog storage media, 'noise' introduced by physical degradation of the medium causes irretrievable loss of information.

Some vendors offer microfilming of original radiographs as a way of solving the problems cited. This raises the problem of loss of resolution in the copying process and does not resolve the issue of the ultimate archival lifetime of film media.

Another solution made possible 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) using data compression and error correcting codes. Should the error correcting codes indicate degradation of the stored data, these can be reread periodically and reconstituted exactly (within the limits implied by the design of the error correcting code). Subsequent use of the data for comparison with continuing ISI can be based on exact verified copies of the master disks, using processes entailing minimal risk for 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 are frequently copies of originals produced by vendors, the architect-engineer or the constructor. Such copies may be subject to considerable fading and may be hardly legible after a few years of storage. Data stored on magnetic tape require careful control of environmental conditions, periodic rewinding and periodic recopying to maintain data integrity.

III.2.3. Integrated plant databases

One way of ensuring the integrity of the data stored and ensuring that the record system contributes to careful management of the plant configuration is to establish a single integrated plant database, which would be the single source of data needed for operation, maintenance and engineering. This would guarantee that different plant organizational units are using the same data describing the plant and its condition. When the plant configuration changes as a result of modifications, the necessary changes in the record system can be made in the single integrated database rather than trying to track down and change data in all the different storage sites. Configuration management of the plant is outside the scope of the present guidance, but configuration management of the record keeping system is an important aspect of both the design and the operation of the system. The general principles of configuration management are becoming well understood, particularly in the contexts of design and construction management and in the field of software engineering and software quality assurance.

The obvious disadvantage of an integrated plant database is the front end cost of setting it up, particularly if data from multiple databases must be converted to a single format and incorporated into the integrated database. This disadvantage is avoided if an integrated database is used from the beginning of a nuclear plant project: from the design phase, through construction and into the operational phase. For an existing plant with existing multiple databases, a careful balancing will be needed of the costs and benefits of converting fully or partly to an integrated plant database. Such integrated databases are a natural combination of the capabilities of database and computer assisted drafting software, and are now commercially available [2].

III.3. DATA RETRIEVAL AND MANIPULATION

Performance objective (e) (Section 3.1) calls for timely and accurate retrieval of plant data and performance objective (f) states the need for effective tools for the analysis and visualization of plant data and for the flexible conversion of those data into various reports and data summaries. These aspects of record keeping are discussed in this section.

III.3.1. Data retrievability

Data retrieval is governed mainly by the design of the record system and the storage media chosen and, to a lesser extent, by personnel training, procedures and the day to day management of the records organization. Storage on hard copy media in a central location (perhaps with computerized indexing) will impose limits on the timeliness of retrieval and will require a large records organization and large records facilities. Comprehensive computerization of the records system, including both digital storage of the basic plant data and electronic delivery of requested data to users, will offer immediate benefits of improved retrievability, increased flexibility, and smaller and more manageable records organizations. One aspect of increased flexibility is the relative ease of introducing new technology into a system that has basic information stored digitally on machine readable media.

The continued increases in the speed and cost effectiveness of central processing units and peripheral equipment and in the power and usability of software can have a significant impact on the management of large databases. Enhanced retrievability and rapid manipulation of large databases are the subject of active research into both the necessary computer hardware and software. Associative memory, pattern recognition techniques, hypertext software, optical disk 'jukeboxes' (optical disk drives containing several disks on line continuously or with the capability of automatically loading disks from a library), and database 'engines' (computer hardware specialized by architecture for the storage and retrieval of data) all offer potential for significantly enhanced data retrievability.

III.3.2. Data review to identify emerging ageing phenomena

As discussed in Section 2.2, the identification of emerging ageing phenomena requires a collection of relevant data on service condition, such as water chemistry data and data on process conditions (temperatures, pressures and flows), ambient environment conditions and noise (neutron, pressure, temperature and audio noise). These data should be reviewed regularly by experienced engineers using software tools (e.g. Fourier analyses codes) that facilitate representation of the data. This provides effective data compression and permits the reviewers to apply the uniquely human capabilities of visual pattern recognition to extract anomalies from the data. Data anomalies usually precede new physical and operational phenomena such as IGSCC, steam generator tube thinning and denting, and pipe wall thinning due to erosion–corrosion. The transformation of some kinds of data into an audio signal may yield similar benefits (e.g. a good mechanic can diagnose some engine malfunctions from the sound of the running engine).

III.3.3. Integrated plant databases

The use of an integrated plant database, described in Section III.2.3, also enhances the retrievability and usability of information.

III.4. QUALITY ASSURANCE IN DATA COLLECTION

This section, based on Ref. [7], outlines the quality assurance (QA) aspects of data collection. For detailed treatment of QA for the overall records system, the IAEA Safety Guide 50-SG-QA2 [8] should be consulted. Quality assurance is of prime importance in any data collection system. First, it is necessary to define clearly and unambiguously what data are to be collected. Responsibilities for data collection and verification should also be clearly defined and periodically confirmed. Data should be verified for completeness, content and unambiguity according to well defined validation procedures. The reporting should be mandatory for all required data, with no optional items.

An independent verification on a sample basis at corporate level is recommended. Data should be screened not only for consistency and content but in order to permit prompt corrective action when necessary. Finally, it is very important that, to the extent possible, data suppliers interact on a regular basis with the database managers and users and make use of the database themselves. Otherwise, in the long term, there is likely to be a reduction in the quality of the data supplied.

III.5. DATABASE SECURITY

General arrangements for database security [7] include the following features:

(a) Clearly defined, limited access to the data, both within the organization and outside;
(b) Measures to prevent unauthorized manipulation or inadvertent destruction of the database; for example, the use of a database that is separated from the primary database and is under the control of the user;
(c) Protection against the loss of data by fire, computer crash or other events; for this purpose, at least one back-up copy of the data file should be made and stored in a controlled area.

The security measures employed should not unduly limit the access of the users to the data but should support their proper use.

REFERENCES

[1] PACHNER, J., NOVAK, S., "Proposed IAEA programme on safety aspects of nuclear power plant ageing and life extension", Nuclear Power Plant Ageing (Proc. Symp Washington, DC, 1988), Nuclear Regulatory Commission, Washington, DC (1989) 39–41.

[2] SMITH, P., Configuration Management of Nuclear Power Plants, Trans Am. Nucl. Soc. **59** (4–8 June 1989).

[3] ELECTRIC POWER RESEARCH INSTITUTE, LWR Plant Life Extension, Rep. NP-5002, Projects 2643-3-11, Interim Report, EPRI, Palo Alto, CA (January 1987).

[4] DEBEY, T.M., Diesel Starting System Monitor — Prototype Development, Rep. SAND 88-7058, Sandia Laboratories, Albuquerque, NM (July 1989).

[5] HOOPINGARNER, K.R., LOUZECKY, P.S., Study Group Review of Nuclear Service Diesel Generator Testing and Ageing Mitigation, Rep. PNL-6287, Pacific Northwest Laboratory, Richland, WA (March 1988).

[6] HOOPINGARNER, K.R., KIRKWOOD, B.J., LOUZECKY, P.J., Study Group Reviews of Nuclear Service Diesel Generator Testing and Ageing Mitigation, Rep. PNL-6287, Pacific Northwest Laboratory, Richland, WA (March 1988).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Evaluation of Reliability Data Sources, IAEA-TECDOC-504, Vienna (1988)

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance Records System, Safety Series No. 50-SG-QA2, IAEA, Vienna (1979).

GLOSSARY

COMPUTER RELATED TERMS

bar code reader. An optoelectronic device for reading one or more of the standardized bar codes for representing textual information.

CD-ROM. Compact disk, read only memory. A digital storage medium identical to the compact disks used for recording and playing back music. Since CD-ROM stores digital rather than analog information, it requires the data to be encoded using error correcting codes to make storage and retrieval insensitive to small blemishes on the disk. The process of putting information onto a CD-ROM 'master' disk is relatively expensive, but for 'publication' applications the cost can be amortized over the numerous copies produced from the master. Typical storage capacities are of the order of 200 to 600 million characters.

error correcting codes. A scheme for storing blocks of information containing not only the original information but also sufficient redundant information to enable the detection of errors up to a certain number occurring in transmission of the data or during storage and the immediate correction of up to a certain (smaller) number of errors.

expert system or knowledge based system. Software combining information about some system with some collection of logical relations dealing with that information and, in some cases, pattern recognition capabilities. Typically, the user is able to provide information to the expert system and to ask it to draw conclusions using its own information and logical rules.

help file. File associated with software and capable of being accessed while the software is being run and providing user documentation (in some cases, precisely that information relevant to the context at the time that help is requested by the user).

laser cards. Information storage medium similar to CD-ROM or WORM optical disks, but in a format similar to that of a credit card. Typical storage capacities are of the order of one to two million characters.

modem. Modulator/demodulator: an electronic device for converting digital information to an analog form (and back to digital) for transmission by telephone or by radio.

optical character recognition. Computer hardware and software designed for the task of recognizing typewritten and printed material and converting it to machine readable files that can be processed using word processors and other software.

transponder. An electronic device for sending a set message when interrogated. An active transponder has its own power supply and transmitting device; a passive transponder utilizes the energy of the interrogating signal to respond.

WORM disks. Write once, read many: an optical disk similar to CD-ROM but such that the end user can initially write data onto the disk which then cannot be erased. WORM disks can be written onto and read from with a small and relatively inexpensive disk drive attached to a computer. Typical storage capacities are of the order of 200 to 400 million characters.

AGEING MANAGEMENT RELATED TERMS

condition monitoring. Monitoring the extent of degradation in a component by continuous or periodic non-destructive measurement. The data gathered are used to predict whether the component can perform its specified functions (including functions under postulated accident and post-accident conditions) at a future time.

equipment qualification. The generation and maintenance of evidence to ensure that equipment will operate on demand to meet the system performance requirements throughout its service life. This evidence is generated through a process of equipment preageing, accident testing and analyses that demonstrate required performance under specified service conditions including accident and post-accident conditions.

failure. An occurrence when a component is unable to meet its minimum performance requirement.

incipient failure. A degraded condition observed in a component indicating potential future failure.

normal service conditions. Environmental, loading, power and signal conditions resulting from normal operating requirements, including expected extremes (transients) in operating requirements; postulated accident and post-accident conditions are excluded.

predictive maintenance. Preventive maintenance initiated on the basis of condition monitoring. The timing and the type of maintenance work are determined by the use of trends of both absolute and relative comparisons of component conditions. (Also characterized as condition directed maintenance.)

preventive maintenance. Inspection, testing, surveillance, repair, refurbishment and replacement activities designed to preserve the functional capabilities of nuclear power plant components for operational and emergency use.

reliability centred maintenance. A systematic method for developing and optimizing preventive maintenance programmes by evaluating and prioritizing preventive maintenance actions according to their effectiveness in reducing the probability of system failure, their economic viability being taken into account.

scheduled maintenance. Preventive maintenance initiated on the basis of a schedule, i.e. time directed maintenance. The timing and the scope of maintenance work is initially based on manufacturers' recommendations, warranty and regulatory requirements, and the experience of plant staff, and should be periodically reviewed and optimized on the basis of operating experience.

service conditions. Environmental, loading, power and signal conditions resulting from normal operating requirements, expected extremes in operating requirements and postulated accident and post-accident conditions resulting from the design basis events of the plant.

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Consultants Meeting
Vienna, Austria: 10–18 July 1989

Technical Committee Meeting
Vienna, Austria: 20–24 November 1989

Consultants Meeting
Vienna, Austria: 19–23 March 1990

LIST OF NUSS PROGRAMME TITLES

It should be noted that some books in the series may be revised in the near future. Those that have already been revised are indicated by the addition of '(Rev. 1)' to the number.

1. GOVERNMENTAL ORGANIZATION

50-C-G (Rev. 1)	Code on the safety of nuclear power plants: Governmental organization	1988
	Safety Guides	
50-SG-G1	Qualifications and training of staff of the regulatory body for nuclear power plants	1979
50-SG-G2	Information to be submitted in support of licensing applications for nuclear power plants	1979
50-SG-G3	Conduct of regulatory review and assessment during the licensing process for nuclear power plants	1980
50-SG-G4	Inspection and enforcement by the regulatory body for nuclear power plants	1980
50-SG-G6	Preparedness of public authorities for emergencies at nuclear power plants	1982
50-SG-G8	Licences for nuclear power plants: content, format and legal considerations	1982
50-SG-G9	Regulations and guides for nuclear power plants	1984

2. SITING

50-C-S (Rev. 1)	Code on safety of nuclear power plants: Siting	1988
	Safety Guides	
50-SG-S1 (Rev. 1)	Earthquakes and associated topics in relation to nuclear power plant siting	1991
50-SG-S2	Seismic analysis and testing of nuclear power plants	1979
50-SG-S3	Atmospheric dispersion in nuclear power plant siting	1980
50-SG-S4	Site selection and evaluation for nuclear power plants with respect to population distribution	1980

50-SG-S5	External man-induced events in relation to nuclear power plant siting	1981
50-SG-S6	Hydrological dispersion of radioactive material in relation to nuclear power plant siting	1985
50-SG-S7	Nuclear power plant siting: hydrogeological aspects	1984
50-SG-S8	Safety aspects of the foundations of nuclear power plants	1986
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